Polar Codes with Local-Global Decoding

Presenter: ***Ziyuan Zhu***, Graduate Student, ECE

Researcher: ***Ziyuan Zhu***, Graduate Student, ECE

Collaborators: ***Wei Wu***, Former Graduate Student, ECE

Advisor: ***Paul H. Siegel,*** Professor, CMRR

In this paper, we investigate a polar code architecture that supports both local and global decoding by coupling several parts of polar codes. This local-global construction is motivated by practical applications in data storage and transmission where reduced-latency recovery of sub-blocks of the coded information is required. Local decoding allows random access to sub-blocks of the full code block. When local decoding performance is insufficient, global decoding provides improved data reliability. For this, we use a systematic polar code as outer code in the coupled polar code structure proposed by [1], together with a modified mapping of outer codewords to semipolarized bit-channels of the inner codes. For global decoding, a coding gain of 0.2 dB at a bit error rate of 10^{-5} can be observed for the same total rate and length compared with conventional polar codes. Further, we discuss design issues affecting the trade-off between local and global decoding performance.

[1] A. Elkelesh, M. Ebada, S. Cammerer and S. t. Brink, "Flexible Length Polar Codes through Graph Based Augmentation," SCC 2017; 11th International ITG Conference on Systems, Communications and Coding, 2017, pp. 1-6.

Code-Aware Storage Channel Modeling via Machine Learning

Presenter: ***Simeng Zheng***, Graduate Student, ECE

Researcher: ***Simeng Zheng***, Graduate Student, ECE

Advisor: ***Paul H. Siegel,*** Professor, CMRR

With the reduction in device size and the increase in cell bit-density, NAND flash memory suffers from larger inter-cell interference (ICI) and disturbance effects. Constrained coding can mitigate the ICI effects by avoiding problematic error-prone patterns, but designing powerful constrained codes requires a comprehensive understanding of the flash memory channel. Recently, we proposed a modeling approach using conditional generative networks to accurately capture the spatio-temporal characteristics of the read signals produced by arrays of flash memory cells under program/erase (P/E) cycling. In this paper, we introduce a novel machine learning framework for extending the generative modeling approach to the coded storage channel. To reduce the experimental overhead associated with collecting extensive measurements from constrained program/read data, we train the generative models via transferring knowledge from models pre-trained with pseudo-random data. This technique can accelerate the training process and improve model accuracy in reconstructing the read voltages induced by constrained input data throughout the flash memory lifetime. We analyze the quality of the model by comparing flash page bit error rates (BERs) derived from the generated and measured read voltage distributions. We envision that this machine learning framework will serve as a valuable tool in flash memory channel modeling to aid the design of stronger and more efficient coding schemes.

Presenter: Ben Erbin QIU

Title: Emergence of stochasticity from synchronization

Abstract: Synchronization of two coupled oscillators, a ubiquitous phenomenon in natural and physical systems, is the basis for the behavior of dynamically coupled network systems. Here, we investigate the synchronization of two thermally coupled, but electrically decoupled, spiking oscillators in close physical proximity. The driving input voltage of one oscillator governs the development of unique emergent synchronization patterns between oscillators. Interestingly, a stochastic pattern emerges in between synchronized oscillation patterns. Our work shows that coupling spiking oscillators can lead to unexpected, emergent behavior, which has not been previously predicted. This has important implication for the practical hardware-level implementation of spiking neural networks.

Presenter: Fernando Ajejas

Title: Manipulation of exchange bias using spin orbit torque through an antiferromagnetic insulator

Fernando Ajejas, Ali C. Basaran, Pavel Salev and Ivan K. Schuller

University of California, San Diego. Department of Physics and Center for Advanced Nanoscience, La Jolla, CA, 92093, USA

The development of antiferromagnetic (AFM) spintronics is an active field with great potential for improving energy consumption, reducing interference and decreasing sizes when compared to traditional spintronics. This requires the development of novel concepts and functionalities which allow control over the properties of a device containing an AFM layer.

We present in this work a device concept in which the spin configuration of an AFM insulator (FeF_2) can be modified taking advantage of spin-orbit coupling (SOC) existing in heavy metals (HM) such as W or Pt. The device consists of a trilayer: HM|AFM|FM, where the top FM interface can be used to monitor the changes in the AFM spin configuration.

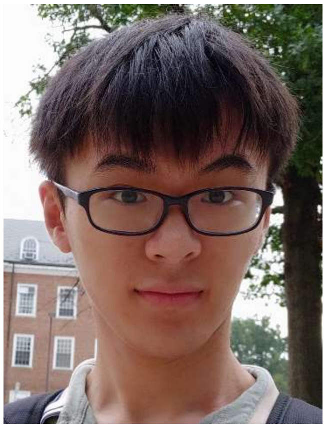
We performed Magneto-Optical Kerr effect (MOKE) to measure the FM hysteresis loops as a function of temperature (T) and applied current (I). We found that the exchange bias (EB) and coercivity (H_c) produced at the top AFM|FM interface can be strongly modified by a current (I) passed through the HM at the bottom interface. This shows that an active spin-orbit torque (SOT) is produced at the HM|AFM bottom interface that reaches the AFM|FM top interface and modifies amplitude and sign of EB. We find a critical current (I_c) beyond which the effects on the EB and Hc are irreversible. Temperature-dependent control experiments using normal metals (NM) such as Au in NM|AFM|FM and without AFM in HM|FM confirm that the effect is produced by the SOT induced by the HM and is not caused by thermal heating, Oersted field or other potentially spurious effects.

This research was supported by the Department of Energy's Office of Basic Energy Science, under grant # DE-FG02-87ER45332.

Presenter: SeongUk Yun
Lab Group: Andrew Kummel

Title : Low Temperature Plasma Enhanced Atomic Layer Deposition of Crystallized Gallium Nitride on Si

Abstract
Crystallized gallium nitride epitaxial thin films were successfully deposited on Si (111) at 275°C with plasma enhanced atomic layer deposition showing smooth surface morphology. Self-limiting thin film growth was achieved for both gallium and nitrogen precursors in thermal atomic layer deposition by tuning the process parameters. Using additional ALD pulse of Ar plasma with controlling the DC substrate bias has a key role to improve the crystallinity of gallium nitride epitaxial thin films and reduce the impurities in the thin films.



Transformer Quantum State: A Multi-Purpose Model for Quantum Many-Body Problems

Presenter(s): ***Yuanhang Zhang***, Graduate Student Researcher, Department of Physics

Researcher(s): ***Yuanhang Zhang***, Graduate Student Researcher, Department of Physics

Advisor(s): ***Massimiliano Di Ventra***, Professor, Department of Physics

Recent advancements in machine learning have led to the introduction of the transformer, a versatile, task-agnostic architecture with minimal requirements for hand-crafting features across different tasks. Here, we show that with appropriate modifications, such an architecture is well suited as a multi-purpose model for the solution of quantum many-body problems. We call the resulting model the transformer quantum state (TQS). In sharp contrast to previous Hamiltonian/task-specific models, TQS is capable of generating the entire phase diagram, predicting field strengths with as few as one experimental measurement, and transferring such knowledge to new systems it has never seen before, all within a single model. When focusing on a specific task, fine-tuning on a pre-trained TQS produces high-accuracy results with small computational cost. Versatile by design, the TQS architecture can be easily adapted to new tasks, thereby pointing towards a general-purpose model for various challenging quantum problems.

Work supported by DOE and CMRR.

[1] Zhang, Yuan-Hang, and Massimiliano Di Ventra. "Transformer Quantum State: A Multi-Purpose Model for Quantum Many-Body Problems." arXiv preprint arXiv:2208.01758 (2022).

Soumil Jain, Gopabandhu Hota, Yuhan Shi, Sangheon Ho, Jiajia Wu, Preston Fowler, Duygu Kuzum, and Gert Cauwenberghs
UC San Diego

Presenter: Soumil Jain

Title: A Versatile and Efficient Neuromorphic Platform for Compute-in-Memory with Selector-less Memristive Crossbars

Memristive crossbar arrays have become essential building blocks in the realization of large-scale neuromorphic systems with high-density synaptic connectivity. Traditionally, memristor-based accelerators are equipped with selector elements to reduce crosstalk through sneak paths along unselected lines. However, due to the large drive strength required for selector elements, it comes at the cost of synaptic crossbar density. Selector-less alternatives require careful design of crossbar peripheral circuits to mitigate or eliminate sneak path-induced crosstalk. We propose a hybrid integrated platform that interfaces a selector-less memristor crossbar array with peripheral row and column instrumentation for array-parallel programming and readout for AI learning and inference applications. The proposed switched-capacitor voltage-sensing instrumentation avoids the need for current-sensing schemes with voltage-clamped sense lines that are typically used to mitigate the sneak path issues in selector-less crossbars but are less energy-efficient than voltage-sensing. Our board-level platform is implemented using commercial off-the-shelf (COTS) data converters and switched capacitors and is controlled by a Xilinx Spartan-6 FPGA. The system offers programmable sense times to characterize memristors over a wide range of resistances and the capability to switch between a transient-domain measurement and steady-state measurement to offer the desired trade-off between accuracy and energy efficiency during inference parallel readout. We implement a differential weight-encoding scheme to improve the accuracy of matrix-vector multiplication. The system also supports an array-level programming scheme for parallel write access as well as online learning-in-memory for neuromorphic applications through outer-product incremental decomposition of the weight matrix. Thus, our system offers a generic, user-configurable, and versatile platform to support a wide dynamic range measurements of synaptic crossbar arrays and cognitive neuromorphic computing with emerging non-volatile memory devices.

Control of Ambipolar Operation of SnO-TFT and Complementary Circuit Application

Presenter: ***Yong Zhang***, PhD Candidate, Department of ECE

Collaborator: ***Chi-Hsin Huang***, PhD Candidate, Department of ECE

Advisor: ***Kenji Nomura***, Associate Professor, Department of ECE

Abstract

Tin monoxide (SnO) is a promising oxide semiconductor for oxide thin-film transistor (oxide-TFT) to develop oxide-based complementary circuit technology because of the reasonable high hole mobility of 2 cm^2/Vs and low temperature processability. It is known that SnO-TFTs exhibit ambipolar behaviors, in which both electrons and holes can concurrently contribute to the field-effect conductions. The feature makes it also a promising candidate to develop novel logic circuits and neuromorphic device applications. Therefore, it is important to understand and control the TFT operation mode to improve the electrical characteristics.

In this review, we present the mechanism and control of ambipolar operations in SnO-TFTs and their circuit applications including complementary CMOS-like inverter and ring oscillator circuits. It was found that the TFT devcie operation modes was varied by the back-channel defect state in an inverted staggered device structure. The pristine device without any passivation exhibited a weak amibipolaty with strong *p*-type and very weak *n*-type behavior, but clear improved ambipolar transport with hole mobility of ~1.2 cm^2/Vs and electron mobility of ~0.1 cm^2/Vs was obtained by reducing back-channel defect by low-temperature ALD-Al_2O_3 passivation. It was also confirmed that excess back-channel defect turned to *p*-channel operation only. The CMOS-like inverter using two identical ambipolar-SnO-TFTs was fabricated, revealed that voltage transfer characteristics were controlled by the majority/minority carrier mobility ratio. We also demonstrated 3-stage ring oscillator by cascading CMOS-like inverters.

[1] Y. Zhang, C.-H. Huang, and K. Nomura, **Voltage Transfer Characteristics of CMOS-Like Inverters for Ambipolar SnO Thin-Film Transistors**, *IEEE Electron Device Letters* **43**, 1 (2021), 52-55.

Presenter: Alicia Kim

Title: Material design via digital twin

Abstract: With increasing computational power and sophisticated mathematical techniques, today's material design is turning to the paradigm of digital twin. The multiscale and multidisciplinary nature of a material system makes it a classic complex system, which would benefit from the digital twin approach. A digital twin is constructed by coupling multiple disciplinary models and physical governing equations such that the coupled behavior across different physics and scales can be efficiently and effectively simulated, which in turn, informs decision-making. In a complex system, this coupled behavior can be emergent and unintuitive, and high-fidelity models are necessary to correctly capture and translate the full effects. Another challenge in such model-based design is that the behaviors are often unintuitive thus, communicating simply the response often do not provide sufficient information to make design decisions. This seminar presents the multiscale multi-physics design optimization approaches that aim to utilize the high-fidelity model information and optimize a coupled system to assist in the design decision making. A series of numerical case studies will demonstrate the potential for future material systems.

Dr. H Alicia Kim is Jacobs Scholar Chair Professor in the Structural Engineering Department of the University of California San Diego. She leads the Multiscale Multi-physics Design Optimization (M2DO) lab. Her interests are in level set topology optimization, multiscale and multi-physics optimization, modeling and optimization of composite materials and multifunctional structures. She has published over 250 journal and conference papers in these fields including award-winning papers at the AIAA conferences and World Congresses on Structural and Multidisciplinary Optimization. Her research in topology optimization began in the 90's at the University of Sydney, Australia where she developed one of the first boundary based topology optimization methods. She continued her research at the University of Warwick and the University of Bath, UK for 15 years before moving to the current position in 2015.

Effect of magnetic ordering on the spin Hall angle of epitaxial Ho(*0001*) thin films.

Biswajit Sahoo, Yuxuan Xiao, Eric E Fullerton

The operation of numerous spintronic devices are enabled through spin currents and thus, it is important to study how the generation, polarization and transmission of spin currents can be controlled by the local magnetic/electronic environment. Holmium is a rare earth metal which undergoes a paramagnetic to anti-ferromagnetic (AFM) transition at T_N=131K and an AFM to ferromagnetic (FM) transition at T_c=20K. The AFM phase is characterized by an incommensurate spin helix in which the average moments are ferromagnetically aligned within the basal planes but rotate from plane to plane along the *c* axis with an average turn angle varying from 50^0/layer at T_N to to 30^0/layer at T_C . Ho is further expected to have a good charge to spin conversion efficiency owing to its high atomic number and initial results of ploy-crystalline Ho films at room temperature show a spin Hall Angle (SHA) of 0.14[1]. Here, we explore the SHA of epitaxial Ho thin films in the paramagnetic, AFM and FM phases to observe the effect of magnetic ordering on the generation of spin current. We deposited epitaxial Ho (*0001*) using Al_2O_3(*0001*) as a substrate with a 20nm W(*110*) as a seed layer and confirm the different magnetic phases via magnetometry and transport measurements. We create the following thin-film stack: Al_2O_3(0001)/W(3)/Ho(10)/W(1)/Py(7)/W(1.5) (where the thicknesses are in nm) and study the SHA of Ho via spin torque ferromagnetic resonance experiments. We systematically vary the temperature down to 10K to study the charge to spin conversion efficiency. By relating various magnetic parameters such as effective magnetization, gilbert damping and SHA at various temperatures, we explore how the magnetic ordering affects the spin dynamics in this system.

References:

[1] N. Reynolds *et al.* Phys. Rev. B **95**, 064412 (2017)

Acknowledgement:

This work was supported as part of Quantum Materials for Energy Efficient Neuromorphic Computing (Q-MEEN-C), an Energy Frontier Research Centre funded by the U.S. Department of Energy (DOE), Office of Science, Basic Energy Sciences (BES), under Award # DE-SC0019273.

Crystal symmetry dependent magneto-transport properties of hcp cobalt and holmium films

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[2]University of Illinois, Urbana-Champaign, Urbana, Illinois 6180, USA

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We will discuss anisotropic magnetoresistance (AMR), anomalous Hall effect (AHE) and planar Hall effect (PHE) measurements of epitaxial hcp Co and Ho films. These magneto-transport properties are typically described as dependent on the angle of magnetization relative to the current. However, we find that for both Co and Ho there are unusual magneto-transport properties that depend strongly on the direction of the current (I) and the applied magnetic field (H) relative to specific crystallographic axes. For epitaxial Co(0002) and $(10\bar{1}0)$ films the AMR, AHE and PHE depend strongly on the orientation of I relative to the Co c-axis. At low temperatures the AMR is highest (14%) when $I \parallel c-axis$ and the angular response depends on the angle of H relative to the c-axis and not the current. At room temperature the highest AMR arises when I is 50 degrees from the c-axis whereas the anomalous Hall conductivity is largest when $I \parallel a-axis$. For Ho(0001) films we observe the presence of the helical antiferromagnetic phase below T_N=132 K that transitions to the conical ferromagnet phase at T_C=20 K expected from studies of bulk Ho. In the helical phase the high field AMR in the basal plane possesses sharp delta-function-like six-fold symmetric peaks in the AMR whenever H is parallel to the a-axis. Calculations show that Ho, when in the helical spin antiferromagnetic phase, is a Weyl semimetal that may give rise to the six-fold component where the additional 2-fold term in the ferromagnetic phase arises from magnetostrictive contributions. These results show that care is need in interpreting magneto-transport properties, particularly in materials with low crystal symmetries and anisotropy conductivities.

Synchronization of spin-torque nano-oscillator

Presenter: ***Fangzhou Ai***, Ph.D. student, Material Science and Engineering Department

Advisor: ***Prof. Vitaliy Lomakin***, Professor, Electrical and Computer Engineering Department

Spin-transfer nano-oscillators (STNO) can generate a microwave voltage output based on a DC input current. However, a single oscillator generates a relatively small amount of power. To address this issue, a solution is to have an array of STNOs and synchronize them, thus leading to much greater generated power. Achieving synchronization in a large array of oscillators can be challenging due to the complexity of interactions. Here, we proposed a structure that can allow synchronization in a large array of STNO by means of spin waves in a thin magnetic film. The structure is based on a honeycomb configuration, which has low-damping hexagonal regions with high-damping embedded triangle regions (Fig. 1). STNOs are placed at each narrow neck of the pattern. The spin waves generated by the STNO propagate within the low-damping region, whereas they are damped in the high-damping regions. The narrow neck width is smaller than the spin wave wavelength, so that the spin waves do not pass there. Thus, each STNO only have nearest-neighbor interactions (Fig. 2). By limiting the range of interaction, synchronization in a large array of STNOs is possible. Furthermore, the coupled oscillations can be tuned by either changing the STNO driving current or using extra current on high damping region to reduce the effective damping constant to allow more connections among adjacent STNOs within a certain region.

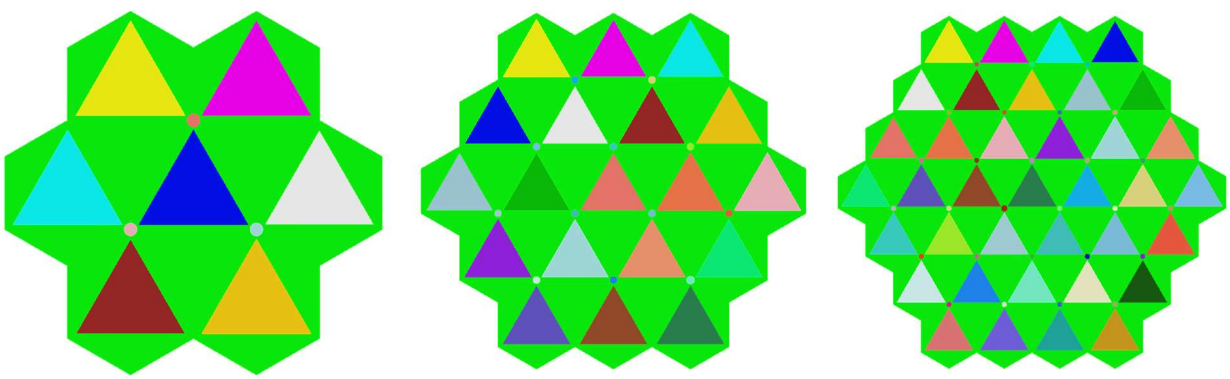

Fig 1. Illustration of the model. The green regions are of low damping allowing for the spin wave propagation. The colored triangular regions have higher damping to absorb spin wave. STNOs are shown as the small dots.

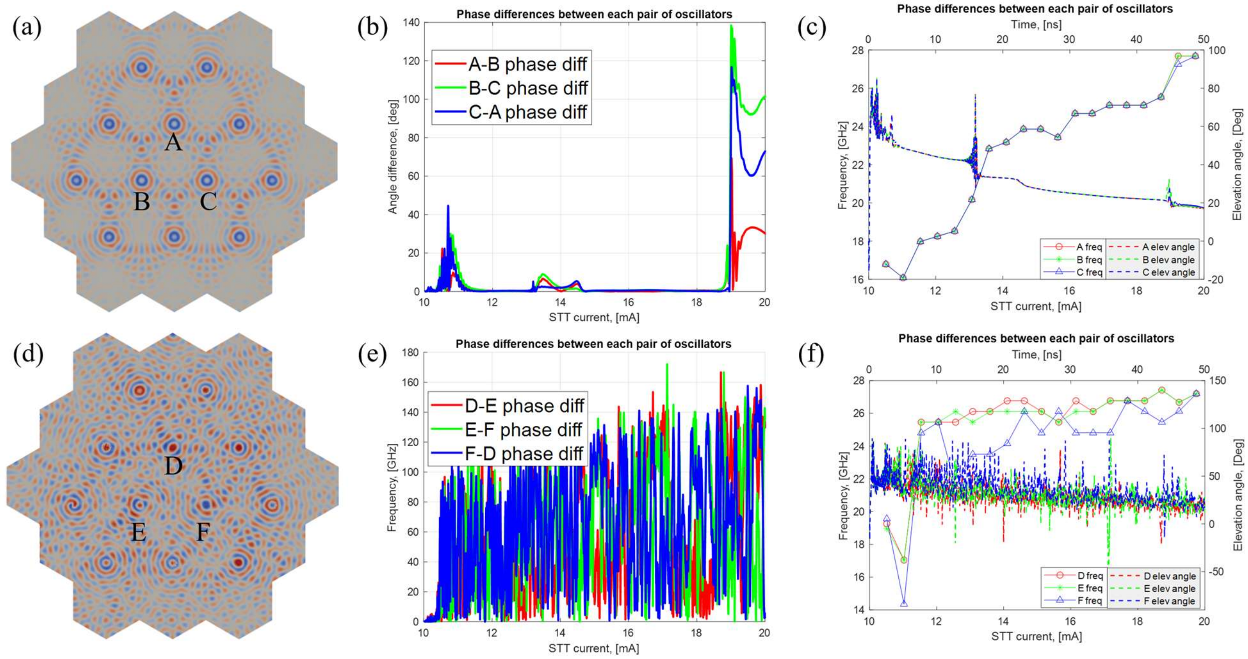

Fig 2. Synchronization of 12 oscillators under different STT currents. (a) the spin wave interference pattern with high-damping regions present. (b) time dependence of the phase differences between oscillators A, B, and C with the linearly increasing current. The stable phase difference indicates synchronization. (c) time dependence of the frequency and elevation angle. (d-f) present the same results as in (a-c) but for the case with no high-damping regions. Here, no synchronization is achieved.

Carousel phase retrieval algorithm (CPRA) for 3D coherent X-ray diffraction imaging

Presenter: ***Fangzhou Ai***, Ph.D. student, Material Science and Engineering Department

Advisor: ***Prof. Vitaliy Lomakin***, Professor, Electrical and Computer Engineering Department

Abstract: Coherent X-ray Diffraction Imaging (CXDI) is a computational approach to reconstruct images at nanoscale resolution using X-ray diffraction. CXDI allows reconstructing the material structure using a series of images obtained in synchrotron experiments. CXDI uses an iterative procedure based on forward and backward FFTs, which allows extracting the phase information from solely intensity measurements. The ability to obtain both the intensity and phase leads to a high-resolution reconstruction. However, CXDI for reconstructing 3D objects can be highly computationally expensive and computations can take significant time, which prevents using it in real time while performing measurements. The long computational time is related to the need to do many 3D FFTs and have many iterations for the phase extraction, which, for large systems, may become slow and occupy large memory.

We present an algorithm for 3D CXDI reconstruction. The algorithm is based on the Fourier slice theorem and difference-map iterative algorithm. The idea is instead of performing phase reconstructions iterations using 3D FFTs to reconstruct a set of 2D images. Each such 2D image is reconstructed for a 2D slice at a specific measured angle. Based on this set of 2D reconstructed images, we complete a 3D reconstruction step. This 3D reconstruction is rapidly converging since the 2D images already contain both intensity and reconstructed phase information. The reconstruction of the set of the 2D images still has challenges related to uncertainties in the phase reconstruction. To address these challenges, we developed an approach, allowing using a reconstruction for some of the 2D images as a guess of the close in angle images. The benefits of the introduced algorithm include the reduction of the iterations needed for convergence, the ease in processing a large number of images in parallel, a major reduction of the memory consumption, increased accuracy, and improved robustness. The reductions of the memory consumption and ease of parallelization, the proposed algorithm is well-suited for implementations on massively parallel graphics processing units (GPUs) with major speed improvements. The GPU accelerations involves creating suitable data structure, properly addressing CPU and GPU memory, and executing operations in parallel. The GPU can accelerate the required Fourier transforms and products with significant speed-up rates. In our experiment we can either achieve around 100X speedup with same reconstructing quality, or around 10X speedup with a much higher resolution for the reconstruction (Fig. 1).

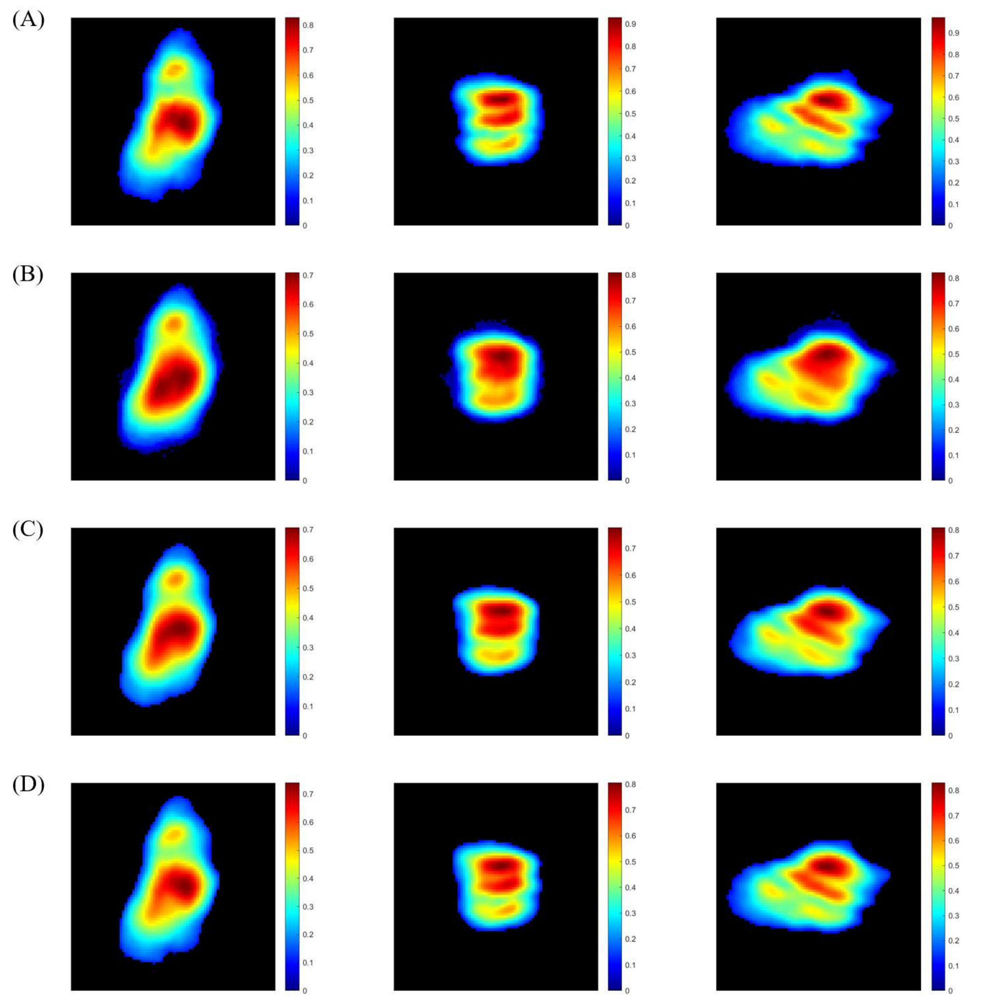

Figure 1. Central slices through X-Y (first column), Y-Z (second column), Z-X (third column) plane, (A) original object, (B) reconstructed object from conventional approach, (C) reconstructed object from CPRA with 1 episode and 2 iterations per episode, (D) reconstructed object from CPRA with 1 episode and 20 iterations per episode. (D) looks most like (A) with many similar features, for example, the small notch of density in the lower part of the X-Y plane slice. (C) is still better than (B) for there're clear boundaries of density in Y-Z and Z-X plane slices.

Linear and Harmonic Balance Landau-Lifshitz-Gilbert Equation Solver

Presenter: ***Zhuonan Lin***, Department of Electrical and Computer Engineering

Advisor: ***Dr. Vitaliy Lomakin***, Professor, Department of Electrical and Computer Engineering

We first present a linear frequency domain Landau-Lifshitz-Gilbert (FD-LLG) equation solver. The FD-LLG equation solver provides a linearized magnetization solution as a response to a dynamic excitation, e.g., the applied field, which is a characterized by a given frequency. Considering a given frequency allows formulating a time independent linear equation for a complex magnetization amplitude, which can, then, be used to provide linear time domain solutions. The FD-LLG equation solver is developed based on the finite element based micromagnetic simulator FastMag. The linear system is solved effectively with an iterative solver. The number of iterations is significantly reduced using a linear preconditioner. Solving the FD-LLG equation is much more efficient and provides a more physically insight than solving the original LLG equation.

Next, we consider the magnetization response to a time-harmonic excitation in the regime of "weak" non-linearities, in which the magnetization can be represented in terms of an expansion over a series of higher-order harmonics accounting for higher-harmonic generation phenomena. We refer to the method described next as to Harmonic balance method (HBM). The HBM is related to techniques used to solver for nonlinear dynamic excitation in various systems, such as circuit solvers.

Title: Forward flux sampling method for computing attempt frequencies in magnetic recording media

Presenter: Jiawei Duan

Professor: Vitaliy Lomakin

Industrial collaborator: Byron Lengsfield

Predicting the thermal stability of magnetic structures is important for numerous technological applications, such as the design of magnetic recording systems and magnetic memories. Direct methods for calculating lifetime/attempt frequency are not applicable when the energy barrier is high. We use Forward Flux Sampling (FFS) method to study multilayer magnetic media used in magnetic recording and analyze effects introduced by different inter-granular exchange and temperature on the lifetime and attempt frequency.

FFS method is a path sampling method that can facilitate simulations of rare events. Lifetime τ can be obtained as the inverse of the transition rate k^{-1}, which is governed by an Arrhenius-Neel relation $k = f_0 e^{-\beta\Delta t}$. By setting up a series of non-overlapping interfaces between equilibrium states A and B, the Landau-Lifshitz-Gilbert equation based simulations can be conducted to model transitions between a set of interfaces between these states. The overall transition rate is derived from the product of pass rates of LLG simulations per interfaces. The FFS method can significantly decrease the time need for estimating lifetime. We demonstrate how to choose the interfaces and distance parameters to make decisions about passing through the interfaces. We show that the results obtained via the FFS method agree with analytical solution obtained via Brown's and Kalmykov's formulars. We then demonstrate a study of the attempt frequency in multi-layer multi-grain media. We demonstrate that the attempt frequency decreases with the lateral exchange, which is opposite to the estimated result from a modified Brown's formula. We also show that the attempt frequency can be significantly affected by the temperature.

Presenter: Brian Li
Lab Group: Frank Talke

Title: Digital image-based characterization of a silicon-polyurethane composite for vaginal tissue analog

Proper stress response behavior of materials is critical for developing accurate medical analogs. This study aims to analyze a range of composites in terms of their materials properties and relevance for use in diagnostic vaginal models. To simulate the biomechanics of vaginal tissue, we use a composite consisting of a silicone elastomer matrix with a 3D-printed thermoplastic polyurethane scaffold. This two-material composite allows us to tune the stress-strain response of our vaginal tissue analog and create the required material properties using 3D printing. Obtaining desirable material properties and tuning the stress-strain response is critical to mimic the symptoms of vaginal stenosis. The mechanical stress-elongation behavior of the silicone-polyurethane composite is analyzed using digital image correlation and uniaxial tensile tests, allowing for the comparison of varying volume percentages of the scaffold design and the effect of changing the matrix and scaffold materials.

Presenter: Daria Tsui
Lab Group: Frank Talke

Title: "Design of a surgical navigation system via positional tracking of fiducial markers".

Low back pain is the leading cause of non-fatal health loss and years lived with disability. Current interventional pain management therapies include epidural steroid injections and radiofrequency ablations, which can provide short-term and long-term relief. However, these therapies often utilize fluoroscopy, which exposes both the patient and medical practitioner to radiation. We explore whether an augmented reality navigation (AR) system can be interfaced with a preoperative image from magnetic resonance imaging (MRI) to reduce radiation exposure, provide a low-cost alternative to existing technologies, and improve needle position tracking. Non-invasive skin markers (ArUco) were utilized to identify the surgical field. An XYZ tracking platform with linear Kalman filtering was used to test the feasibility of marker tracking in various operating room environments. Line-of-sight obstruction was observed to affect camera tracking significantly. Future directions include the development of a multi-camera model, a three-dimensional (3D) marker tracking system, and the implementation of optimal ArUco marker materials.

Portable Multi-Functional Ophthalmic Device for Remote Self-Examination of the Eye

Presenter: *Avinash Laha, Graduate Student, CMRR & MAE*

Collaborator: *Dr. Gerritt Melles, Netherlands Institute of Ocular Surgery*

Advisor: *Dr. Frank Talke, CMRR & MAE*

Abstract:

In order to detect early onset of common eye disease such as diabetic retinopathy, cataracts, and glaucoma, regular ophthalmic examinations must be performed on a regular basis (at least twice per year). Such routine eye examinations like testing a patient's intraocular eye pressure (IOP) and observation of the anterior segment can be time consuming to perform, and require the availability of expensive instruments operated under the expertise of an optometrist. Visits at the eye doctor can be challenging for elderly or sick patients who may not be mobile or reside far away from an optometrist. Furthermore, patients who must see the eye doctor for post-operative follow-up must also plan on regular visits with the eye doctor.

Our proposed device attempts to combine and miniaturize the most commonly used ophthalmic instruments (a tonometer for measuring IOP, a visual acuity tester, and a slit lamp microscope for observing the anterior eye chamber) in a portable, internet-connected, and handheld device, the so-called 3-in-1 device. The primary goal of this approach is to make ophthalmic care accessible to a wide patient population for quick, repeated use. Additionally, the 3 in 1 device would also contain internet-enabled features for easy sharing of test results with a qualified professional remotely. Hence, the new device will meet the growing need for eye monitoring and improved ophthalmic care, and allow self-examination of the eye from the comfort of a patients' home. The challenge we face with our device translation is commercializing our innovation and initializing the FDA's approval process. Our team at UCSD has been dedicated to match the non-invasive standard of modern ophthalmic devices while maintaining low cost and functionality to address these technical challenges. A cross section of our 3 in 1 device is shown in Figure 1, indicating the three functions: slit lamp (on the left) for examination of the cornea and the intraocular lens, visual acuity measurement (middle), and intraocular pressure measurement (right) using an air puff.

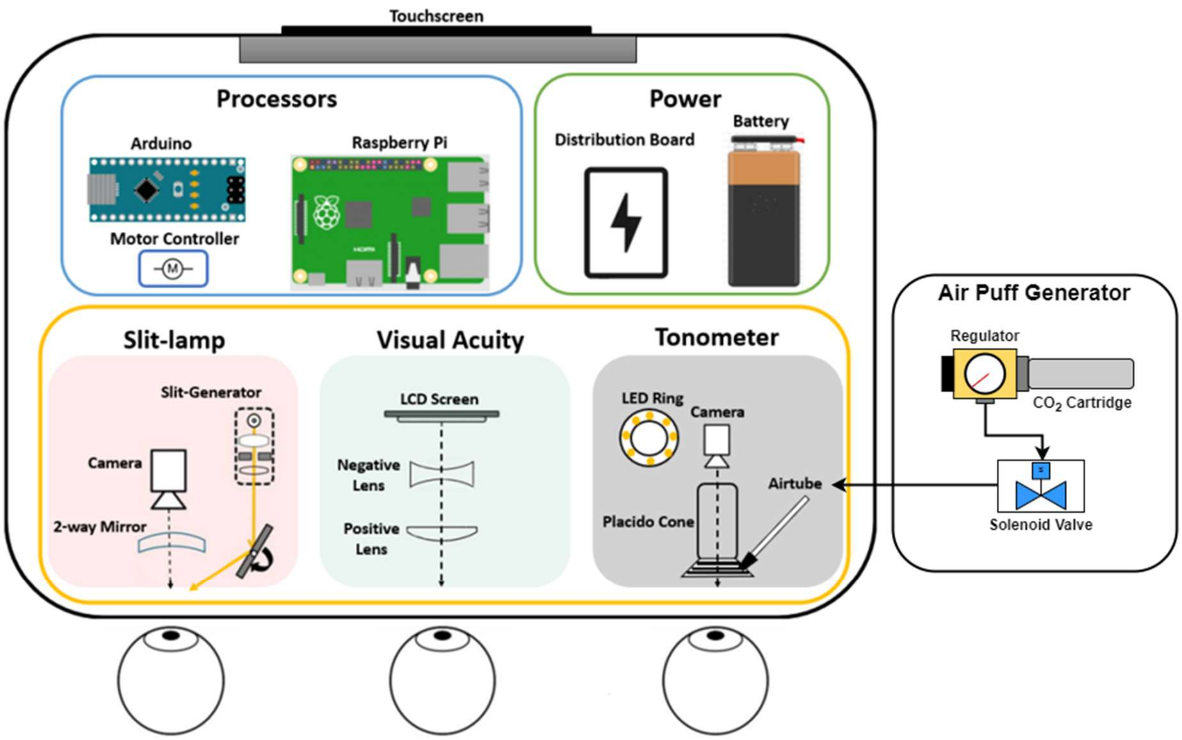

Figure 1. Schematic overview of the major components in the proposed 3-in-1 Ophthalmic Device.