**NSERC USRA opportunities Summer 2025, Levi Lab (ECE and BME)**
**Background:** The Levi lab (**http://biophotonics.utoronto.ca/**) develops optical sensors and imaging systems for biomedical applications. We are 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 2025 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.). Our lab is affiliated with the Electrical and Computer Engineering Department (ECE), the Institute for Biomedical Engineering (IBME), the Transform Heart Failure (Transform HF, **https://transformhf.ca**) collaborative network, and the CRANIA NeuroModulation Institute (CNMI).

**How to apply:** Please send the following to sidy(dot)ndiongue(at)mail(dot)utoronto(dot)ca:

1) Subject Line: NSERC USRA Summer 2025 Opportunity
2) Your preferred project/role (see below)
3) CV
4) Unofficial transcript (e.g. printout of complete academic history from Acorn).

**Eligibility:** Please ensure you meet the following requirements before applying:

1) 2 or more years of engineering/physics undergraduate studies by summer 2025.
2) Eligible to submit an NSERC USRA application (see below).
3) ML/AI is not the main theme of your summer research interests.

Applications are currently being considered on a rolling basis so prompt submission is recommended. Interviews will start during reading week from February 20th.
Additionally, prospective applicants should also review the information available at the ECE's NSERC USRA page, with newly updated instructions for this year on how to apply, application eligibility requirements and related application deadlines.
A link to the centralized **UTEA & USRA Award Submission MS Form** can be found here.

**Area 1: Remote patient monitoring**

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. Biological signals of interest include blood pressure, blood oxygenation, heart rate, respiration rate, etc. While some vital information can be gathered from simple cameras, these systems are typically limited in constant monitoring as frequent direct user engagement is required. Our end goal is to develop systems and optimal acquisition algorithms that are robust enough for use in real-world scenarios. These systems should be designed with accessibility in mind and be capable of continually monitoring vital sign information without imposing a burden on the user. Moreover, we wish to determine the simplest, most cost-effective, and most accessible technological approaches to achieve these goals.

We aim to identify people's vital signs via a low-cost, always-available technology. We use customized optical imaging technologies, machine vision algorithms, automated subject tracking via pre-trained machine learning algorithms, and collaborate with research teams in hospitals and industry to ensure that our outcomes benefit patients. This research is part of a collaboration with the Computational Imaging group in CS, Laval University and Thales Canada, and the Institute of Optics (INO) in QC.

**Example projects / collaborations:**

**Remote monitoring of tissue**

Spatial frequency domain imaging (SFDI) is a non-invasive tissue oxygenation imaging technique (Gioux 2019). We aim to design and demonstrate a remote optical tissue oxygenation monitoring system that can map tissue oxygenation values from various distances (up to 2 meters away) with SFDI. We wish to incorporate computational imaging algorithms and optimized hardware (e.g., miniature light sources, light modulators) to improve system accuracy and motion robustness, reduce bias due to skin color, reduce error due to defocus, leverage coherent effects, and extract oxygenation data from variable depths in tissue. Additionally, we apply computer vision techniques in infrared/depth video imaging to extract vital signs (heart rate, breathing rate) from a moving subject.

**Integration of blood flow evaluation with remote oxygenation monitoring**

Blood flow is an important vital sign to assess the cardiovascular conditions of patients, which could be measured through Laser speckle contrast imaging (LSCI). Speckles are formed with the illumination from a coherent light source (i.e. lasers), where analysis can be performed to calculate the contrast of speckles, that tells information of fluid movement underneath the surface. We aim to design and construct tissue mimicking phantoms combined with microfluidic channels, simulating blood vessels in the tissue and measure flow rates. The goal is to design a robust platform for blood flow measurements with lasers, which could be integrated with the blood oxygenation evaluation in a compact system.

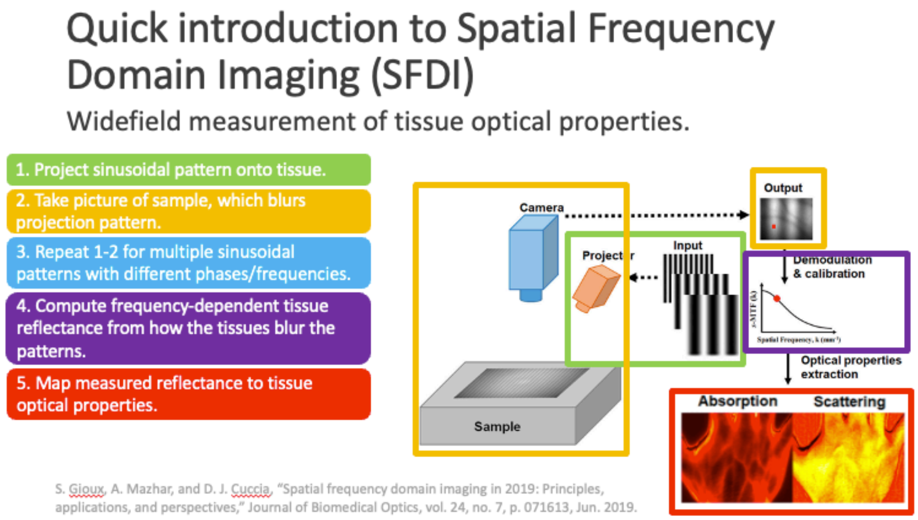
**References:**

Sylvain Gioux, Amaan Mazhar, David J. Cuccia, "Spatial frequency domain imaging in 2019: principles, applications, and perspectives," J. Biomed. Opt. 24(7) 071613 (20 June 2019).

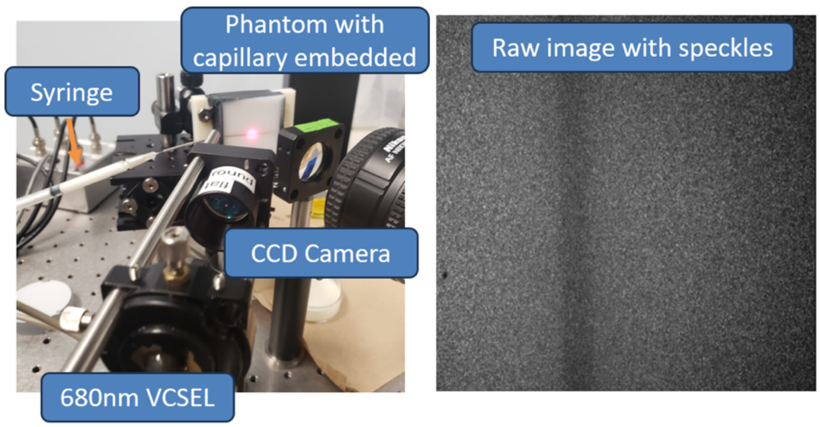
Ryan Chu, Lindsay Kuramoto, Dene Ringuette, Eric Zhu, Ofer Levi, "Correlation of near-infrared intensity and depth channels for remote vital signs monitoring," Proc. SPIE 11651, Optical Diagnostics and Sensing XXI: Toward Point-of-Care Diagnostics, 116510F (5 March 2021).

D. Ringuette, M. A. Jeffrey, S. Dufour, P. L. Carlen, and O. Levi, “Continuous multi-modality brain imaging reveals modified neurovascular seizure response after intervention,” Biomed. Opt. Express **8**, 873–889 (2017).

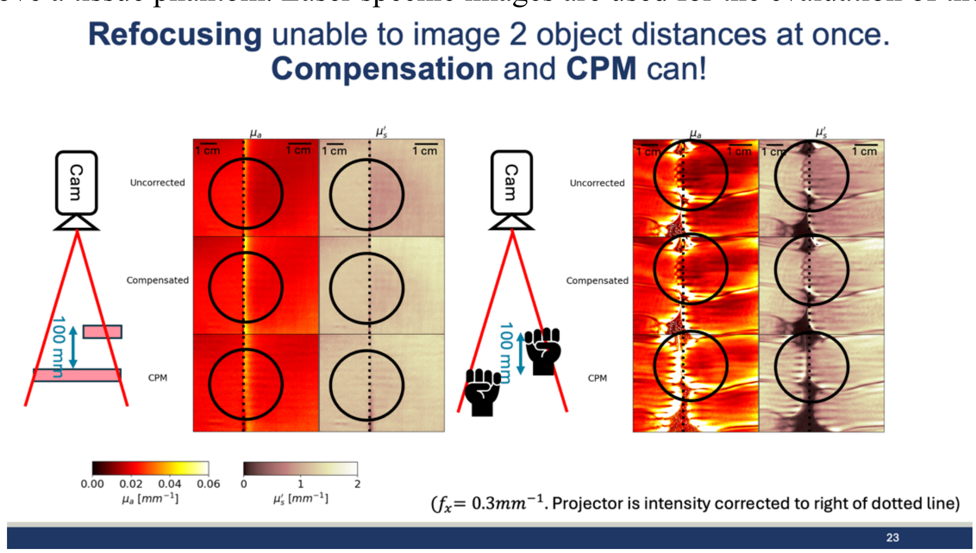
I. Sigal, M. M. Koletar, D. Ringuette, R. Gad, M. Jeffrey, P. L. Carlen, B. Stefanovic, and O. Levi, “Imaging brain activity during seizures in freely behaving rats using a miniature multi-modal imaging system,” Biomed. Opt. Express 7, 3596–3609 (2016).




Summary of spatial frequency domain imaging technique (Adapted from Gioux 2019).




Flow measurement system with a laser (680nm VCSEL). The fluid is flowing into a micro-capillary, located above a tissue phantom. Laser speckle images are used for the evaluation of the flow rate.




Defocus correction techniques (compensation, cubic phase mask)
used to correct defocus/image blur due to subject movement.

**Area 2: Optimization of integrated optical ultrasound sensors for biomedical applications.**
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 for real-time monitoring in laser-based retinal surgeries, to measure 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.

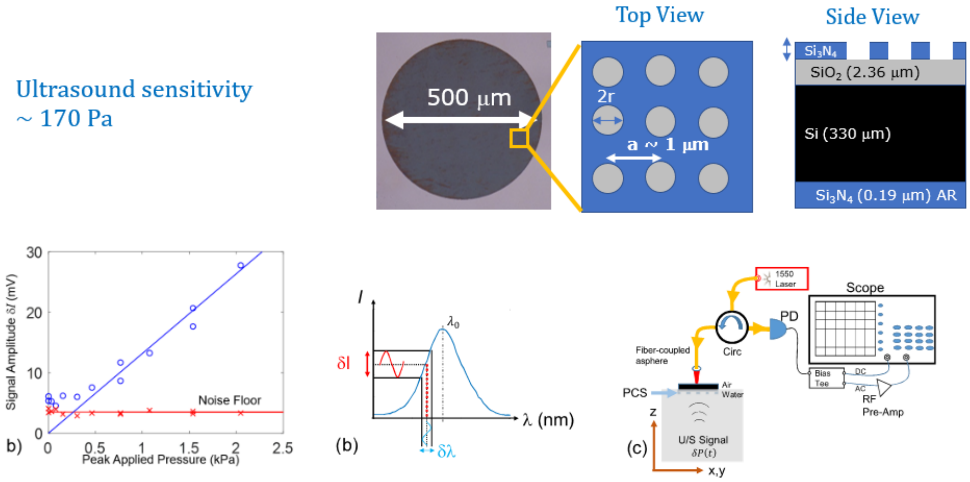
Our aim is to develop new more-sensitive all-optical integrated ultrasound sensors, optimized for *in vivo* tissue imaging applications, as building blocks for future PAI systems for use within clinical settings. Our current sensor designs leverage silicon photonics-based fabrication techniques to integrate multiple optical devices (photonic integrated circuits) onto a single chip. The student will be engaged in simulation and experimental work involving optics, electromagnetics, and numerical scientific computing methods to help us optimize and evaluate new designs for nanophotonic devices and sensors.

**Example projects**

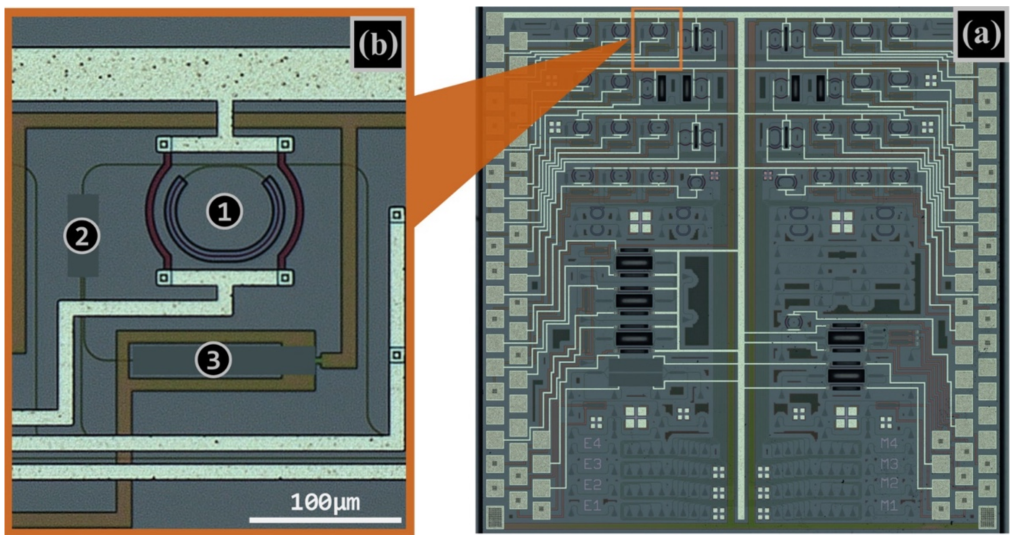
**Simulation-based modelling of all-optical ultrasound sensors**
Our lab uses several optical simulation tools to design and evaluate optical sensor performance by simulating the effect of incident ultrasound waves. We aim to explore multiple designs for integrated silicon photonic sensors capable of detecting ultrasound, such as ring and linear waveguide resonators, and photonic crystal slabs (PCS). This work will involve simulations to explore and optimize sensor performance for ultrasound sensing. In these modelling activities, the student will gain valuable experience with standard simulation techniques such as time-domain (Finite-Difference Time Domain - FDTD) and frequency-domain (Rigorous Coupled-Wave Analysis - RCWA, Finite-Difference Eigenmode (FDE), Plane Wave Expansion - PWE) methods for determining the optical properties of nanophotonic metamaterial-based devices, which can be applied towards biomedical sensing and ultrasound detection applications.

**Empirical evaluation of all-optical ultrasound sensor performance**
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 the performance of our new sensor designs to determine whether their real-world performance remains within optimal simulated ranges. To characterize sensor performance, laser light is coupled into and out of individual sensor devices to measure their optical and ultrasound sensitivity. We seek to evaluate different approaches for interrogating on-chip sensors and to improve our manual interrogation process to allow for faster, more repeatable characterization of multiple integrated devices through the use of cameras and machine vision algorithms.

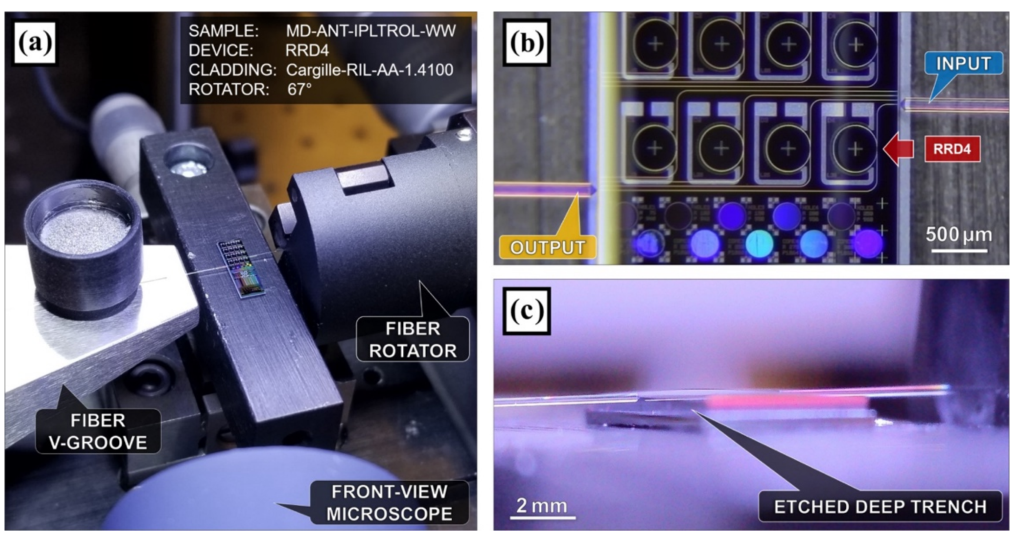
**References:**
E. Y. Zhu, M. C. Charles, C. Rewcastle, R. Gad, L. Qian and O. Levi, "Real-time ultrasound sensing with a mode-optimized photonic crystal slab ", Optics Letters, 46(14), 3372-3375 (2021)
M. A. Downing, "Active Integrated Silicon Photonic Refractive Index Sensors for Biosensing Applications," M.S. thesis, University of Toronto, Toronto, Ontario, September 2024.




Ultrasound sensing with photonic crystal slab (PCS) nanostructure chip.




Silicon photonics biosensor test chip fabricated through AMF (Singapore).




Optical interrogation setup for silicon photonic biosensors.