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New Jersey Institute of Technology

Ronald E. McNair Postbaccalaureate Achievement Program

NSF – REU Optics and Photonics: Technologies, Systems, and Devices

Heritage Institute of Technology

Summer Research & Innovation Symposium

2026 Pathway *to the* PhD

Research. Mentorship. Achievement.

July 29 – 30, 2026

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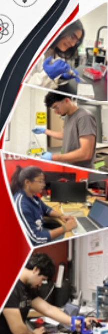

Empowering Future Scholars

" Research is formalized curiosity. It is poking and praying with a purpose. It is a seeking that he who wishes may know the cosmic secrets of the world and they that dwell therein.”

~Zora Neale Hurston

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Ronald E. McNair Postbaccalaureate Achievement Program

July 30, 2026

Welcome to New Jersey Institute of Technology's 2026 International URI Undergraduate Summer Research and Innovation Symposium. It is an honor and privilege to be part of this year's Symposium. Ten participants of the Ronald E. McNair Postbaccalaureate Achievement Program started their summer research program on May 26, 2026. Five students from Heritage Institute of Technology (HIT), India started their research from June 24, 2026. Ten students from NSF REU Site: Optics and Photonics: Technologies, Systems, and Devices also participated in this year's summer research program from May 26, 2026. The students worked very hard to carry out their research projects with literature review, data analysis and simulation in addition to lab experiments.

The successful student exchange program during summer for research between NJIT and HIT has entered its 19th year this year. The purpose of this exchange is to promote international understanding, scholarly collaboration, cultural interaction, and friendship by supporting educational professional and cultural activities among faculty and students of the two institutions.

The NSF REU Site on Optics and Photonics: Technologies, Systems, and Devices will continue into 2026. Students from all over the United States are participating in this program. All the 25 students participated in research, attended many seminars and workshops throughout the summer program.

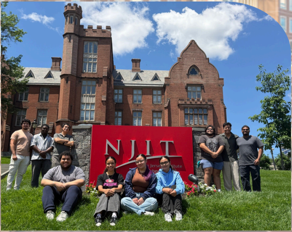
This year's success comes because of Ms. Zara Williams, Assistant Director, Prof. Ashish Borgaonkar, the Faculty Coordinator of the Ronald E. McNair Program and Prof. Abdallah Khreishah, Director of NSF REU Site for their efforts in coordinating the overall program. Staff members of the Research Office, Admissions, Office of Global Initiative, Budget Office, Housing, Facility Systems, Photo ID & Parking Services, and ECE Department contributed significantly to the success of the Symposium. The efforts of Mr. Pratham Mathur and Ms. Dhara Patel of the McNair office are recognized for the valuable input in producing this program's brochure. In addition, we have an excellent group of experts presenting seminars and workshops for the students' success.

The students in the Ronald E. McNair Program, HIT Program and NSF REU Program have the opportunity to present their research accomplishments that were completed under the supervision of dedicated NJIT faculty. Without the time and effort of NJIT faculty and graduate student mentors, the outstanding achievement of the students would not have been possible. We are extremely proud of the research efforts of all the students, the quality of the research presentations and grateful for the support of the NJIT administration, faculty, and staff in contributing to the success of the symposium. A special thank you note to our Provost, Dr. John Pelesko, for his strong support of the McNair Program.

Sincerely,

Durgamahab Misra, PhD
Symposium Co-Chair, McNair Program Director, HIT Program Coordinator
Co-Director of NSF REU Site
Professor and Chair, Department of Electrical and Computer Engineering

Ronald E McNair Postbaccalaureate Achievement Program



How the Cookie Crumbles: Using LLMs to Assist Users in Understanding Data Policies in Website-Cookies Agreements

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Consent banners have become an integral part of any website; however, people, especially those who speak limited English, often fail to comprehend what information the banners share and what happens after consenting to cookies. Past literature proves that cookie banners typically contain ambiguous wording, irregular formatting, and "dark patterns" that conceal how personal information is utilized. With this in mind, this project seeks to develop a lightweight prototype based on AI technology that will detect consent banners and give straightforward descriptions of them. To prevent invasion of user privacy, the prototype will be analyzing the text of the banners exclusively and will be showing its results on a small side-panel in multiple layers. During the summer research period, the following steps will be made. First, a structured Python notebook for data gathering will be created; next, multiple examples of cookie banners will be gathered from various websites, and their linguistic and visual characteristics will be explored. Additionally, it is planned to examine how some large language models operate and what explanations they offer depending on prompt strategy. Overall, I expect the project to make users aware of consent and cookie tracking risks and serve as a basis for future research AI-assisted tools that promote more informed and accessible online privacy decisions.

Endocrine Disrupting Effects of Common Preservatives

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More than 90% of the population carries detectable levels of endocrine-disrupting chemicals (EDCs), compounds that interfere with hormonal signaling and reproductive health. Parabens, widely used as preservatives in cosmetics, pharmaceuticals, and foods, have recently emerged as chemicals of concern due to endocrine-disrupting potential. They are present in over 22,000 cosmetic formulations at concentrations up to 0.8%. Several biomonitoring studies have detected parabens in breast tissue, menstrual blood, placental tissue, and ovarian follicular fluid, indicating human exposure and potential reproductive relevance. Among these compounds, butyl paraben (BuP) remains poorly characterized despite its structural similarity to known EDCs such as monobutyl phthalate (MBP) and monobutyl terephthalate (MnBTP). This study evaluates the ovarian toxicity of BuP using an in vitro mouse antral follicle culture model. Follicles were exposed for 96 hours to 0.1–100 μg/mL BuP, reflecting environmentally relevant and high-dose concentrations. Follicle growth was monitored as a marker of reproductive health, and gene expression will be further assessed using quantitative PCR to examine pathways involved in steroidogenesis, peroxisomal proliferator activated receptor (PPAR) signaling, cell cycle regulation, and apoptosis. From our collected results, BuP produced dose-dependent toxicity. At 100 μg/mL, complete follicle death occurred, demonstrating marked cytotoxicity not observed with related compounds. Thus, we can expect an increase in apoptosis markers, a decrease in cell growth genes, as well as decreased expression of hormone-related genes. Overall, these findings indicate that BuP is cytotoxic at high concentrations and may disrupt ovarian function through mechanisms comparable to structurally related EDCs, supporting the need for further evaluation of paraben safety.

Endocrine Disrupting Effects of Common Preservatives

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Elastic properties are fundamental physical properties of any material and are determined by their molecular/atomic structure. For ductile materials, such as metals and many polymers, elastic moduli are routinely measured by tensile testing. However, when materials are brittle, such as ceramics or composites, tensile testing is challenging, because brittle materials are very weak in tension and have no plastic deformation. An alternative is offered by ultrasonic testing but suffers from similar limitations, requiring a large sample size, and a shape which allows use of ultrasonic transducers (flat surfaces), which proves to be challenging for small or spherical samples. This causes a need for an alternative approach to test these materials in a nondestructive way. Another approach involves measuring the coefficient of restitution (COR), determined by retention of kinetic energy after collision. The bouncing ball experimental setup is depicted in Figure 1. While gathering COR data is effective theoretically, it lacks precision due to the practicality of obtaining accurate height, velocity, and time measurements. Using a laser-photodiode and piezoelectric setup will aim to optimize the accuracy and practicality of using the COR to calculate elastic moduli. The data read from experimental setup in figure 2 will give both the time the laser is cut when the ball initially falls through and then the time when the ball bounces and cuts the laser again, in order to calculate COR. Testing will include materials like stainless steel, tungsten, silica gels, and bronze balls with diameters ranging from 3-10 mm. We expect this method to be more practical while accurate to other forms of testing elastic properties in brittle spherical samples. We also aim to test how porous materials behave at different relative humidities, when sorption occurs, as knowing how materials behave under humid conditions is essential to engineering and avoids structural failure.

Developing a Hybrid Defense-Based Framework against RowHammer

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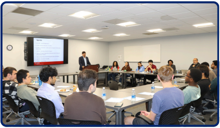
The demand for Dynamic Random Access Memory (DRAM) has surged as modern industries increasingly rely on cloud services, data centers, and remote computing. At the same time, continued device scaling driven by Moore's law has made DRAM denser but also more vulnerable to reliability issues. One of the most critical vulnerabilities is RowHammer, a disturbance error in which repeated activation of a DRAM row induces electromagnetic coupling and causes bit flips in adjacent rows. Prior work has proposed numerous hardware- and software-based defense mechanisms, yet their effectiveness varies, and little is known about how these mechanisms interact when combined. This study evaluates a range of RowHammer defenses using DRAM-Bender, an FPGA-based experimental platform that enables low-level control of DRAM behavior. By constructing controlled test environments and systematically varying attack and defense configurations, we analyze the performance, overhead, and robustness of different defense combinations. The goal is to determine whether a future-proof RowHammer mitigation strategy can be developed that maintains strong security while preserving power and resource efficiency.



Orientation

Medical Ontology Semantic Auditing and Inspection Controller (MOSAIC)

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Biomedical ontologies are structured, knowledge frameworks that serve as the backbone of modern health informatics. Allowing doctors and insurances to use clinical decision support and semantic connectivity across diverse healthcare systems. However, the constant evolution of medical terminology imposes a significant maintenance burden, requiring rigorous domain expert oversight to ensure structural and semantic integrity. While Large Language Models (LLMs) have emerged as potential auditing tools, their application is frequently constrained by unpredictable reasoning and hallucination. This study introduces the MOSAIC (Medical Ontology Semantic Auditing and Inspection Controller) framework, which utilizes a tool augmented, "verify then correct" pipeline that couples automated semantic scanning with multi-stage logical validation to identify inconsistencies. Testing this framework on specialized musculoskeletal sub-hierarchies, our data revealed critical structural defects, specifically the misclassification of anatomical attributes as structural components and significant coverage gaps within hierarchical relationships. These results establish a baseline performance metric for single agent automated auditing, demonstrating the model's practical utility in flagging relational inconsistencies while revealing inherent limitations in navigating deep, multi-layered logical constraints. By replacing labor intensive manual review. With the use of this intelligent, AI-assisted surveillance method provides a scalable, accurate approach to ontology engineering, offering a practical solution for maintaining accuracy in complex, evolving biomedical domains.

Ultrafast Microdroplet Acceleration of Enzymatic Reaction

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Microdroplet reactions have recently garnered attention for their ability to accelerate chemical and biochemical reactions. While early applications primarily focused on small-molecule reactions, microdroplet technology has been developed for enzymatic reactions involving biomolecules. Traditional bottom-up biomolecular characterization workflows involve overnight enzymatic digestion followed by lengthy liquid chromatography mass spectrometry (LC-MS) runs. Recently, a series of publications have demonstrated that microdroplet reactions can reduce reaction times from hours to seconds or minutes, significantly accelerating analytical workflows. However, microdroplet enzymatic reactions have primarily been applied to antibody characterization and have not been challenged using more complex systems. Membrane proteins account for more than half of all known drug targets but remain difficult to characterize because of their hydrophobicity and resistance to enzymatic digestion. MsbA, a model ATP-binding cassette transporter, provides insight into membrane proteins that are important therapeutic targets. Aside from protein-based systems, oligonucleotides have also gained attention for their therapeutic potential, including use in vaccines (e.g., the Moderna COVID-19 vaccine) and in gene silencing via siRNA. However, characterizing modified oligonucleotide therapeutics such as pelacarsen, which contains numerous backbone and chemical modifications to enhance stability, presents significant analytical challenges. These include lengthy nuclease digestion protocols and complex LC separation conditions that can lead to ion suppression or contamination of MS systems. Therefore, accelerating these workflows and eliminating the need for LC is highly desirable. This work evaluates accelerated biomolecular reactions within microdroplets. To conduct this research, membrane proteins such as MsbA are subjected to trypsin and chymotrypsin digestion within accelerated microdroplets generated using an Agilent 1290 Infinity II coupled to the 6545XT Q-TOF mass spectrometer, while pelacarsen is digested using nuclease P1. In addition to peptide and nucleotide mapping, ion mobility separation is evaluated as an orthogonal analytical dimension to differentiate structural isomers and investigate the potential for distinguishing phosphorothioate stereoisomers. This may provide insight into R and S configurations that influence oligonucleotide biological activity and therapeutic performance. Microdroplet reactions are expected to improve peptide and nucleotide mapping workflows by accelerating characterization and identification compared to conventional methods. These findings may provide a rapid strategy for advancing mass spectrometry-based characterization workflows for membrane proteins and RNA-based therapeutics.

Wearable Sensor-Based Human Upper Limb Motion Tracking

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For many stroke survivors, upper-limb motor impairment makes even simple daily tasks challenging. Although nearly 80% experience some degree of hand dysfunction, affordable rehabilitation systems continue to center on larger joints like the knee or hip. This leaves a critical gap in accessible tools designed to support the recovery of hand and wrist movement—areas essential for fine motor control. Patients with paralysis often struggle with weakness, stiffness, and reduced grip strength when attempting to use current physical controllers. This research investigates a wearable sensor-based approach for tracking hand motion and estimating joint angles for rehabilitation applications. The system employs LPMS-Research inertial measurement unit (IMU) sensors that collect tri-axial accelerometer, gyroscope, and magnetometer data. Python-based software streams real-time motion data and implements algorithms for orientation estimation and joint-angle calculation. The experimental design includes sensor calibration, data filtering, and the selection of sensor-fusion techniques to improve measurement accuracy. System performance will be validated by comparing calculated joint angles with measurements obtained from a motion-capture camera system. The anticipated outcome is a low-cost, portable prototype capable of reliably estimating hand joint angles in real time using IMU hardware. By providing an accessible method for monitoring limb movement, this work has the potential to support the development of rehabilitation tools for patients recovering from stroke and other conditions that impair hand mobility. Future work will involve patient testing, system optimization, and integration of joint-angle measurements into interactive rehabilitation exercises.

VIRS: Visual Interaction for Robotic Swarms

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Swarm robotics has demonstrated strong potential in implementations in environmental monitoring, autonomous exploration, distributed sensing, and search-and-rescue operations. However, many existing swarm robotics platforms rely on specialized hardware, complex communication systems, and steep learning curves, which limit accessibility for students and learners seeking an introduction to the field. As a result, users must understand multiple technical layers before they can interpret how an individual robot's actions contribute to a collective swarm behavior. These advanced conditions create barriers that limit access to swarm robotics education, experimentation, and awareness. The Visual Interaction for Robotic Swarms (VIRS) project addresses these challenges by developing an educational swarm robotics platform that makes collective robotic behavior more observable, understandable, and accessible. Rather than having users interpret internal communication and decision-making processes, VIRS relies on projected environmental interactions to help users visualize behavioral information. The platform will use readily available technology commonly found in classrooms and educational environments, such as projectors and whiteboards, to reduce deployment barriers. The projected environment provides specific instructions for navigation, behavior selection, and coordinated interactions. By making behavioral rules visible within the environment, users can directly observe how environmental information influences swarm behavior in real time. The objectives of this study are to: (1) develop a multi-robot swarm platform capable of supporting coordinated interactions among robots, (2) implement RGB-based environmental sensing using projected visual information, and (3) demonstrate swarm behaviors through projected environmental interaction. All hardware integration, sensor communication, color detection, and multi-robot interactions will be developed and tested on a whiteboard using the Pololu 3pi+ platform. The expected outcomes of this research are the successful integration of RGB sensors, reliable detection of projected environmental information, implementation of color-based behavioral responses, and demonstration of coordinated swarm interactions. By combining observable swarm behaviors with technologies available in classroom environments, VIRS aims to provide an accessible entry point to swarm robotics, fostering greater participation in a field that shows promise for environmental monitoring, autonomous exploration, distributed sensing, and search-and-rescue operations.

Evaluating the Effectiveness of Non-Speech Information (NSI) Captions Using Behavioral and Physiological Measures.

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As digital video content becomes increasingly prevalent across educational, entertainment, and social platforms, ensuring accessibility for deaf and hard of hearing (DHH) individuals remains a critical challenge. Hearing loss affects more than 1.5 billion people worldwide, including approximately 60 million people in the United States, highlighting the importance of accessible media and communication technologies. While automated captioning systems have improved access to spoken dialogue, many fail to adequately represent non-speech information (NSI), such as environmental sounds, music, and emotional tone. These auditory elements provide important contextual and emotional cues that contribute to viewers' understanding of narrative events and overall engagement with video content. Despite growing recognition of the importance of NSI captions, limited research has examined how they influence viewers' experiences or why these effects occur. To assess how current NSI captions impact DHH individuals' viewing experience, we will employ a mixed-methods approach, conducting an experimental study that evaluates the emotional responses of DHH participants using physiological measures. The participants will be asked to watch the same video stimulus with and without NSI captions. Across these two conditions, physiological data such as heart rate and electrodermal activity will be collected, providing objective evidence of how NSI captions influence participants' engagement and emotional responses during video viewing. Following the experimental study, we will conduct follow-up interviews with several questionnaires to further explore participants' subjective experiences with NSI captions, including their perceptions of the usefulness and helpfulness of NSI captions in accessing and engaging with video content. These interviews will also help us contextualize and better understand the observations and results obtained from the physiological measures. By collecting both quantitative and qualitative data, this study aims to provide a comprehensive understanding of how NSI captions influence the viewing experience of DHH individuals. The findings from this study will contribute to the development of design guidelines for NSI captions, design requirements for automated NSI captioning systems, and NSI caption evaluation dimensions. Ultimately, these contributions will support the creation of accessible media content that better meets the needs of DHH viewers.

Computational Analysis of Sulfenic Acid Reactivity

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Sulfenic acids (RSOH) are part of the organosulfur oxoacid compounds, and they are highly reactive sulfur species. Sulfenic acids play a role in biology, where they are known for their important roles in enzymatic catalysis, protein functions, and cellular signaling. Sulfenic acids are unique species that can act as both electrophiles and nucleophiles depending on the reaction environment. If they act as electrophiles, they should react with the common thiol nucleophiles to form disulfides. Disulfide bonds are important in proteins as they help stabilize tertiary and quaternary structures, helping to maintain the correct folding of the protein. Even though there has been recent interest in sulfenic acids, their reactivity remains poorly studied. We cannot study sulfenic acids experimentally because they are unstable and very difficult to isolate in solution. In this study, we investigated how sulfenic acids react when they act as nucleophiles and electrophiles using computational chemistry methods. A series of substituted sulfenic acids and sulfenate anions were studied with methyl thiolate, cysteine thiolate, penicillamine thiolate, bromomethane, iodoacetamide, and chloroethane acting as nucleophiles and electrophiles. We optimized each structure using Density Functional Theory in Gaussian 16, using an implicit solvation model to mimic the effect of water. For each substituted system, we calculated the reaction free energies (ΔG) and activation free energies (ΔG‡). These values will tell us about the thermodynamic and kinetic favorabilities of these reactions. We expect to clarify the preference between oxygen and sulfur attacks when sulfenic acids act as nucleophiles. We also expect to determine the relative reactivity of sulfenic acids and their sulfenate anions when reacting with reagents such as cysteine thiolate and penicillamine thiolate. This research will advance our

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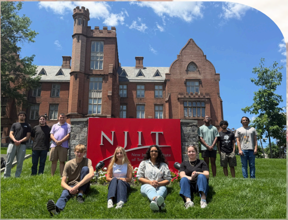

Predicting the Mechanical Properties of Complex Lattice Metamaterials Using Graph Neural Networks

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Lattice metamaterials are engineered solids whose performance is governed not only by constituent material properties, but also by their geometric architecture. Despite their promise as lightweight, strong, and multifunctional materials, uncertainties in their mechanical properties, including stiffness and fracture resistance, raises concerns about their reliability in practical applications. Such uncertainties arise from imperfections and randomness in the dimensions and spatial arrangements of structs introduced during additive manufacturing. These effects are beyond the capability of classical analytical models, which typically assume idealized, perfectly periodic unit cells. Finite element (FE) simulations can resolve these complexities, but they become computationally prohibitive when used to explore the vast space of possible topologies and defect configurations. This work addresses this challenge by developing a fast, topology-aware surrogate model that frames the prediction of stiffness and fracture resistance as a graph learning problem. A lattice can be naturally represented as a graph, where nodes denote joints, edges denote struts, and features encode geometry and boundary conditions. Graph Neural Networks (GNNs) operate on this representation and propagate information along connected edges in a way that mirrors physical load-path transmission through the lattice, thereby enabling mechanical property prediction. The research methodology proceeds in two phases. First, a synthetic dataset is generated using a custom Abaqus scripting pipeline that produces randomized Voronoi-like beam-lattice geometries. Second, a Graph Convolutional Network (GCN) is trained on this dataset, using node coordinates and graph connectivity as inputs to predict global lattice stiffness. Longer-term goals include extending the model to predict fracture behavior of random and imperfect lattice materials, validating its prediction against Fleck-Deshpande-Ashby scaling laws, and testing generalization to unseen topology families. This approach has the potential to reduce the cost of lattice design iterations by orders of magnitude relative to full FE simulations, enabling defect-aware optimization of metamaterials for aerospace, biomedical, and energy absorption applications.

Process Optimization of HfO2-Based RRAM Devices for Low-Power In-Memory Computing Applications

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Due to the circumstances described by the von Neumann bottleneck, computers continue to struggle with reducing power consumption because of the separation between the processing unit and memory unit. Resistive Random-Access Memory (RRAM)-based in-memory computing provides a promising solution by combining processing and memory functionalities. RRAM is nonvolatile, meaning that continuous power is not required for the device to function. RRAM devices consist of a top electrode and a bottom electrode with a metal oxide layer sandwiched between them. As shown in Figure 1, when a voltage is applied to an electrode, oxygen atoms distributed throughout the metal oxide migrate toward the pulsed electrode, leaving behind oxygen vacancies (Vo) through which electrical current can tunnel through. These oxygen vacancies form the conductive filament (CF). By applying a voltage to either electrode, the filament can be formed and ruptured to varying degrees, allowing data to be written and erased as needed; this process is known as the switching mechanism. In this way, RRAM can be implemented in a wide variety of applications. However, further research is needed to determine which metal oxide compositions provide the optimal switching properties, including long endurance, pulse separation, and low forming power. In addition, limited research has been conducted on how the deposition temperature of the metal oxide during fabrication affects these properties. Zeinati et al. demonstrated that hydrogen plasma (H-plasma), when applied during the fabrication process, promotes the formation of additional oxygen vacancies within the metal oxide, resulting in improved switching behavior. Their study showed that hafnium oxide (HfO_2)-based devices perform particularly well with H-plasma treatment, exhibiting endurance exceeding 10^8 cycles while maintaining a forming power of 3.8 nW. This experiment investigates how deposition temperature affects the switching properties and endurance of RRAM devices in conjunction with H-plasma treatment by comparing two devices with the structure 50 nm TiN/6.5 nm HfO_2 (with H-plasma)/Ti/50 nm TiN fabricated at deposition temperatures of 300˚C and 350˚C, as shown in Figure 2.

Monitoring Crack Initiation and Propagation in Concrete Using Embedded Plastic Optical Fiber Sensors

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Concrete is one of the most widely used construction materials in the world, and it is a critical component of bridges, buildings, transportation systems, and other infrastructure. Over time, concrete structures are subjected to mechanical loading, the effects of the environment, and material deterioration that can lead to the initiation and propagation of cracks. When left undetected, cracking can affect structural integrity, reduce service life, and increase maintenance costs. Traditional inspection methods rely heavily on visual observations and periodic evaluations which may not detect damage until significant deterioration has occurred. This has resulted in an increasing interest in Structural Health Monitoring (SHM) systems, which can monitor the state of concrete structures continuously and provide early signs of damage. This research investigates the use of embedded plastic optical fiber (POF) sensors as a cost-effective approach for monitoring crack development in concrete. Plastic optical fibers offer many advantages, including low cost, immunity to electromagnetic interference, flexibility, and very easy installation. Plastic optical fibers will be embedded within concrete beam specimens during casting and curing. The fibers will be positioned at critical locations within the structure. The sensing system will consist of a laser light source, plastic optical fiber, photodetector, and a computer to collect the data. As cracks initiate and propagate within the concrete, deformation and microbending of the embedded fiber are expected to cause changes in transmitted light intensity that will be measured by the photodetector. Controlled loading tests will be performed to evaluate the relationship between optical intensity loss and structural damage. Sensor responses will be analyzed to determine the effectiveness of the system in detecting crack formation and monitoring damage. This study is expected to demonstrate the possibility of using embedded plastic optical fiber sensors for real-time monitoring of concrete structures. Successful implementation of this sensing approach could provide a low-cost alternative to more expensive sensing technologies while improving the ability to detect and track structural damage. The results of this research will contribute to the development of practical SHM systems, which would enable more efficient strategies for maintenance and improved structural safety. Future work may focus on optimizing sensor placement, improving measurement accuracy, and expanding the technology for long-term monitoring on real-world infrastructure.

AI-Assisted Photonic Integrated Circuit Design based on PICasso Framework

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Over the past few years, Large Language Models (LLMs) have been explored in automating engineering design tasks, including the construction of Photonic Integrated Circuits (PICs). As PICs emerge as a key technology for high-speed, energy-efficient computing systems, the need to explore design automation in this field has become increasingly vital. One such LLM framework is PICasso, which reduces the time and labor required for design workflows. However, its current capabilities are limited by restricted component coverage and relatively small evaluation datasets that do not fully reflect the diversity of modern photonic research. This research aims to improve the adaptability and robustness of PICasso by constructing an expanded problem dataset, thereby creating a more comprehensive testing framework. The current benchmark consists of 36 photonic design problems spanning complexity levels 1–3, with complexity 1 featuring fundamental circuits and complexity 3 featuring multi-stage circuits. However, PICasso uses only a subset of the components available in the GDSFactory library, a widely used open-source framework for designing, simulating, and fabricating photonic integrated circuits. Despite the library containing over 200 distinct photonic elements, many of these components are not represented in the current PICasso evaluation dataset, limiting the framework's ability to generalize to broader and more realistic design tasks. To address this limitation, we introduce additional problems, including three complexity-2 and two complexity-3 tasks, and incorporate five previously unused components to increase structural diversity and functional coverage. These new problems will be evaluated by PICasso, which already implements Design Rule Checking (DRC) for physical limitations, Layout Versus Schematic (LVS) validation for wiring consistency, and SAX-based simulation for functional performance. Additionally, different LLM models will be compared to determine which yields the best pass rate. The expectation is that the expanded problem set is largely solvable within the current PICasso framework, while also revealing failure cases where prompt refinement may improve performance. In order to focus more on co-optimization of spacing and wiring, future directions include the development of graph neural network-based verification methods to unify DRC and LVS into a learned structural validation model for more scalable and intelligent assessment of photonic circuit designs.

Real-Time In-Flow Raman Analysis at Membrane Interfaces Using Microfluidic Platforms for Bacteria and PS

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Membrane fouling is a major issue in biopharmaceutical and desalination technologies causing increasing maintenance costs, shorter membrane lifespans, and decreased product quality. Microfluidic platforms integrated with spectroscopic sensing techniques offer the unique opportunity for real-time analysis of these contaminants under controlled flow conditions. Fouling studies have used PS beads to demonstrate the concentration-dependent behavior but there has been no investigation into contaminants relevant to industry applications (i.e. food, pharmaceutical, or chemicals). This study aims to compare the physical framework that controls PS beads as compared to industrially relevant bacteria. A membrane-based microfluidic device will be utilized to investigate on-chip Raman detection of these particles. The study will compare a bare nylon membrane device with a silver nanoparticle (AgNP)-functionalized membrane device to evaluate the benefits of surface-enhanced Raman spectroscopy (SERS) for signal amplification. The project will begin with concentration-dependent detection of 0.8 μm PS beads under flow to establish Raman detection limits and optimize operating conditions. Following successful optimization, the platform will be extended to concentration-dependent bacteria. The outcomes of this work will lay the foundation for a multimodal membrane sensing platform that integrates Raman spectroscopy with future optical and electrochemical sensing approaches.

Hall Measurement of Sensitized PbSe Films

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Infrared detection has become an essential part of modern-day life, with current and potential uses in medicine, long-range detection and surveillance, missile tracking, astronomy, night vision, and more. Mid-wavelength and long-wavelength infrared (MWIR and LWIR) detectors are of particular interest because these wavelengths both are emitted by everyday objects, bypassing the need for external illumination, and pass through the atmosphere even in adverse conditions such as fog, smoke, and smog. Current state-of-the-art MWIR detectors require cryogenic cooling to reach high performance, but lead selenide (PbSe) sensors are a promising candidate for an uncooled option. Avoiding cooling systems can lower size, weight, power consumption, and cost (SWaP-C). Colloidal quantum dot (CQD)-based solution-processing of PbSe films has recently garnered interest due to its solution processability and smoother integration into mass manufacturing compared with traditional fabrication methods such as chemical bath deposition (CBD) and vapor phase deposition (VPD). For all PbSe films, regardless of fabrication procedure, it is widely understood that a sensitization process is essential in stimulating photoconductivity. However, researchers have found different sensitization processes to be optimal for different production methods. A better understanding of the sensitization of CQD films is likely the key to improving performance, as the exact mechanisms are still under debate. Carrier mobility and carrier density are two characteristics of semiconductors that are influential in photoconductive performance, and both can be determined through Hall measurement. By performing these measurements at different points throughout the sensitization process, we expect to gain insight into how each step affects PbSe CQD films and their photoconductivity.

Multiplex Detection of Alzheimer's Disease Biomarkers using a Microfluidic-Based Capacitive Biosensor

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Early diagnosis of Alzheimer's disease is critical for treatment-based intervention and improved patient are. With more than 7.2 million Americans affected today, a number projected to be 13 million by 2050, Alzheimer's disease places an immense emotional and financial burden on patients, families, and healthcare systems. Unfortunately, current early diagnostic methods such as PET scans and cerebrospinal fluid (CSF) analysis are invasive, expensive, and often highly specialized. These limitations emphasize the need for an accessible and easy-to-use point-of-care (POC) diagnostic device for Alzheimer's disease. In the case of early detection, amyloid beta (Aβ) biomarkers, especially the ratio between Aβ42/Aβ40 are clinically relevant. However, due to Aβ40 and Aβ42 differing by only two amino acids, antibody-based detection methods exhibit cross-reactivity or unintended binding to structurally similar peptide species, introducing measurement error into calculated ratios. As a result, there remains a need for multiplex sensing platforms capable of simultaneously distinguishing and quantifying Aβ40 and Aβ42 with improved specificity and analytical accuracy. This study aims to 1) develop a proof-of-concept multiplex capacitance-based biosensor for simultaneous quantification of Aβ42 and Aβ40 in plasma and 2) evaluate its ability to selectively distinguish closely related amyloid beta isoforms. The current design of the sensing platform includes gold and chromium interdigitated electrodes (IDEs) functionalized with polyethylene glycol and immobilized antibodies of the target analyte. In this work, a non-sensing platform functionalized with non-target analyte antibodies was added into the sensor design. Upon sample introduction to the microchannel, non-target analytes were captured by the non-sensing pad, leaving a clear signal for the IDE. Capacitance measurements were collected following exposure to isolated and mixed amyloid beta solutions prepared under physiologically relevant conditions, and sensor performance was analyzed based on sensitivity, selectivity, and signal discrimination between Aβ42 and Aβ40. The proposed platform is expected to improve analytical selectivity and reduce signal interference associated with cross-reactive biomarker detection. By enabling simultaneous quantification of Aβ42 and Aβ40 within a single assay, this work may contribute to more reliable plasma biomarker analysis and advance development of integrated electrochemical biosensors for neurodiagnostics.

Optimizing PICasso Through Multi-Agent Integration

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Silicon photonic integrated circuits (PICs) are increasingly becoming key components of modern computers — deployed for data transfer using optical connections in data centers, used in LiDAR sensors in autonomous cars, and even used in artificial intelligence hardware for computations at a speed only attainable through photonic acceleration. The demand for silicon photonics is predicted to rise to over $7 billion within the next five years, but the means of designing these circuits have remained the same for more than ten years, with most designs still involving manual drawing where every component has to be wired separately using GUI-based software. PICasso, an automated system built at NJIT, offers an alternative: it employs a large language model to automatically convert a plain language description of a photonic circuit into a verified, manufacturing-ready layout in less than eight minutes, compared to the hour it can take a trained designer working manually, through a pipeline covering natural language to circuit description translation, automatic routing, design rules checking, and simulation-based optimization — increasing functional correctness from close to zero to 52% across 36 photonic design benchmarks. This study addresses a specific failure point at the end of that pipeline: the existing PICasso optimizer uses only the Nelder-Mead technique to adjust phase and coupling values, and since Nelder-Mead is a local search method starting from a single point, it fails on complex circuits like 64-QAM modulators and 90° optical hybrids where the optimization landscape contains multiple local optima. The proposed solution is a multi-agent system where multiple agents each start independently from different points in the parameter space suggested by the LLM based on PDK information, with a meta-agent comparing all results and selecting the most effective design — the diversity of starting points making it extremely unlikely that all agents get trapped in the same local minimum. This paper puts forward the system architecture, discusses the coordination protocol among agents, and identifies the open design questions: how agents communicate during optimization, how the parameter space is distributed among agents for circuits with interdependent phase parameters, and how results are aggregated when agents converge to different solutions with varying tradeoffs — answering these questions will enable PICasso to support all kinds of photonic circuits.

Evaluation of AI-Assisted and Classical Signal Processing Methods for Analysis of Biological Structures in Wrapped Quantitative Phase Images

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Quantitative Phase Imaging (QPI) and Optically Computed Phase Microscopy (OCPM) are label-free imaging techniques that enable biological samples to be studied without fluorescent dyes or stains, which can alter cell behavior, cause phototoxicity, and limit long-term imaging experiments. For quantitative biological analysis, a key limitation is that wrapped phase images can contain artifacts such as phase wrapping discontinuities, background curvature, halo effects, and measurement noise. These artifacts can distort local phase variation and biological structures, and may propagate through phase unwrapping if not addressed early in the processing pipeline. This research develops a quantitative benchmark framework for evaluating classical and AI-assisted preprocessing methods for wrapped QPI/OCPM images. Simulated phase datasets with known ground-truth structures were generated with controlled levels of phase wrapping, background distortion, and measurement noise. Four classical phase-processing pipelines were evaluated by comparing corrected outputs against ground truth using quantitative metrics including Structural Similarity Index (SSIM), Mean Squared Error (MSE), correlation, edge preservation, local contrast retention, and artifact-suppression performance. This enabled direct measurement of how well each method suppresses artifacts while preserving biologically meaningful image structure. The best-performing preprocessing approach was then tested on real OCPM images of C2C12 mouse myoblast cells to assess whether improvements observed in simulation translate to experimental biological data. The resulting benchmark also provides paired noisy/clean synthetic datasets for future deep-learning models, including Residual U-Net, DnCNN, Restormer, and Noise2Void architectures. By combining controlled simulation, quantitative evaluation, classical signal processing, and machine learning, this work aims to identify preprocessing strategies that reduce wrapped-phase artifacts before they introduce errors during phase unwrapping. This approach may improve image quality, preserve biologically meaningful cellular structures, and support future studies of cell morphology, cell detachment, and nanoparticle-cell interactions in label-free phase microscopy.

Deployment of a Field-Deployable Electrochemical Lead Sensor for Monitoring Drinking Water Using Impedance Characterization

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Lead contamination remains a pressing public health concern, particularly within water distribution systems, where corrosion causes lead to leach into household plumbing. While current technologies, such as Inductively Coupled Plasma Mass Spectrometry (ICP-MS), offer high accuracy in detecting lead concentrations, they are often hindered by issues related to cost and portability constraints for real-time monitoring. With an increasing legislative movement advocating for the reduction of the EPA-recommended lead action level from 15 ppb to 10 ppb, the demand for a low-cost, real-time, and field-deployable sensor has become increasingly urgent. We build on the four-electrode electrochemical lead sensor developed by Dr. Wen-Chi Lin et al. and integrate it into the FieldKit platform via I2C communication to create a functional, field-deployable sensor. At a cost of $0.10 per sensor unit, this technology presents a viable opportunity for large-scale deployment. However, two notable limitations of the sensor include its qualitative (binary) nature and its lack of specificity regarding other heavy metal ions. Through this platform, we explore impedance-based calibration methods to facilitate a novel quantitative measurement of lead and other heavy metal ions, thereby improving the sensor's accuracy and selectivity. We specifically investigate threshold levels across changes in various impedance spectra at different concentrations of $Pb^{2+}$to enable effective quantitative monitoring. Furthermore, we use electrochemical impedance spectroscopy (EIS) to help distinguish other heavy metal ions, such as copper, which currently contributes to false-positive results. By integrating the sensor within the FieldKit platform and systematically characterizing its electrochemical behavior, we advance a low-cost, field-deployable solution for continuous monitoring of drinking water quality, targeting detection at or below 10 ppb of lead ion concentration in water.

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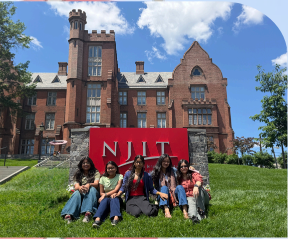

Memory Security

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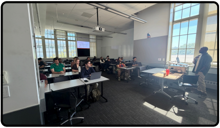
For computer-based data processing and control, all kinds of data is stored in memory. Maintaining the integrity of this data is a crucial factor in computing. To prevent piracy of sensitive information and data, we can use a method known as BlockHammer Technique. The RowHammer is an example which shows how a circuit level failure mechanism can cause widespread system vulnerability in system security. This is when a row is repeatedly accessed in a modern DRAM(Dynamic Memory Access Memory). This repeated accessibility caused bit flips in the physically adjacent rows at consistently predictable bit locations. This is effectively exploited by the malicious wares to gain access to more sensitive information. However, there is a solution to this problem: BlockHammer. As the name suggests, this stops the memory accesses at the hardware memory controller level. It uses checking and reconfirmation techniques to determine if the data has been exploited by malicious ware or not. This is a low-cost technique and effective till date. Here, however, we survey this and discuss what vulnerabilities the DRAM offers and the other types of memories which can threaten the foundation of the secure systems. Our final aim is to predict such attempts and prevent the same.



What is research?

Shear Induced Collagen Fiber Alignment In Bioinks

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Graduate Student mentors: Betelhem S Abay,
Thi Ngoc Hang Truong
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Osteochondral defects remain a persistent clinical challenge, and current treatments have not yet achieved adequate tissue integration to heal the defect. This challenge stems from the complexity of the osteochondral interface, which comprises subchondral bone, calcified cartilage, and articular cartilage (Fig. 1). Among the many components of the interface, collagen fiber is a key component of the extracellular matrix (ECM). The alignment of collagen fibers in each region of the osteochondral interface differs. 3D printing allows the fabrication of a scaffold that can mimic the complexity of the osteochondral interface. Using 3D printing, collagen can be printed with the desired alignment to match the fiber orientation required for each region. Here in this study, we investigated the rheological properties required to print an ink formulation consisting of collagen and methacrylated hyaluronic acid (MeHA). Hyaluronic acid is a component of the ECM, and its functionalization with a methacrylate makes it photocrosslinkable. We use different weight by volume percentage of MeHA to study which combination works the best in creating the required fiber alignment. MeHA is mixed with collagen solution to form the bioinks. The design for printing the bioinks is created on Fusion 360 and it is reviewed through a slicer software. The rheological properties such as the viscosity, flow behavior, and crosslinking time of the bioink are tested with a rheometer. Based on these parameters, the print pressure, speed, and crosslinking time are set on the BIO X printer. The significance of using a BIO X printer is that it allows crosslinking as the material is being printed all the while maintaining a sterile environment. Equally important to these parameters is the nozzle length, inner diameter, and offset which are going to be tested by using different nozzle types. Post printing the construct is observed under a confocal microscope and images are analyzed on ImageJ to assess the fiber alignment with the print direction.

Certifiable Safe-RLHF: Semantic Safety Classification and Exact Penalty Enforcement for LLMs

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Deploying large language models safely remains a critical challenge. The standard Reinforcement Learning from Human Feedback (RLHF) recipe frames safe alignment as a Constrained Markov Decision Process and solves it with primal-dual optimization over reward and cost signals drawn from Bradley-Terry preference models. This recipe has three weaknesses. Its learned scorers tend to react to surface keywords rather than to what a response actually means. Its Bradley-Terry cost model ranks responses only relative to one another, so the pairwise ranking pressure grows with dataset size and can override absolute safety supervision — assigning unsafe scores even to responses explicitly labelled safe, and doing so on datasets of any size. And tuning the Lagrangian dual variables is computationally costly while providing no formal feasibility guarantee, leaving the model exposed to jailbreaks. We study the Certifiable Safe-RLHF (CS-RLHF), a recently developed method, which makes two changes. First, it replaces the comparison-based cost model with a semantic classifier — trained on a carefully curated corpus — that assigns absolute safety labels, fixing the preference-data problem at its source. Second, it swaps the Lagrangian relaxation for a rectified penalty formulation grounded in exact penalty theory, enforcing the safety constraint directly at the optimizer and guaranteeing feasibility without any dual updates. We will investigate whether CS-RLHF is better compared to the existing safe RLHF techniques in helpfulness and harmfulness metrics, including jailbreaking adversarial prompts. Our experimental design involves fine-tuning baseline models under standard Safe-RLHF and CS-RLHF conditions, then evaluating both variants on standard helpfulness and harmlessness benchmarks, and subjecting both models to adversarial jailbreak prompt suites to assess robustness. We anticipate that CS-RLHF will demonstrate a more favourable helpfulness-safety trade-off compared to baseline Safe-RLHF, particularly under adversarial conditions. The absolute safety labels should reduce false negatives on benign responses, while the rectified penalty formulation should provide tighter constraint enforcement and greater resistance to jailbreaks. Future work will explore scaling the approach to larger model families and extending the penalty formulation to multi-constraint settings.

Brain Age Prediction Using Neuroimaging and Machine Learning

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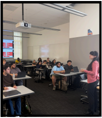
Department of Biomedical Engineering

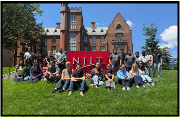
Differences between an individual's brain age and chronological age may reflect variations in brain health that are not defined by age alone. Estimating brain age from neuroimaging data has emerged as a promising approach for understanding healthy brain aging. Th project aims to explore methods to predict brain age from neuroimaging data and understand the relation between predicted brain age and chronological age. The predicted brain age will be compared with the individual's chronological age to investigate whether a greater difference between the two is associated with an increased susceptibility to disorders. The anticipated outcome of this work is a better understanding of brain aging and its potential use as a biomarker for early disease risk assessment contributing to early detection and improved healthcare.

Design of humanoid hand with linkage driven fingers and thumb

Sneha Chowdhury, Advisor: Dr. Cong Wang

Dexterous hands with humanoid fingers and a high number of degrees of freedom (DOFs) are desirable for robots to effectively serve at homes and workplaces. In comparison to the tendon driven designs which are deficient of durability and bi-directional, the linkage driven designs facilitate exceptional articulation due to the presence of multiple DOFs of each actuation joint. However, they face challenges on integrating multiple DOFs to each finger without using complicated mechanisms that require a great number of miniature moving parts. The presence of three bi-directionally actuated DOFs by the MCP joint ensures very few moving parts. The prototype will be tested for finger strength, grip strength, grasp dexterity, and tool usage. . In addition to this, thumb is very important for many hand skills. This project aims to study and improve the existing design of the humanoid robotic hand especially the thumb and making its kinematics as closer to human thumbs and hands.

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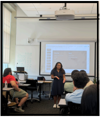

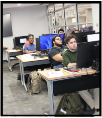

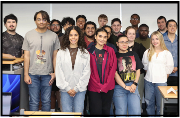

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