NSERC USRA opportunities Summer 2024, Levi Lab (ECE and BME)

Background: Our lab is seeking 2-3 highly motivated Engineering students with experience in hardware and software integration who have completed at least two years of undergraduate studies by summer 2024 for a 4-month long summer research that is co-sponsored by the Levi lab. The students will be submitting HF Transform and NSERC USRA research scholarship applications with Dr. Levi for the summer. The students will be part of a dynamic interdisciplinary research team in the Levi lab and receive one-on-one mentorship with our graduate students. The students should be comfortable with open-ended problem solving and be willing to learn new concepts/skills from multiple engineering disciplines (e.g., biomedical, photonics, computer, electrical, mechanical, etc.). More details about the Levi lab and ongoing research directions can be found at: **http://biophotonics.utoronto.ca**

How to apply: Please send the following to sarvath(dot)sharma(at)mail(dot)utoronto(dot)ca:

1) Subject Line: NSERC USRA Summer 2024 Opportunity
2) Your preferred project/role (see below)
3) CV
4) Unofficial transcript

Project 1: Remote Oxygenation Monitoring of Tissue

1.1 Outline of Proposed Research Project

In the past decade, smartphones, and wearable devices (e.g., smartwatches) have become ubiquitous. We wish to use small, smartphone scale cameras to identify various vital sign measures from people in an unobtrusive manner. Signals of interest include but are not limited to blood pressure and blood oxygenation. Monitoring vital signs is key to tracking changing health conditions in elderly patients and in those recovering from heart surgeries. Our end goal is to develop measurement systems that are robust enough to be applied in real-world scenarios, allowing us to continually monitor vital sign information in a remote manner, without burdening the user. Moreover, we also wish to determine the simplest, cheapest, and most accessible technologies that are capable of achieving these goals. In this project, we aim to design and demonstrate a remote optical tissue oxygenation monitoring system that can quantize tissue oxygenation values at shallow tissue depths (~ 1-3 mm) from various distances (up to 2 meters away). To improve system motion robustness, we wish to leverage coherent illumination and structured light optimization techniques. Our intention is to apply this system towards both short or long-term patient health monitoring applications in clinical settings or for rapid health screening of large populations in high throughput scenarios.

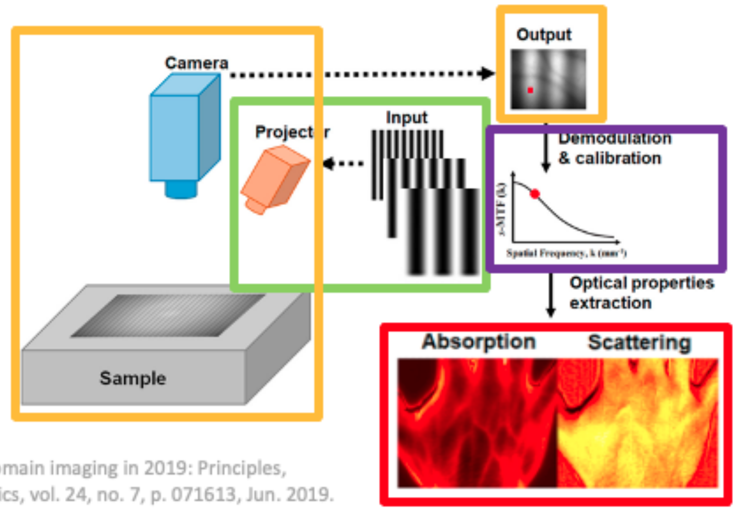
1.2 Outline of Student's Role

The student will focus on setting up an optical imaging system to collect data about tissue oxygenation values, from both tissue phantoms and subject hands in a controlled lab setting. This will include hardware and software integration for data acquisition and recording of oximetry values from different tissue penetration depths. Exploring the depth dependency on collected data such as light absorption and scattering, can be useful to develop more robust algorithms that compensate for depth variation. The student will be trained to work with different types of lasers as coherent sources and will study the unique phenomenon of coherent illumination. Various algorithms will be studied for optimizing structured light, including the use of a spatial light modulator. The student will be able to construct an overall understanding about light-tissue interaction, and design better systems that serve to measure tissue oxygenation level with remote optical settings.

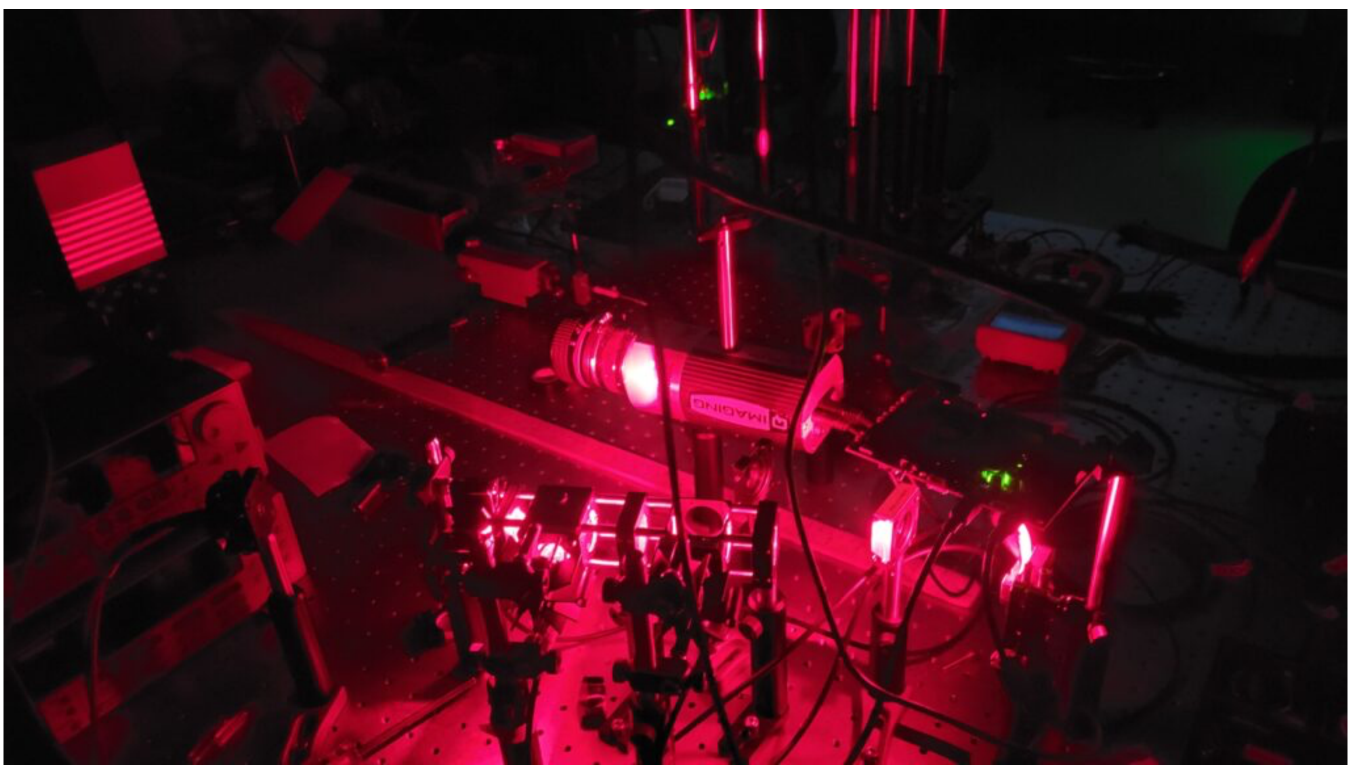
Quick introduction to Spatial Frequency Domain Imaging (SFDI)

Widefield measurement of tissue optical properties.

1. Project sinusoidal pattern onto tissue.
2. Take picture of sample, which blurs projection pattern.
3. Repeat 1-2 for multiple sinusoidal patterns with different phases/frequencies.
4. Compute frequency-dependent tissue reflectance from how the tissues blur the patterns.
5. Map measured reflectance to tissue optical properties.



S. Gioux, A. Mazhar, and D. J. Cuccia, "Spatial frequency domain imaging in 2019: Principles, applications, and perspectives," Journal of Biomedical Optics, vol. 24, no. 7, p. 071613, Jun. 2019.



<u>Project 2:</u> <u>Optimization of Sensitive Optical Ultrasound Sensors for Biomedical Applications.</u>

2.1 Outline of Proposed Research Project

Photoacoustic Imaging (PAI) is a hybrid imaging modality that combines the benefits of both optical excitation and acoustic detection. When PAI systems irradiate tissue with high intensity pulses of non-ionizing radiation, the resulting localized heating and cooling leads to the formation of propagating ultrasound waves (travelling pressure waves), which can be subsequently measured and used to reconstruct absorption-contrast-based 2D or 3D images of deep tissue regions. PAI systems can be used to monitor cell and tissue properties of organ-on-a-chip samples as part of lab-on-a-chip system, to provide real-time feedback for blood clot removal to improve blood circulation for heart patients, and to generate higher spatial resolution images for assessing tissue circulation than those obtainable through more traditional ultrasound imaging techniques.

Our current aim is to develop new more sensitive all-optical integrated ultrasound sensors, optimized for *in vivo* tissue imaging applications, as building blocks for future PAI systems for use within clinical settings. Our current sensor designs leverage silicon photonics fabrication techniques to integrate multiple optical devices (photonic integrated circuits) onto a single chip. We seek an upper year undergraduate student with experience in optics, electromagnetics, and numerical scientific computing methods to help us explore and evaluate new designs for nanophotonic devices and sensors.

2.2 Outline of Student's Role

2.2.1 Modelling of All-optical Ultrasound Sensors

Our lab currently uses various simulation tools (e.g., Ansys-Lumerical, S4) to evaluate and optimize new sensor designs by modelling how electromagnetic waves propagate through and interact with their geometry. This research will be focused on the exploration and optimization of different refractive index sensor designs and system architectures for ultrasound detection.

The student will learn how to optimize the geometry and layer composition of new sensor designs so that they are able to achieve higher sensitivities while maintaining fabrication compatibility with current silicon photonic foundry fabrication processes. The student will gain experience setting up, running, and analyzing data for both lower-level simulations to model individual integrated sensing system components and higher-level simulations to model how multiple optical components interact with one another in different system configurations. Through the aforementioned modelling activities, the student will gain valuable experience in time-domain and frequency-domain methods for determining the optical properties of nanophotonic metamaterial devices.

2.2.2 Evaluating the Properties of All-Optical Ultrasound Sensors

Real-world sensor performance can differ greatly from simulated performance due to manufacturing variations or defects inherent to a given fabrication process. Our lab fabricates and empirically evaluates new sensor designs to determine the degree of deviation between their simulated and real-world performance.

To empirically evaluate integrated optical devices, laser light must be coupled to/from on-chip grating couplers and/or edge couplers. The associated alignment process is currently conducted manually, with multiple digital microscopes providing visual aids for precise localization. An operator must first determine the location of a given device and then precisely align interrogating fibers with micron-level precision to achieve adequate light coupling. We would like to develop new algorithms/routines/tools to automate/partially automate this manual alignment and evaluation process to allow for faster and more repeatable characterization of multiple on-chip devices.

In this area, the student will first aim to gain a thorough understanding of how to manually interrogate individual integrated optical sensors (i.e., how to align to and measure key sensor performance metrics such as spectral location, quality factor, extinction ratio, and spectral sensitivity). They will then aim to optimize/automate various aspects of the current chip interrogation process to reduce the need for human interaction when evaluating multiple devices sequentially. They will then assess and compare the relative performance of the modified system to the original using quantifiable metrics (e.g., alignment accuracy, runtime, repeatability, etc).