Designs in Fabrication

Prototyping Report

April 2022 – March 2023

CMC Microsystems | www.CMC.ca

CMC Microsystems

Lowering barriers to technology adoption

CMC Microsystems is a not-for-profit organization that accelerates research and innovation in advanced technologies including microelectronics, photonics, microelectromechanical systems (MEMS), Internet of Things (IoT), Artificial Intelligence (AI), and quantum software and hardware. Founded in 1984, CMC lowers the cost and complexity of technology adoption by creating and sharing platform technologies including access to state-of-the-art design, manufacturing, and testing capabilities. CMC enables research, development, and the training of highly qualified personnel (HQP) for an international network of over 10,000 researchers and more than 1,200 companies developing innovations in advanced technologies. The key values of CMC are: benefits to Canada, a role as an honest broker, and research impact.

CMC Microsystems' fabrication reports – describing designs that have progressed to fabrication – are published for distribution at:

www.CMC.ca/FAB

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Amidst Ongoing Semiconductor Shortage, CMC Continues to Grow Chip Designers of Tomorrow

CMC's foundry partners fabricate over 480 designs

May 10, 2023: In a global environment of ongoing tumultuous shortage of semiconductor chips and significant government investments in advanced technology initiatives, CMC logged another stellar year of prototyping, with over 480 chip designs manufactured. That number is expected to grow by at least ten percent in 2023.

CMC is playing a key role in helping to build Canada's semiconductor sector. Each of these manufactured chips are unique engineering prototypes with the potential for breakthroughs leading to licensed technology or start up companies. 386 of the prototypes were designed by academics in Canada, 71 from academics internationally, and 26 from industry and other organizations.

CMC has agreements in place with 68 Canadian universities and colleges through which students can access specialized software to design chips. They also have access to testing equipment and, most importantly, again through CMC, they can have their prototype chips manufactured by a chip foundry. This is critical to developing the next generation of innovators for industry in Canada.

Applied Nanotools (ANT) and Teledyne MEMS both of Edmonton are two companies with whom CMC has agreements in place to facilitate the manufacture of university researcher's designs.

Teledyne MEMS Plant Manager, Steve Bonham is proud of his firm's role in training new chip designers. "To be truly effective, researchers must have the tools and the processes to not only design integrated devices, but they also need to have their prototypes fabricated. It is the true test of their designs, and we are pleased to play a role in this network."

Mirwais Aktary, President and CEO of Applied Nanotools has a similar take on his firm's role with CMC. "We believe it's important to support Canadian university designers because these individuals are the future of the industry in Canada."

Gordon Harling, President of CMC said the demand for design and fabrication services continues to grow. "We make chip design and fabrication, an affordable and real-world process. And that makes for more highly qualified graduates that can join existing Canadian companies or start their own firms".

FAB

www.CMC.ca/cmc-NEWS

Looking for Collaborative Opportunities?

For further information we encourage you to contact researchers directly, or contact us:

FAB@cmc.ca

Join the conversation …

CMC's Micro-Nanotechnologies R&D Community LinkedIn Group
www.linkedin.com/groups/1891075/

CMC Microsystems and Canada's National Design Network®

CMC and Canada's National Design Network (CNDN) were established in 1984 with support from the Natural Sciences and Engineering Research Council of Canada (NSERC). The CNDN project closes in 2023/24. We wish to thank NSERC together with the Canada Foundation for Innovation (CFI) for **40 years** of funding innovative microchip (chip) prototype manufacturing and invite researchers to follow us and learn about CMC's newest semiconductor ecosystem initiatives. www.CMC.ca

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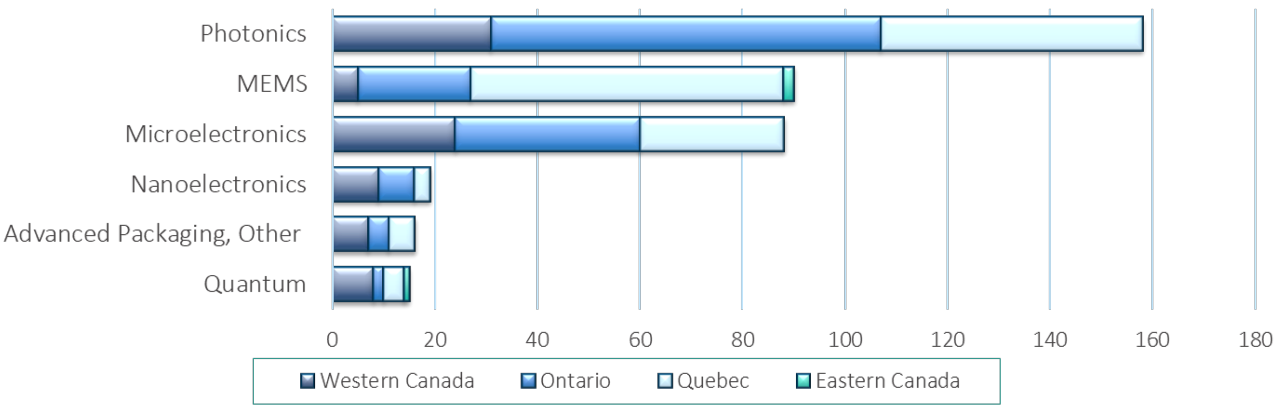
Introduction

CMC Microsystems (CMC) delivers key services including industrial-scale multi-project wafer (MPW) manufacturing services, value-added packaging and assembly services and in-house expertise for first-time-right prototypes.

In the past year, 483 designs were fabricated through CMC's global network

- **414** (of 483) designs were fabricated through CMC's global supply chain of multi-project wafer (MPW) services; **69** designs were developed through a micro- nano technologies (MNT) network of 40 university-based labs in Canada.
- **386** (of (483) by academics and 5 by industry in Canada; 71 by academics and 21 by industry and other organizations not-in-Canada

This report provides a view into the activities of researchers in Canadian post-secondary institutions by describing academic designs that have progressed to fabrication (FAB) between April 2022 and March 2023.



n = 391 (of 483) | Other includes advanced packaging, special requests, and microfluidics.

Figure 1 – Researchers and Industry in Canada, 2022/23

A World-wide Industrial Supply Chain

CMC's strategies focus on a supply chain ecosystem of more than 100 organizations – over 50 operating in Canada – that enables world-class industry/academic collaboration and expands support for industrial R&D. For example:

GlobalFoundries and the GlobalFoundries® logo are trademarks or registered trademarks of GlobalFoundries Inc.

Three-year highlights: 1,220 designs fabricated

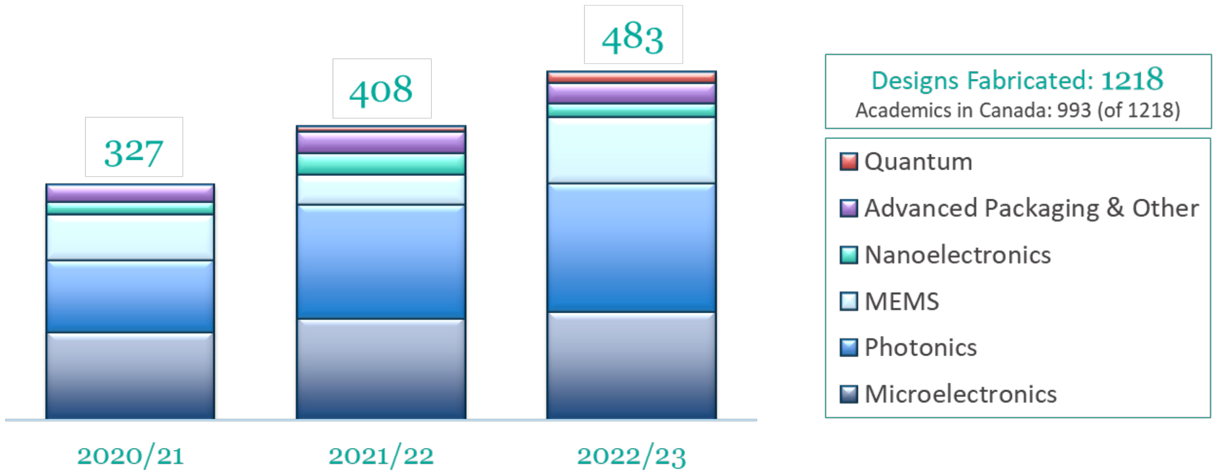
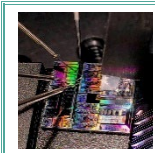


Figure 2 - Designs Fabricated 2020/21 – 2022/23

- Quantum introduced in 2021/22 (7 designs) and 2022/23 (15 designs)
- GlobalFoundries® (GF) sponsored designs in 2022/23: 40
- Other includes special requests and microfluidics.



- 1,305 photonics designs fabricated, 2007/08 through 2020/23
- 909 (of 1,305) silicon photonics designs (includes fabrication training program)

CMC's Collaborative R&D & Commercial Services

- **VIE – Virtual Incubator Environment** for start-ups offers access to design tools and technologies, CMC's technical expertise, and state-of-the-art fabrication. Visit: www.CMC.ca/VIE
- **Commercial R&D – f**abrication, packaging and assembly – backed by CMC's technical expertise and global supply chain, training workshops, and networking events. Visit: www.CMC.ca/Commercial-Services
- **CMC SponsorChip™** is an opportunity for companies to accelerate their R&D, access talent, and support research in Canada through sponsorship. Contact sales@CMC.ca to discuss your interests and subscription options.

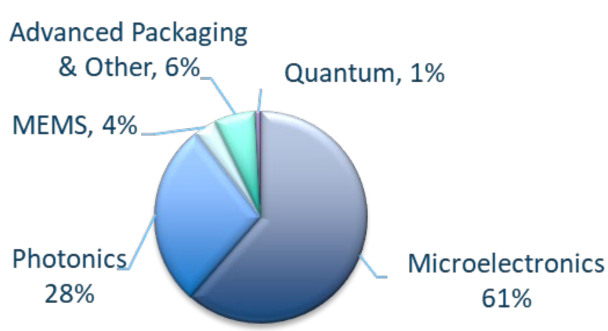


Figure 3: Five-year Industrial & Academic Located-Outside-Canada Designs Fabricated

- Period: 2018/19 – 2022/23
- Quantum introduced in 2021/22
- Actual designs: 257. Representing 14% of total fabricated in period)

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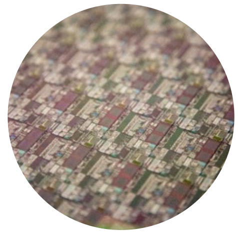

MICROELECTRONICS

Strategic partnerships ensure CMC has access to technologies across various foundries including AMS, GlobalFoundries®, STMicroelectronics, Taiwan Semiconductor Manufacturing Company (TSMC), and X-FAB. This portfolio supports researchers across a variety of growth areas, including Analog, RF, Mixed signal, RF, Digital and Optoelectronics. **Spotlight on microelectronics:** www.CMC.ca/Microelectronics

Technology: 12-nanometer FinFET CMOS

GF 12LP

Detection and Compensation for Process Variation and Aging in FinFET Technology

Applications include: ICT (Microelectronic reliability in high speed, low power telecommunications circuits)

We propose to build a set of sensing circuits based on delay chain topologies that allow us to detect threshold voltage (VTH) and drain current (ID) variation in devices of interest. Sensor readings will be verified by a complementary RF S-parameter test bench that focuses on an analogous set of devices under test. Additional parameters such as CISS, gm, and transients will be measured. From sensor readings, adaptive circuits will correct bias conditions on a live logical circuit to compensate for data integrity due to both PV and aging effects. The application is intended for both active compensation in live circuit operation as well as providing data for FinFET model advancement.

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Study Single Event and Total Ionizing Dose Effects in 12nm FinFET Technology

Applications include: Aerospace

FinFET transistors have become a high-demand technology for a variety of computing applications due to their superior gate control, low power consumption, and lower leakage current compared to similar bulk technologies. This also makes them attractive for use in high reliability applications, however the effects of energetic particles and total ionizing dosage from radioactive sources needs to be evaluated before it could be used for such applications as servers, automobiles, and space. The objective of this project is to study and evaluate soft error rates in digital circuits implemented in a 12nm FinFET test chip and to provide guidelines for engineers and researchers in the radiation effects and reliability community. The test chip design includes various types of flip flops from standard designs to fault-tolerant ones. It will also include some ring oscillator circuits and a high-speed clock tree to drive the flip flop circuits from an on-chip clock generator. The flip flop circuits will be monitored via both on-chip and off-chip detecting circuits for soft errors. The RO circuits will be monitored for changes in frequency degradation and power consumption during ionizing radiation tests. The obtained results can provide valuable information about soft error rates in this technology and give support for improving the reliability of the integrated circuits.

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Technology: 22-nanometer FDSOI CMOS

GF 22nm FDX

AI Front-End

Applications include: ICT

The proposed solution aim to realize a complete Analog Neural Network for Wireless RX optimization

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Analog ASIC Artificial Intelligence at the Edge C1

Applications include: ICT

Analog Neural Network and Tunneling Current Control

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Battery Lifetime Optimization for AI @ Edge Devices

Applications include: ICT (semiconductor IP design)

This project aims to build a multi-sources energy harvester with optimized and ultra-low power conditioning and battery charging system design. It aims to develop a flexible architecture in advanced 22nm CMOS technology in order to efficiently benefit from several energy sources simultaneously and accommodate different power network applications. The project involves several wireless power charging systems: DC energy harvester (ring oscillator, and charge pump), and an inductive power and data transfer system (Gate driver for class E power amplifier, Voltage regulator, OOK modulator/demodulator, and LSK modulator/demodulator). The primary objective is to test some innovative ideas in the design like the ring oscillator (for DC EH), and the OOK demodulator (for the inductive system) and validate the functionality and performances of the proposed systems.

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Battery Lifetime Optimization for AI @ Edge Devices

Applications include: ICT (semiconductor IP design)

The next generation of IoT devices will be wireless due to inconvenience, costs, or in some cases, the inability to wiring them. In addition, many of them might have strict size constraints. Powering and ensuring ultra-long autonomy for devices with no cord for power and limited space for a battery becomes a daunting challenge. Further, in order to make the smart objects paradigm come true (devices with embedded intelligence and high level of autonomy and communication) we are developing self-power managed system with data communication ability which has an ultra-low power consumption, small and simple implementation, and overall optimized performance. This project aims to build a multisource energy harvester with optimized and ultra-low power conditioning design in advanced 22nm CMOS technology. The project involves several blocks of three wireless charging systems: RF energy harvester (Impedance matching circuit and RF rectifier). The primary objective is to test some innovative ideas in the design of the RF rectifier (for RFEH).

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Filter-Bank MultiCarrier

Applications include: ICT

In the pursuit of approaching Shannon's capacity, alternative high-speed wireline modulation schemes other than PAM4 are being investigated. One promising candidate is Filter-Bank MultiCarrer (FBMC) as it enables precise control over the transmitted signal's spectral utilization. This tapeout's primary objective is to determine the feasibility and potential data rate performance benefits available from this technology. This will be accomplished by implementing a complete FBMC system. First, an on-chip transmitter will encode a PRBS sequence into an FBMC signal. Next, this signal will be transmitted to an on-chip receiver, where digital impairments such as a channel response, quantization, noise, non-linearity, and jitter will be added. These impairments emulate the impairments found in practical links. Finally, the received signal will be decoded and analyzed using an on-chip Bit-Error-Rate-Tester (BERT).

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Low-phase-noise Oscillator

Applications include: ICT

Oscillators generate reference timing for bit streams in a wireline system, and carrier signals in wireless communication and radar systems. The objective for this design is to realize a fully-integrated oscillator in 22-nm silicon CMOS operating at GHz frequencies and relying on a series-resonant L-C bridge. The applicant's expertise in the design of L-C passives, low-noise amplifiers and power amplifier stages will be applied to implement the high-quality electronics and bridge resonator required to realize the desired phase noise performance. On-chip digital tuning and calibration methods will be applied rigorously to compensate for imperfections in the oscillator realization.

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Radiation Effects Studying on PLLs and VCOs using FDSOI 22nm Technology

Applications include: Aerospace, Automotive, Other (safety, security)

PLLs have been widely used in different applications, such as frequency synthesis, clock recovery circuits, local oscillator (LO), frequency generators, etc. The main function of the PLL is to produce an output signal at a specific frequency. A PLL generally comprises a phase detector (PD), charge pump, loop filter, a voltage-controlled oscillator, and a fractional divider. For electronic systems applied in space applications, PLL circuits are exposed to various sources of radiation that can have a catastrophic effect on their performance. The single event transient (SET) effects induced by radiation particles will impact the performance of the PLL circuits, causing a phase noise degradation or frequency shift. It in turn may cause the loss of PLL frequency lock, generally due to failures in the operation of the charge pump or the VCO, which are the most sensitive blocks in the entire system at the presence of single event effects. If the CP is hardened-enough to SETs, the VCO becomes the most sensitive block, causing the majority of the single event transients (SETs) generated in the PLL. In this project, different sensitive sub-circuits of the PLL will be designed and tested to investigate their radiation sensitivity. Two different voltage-controlled oscillators will be implemented and tested to identify their advantages regarding functionality and radiation tolerance. First a Voltage controlled Ring Oscillator with current level control will be implemented to study the relationship between current levels and SET. Additionally, a multi-pass differential VCO will be fabricated as a possible hardening technique. LDO and op amps are also designed and embedded in the PLLs to achieve better performance in terms of less jitter and stability. Finally, two fully integrated PLL in FDSOI 28nm process will be implemented for radiation analysis, taking advantage of some characteristics offered by this technology such as extremely small charge collection volume.

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Software Defined Wireless RX

Applications include: ICT

The proposed solution aim to realize a complete wireless receiver only with a quantized analog structure based on an LNA and an analog to digital converter without the need of mixers and fractional PLL or analog base band filters. This approach will make the radio fully reconfigurable for future standards and very low power. An equivalent 12-bit SAR ADC architecture sample at 3GHz will be implement by consuming a fraction of the power of the state-of-the-art ADCs in the same range

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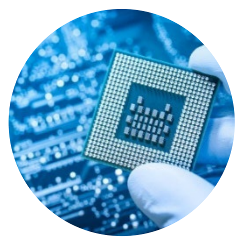

Technology: 28-nanometer Bulk CMOS

TSMC 28nm HPC+

Neural Recording Chip for Epilepsy Monitoring

Applications include: Health/Biomedical

This project aims to design the electronics of a cortical implant for seizure forecasting up to 24 hours before occurrence for people suffering from epilepsy. The forecasts will enable patients to take precautionary measurements to prevent injury and allow time-specific treatment. The system is composed of four neurorecorders wired to a central hub. The ASIC submitted in this request for manufacturing is the central part of the neurorecorder. Each implant consists of a neural recording ASIC encapsulated in a biocompatible package with its ancillary electronics, implanted into the brain.

More specifically, the neural recording chip is a mixed-signal ASIC consisting of an array of 49 pixels individually coupled to 49 low-noise amplifiers that can acquire neural spikes with an amplitude up to 1 mV with noise not exceeding 5 uV. These spikes are digitized with a shared ramp ADC then processed with a digital controller that compresses, serializes and transmits the data via a wired link. The controller digital spike compression unit enables high resolution recording with a reduced outgoing data rate and hence low power consumption.

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Technology: 45-nanometer RFSOI CMOS

GF 45nm RFSOI

37-41 GHz Front-end Module For 5G Mobile and Satellite Communication Transceivers

Applications include: ICT

Lately, millimeter-wave (mm-wave) frequency bands have been gaining lots of research interest as they can provide high data throughput and improved system capacity required by future mobile and satellite communication systems.

This project aims to design a complete transceiver IC for 37-41 GHz mobile communication. This design builds on the previous runs where building blocks, including the switch, phase shifter, and PA was designed and tested at the component level and promising results were obtained.

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Broadband Multiline TRL Calibration Substrate

Applications include: ICT

Lately, millimeter-wave (mm-wave) frequency bands have been gaining lots of research interest as they can provide high data throughput and improved system capacity required by future mobile and satellite communication systems.

The integrated circuit design (IC) design at these frequency bands is the preferred solution due to its compactness and low cost. Hence, the calibration of the fabricated IC is critical in the measurement process to ensure accurate measurement . This project includes a multiline TRL calibration substrate that is targeted to be used in the calibration of our fabricated ICs to de-embed the effect of the RF probes.

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Professor: Slim Boumaiza | Email: slim.boumaiza@uwaterloo.ca

Mm-Wave Transceiver Design for Future Mobile and Satellite Communication

Applications include: ICT

Wireless communication systems have been experiencing wide expansion to millimeter-wave (mm-wave). This shift was motivated by the demand of high data throughput and improved system capacity imposed by future Mobile and Satellite communication systems.

This project is an initial step in the design of a whole transceiver IC where different building blocks of passive and active components compatible with Mobile and Satellite communication frequency bands are designed for performance validation.

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Professor: Slim Boumaiza | Email: slim.boumaiza@uwaterloo.ca

Technology: 65-nanometer CMOS

TSMC 65nm CMOS

8-bit Segmented Electro-Optic Digital-to-Analog Converters (DAC) (I – VI)

Applications include: ICT

Low bit resolution CMOS drivers for driving highly segmented ring modulators to construct 8-bit electro-optic DACs. The objective is to design, fabricate, measure, and demonstrate 8-bit electro-optic DACs with bit resolutions segmented in the electrical and optical domains.

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Designer: Victor Sira | Email: vsira@student.ubc.ca
Designer: Chen Yuan | Email: cyuan@ece.ubc.ca
Professor: Lukas Chrostowski | Email: lukasc@ece.ubc.ca

A 15Gbps+ ring Modulator Driver with 4Vpp Output Swing

Applications include: ICT

This design consists of one electrical driver and two differential drivers for the micro-ring modulator. The electrical driver is for testing purpose. The two ring modulator drivers aim to support 15Gbps+ NRZ signal with a high output voltage swing of 4Vpp.

Concordia University
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A 25Gb/s digital Phase Interpolator in 65nm Technology

Applications include: ICT (High speed serial communication links)

The exponential growth of cloud computing and social networking is rapidly increasing the bandwidth demand on data communication. To support such a high bandwidth demand in future, the next generation 400GbE or higher data rates will be possibly employed by multi-lane high speed serial links. Among other components in these high-speed links, SerDes transceiver plays an important role in making up of a successful communication connection. SerDes transceiver makes use of a CDR circuit to recover data and clock information using phase interpolators. The goal of this project is to design a low power, compact, high-speed digital phase interpolator for CDR architectures. The project design will be done using digital techniques and circuits which will alleviate the design complexity and high-power requirements of an analog design. This project will also incorporate a digital injection locked oscillator along with an open loop delay line to generate high speed reference clocks for the phase interpolator. Clock synthesis through digital means will help make the design less susceptible to noise which in turn would improve the jitter performance on the recovered clock.

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A Compact Low Power Ultra-Wideband Inductorless Low Noise Amplifier

Applications include: Entertainment

This chip includes five novel inductorless ultra-wideband Low Noise Amplifier (LNA) architectures to design a low-noise and highly linear receiver for the Software Defined Radios over a frequency range of 2 GHz to 10.5 GHz. The proposed LNAs uses a single-ended input while provide a balanced output. Negative feedback has been used in the design to provide the process-variation tolerance and higher linearity. Also, current reuse and gm-boosting techniques are employed to lower the power consumption of the LNAs, operating at 1.0 V supply. Further, the proposed architectures utilize simultaneous noise and distortion cancellation to compensate the noise-performance degradation in low-power designs. This chips also includes an input matched source follower to de-embed the influence of the output buffer in cascade with the LNA from the measured results.

École de technologie supérieure
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A Highly Reliable, and High-performance Class-C VCO

Applications include: ICT

The focus of this research is on implementing a high-performance state-of-the-art Voltage Controlled Oscillator (VCO) at 5GHz operation frequency. VCOs are one of the most sensitive as well as power-hungry building blocks of phase-locked loops (PLLs), which are among the ubiquitous components of almost all communication systems. Approximately more than 60% of PLL's power consumption is due to VCO. Therefore, designing a very low power and phase noise VCO always intrigues RF designers. Our design proposes a very low power and phase noise oscillator which meets most of the communication standards' requirements such as IEEE 802.11 Wireless Standard. In addition, the aim of this project is to design and implement a highly reliable Class-C VCO operating at 5 GHz with a low phase noise performance.

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An Ultra-Low-Power 2.4GHz Fractional-N PLL for IoT and Biomedical Applications

Applications include: ICT

In this project, an ultra-low-power (ULP) fractional-N phase-locked loop (PLL) operating at 2.4GHz will be fabricated. The PLL is intended for use in Internet of Things (IoT) and biomedical applications where the reduction of the power consumption with minimal impact on the performance is a key design metric. We propose an approach to eliminate the power-hungry and noisy divider in the PLL's loop during the phase-locked state, which results in lowering the power consumption to 250 µW. To this end, a novel Edge Selection Block (ESB) has also been added to the loop structure. This ESB block guarantees the correct operation of the Fractional-N loop in the absence of a divider. A low power and low noise Truncated Constant Slope digital-to-time converter (DTC) is also used to further lower the power consumption. To detect locking, a mode detector circuit is included. The block detects the functional state of the loop. Depending on the status of the loop (locked or unlocked), the PLL structure changes, powering down some of the blocks from the loop without affecting the performance. Considering the PLL output frequency is adjusted to $(N+\alpha)\ f_{REF}$, where $0<\alpha<1$ and N is an integer, three states are defined for the loop:

1) Integer-frequency locking transient, in which PLL is going to lock to the integer frequency. ((N) f_REF). In this mode, the Loop structure is a standard integer-N loop, including the divider in the feedback path.
2) Fractional-frequency locking transient, in which PLL frequency is going from (N) f_REF to (N+α)f_REF. In this mode, the divider block is removed from the loop and is replaced by the Edge Selection Block(ESB). The required fractional phase error is injected using a 7-bit low-power DTC which is controlled by MASH-11 DSM. Also in this mode the Charge Pump current will be increased to reduce the locking time.
3) Phase-locked state, in which the PLL is already locked to the final frequency. In this mode, by subsampling the power will be reduced.

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Amplifier for quantum number generator

Applications include: Defence (Safety, Security)

Secure communications have been an important issue for over a century. With the number of connected devices constantly increasing, the need for generating encryption keys is constantly growing and the demand for circuits capable of generating these keys securely is growing at the same time. The goal of the project is to fabricate a novel random number generator for which the risks of intrusion, decryption and hacking is extremely low using a low-cost CMOS technology.

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Antenna and Circuits Integration

Applications include: ICT

The chip being fabricated integrates different prototypes of active circuits unified with a radiating surface (acting as an antenna) operating at millimeter-wave and terahertz (THz) frequencies (300 GHz). This project is a continuation of a PhD research work that has demonstrated the next generation of highly integrated, low loss and reconfigurable millimeter-wave/THz front-end systems. It is part of our recent works on future integration strategies of millimeter-wave and THz systems-on-chip. The radiating surface (the chip) unifies signal generation, amplification, combination and radiation properties into a single device, i.e simultaneously generates, amplifies, combines and radiates the THz signal, resulting in higher integration and higher effective generated and radiated power on-chip (ERP) with lower losses. Besides, the DC bias network programmability helps in achieving the reconfigurable features of beam steering, frequency tuning and the mode conversion. So far, the concept has successfully been analyzed and demonstrated at lower frequency, and we are certain that it performs even much better at THz and millimeter-wave frequencies (our intended design bands) for upcoming and future applications of millimeter-wave/THz technologies in wireless communications such as 5G/6G technologies and systems.

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Biosensor Readout Circuit

Applications include: ICT (Data readout circuit)

The design includes a transimpedance amplifier (TIA), automatic gain correction (AGC) along with an ADC to be used in optical readout circuits, especially for biosensor applications. Replicas of the TIA with AGC will be included for standalone analog testing as well without the ADC.

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Capacitive ECG Low Cutoff Frequency Control

Applications include: Health/Biomedical

This chip will address an important problem in capacitive electrocardiography (ECG), the fluctuations in the low cutoff frequency. Because capacitive ECG electrodes do not stick to the patient's skin similar to the standard wet ECG electrode, patient movements change the pressure or create air gaps between the electrode and skin. Hence the skin-electrode capacitance changes, varying the low cutoff frequency formed with the input resistance of the analog front-end.

Hence, the proposed chip addresses this problem by adding a control loop that senses the low cutoff frequency and adjusts the input resistance to keep it fixed at the desired value. In summary, this is achieved by injecting a high-frequency signal into the input node through a small on-chip capacitor. This injected signal sees a capacitive voltage divider between the on-chip capacitor and the skin-electrode capacitance. Thus, the signal measured by the input buffer has the ECG signal and the excitation signal attenuated proportionally to the skin-electrode capacitance.

The input resistance is defined by a controllable pseudo resistor. By identifying the attenuation of the excitation signal, the control loop changes the resistance of the pseudo-resistor accordingly. Simulation results show that without the control loop, a targeted cutoff frequency of 0.5 Hz can change by a decade (0.05 Hz to 5 Hz), while with the control loop, the error is smaller than 200 mHz.

Concordia University
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CMOS Distributed Driver for 400G Optical Systems

Applications include: Aerospace, Defence (Safety, Security), ICT (Optical Transceivers and Communications)

This project will develop a CMOS distributed driver for 400G optical systems. The driver will interface with a Electro-Absorption Modulator (EAM) for ultra fast performance. The distributed driver will have an asymmetric topology for high efficiency and low output impedance to improve bandwidth. The proposed driver will have a bandwidth of 40 GHz to support 56 Gb/s.

Carleton University
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CMOS Readout and Driver circuits

Applications include: Health/Biomedical

The design includes CMOS circuits that have both linear amplifiers, PDM drivers as well as readout circuits (TIAs + amplifiers) to drive photonics circuits and read the output signals.

University of British Columbia
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Delay Circuit

Applications include: Other (Astronomy)

The proposed circuit consisted of a delay circuit for an ultra-energy-efficient, high-speed (10GS/s) and high-resolution (7-bit) ADC integrated using cost-effective CMOS technology. This novel inductor less delay circuit is easily cascadable compact gm-C all-pass filter cell for 0–5 GHz and provides a high figure of merit in comparison to state-of-the-art delay circuits.

University of Calgary
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Designing a Low Power Voltage to Current Converter

Applications include: Health/Biomedical

This project aims to design a low-power and small-area voltage-to-current converter to output the voltage from a temperature sensor into a proportional current. It will be used within the larger system for wearable technology.

McGill University
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Full-Duplex Backscatter SIC

Applications include: ICT

High resolution RF Self interference cancellation (SIC) filter that enables full-duplex (FD) backscatter reader and hence a backscatter communication operation. The FD backscatter operation is enabled by implementing an integrated high-resolution hierarchical RF canceller operating at 2.4GHz.

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High Frequency All Digital Phase Locked Loop

Applications include: ICT

This integrated circuit will demonstrate a novel digital PLL feedback mechanism operating above the highest reported frequency of a digital divider. In this design, a high frequency ALL all digital phase locked loop will be designed and fabricated. The design consists of a 13-bit digitally controlled oscillator (DCO), a set of current mode logic(CML) samplers, a phase-frequency detector (PFD), an ideal alias generator and a digital loop filter (DLF). The proposed phase lock loop will achieve locking in phase by two control regimes: a tunable Coresidual Alias-Locking for high phase and frequency error and a Bang-Bang control for low phase and frequency error. The tuning frequency range of the DCO is 80-90 GHz with a resolution of 10 MHz. The CML latch sampling set digitizes the signal and generates an alias signal accordingly. The PFD detects the phase difference between the feedback alias signal and the reference signal generated by the ideal alias generator. The DLF interprets and integrates the PFD output and generator control signals to the DCO. The proposed model is able to function at high frequency range with low phase error, and it has high potential in the applications of 5G mobile phones.

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Low Power Analog Front End (AFE) for PPG Sensors

Applications include: Health/Biomedical

The project aims to develop a high range low power analog front end (AFE) to read the photoplethysmography (PPG) signal from the photodiode and temperature sensor. The PPG AFE directly converts light to digital signal without any need to convert the photodiode output current to voltage. However, the temperature sensor's output voltage is converted to current by the voltage-to-current block in order to digitize with the implemented AFE. In this run, each block of the PPG AFE and the voltage-to-current block will be implemented and evaluated.

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Low-power Display, In-memory Computing and Flip-flops

Applications include: ICT

Low-power and low-energy have become overreaching requirement for portable, and wearable applications to increase its battery life. Flip-flops are the key components of digital circuits and affect the overall behavior of digital system. Thus, ultra-low-power and ultra-low-energy flip-flops would improve the overall performance of digital circuits. Ising machine would have wide applications in industry from low-power robotics to high-performance-computing data center applications. This test chip will have at least four different components: (i) Low-power display circuit (ii) Low-power in-memory computing, (iii) Low-power, low-energy, single clock-phase, static flip-flops, and (iv) Novel analog oscillator using machine circuit for approximating solutions to certain np-hard optimization problems.

University of Waterloo
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Multiport Interferometric Receiver

Applications include: ICT

The chip to be fabricated integrates the newly proposed receiver architecture that uses phase difference of incoming signals, thus propelling multiport interferometric receiver techniques to efficiently operate (on-chip) at terahertz (THz) frequencies (> 500 GHz). This project is a continuation of a PhD research work, and it is part of our recent works on future integration strategies of millimeter-wave and THz systems-on-chip. The chip implements a novel receiver architecture, suitable for future smart multifunction wireless systems. The concept benefits from using multiport interferometric receivers spatially integrated, therefore offering an unprecedented solution of providing unparalleled degrees of freedom to implement multiple functions such as data reception, angle-of-arrival (AoA) detection, and imaging operations among many others in a single receiver architecture. So far, the concept has successfully been analyzed and demonstrated at lower frequency (28 GHz) and for various modulation schemes including QPSK, 16-QAM, and 32-QAM. We are certain that it performs even much better at THz frequencies (our intended design bands) for upcoming and future applications of millimeter-wave/THz technologies in wireless communications such as 5G/6G technologies and systems for enhancing their functionality, capacity, agility, and speed.

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High-Precision TDC for SPAD-based Biomedical Imaging System

Applications include: Health/Biomedical, ICT

The integration of highly sensitive photodetectors, known as single-photon avalanche diodes (SPADs) with time-to-digital converters (TDCs) provide the possibility of developing high-performance and low-cost sensors known as digital silicon photomultipliers (dSiPMs). In recent years, dSiPMs have demonstrated great uses in biomedical imaging applications such as diffuse optical tomography (DOT), positron emission tomography (PET), fluorescence lifetime imaging microscopy (FLIM), and Raman spectroscopy. High-precision TDCs are needed for the SPAD-based biomedical imaging system to provide accurate timing information. In this work, we plan to use the TSMC's 65 nm process to develop a Time Amplifier (TA) based TDC using stochastic phase interpolation (SPI) encoding scheme for improved PVT (process voltage temperature) tolerance and lower power consumption. We plan to perform a comparison of the performance of the proposed TDC with TDCs proposed in recent years, in order to assess improvements made to the TDC using this topology. In summary, in this design we plan to achieve the following primary objectives:

- TDC with Delay Locked Loop (DLL) for delay control to achieve a competitive precision.
- Full characterization of the TASPI TDC's performance in various output modes.
- Detailed comparison of the performance characteristics of our proposed TASPI TDC with recently published TDCs.

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Low-Power Microdisplay Design

Applications include: ICT (Display design, Low-power microdisplay design)

This test chip will have at least three different components: (i) Three arrays of low-power microdisplay using 3 different low-power methods to reduce the power consumption of the display's driver. (ii) We also included circuits that evaluate a new strong physical unclonable function architecture, which uses non-monotonic response quantization. (iii) Flip-flops are a basic component of sequential circuits and their power consumption and speed significantly affect the overall performance of a digital system. Moreover, a clock network in a complex System on a

Chip (SoC) consumes substantial power, and often pipelines are used to enhance the system throughput which puts an additional burden on the clock network. Consequently, a flip-flop with a low clock load will be important to reduce power consumption. Therefore, research on flip-flops continues to design new architectures and techniques to optimize their power, speed, and energy.

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Sub-circuits for An Ultra-energy-efficient, High-speed (10GS/s) Analog-to-Digital Converter for Radio Astronomy

Applications include: Other (Astronomy)

The proposed circuit consisted of a delay circuit and a residue signal calculator circuit for an ultra-energy-efficient, high-speed (10GS/s) and high-resolution (7-bit) ADC integrated using cost-effective CMOS technology. This ADC consisted of two high-speed flash ADCs as coarse and fine ADCs which have been implemented and tested before. In this tape out I have focused on implementing the delay circuit, subtractor and amplifiers which provide residue signal as an input signal for the Fine ADC. This will provide a novel high-speed ADC design that exhibits a nearly two-order of magnitude improvement on the standard energy-efficiency Figure of Merit when compared to the state-of-art ADCs.

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Switched-Capacitor Gearbox with Fractional Conversion Ratio

Applications include: ICT

This project has the objective to compare the performance of different types of switched-capacitors power converters in TSMC 65-nm technology. The design will include a switched-capacitor power gearbox, which will operate with one, two or three stages in boost and buck mode. It will also have the possibility to change between two different configurations, providing five different conversion ratios in total. A new topology with fractional conversion ratios (i.e., 1.5 and 1.33) will be also included. The goal of the design is to validate the feasibility and performance of the gearbox. This will enable the development of fully-integrated power converters that deliver variable conversion ratios depending on source and load variabilities. Such converters will be used in portable applications where small form factor, high conversion efficiency and use of unsteady energy sources like energy harvesters are key.

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Time-Gated Integrated Circuits for SPAD-based Optical Wireless Communication

Applications include: ICT

One type of the highly sensitive photodetectors, known as single-photon avalanche diodes (SPADs), allows for the development of high-performance and low-cost sensors for optical wireless communication (OWC) systems. Further, SPAD-based optical receivers have great potential for OWC applications due to their high sensitivity, high photon detection efficiency and accurate timing resolution. For OWC applications, an important research topic is how to reduce the SPAD's dead time without significantly trading off the photon detection efficiency to increase the signal-to-noise ratio and lower the low bit error rate (BER). One promising solution is to use time-gated integrated circuits to enable the SPAD sensor to have better performance for high data rate communications.

In this research, we plan to use the TSMC 65 nm process to develop a time-gated SPAD array and two time-gated circuits for high data rate OWC applications. We plan to compare the performance of the time-gated mode with free-running mode to prove the effectiveness of using time-gated circuits in OWC applications. In addition, adjustable hold-off time in the SPAD circuit is designed to investigate the relationship between the hold-off time of the SPAD circuit and the sensor performance. In summary, in this design, we plan to achieve the following primary research objectives:

- The design of a SPAD array with dynamic hold-off time.
- Two time-gated circuits with different time-gated functions.
- Full characterization of the SPADs.
- Performance comparison between the two proposed time-gated modes and free-running SPAD mode in different OWC conditions.
- OWC system performance comparison of SPAD array with different hold-off time.

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Ultralow-Power Capacitive Array-Based IR-UWB Transmitter

Applications include: Health/Biomedical

An ultralow-power UWB transmitter based on capacitive array is proposed that decreases dependency of data rate to pulse repetition frequency as well as power consumption. Here, capacitive array is used to provide a new digital-to-time modulation technique that converts a 5-bit sequence to a single pulse.

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Wirelessly-powered Reconfigurable Spatially Zooming Neural Brain Machine Interface

Applications include: Health/Biomedical

This request for area allocation is for the development of a next-generation integrated circuit based on our [two] previous designs. This design implements a 1024-channel closed-loop brain machine interface with built-in wireless powering and data telemetry capabilities, targeting ultra-low power operation. This integrated circuit is meant to operate as a monolithic neural interface that operates without batteries and can be implanted e.g. on the brain cortex or onto peripheral nerves. The custom-laid out on-chip inductor, interfaced by a novel power management and clock + data recovery unit, allows for simultaneous powering and data commands reception. The 32 x 32 mostly-digital neural recording array operates dynamically in three different modes, which trades spatial resolution for quantization accuracy, depending on the desired neural activity to be monitored. This system employs ultra-low power pulse-based data transmission, which, in comparison to recent closed-loop neural systems, enables wireless shipment of raw recordings with lower energy consumption and higher throughputs. This allows for the recording & stimulation loop to be closed wirelessly, migrating computationally intensive decision blocks to a system outside the body, which further lowers the invasiveness of the proposed implanted system. Reconfigurable current digital-to-analog converters are used to apply tailored stimulation paradigms to enhance stimulation selectivity. The co-design of the aforementioned blocks in a complete fully wirelessly powered system-on-chip could lead to breakthrough applications in brain machine interfaces, or in closed-loop neurostimulation implantable devices for diagnosis and treatment of neurological disorders such as epilepsy and Parkinson's disease.

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Technology: 90-nanometer SiGe BiCMOS

GF9HP

Compact, Linear and Wideband Differential Doherty Power Amplifier for mm-wave 5G Beamforming

Applications include: ICT

In this work, we propose to develop a compact, linear and wideband Doherty power amplifier (PA) for mm-wave 5G beamforming applications, allowing increased communication bandwidth and low latency. Integrated silicon phased array antenna transceivers (PAAT) are highly desirable for mm-wave communications, reducing size while increasing the functionality of the transceivers. Inside a PAAT, multiple transmit and receive chains operate at high speed, with a limited power budget, and in a limited area. One of the most power-consuming blocks in a phased array transmitter is the PA. Its bandwidth and linearity define the maximum achievable data rate in the transmitter, and its power efficiency significantly impacts the system's energy efficiency. Spectrally efficient, high-order modulation signals such as quadrature amplitude modulation (QAM) particularly 256-QAM, are widely used in modern communication systems, however, they impose very stringent requirements on the PA's linearity and power efficiency. In a PAAT with a large number of elements such as 256 elements in base stations or 4 to 8 elements in the mobile device, the power efficiency of PA is attracting more attention than ever before. Higher-order modulation schemes show a higher peak to average power ratio (PAPR) and need highly linear PAs. The large peak to average power ratio of 5G communication signals brings more challenges for circuit designers. For example, PAs usually are designed to achieve the best efficiency at the peak power region. However, the high PAPR of high-order modulation signals in modern communication systems puts the PA to operate in the (off-peak power) back-off region. This could lead to a dramatic reduction in the power efficiency of the PA. Any improvement in the power efficiency of PA at the peak power and back-off region is multiplied by the number of elements in the PAAT and is highly desirable.

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Development of next-generation optical receivers: high speed and low noise designs

Applications include: ICT

This project aims to develop high speed and low noise optical receivers to serve modern data center and telecommunication applications. BiCMOS is used to implement front end transimpedance amplifier (TIA). Multistage architecture is developed along with bandwidth extension circuitry to achieve high gain for high data rates while achieving less input referred noise.

McGill University
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Technology: 130-nanometer CMOS

TSMC 0.13µm CMOS

3D-Integrated Electro-optic (EO) neural implant

Applications include: Health/Biomedical

This ASIC (130-nm CMOS, TSMC) will allow to extract and digitize the brain activity of laboratory mice disease models through an implantable probe interfaced with custom biomedical instrumentation circuits [3], [4]. The chip will include a low-noise bioamplifier with high SNR (≥ 74 dB) a low-power Analog-to-Digital Converter (ADC) to digitize the neural signals on 12-bits and a low-power microcontroller for on-chip data management. The ASIC will be flip-chipped on a silicon interposer developed through an on-going Alliance project in collaboration with U. of Sherbrooke and U. of Toronto, and encapsulated with a biocompatible epoxy, with routing to precisely control the µLED and the photodiodes. A low-power BLE5 wireless transmission module (0.5 cm^2), such as Murata's MBN52832, will be used to transmit the neural data to an Internet gateway. Solder pads will be added on the interposer to connect the LiPo battery (12 mAh, 0.9 cm^2) and to program the controller. The estimated size of the final device w/o the battery will be 7 x 7 x 3 mm^3.

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An Adaptive Clock-less Non-uniform Sampling

Applications include: Automotive, Health/Biomedical, ICT, Natural Resource/Energy

In out previous project, we designed a low-power Analog-to-Digital converter (ADC) with applications in wireless sensors and biomedical implants. We accomplished a non-uniform signal-dependent sampling (SDS) technique in our last tape-out that reduces the number of required sampling points by ADC that is required to reconstruct an input signal. This will save power of whole system to have a longer battery life. In this design, we want to eliminate the clock of the system so that it can work at higher frequencies and save more power at those frequencies. Eliminating the clock also makes the system more accurate as it will not generate any glitches.

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A High-Efficiency RF Energy Harvester Using Gate-Body-Biasing Threshold Voltage Compensation Technique

Applications include: ICT, Natural Resource/Energy

In this project, an RF energy harvester using the gate-body-biasing threshold voltage compensation method will be designed and fabricated. This project aims at solving the existing problem of conventional diode-connected rectifiers caused by nonlinearity. The designed RF rectifier can cover a wide input power and frequency range using the proposed topology while maintaining high sensitivity and output power efficiency.

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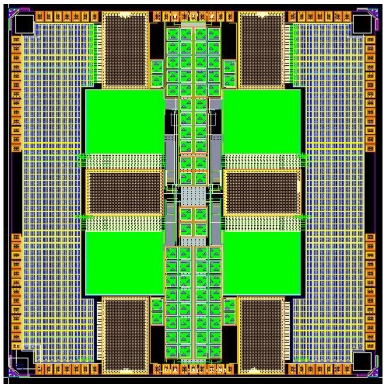
A TCM differential Power Processing Converter for single junction PV cells

Applications include: Natural Resource/Energy



One of the most important challenges of photovoltaic systems is the power yield reduction due to the mismatch of series connected PV cells. The mismatch may exist due to the various causes, such as partial shading, manufacturing variability, thermal gradients, nonuniform aging, etc. In this project we will design and fabricate an on-chip buck-boost converter to improve the power yield of series connected PV cells through the differential power processing method. The proposed converter can improve the efficiency of maximum power point tracking (MPPT) by compensating the impact of submodule-level mismatch on captured power. Compared to other submodule MPPT equipment like DC optimizers, the approach of using integrated converters makes it possible to improve the MPPT efficiency and reduce the total cost of system due to the mass production benefits. Moreover, the oscillator-embedded duty cycle controller of designed converter reduces the complexity, required chip area and the power loss of final prototype.

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Bi-Directional Gated Ring Oscillator Time Integrator for Time-Based Signal Processing

Applications include: ICT

This project develops a bi-directional gated ring oscillator (BiGRO) time integrator for time-based mixed-signal processing. The proposed time integrator features full compatibility with technology, rapid integration, low power consumption, a virtually unlimited dynamic range, a small silicon area, built-in dynamic element matching, and self-digitization. A new low-power high-speed 2-level bi-directional gated delay line (BDGDL) up / down counter is also proposed as part of the time integrator.

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CapstoneADC

Applications include: Aerospace, Automotive, Entertainment, Defence (Safety, Security), ICT, Health/Biomedical

Design of a Delta Sigma ADC for Image Sensor Applications.

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High-resolution CMOS neural interface for synchronized optogenetics and electrophysiology (Phase IIIA)

Applications include: Health/Biomedical

This design, consists of a revision of our previous Phase-III CMOS SOC, including mixed-signal and digital building blocks described below. In particular, this design is critical to improve the overall robustness of the SOC, and to revise the wireless power transfer circuits providing them with more reliability as well as a higher efficiency compared to the previous design. In this project funded by NSERC, CIHR and the Weston Brain Foundation, we are developing a complete high-resolution multimodal CMOS brain implant on a chip. This SoC will provide high-resolution multimodal electrophysiological recording, optogenetic photo-stimulation, and electrical stimulation capabilities within a single IC for studying brain microcircuits of mice by enabling synchronized brain stimulation and neural activity recording through a closed-loop system. In the phase I (design ICXLVOPT), we implemented an innovative multichannel analog-to-digital interface prototype for this SoC. This IC includes a 4-channel low-power

LED driver to illuminate light-sensitized neurons in the brain, a 10-channel low-noise and power efficient analog-front-end to collect the bioelectrical activity, 10 in-channel low-power third-order MASH Sigma-Delta modulators for analog-to-digital conversions, a CIC4 decimation filter and a digital controller to control all building blocks. In the phase II (design ICXLVPII), we added a low-power programmable digital controller to perform closed-loop optogenetics using the circuits developed in the phase I. In the phase III, we added circuits for 1) wireless power recovery and 2) for electrical brain stimulation. In phase IIIA (this design), we propose a revision of the previous design including a revision improving the robustness and efficiency of the IC and of the wireless power transfer circuits. This SoC will be used to study the brain of freely behaving mice through an application paradigm related to the discovery of therapeutics against neurodegenerative diseases.

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High-resolution smart band for medical monitoring (Phase I)

Applications include: Health/Biomedical

In this project funded by NSERC through an INNOV phase I subvention, we are developing a multisensory device to monitor key vital signs on athletes. The system will be a stretchable device, i.e., a smart band built using stretch-PCB technologies that will be designed around a custom system-on-chip (SoC). Among others, the CMOS SoC will provide multimodal and multichannel electrophysiological recordings (EMG, ECG, EEG, etc.), along with impedance spectroscopy and analog-to-digital conversion. The design will be optimized to perform 8-leads ECG recording and simultaneous multisite impedance spectroscopy measurement. When placed on the torso, the smart band will provide a medical grade, real time, ECG, while the multisite impedance spectroscopy will allow to probe the muscles under the band in a 3-D fashion. In this phase I, we plan to integrate the electrophysiological and analog-to-digital conversion features, while the bioimpedance will be integrated in the next chip revision.

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Miniature multimodal probe with vital signs monitoring for study of lung diseases

Applications include: Health/Biomedical

In this project funded by NSERC and in partnership with SCIREQ, Montreal, we are developing a miniature wireless device incorporating several complementary experimental modes allowing the observation of key vital signs to study lung diseases in mice using a single implantable platform. More specifically, it involves drastically reducing the size, reducing the costs and adding essential functionalities to the SCIREQ existing systems, thanks to CMOS microelectronics. We intend to incorporate on the same ASIC multiple vital sign sensors essential for studying lung disease. The on-chip sensors will be (1) photoplethysmography (PPG), (2) impedance spectroscopy, (3) electrocardiogram (ECG) and (4) body temperature measurement. A complementary blood pressure reading mode is also envisaged in the long term, in a later ASIC development phase. In addition to all these sensors circuits, the ASIC will also incorporate a digital controller, with an SPI communication module, and multiple ADCs, as to form a complete system-on-chip (SoC). These circuits will allow our device to capture the vital signs of small rodents with lung diseases during experiments with free-moving mice.

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Miniature multimodal probe with vital signs monitoring for study of lung diseases (II)

Applications include: Health/Biomedical

In this project funded by NSERC and in partnership with SCIREQ, Montreal, we are developing a miniature wireless device incorporating several complementary experimental modes allowing the observation of key vital signs to study lung diseases in mice using a single implantable platform. More specifically, it involves drastically reducing the size, reducing the costs and adding essential functionalities to the SCIREQ existing systems, thanks to CMOS microelectronics. This application is for a version 2 of a chip previously fabricated (ICXLVEMK) through CMC. This revision differs from ICXLVEMK by fixing a critical problem in the power ring that prevented the routing in/out of the signals from the chip. In this design, we intend to incorporate on the same ASIC multiple vital sign sensors essential for studying lung disease. The on-chip sensors will be (1) photoplethysmography (PPG), (2) impedance spectroscopy, (3) electrocardiogram (ECG) and (4) body temperature measurement. A complementary blood pressure reading mode is also envisaged in the long term, in a later ASIC development phase. In addition to all these sensors circuits, the ASIC will also incorporate a digital controller, with an SPI communication module, and multiple ADCs, as to form a complete system-on-chip (SoC). These circuits will allow our device to capture the vital signs of small rodents with lung diseases during experiments with free-moving mice.

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SAR TDC with Time-Interpolated Vernier DTC and Repetitive Time-Input Generation

Applications include: Environment, Health/Biomedical

We explore a novel time-interpolated Vernier Digital-to-Time Converter (DTC) with applications in a successive-approximation register (SAR TDC). A SAR TDC has demonstrated its merit as a low-power data converter. For an energy-efficient SAR TDC, an all-digital DTC is a key block. We demonstrated suitability of a pre-skewing signal-based DTC for a SAR TDC. However, a pre-skewing signal-based DTC has a drawback due to exponentially increasing power consumption with respect to high resolution. Meanwhile, a Vernier-Delay-Line (VDL) DTC provides high resolution while requiring linearly increasing power consumption, this is an advantage for a low-power application.

The team demonstrated the operation and performance of such SAR-TDC based on a time-interpolated VDL DTC with BSIM 3.3 device models. We would like to test the operation and performance of the SAR TDC based on proposed VDL DTC on a silicon-level. We aim to test it on silicon due to the applications that a proposed SAR-TDC can be applied to such as energy-efficient biomedical devices and portable measurement instruments.

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Ultra-Low Power UWB Transmitter for Energy Harvesting IoT Sensors

Applications include: Automotive, Health/Biomedical, ICT

In this project, an ultra-low power ultra-wideband (UWB) transmitter that can be powered by radio-frequency (RF) energy harvesting systems is designed. The proposed UWB transmitter combines a very short pulse transmission method with an intermittent operation scheme to minimize power consumption. By designing the pulse generator to be process, voltage and temperature (PVT) invariant, the UWB transmitter can operate and transmit the correct temperature data with a variable supply voltage provided by an energy harvesting system. This is combined with a novel modulation method using temperature modulation to produce an ultra-low power wireless temperature sensor.

University of Alberta
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Ultra-small vital-signs-monitoring multi-sensing microsystem for COVID-19 management

Applications include: Health/Biomedical

In this project funded by MITACS and NSERC, we develop a vital signal monitoring device that includes the detection, stimulation, and amplification circuits to measure Electrocardiogram (ECG), Photoplethysmography (PPG), and bio-impedance (BI). Such a device aims to record the heart rate, control the volumetric variations of blood circulation, and monitor the respiratory rate (RR) and pulse wave velocity (PWV) in patients infected by COVID-19 and could also be beneficial for healthy people. Typically, bio-impedance is used to determine the composition of fat, muscle, and bone in the human body. In this project, we exploit bio-impedance to detect the movement of the pulse wave in an artery for PWV measurements and volume change in the abdomen for respiration monitoring. It is possible to exploit the bio-impedance to measure vital signs such as heart rate (HR), blood pressure (BP), RR, and PWV. For instance, RR can be monitored using a BI sensor at the abdomen. The operation principle of RR detection is based on utilizing an AC current injected into a local body and measuring the voltage across the same part. The volume changes of the abdomen due to inhalation and exhalation cause impedance variation, generating an amplitude-modulated signal, which the BI technique can monitor. BI circuits include a low-power and high-efficiency switched current stimulus (CS), a low-power and high-CMRR instrumentation amplifier (IA), a passive mixer, and a digitally programmable gain amplifier (PGA) with a band-pass filter. In addition, the design includes a novel LED driver circuit for PPG stimulation, a low-power linearized transimpedance amplifier, and a digitization unit to transmit the PPG raw signal to the Bluetooth unit.

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UNICO - Unsupervised spiking neural networks with analog memristive devices for edge computing

Applications include: Health/Biomedical, ICT

We propose to validate ultra-low power and robust computing with limited resources for Edge Computing (EC) applications. To this end, we propose to explore the hardware implementation of spiking neural networks (SNN). SNNs presents a real opportunity for EC since they can combine low-power operation and non-trivial computing functions as biological neural networks do. Nevertheless, SNNs suffer for the moment from the lack of dedicated hardware for their material implementation. The present chip is proposing a design of analog spiking neurons for proof of concept of on-chip learning SNNs. An important innovation of this project is to integrate memories on top of CMOS in the Back End Of Line (BEOL). BEOL integration will be realized by post-processing of the CMOS chip in our state-of-the-art cleanroom at Université de Sherbrooke. This first SNNs design is targeting small density SNNs and will gather various building blocks design (different number of neurons, the different density of memory, different topologies, ...). By combining material sciences, device engineering, neuromorphic engineering and machine learning techniques, we will explore how SNNs can be deployed on various computing tasks of interest for EC applications. We intend to demonstrate adaptive learning and inference system on a chip.

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Technology: 180-nanometer CMOS

TSMC 0.18µm CMOS

1024-channel wireless implantable bidirectional optogenetic neurostimulator

Applications include: Health/Biomedical

The main objective of this project is to design, develop, and test an implantable system-on-a-chip (SoC) used for conducting optogenetic stimulation in patients with retinal degeneration. Once developed, the device will be the first implant that uses optogenetics to treat retinal degeneration, a major cause of irreversible blindness.

Compared to electrical neurostimulators, this device offers better spatial, temporal, and cell-type specificity, which are critical for the above-mentioned application. With optogenetic stimulation, we can independently stimulation different retina cell types and avoid sending contradictory information to the brain. Fabricated prototypes will be validated in vivo in collaboration with neurologists at York University. The SoC will include an array of optical stimulation and electrical recording channels as well as modules for data compression, signal processing, wireless data communication, and inductive power management.

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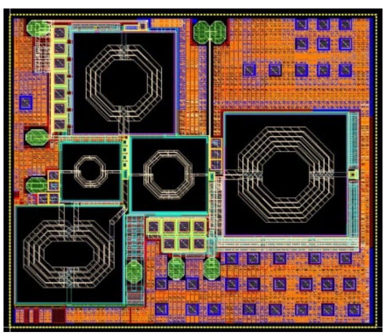
A Novel Ultra-Wideband Low-Noise Amplifier Using an Extended Bandwidth RLC Topology

Applications include: Health/Biomedical



In this design, a novel circuit technique is presented to extend the bandwidth of an ultra-wideband (UWB) low-noise amplifier (LNA). The proposed circuit consists of a standard symmetric center-tapped inductor and an RC series network that is connected to the center-tapped pin. Removing the series resistor in the shunt-peaking method allows increasing the headroom voltage of the LNA. Consequently, the DC current can be increased to benefit from larger S21. A differential common-gate LNA using the presented circuit is implemented in a CMOS 0.18-µm TSMC technology. The LNA operates from 4.33 GHz up to 13.9 GHz while S_{21} is 11.3±0.5 dB and S_{11} is less than -10 dB over the whole of the bandwidth. Furthermore, the LNA using a combination of the proposed approach and a conventional cross-coupled capacitor (CCC) technique achieves a minimum noise figure (NF) of 3.84 dB. Post-layout simulation shows power dissipation of 2.5 mW, while the supply voltage is 0.75 V.

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A High speed Capacitive-Based Digital Isolation System Intended for Industrial Sensor Interfaces

Applications include: Aerospace

In this work, we propose a high-voltage digital isolator utilizing pulse amplitude modulation scheme using capacitive coupling as an isolation barrier. The isolator consists of three main components: the transmitter and the barrier (in one die) and the receiver (in another die) that supports one data communication channel transmission. Firstly, the input digital signal form a microcontroller unit is transmitted using digital-to-analog modulation scheme through transmitter blocks (i.e. pulse detector, voltage level limiters and multiplexers). Then, capacitive coupling on each die will be integrated to transfer the modulated signal to the bondpads, which then transferred from the low-voltage side to the high-voltage side through bondwires. Thirdly, the aim is to design the building blocks at the receiver side, the Schmitt trigger will be designed to generate the data and clock digital signals by comparing the high and low amplitudes of modulated signal. These two generated signals will be processed to the D Flip-Flop to reconstruct the digital signal at the output. This reconstructed microcontroller's input digital signal will be delivered to the Insulated Gate Bipolar Transistor (IGBT) gate driver at the high-voltage regime.

Polytechnique Montréal
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A high speed, high current hybrid LDO with current feedback

Applications include: Automotive

There are many applications in industry requiring stable high current power supplies. Such applications include CPU's, automotive industry, and many industrial applications. This project focuses on designing a fast transient hybrid LDO for high current applications. The design uses a current feedback loop that enables a fast transient response and stable output with varying load conditions. Digital synchronous feedback helps improve the transient response and keep the current consumption at a minimum.

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An Artifact-Tolerant Wearable EEG Recording Microsystem with Distributed Digital Signal Processing

Applications include: Health/Biomedical

The main goal of this project is to design, develop, and experimentally characterize an integrated circuit used to build a stand-alone active electrode for electroencephalography (EEG) recording. In addition to amplification and digitization, the IC will include modules for EEG signal processing allowing for conducting in-channel motion artifact removal, a major challenge in all wearable EEG recording devices. A novel CMRR enhancement technique will be employed in the recording circuit that enables integration of many copies of the microchip in the form of a wearable system, without the need for a central controlling unit. Furthermore, the recording circuit architecture allows for significant reduction of number of interconnecting wires required for making the above-mentioned wearable device, resulting in better scalability. The prototyped IC will be integrated on a mini PCB together with a dry electrode , a mini battery, and peripheral components for electrical and mechanical connections.

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Broadband EIC-PIC Co-Packaged Photonic Transceiver for SATCOM Applications

Applications include: ICT

In this MPW run we will design high-speed modulator drivers and low noise TIA amplifiers for co-packaged photonic transceiver. This design will address the need for true time delay in optical datalink for Satellite Communications including high-speed RF front-end for antenna array. This chip will also be co-packaged on same PCB with electronics ICs for MZM drivers and RF amplifiers for integrated PDs using wire bonding technique. Specifically, we wish to demonstrate tunable time delay in an integrated PIC consists of rings, modulator and photodetectors and its controlling and output RF circuits on same PCB. We will also integrate high-speed modulators drivers and low noise RF amplifiers. In addition, we will integrate PIC and electronics IC on same the PCB for co-packaging of PIC-EIC. This work involves several researcher and graduate students from McMaster University in collaboration with Canadian company MacDonald Detwiler Associates (MDA), Montreal. The work will generate new knowledge and has a route to technology transfer for the betterment of Canadian industry. The partnership with MDA is ongoing and this new proposal will specifically allow the prototyping of a PIC-EIC on the same PCB. Therefore, it is envisaged for high-speed data link in high-throughput satellite (HTS).

McMaster University
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High Spatial Resolution X-Ray Detector for Imaging Nanostructured Materials

Applications include: Natural Resource/Energy, Pharmaceutical (Biopharmaceutical, Chemical)

Reducing pixel size helps to enhance the spatial resolution of CMOS X-ray image sensors. However, it is challenging to achieve high spatial resolution using scintillators because of the trade-off between X-ray absorption and inherent spatial resolution of the scintillator material. To overcome these challenges, we will design a 3000 x 3000-pixel direct-conversion CMOS X-ray ptychography imager featuring 1 µm x 1 µm passive pixels and amorphous selenium (a-Se) as the X-ray sensor. Although passive pixel sensors normally exhibit low signal-to-noise ratio (SNR), we will implement a code-division multiple access (CDMA) encoding scheme in the analog domain to enhance the SNR of the readout.

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RISC-V Based Processor Architecture for an Embedded Visible Light Spectrophotometer (II)

Applications include: Health/Biomedical

The sensing of neurotransmitters is a current challenge in the field of biomedical research. The design of a new compact and accurate sensor would benefit greatly the research being done on neurotransmitters. The field of optics was chosen for the sensor because it is non-invasive and does not alter the sample while testing. The use of optoelectronic sensors is very useful in that regard especially by using visible-light spectroscopy for molecular detection. The basis for this sensor's geometry is the Grism. The system was designed at first to be either in transmission or reflection depending on the type of grating chosen in the Grism. For the tests in the laboratory, the transmission geometry was chosen and adapted to fit commercially available components. The system was then assembled and calibrated to measure its resolution as well as spectral range. An image sensor that is programmed to be self calibrating and user friendly was also fitted to the system.

A RISC-V core with 1k of embedded memory is attached to the required SPI, I2C and UART peripherals to enable edge computing for a visible light spectrophotometer which uses a OV5642 sensor camera at around 200fps. The processing application requires a processor than can perform image processing and neural network computations very quickly. This design connects the core's cache along with debbuging interfaces to the memory and memory-mapped peripherals through a 64bit wide AXI4 crossbar to enable testing of the architecture. A single core RV32 core with M extension is used to provide a powerful computing environment. We choose this architecture for the ease of implementation as well as the additionnal computing performance for potential graphics processing applications.

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RRAM Backend-of-line

Applications include: ICT

Backend-of-line (BEOL) integration of resistive random-access memory (RRAM) on CMOS chips.

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Silicon Photonics Enabled Optical Beam Forming Network

Applications include: ICT (High-speed Low Noise RF Amplifiers for Optical Beamforming Networks)

This design will address the need for true time delay in Satellite Communications (SatCom) including high-speed RF front-end for antenna array. Specifically, we wish to demonstrate tunable time delay in an integrated PIC consists of rings, modulator and photodetectors and its controlling and output RF circuits on same PCB. We will also integrate high-speed modulators drivers and low noise RF amplifiers. In addition, we will integrate PIC and electronics IC on same the PCB for co-packaging of PIC-EIC. This work involves three McMaster University groups in collaboration with Canadian company MacDonald Detwiler Associates (MDA) of Montreal. The work will generate new knowledge and has a route to technology transfer for the betterment of Canadian industry. The partnership with MDA is ongoing and this new proposal will specifically allow the prototyping of a PIC-EIC on the same PCB. Therefore, it is of highly efficient on-chip demonstration of a SatCom application.

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Single-Photon-Counting X-Ray Imager with Frequency Division Multiplexing

Applications include: Health/Biomedical

This IC contains a pixel array that is designed to perform the readout function of a spectrographic single-photon-counting X-ray imager using amorphous selenium as the sensor material. Conventionally, the photon counting operation is performed inside the pixel area with a digitization block and counting circuitry. However, this limits both spatial and spectral resolution due to the required silicon area. To address these issues, this design makes use of frequency division multiplexing, allowing a bank of pixels to share a single ADC for digitization outside of the pixel array. Digitizing the sensor signal externally allows for higher resolution energy discrimination and minimizes the pixel circuit area by displacing those circuits from the main imaging core. The primary objective of this IC is to demonstrate an implementation of the design for a line scan array mammography system with a high-count rate and high spatial resolution.

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Stand-Alone Energy Storage Maximizer IC for Resonant Inductive Wireless Power Receivers

Applications include: Health/Biomedical

The main goal of this project is to design a stand-alone integrated circuit (IC) that automatically maximizes the energy storage efficiency in a resonant inductive wireless power receiver. The IC is intended to adaptively detect and control the optimal operation of the power management unit (power delivery and storage) in a brain implanted SoC, which is going to be used for treatment of different neurological disorders such as Alzheimer, epilepsy, and Parkinson’s disease. The power consumption profile of such implants varies depending on the receiver’s mode of operation where the instantaneous power consumption during stimulation and data transmission is much higher than the average power consumption during signal recording and processing. The high instantaneous power could not be directly provided through the established wireless link. Hence, the surplus energy during normal power consumption is to be stored and recycled later during the high-power events. Therefore, the power management unit should be capable of (i) maximizing the energy storage while delivering power for normal operation of the implant and (ii) recycle the stored energy for the purpose of maintaining the instantaneous high-power events. As the magnitude of the induced energy at the receiver is highly relative to the coupling strength between the transmitter and receiver coils and the actual load value, the controller in the power management unit needs to automatically track and detect the optimum operating point and accordingly control the receiver. This would eliminate the need for a real-time wireless communication between receiver and transmitter to extract/estimate the link’s operating conditions.

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Sub 6GHz Power Amplifier with Dynamic Biasing for Mobile Application (I, II & III)

Applications include: ICT (Telecommunication systems)

The main goal is to increase the performances of the power amplifiers for microwave applications such as the sub 6GHz band for 5G network. The target parameters are linearity and efficiency improvement with dynamic biasing for limited battery size application (mainly mobile). The 180nm process was chosen because it can provide enough power gain for sub 6Ghz design while providing enough robustness against voltage breakdown for PA design.

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Time-to-digital conversion with multiple Vernier stages

Applications include: Aerospace, Health/Biomedical, ICT

The Groupe de Recherche en Appareillage Médical de Sherbrooke (GRAMS) has a pending patent published on December 9th, 2021, with a PCT (WO/2021/243451) on an innovative Time-to-Digital Converter (TDC) architecture using the Vernier principle and Ring Oscillator (RO) as delay elements. By adding other stages, it can measure the time residue normally created by a typical Vernier TDC in order to get a better conversion time, power consumption and precision.

The proposed design, build in TSMC 180 nm CMOS technology, implements two typical TDCs with a single Vernier stage for reference purposes and three pairs of TDCs utilizing the patent pending architecture from two Vernier stages to four Vernier stages. The goal of this device is to characterize the architecture and confirm its theorized advantages. Through this Request for Manufacturing Resource (RFMR), the requested funds will enable the fabrication of the first prototype and will lead to the first publications on this architecture.

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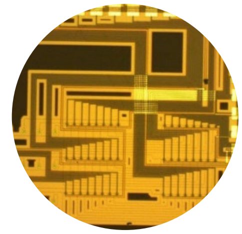

PHOTONICS & OPTOELECTRONICS

CMC delivers a program that includes fabrication access to silicon photonics platforms for chip-level monolithic integration, methodologies for scalable integrated photonics design, and training in the design, fabrication, and testing of photonic integrated circuits. CMC enables photonics integration with a strong emphasis on putting more photonic functionality onto each chip, integrating photonics with other technologies including microelectronics, and using both hybrid and monolithic approaches.
Spotlight on photonics: www.CMC.ca/Photonics

Technology: 220-nanometer Silicon-on-Insulator

ANT E-Beam 220nm NanoSOI

Deep Learning Based Prediction and Correction of Fabrication-Process-Induced Structural Variations in Nanophotonic Devices

Applications include: ICT

The performance of photonic devices is sensitive to small fabrication variations. This sensitivity is worse for next-generation devices that use small features to push the limits of performance. We have created a deep learning model and methodology that quickly and easily predicts and corrects fabrication variations in silicon photonic devices. With this model, designers can easily create robust designs that perform closer to their design target.

This chip design contains multiple topologically optimized (inverse designed) photonic devices (e.g., WDM demultiplexers, bends, couplers) with multiple sizing and performance variations. Each structure contains many fine features that will experience significant fabrication variations. Some designs will be corrected by the deep-learning-based model (previously trained on Applied Nanotools Inc. SEMs) to pre-emptively account for fabrication variations and to improve experimental performance.

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Demonstration of Multi-transverse Mode Operation Toward Scaling-up the Photonic Processors

Applications include: ICT

(1) MRR-based photonic processors deploy MRR weight banks that enables performing photonic weighted addition or multiply and accumulate (MAC) operation which is the cornerstone of photonic processors and can promote extensive applications in this domain. Each MRR in the weight bank is working as a tunable spectral filter that can independently control the transmission level of each frequency component of the WDM signal. The final objective of research in this domain is to evaluate the feasibility of MAC operation using multi-transverse mode signals. This project can provide a proof-of-concept design to further improve the scalability of the MRR-based photonic processors. To realize this goal, the classic MRR weight bank design is investigated and different single and multi-mode designs are conducted. One enabling building block of this design include tunable multi-transverse mode directional couplers that is explained in sub-project 2; however, this can also support multiple other applications.

(2) MZI-based programmable optical processors are promising for fast and low-power optical computation. In particular, they are useful for performing vector-matrix multiplication in optical neural networks (ONNs). This is due in part to the inherent parallelism present in optics and to the low-energy cost of computation for various linear optical

transformations. Additionally, we can boost processing speed by improving optical network transmission capacity. Using mode division multiplexing (MDM), multiple modes can be transmitted over the waveguide at the same time. It is our goal to design multi-transverse mode directional couplers that can couple and direct each mode while compensating for fabrication errors, which can be achieved by applying a TiW heating layer above the directional coupler, which will allow the splitting ratio to be adjusted slightly.

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Diamond Mesh-based Optical Processor

Applications include: Other (photonics for AI and machine learning)

Interferometric based programmable optical processors are promising structures for fast and low power optical computation. Particularly, they can be used to efficiently perform the vector-matrix multiplication task of optical neural networks (ONNs). Employing power efficient computational accelerators in silicon photonic (SiPh) platforms will allow the construction of larger ONNs while maintaining low energy consumption, thus meeting the computational demands of future ML applications. We proposed and demonstrated a diamond mesh-based optical processor which is tolerant to phase error and insertion loss of the MZI due to its symmetric topology. This work as been published in a peer-reviewed journal. We intend to fabricate this design to experimentally validate the performance of the device. Our proposed design is a 4 x 4 diamond mesh optical processor which consists of nine Mach-Zehnder Interferometers (MZI) arranged in a diamond topology. Each of this MZI has two thermo-optic controlled phase shifters (one internal and one external), hence, the entire structure consists of a total of eighteen phase shifters. Light will be coupled in and out of this device using vertical grating couplers. This would be the first experimental demonstration of the diamond mesh optical processor.

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Dual Mode Bulk Sensing on Subwavelength Gratings Slot Waveguides

Applications include: Environment, Health/Biomedical, Pharmaceutical/Biopharmaceutical

Sensitivities of slot, subwavelength grating (SWG), and subwavelength grating slot (SWGS) waveguide sensors are aimed to be fabricated, tested, and compared. The primary objective is to prove that SWGS sensors can overperform the other types of waveguide sensors in terms of bulk sensitivity and fabrication tolerance.

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Experimental Validation of Hybrid Numerical-Analytical Model for Broadband PS-CRDS-based Biosensors

Applications include: Health/Biomedical

Our objective is to design high-Q optical microcavity sensors for the purpose of point-of-care diagnostics, with the specific aim of validating analytical and numerical models for sensitivity and performing proof-of-principle experimental demonstrations. The main novelty in our design lies in developing highly effective sensors that employ a broadband source instead of a tunable laser; this will substantially lower the costs and complexity of the system in comparison to the standard frequency-based approach. Typically, measurements are performed in the frequency domain, and hence, require the use of a tunable laser. Thus, we have been investigating an alternative approach whereby the tunable laser can be replaced with an intensity-modulated broadband source via interrogating the microcavities in the time-domain using phase-shift cavity ringdown spectroscopy (PS-CRDS). In PS-CRDS, an intensity-modulated sinusoidal signal is injected into a biofunctionalized cavity, where the finite photon lifetime of the cavity causes the output signal to be phase-shifted with respect to the input signal; measurements are done in the time-domain which ensures the feasibility of employing a broadband source.

Our group has successfully demonstrated time-domain, PS-CRDS-based biosensing using a tunable laser, as well as developed an analytical model for the response of microcavities to partially coherent time-modulated signals; our model indicates that an absorbing analyte should produce a measurable phase-shift at the drop port while achieving high sensitivity. Since it is not sufficient to use a simple continuum approach, where a bulk change in sensing medium is assumed, as it neglects scattering from discretely bound molecules, we are presently developing a hybrid analytical/numerical model which captures the effects of scattering due to bound molecules on overall sensitivity. Hence, we seek to validate our models and the broadband PS-CRDS-based sensing concept experimentally.

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High FOM Metasurface Biosensor

Applications include: Health/Biomedical

The project aims to explore the potential of intrinsic dual dipole Fano resonance based optical biosensors in an all-dielectric Si platform. In this regard, we optimized the sensitivity, Q-factor, and transmission dip using the home built RCWA algorithm. We plan to fabricate these densely packed nanostructures (2D metasurface) which resonates in the optical communication regime, making the sensor lossless. Our designed metasurfaces can reach a FOM of close to a million. The characteristic peak shifts in response to a change in the surrounding medium refractive index. Our goal is to leverage such sharp features to develop ultra sensitive lossless all-dielectric optical biosensors.

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Integrated Circular Optical Phased Array

Applications include: Automotive (light detection and ranging; autonomous vehicle)

Implementation of an SOI-based on-chip integrated circular phased array which provides a large steering range and high angular resolution. One key application of the phased array circuit is an emitter of an integrated photonic lidar for autonomous vehicles.

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Novel Four Arm Grating Couplers for Wavefront Sensing

Applications include: ICT (Telecommunications)

Optimized four arm grating couplers measure incident angle and polarization through analysis of transmission through each of the four output ports. Various designs optimized for coupling efficiency, incident angle sensitivity and compactness are fabricated. Applications include wavefront sensing for atmospheric turbulence mitigation in free space optical satellite downlinks.

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Photonic Crystal Cavities

Applications include: Other (photonics; quantum computing)

The design has devices to measure the transmission and reflection of various 1D and 2D photonic crystal cavities and devices for testing with photonic wire bonds. The main goal is to develop 1D cavities for waveguide integrated single photon detectors and develop ultra high Q photonic crystal cavities for post-fabrication trimming solutions.

University of British Columbia
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Pixelated Metasurface Spectroscope

Applications include: Health/Biomedical

The project aims to explore the potential of pixelated metasurface for spectroscopic application on an all-dielectric Si platform. In this regard, we designed and plan to fabricate densely packed nanostructures (2D metasurface) which has multiple resonances in the optical communication regime, making the sensor lossless. The resonances correspond to the characteristic absorption profile of specific chemicals. Our goal is to leverage such multiple sharp features to develop ultra sensitive lossless all-dielectric optical chemical sensors and optical biosensors. The project aims to identify specific chemicals or biomolecules hazardous to living organisms and the environment.

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Silicon Metasurface for Biosensing

Applications include: Health/Biomedical

The project aims to explore the potential of Fano resonance based optical biosensors in an all-dielectric Si platform. In this regard, we designed and plan to fabricate densely packed nanostructures (2D metasurface) which resonates in the optical communication regime, making the sensor lossless. The resonance spectrum has numerous electric and magnetic multipole signatures. The dense nature of the architecture helps couple these multipoles giving rise to a strong Fano resonance, which demonstrates a very sharp reflection peak. The characteristic peak shifts in response to a change in the surrounding medium refractive index. Our goal is to leverage such sharp features to develop highly sensitive lossless all-dielectric optical biosensors.

University of Toronto
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Professor: Stewart Aitchison | Email: stewart.aitchison@utoronto.ca

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Silicon Photonics Accelerometer

Applications include: Other (structural and machine health monitoring)

The aim of this project is utilizing a silicon photonics chip to detect mechanical movements, particularly vibration. The device is immune to EM field, small and compatible with optical networks. The goal is to design and fabricate a PIC chip that can provide measurable optical signal related to the applied mechanical vibration in a wide frequency range.

University of Toronto
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Silicon Photonics for Modern Communications

Applications include: ICT

Microwave photonic (MWP) beamforming systems seek to miniaturize the conventional electronic beamformer with the aim of making devices more cost effective and power efficient. This is especially important for the applications in satellite communication where minimizing payload and power consumption are critical. One particularly important component in such systems is an optical delay element for beamforming. This can be realized in the silicon photonics platform using an embedded ring resonator. The objective of this fabrication request is to test the effects of multiple parameters on the performance of the delay element in order to better understand how each affects the true time delay. More specifically, this project looks to modify parameters of the delay ring to determine a more appropriate round-trip structure length and composition. We will include heaters in the design to afford the tunability of both portions of the ring. Coupling length, distance, round-trip time, are all factors that will be changed, as well as position of the heaters for MZ coupling are all parameters that will be modified. Multiple variations will be made, with the aforementioned parameters being changed for each.

McMaster University
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Professor: Andrew Knights | Email: aknight@mcmaster.ca

Silicon Photonic Vernier Ring Reflector

Applications include: ICT

We propose a wavelength-tunable ring reflector on silicon-on-insulator of 220-nm-thick silicon layer. Our design consists of two symmetrically coupled Vernier ring resonators with slightly different free spectral ranges (FSRs) in add-drop configuration.

McGill University
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SWG-based Mode Sensitive Thermo-optic Phase Shifter

Applications include: Other (photonics for AI; machine learning; mode-division-multiplexing (MDM) in silicon photonics)

Interferometric based programmable optical processors are promising structures for fast and low power optical computation. Particularly, they can be used to efficiently perform the vector-matrix multiplication task of optical neural networks (ONNs). Employing power efficient computational accelerators in silicon photonic (SiPh) platforms will allow the construction of larger ONNs while maintaining low energy consumption, thus meeting the computational demands of future ML applications. We recently proposed a novel multi transverse-electric mode optical processor (MTMOP) offering low-cost, fast, and practical training procedure. In conventional programmable optical processors, one needs a coherent detector to measure the optical phase of phase shifters and calibrate/program the processors. Use of coherent detectors considerably increases the cost and complexity of the calibration / programming. In the MTMOP design, we have overcome this challenge by introducing a new building block that enables on-chip calibration of phase shifters without coherent detection techniques. The MTMOP design was submitted for fabrication through (CMC ANT 2101PJ-Design IPJMG-ON1). We fully tested the fabricated device, submitted the results for publication in IEEE Journal of Selected Topics in Quantum Electronics, and also submitted a patent application on the idea of MTMOP. In continue, to improve the performance of MTMOP, we design a thermo-optic phase shifter offering largely different thermo-optic coefficient for the fundamental and first transverse-electric optical modes. The submitted design is based on engineering the refractive index of the waveguide using subwavelength grating (SWG) structures.

McGill University
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Professor: Odile Liboiron-Ladouceur | Email: odile.liboiron-ladouceur@mcgill.ca

Taper Structure for High Coupling Coefficient Bragg Resonator in the Context of Slow-light Modulation

Applications include: ICT

The proposed design is an integrated taper use for slow-light bragg grating resonator structure. This new structure would be characterized as a coupled-resonator waveguide (CROW) and have for objective to reduce the coupling loss caused by a straight waveguide going directly into the bragg grating. As the given bragg grating structure posses a high coupling coefficient, this also mean that the coupling loss are high. The proposed structure would be able to smooth the mode transition from straight waveguide to the bragg grating. As this structure is use in the context of slow-light modulator, this might allow to use even stronger slow-light structure, allowing to shorter modulator. To the best of our knowledge, such kind of taper structure has not been reported yet for those purpose. The challenge lies in the design of the CROW taper as the shape will not be the same as conventional taper and should also be low loss and adiabatic for the given resonant structure. We will address this issue using a simulation model from analytical and numerical analysis.

Université Laval
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Tunable Optical Directional Coupler for Optical Processors

Applications include: Other (photonics for AI and machine learning)

MZI-based programmable optical processors are promising for fast and low-power optical computation. In particular, they are useful for performing vector-matrix multiplication in optical neural networks (ONNs). This is due in part to the inherent parallelism present in optics and to the low-energy cost of computation for various linear optical transformations. Several reasons, including fabrication variations and phase errors in MZI, have made calibration and programming these processors challenging. Splitting and combining ratios of the 50/50 directional couplers at input and output of each MZI could vary slightly due to fabrication variations. Our project is to design a tunable optical directional coupler to compensate fabrication errors, which can be achieved by applying a TiW heating layer above the directional coupler, which will allow the splitting ratio to be adjusted slightly.

McGill University
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Technology: Silicon Nitride (NanoSiN)

ANT NanoSiN

Compact Grating Couplers

Applications include: ICT

In recent years, the design of Silicon Photonics devices has undergone a paradigm revolution. Generally, devices were optimized based on solid physical knowledge and by tuning selected parameters of the structure. In this work, we will test the design of TE and TM grating couplers in a Silicon-Nitride-on-Insulator (SiNOI) platform for L and O communication bands via inverse design.

École de technologie supérieure
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Optical Frequency Comb in Large Normal Dispersive Silicon Nitride Micro Resonator Using Four Wave Mixing

Applications include: Health/Biomedical, ICT

Optical frequency comb (OFC) is an interesting and demanding research topic for its vast application in different fields such as optical communication, biosensing, meteorology, spectroscopy, etc. It provides large bandwidth, high speed, and high sensitivity in terms of absorption sample. Several methods have already been established to generate optical comb in the recent decade, such as cascading modulators, highly nonlinear fiber loop, mode locked laser etc.

Integrated photonic chip based optical comb is making it more compatible and efficient device due to low power consumption instead of high power in conventional fiber combs. Silicon nitride (SiN) is one of the best nonlinear mediums due to its high index contrast, and low temperature sensitivity for OFC generation. The generation of OFC silicon nitride based micro-resonator is efficient due to its high-Q factor and high confinement of light into the ring cavity. Kerr nonlinear effect such as four wave mixing (FWM) is one of the most promising approaches to generate OFC in micro-resonator in large dispersion region. The proposed design for OFC generation based on the thin silicon nitride micro-resonator is a new approach to reduce large normal dispersion and increase FWM conversion efficiency to generate broadband spectrum lines.

McGill University
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Optical Nonlinearities in a Thin Silicon Nitride Integrated Photonics Platform

Applications include: Other (data communications; quantum photonics)

Nonlinear optical devices in integrated photonics have significantly advanced over the last several years and have impacted many areas such as optical signal processing, ultra-low power all-optical switching and quantum photonics. Silicon nitride (SiN) has played a large role in the success of these integrated photonic devices thanks to its negligible two photon absorption enabling low nonlinear losses. Various nonlinear devices based on integrated SiN have been demonstrated for supercontinuum generation, broadband frequency comb generation and four-wave mixing. This design aims to build on the work of these devices by incorporating amorphous tellurium oxide (TeO_2) films directly on the SiN devices for enhanced nonlinearity and dispersion engineering. The design contributes to our ongoing project integrating TeO_2 with SiN and shows great promise in developing cutting edge nonlinear optical devices for many applications in integrated photonics.

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Technology: Silicon Photonics – Active & Passive Silicon on Insulator

AMF Silicon Photonics

Coherent Photonic-electronic Computing Prototype

Applications include: ICT

Our primary objective is the fabrication and experimental demonstration of a coherent photonic-electronic computing prototype leveraging AMF's silicon photonics process. Our proposed hybrid accelerator will combine a photonic integrated circuit with a CMOS image sensor to perform large-scale matrix-matrix multiplication with high speed and quantum-limited efficiency. Our proposed approach is tolerant to fabrication variability while bypassing the requirements of high-speed electronic readout and frequent reprogramming of analog weights—three major factors that limit scalability for current analog AI accelerators.

Queen's University
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Cryogenic Sources, Detectors, and Design Kit

Applications include: ICT

Our objective is the creation of a preliminary design kit for cryogenic silicon photonics. Optoelectronic physics are radically different at low temperatures (4 K – 70 K), potentially enabling applications in single-photon detection, all-silicon light sources, and nonlinear optics. Silicon crystal can emit light below 30 K when embedded with defect centres, addressing perhaps the greatest challenge of silicon photonics: monolithic light sources. Our primary objective is to demonstrate and optimize optically- and electrically-pumped sources, both incoherent and, prospectively, coherent. Avalanche detectors based on silicon/germanium have shown single-photon detection at low-temperature in free-space. Our secondary objective is the development of waveguide-integrated single-photon Si/Ge avalanche detectors. A tertiary objective is general characterization of conventional devices at cryogenic temperatures, making strides towards a complete design library for cryogenic sources, detectors, passives, modulators, and configurable elements.

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High-performance Chip-scale Optical Frequency Comb for Optical Communications

Applications include: ICT (Optical communication)

The first objective of this project is to develop low loss microring resonators for microcomb generation. The proposed design uses innovative SiN waveguide structures to realize microresonators with near-zero anomalous dispersion profiles. Variations of critical parameters such as the free-spectral-range, the coupling, and the dispersion will be implemented to optimize the component.

The second objective of this project is to develop high bandwidth, low power optical phase modulators. The proposed design uses MRM with racetrack configuration as the main building block to modulate the phase of the optical wave. Variations of the IQ modulators, chirp free push pull IQ modulator, and other building blocks have been implemented in this design.

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High-performance Optical Resonator Modulators

Applications include: ICT

The main objective of this project is to develop an ultra-high-bandwidth (> 70 GHz), low-power optical modulator. The proposed design uses a novel configuration of cascaded resonator modulators including microring and Bragg grating modulators. Variations of critical building blocks will also be implemented to optimize the component design and link configuration. Moreover, differentially driven microring modulators will be developed in this project.

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High-speed Low-power Transceivers for Short Reach Applications

Applications include: ICT

This project aims to develop a high-speed low power transmitter and receiver for short reach applications. The proposed design uses a novel configuration of arrayed waveguide gratings designed to support high number of wavelength division channels on the receiver side. Variations of critical building blocks will also be implemented to optimize the component design and link configuration.

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High speed PAM-4 generation using DAC-less ring based modulator

Applications include: ICT

The ring-based PAM-4 modulator consists of a ring and MZI (Mach Zehnder Interferometer) acting as the coupler. The device .benefits from the compactness and speed of the ring and the wide bandwidth of MZI. The device is segmented and driven by two independent NRZ driver voltages and the device is made DAC-less (Digital to Analog Convertor) to generate PAM-4 signal. The device proposed would work on the principle of intercoupled ring modulator and the heater in the design is used to tune the modulator and the segmented phase shifters to modulate signal. This modulator will be designed for speed of 50Gbps relative to its predecessor which was 25 Gbps. This device is useful for short reach interconnects between data centres and to improve the optical communication.

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Ring Modulator Based Optical Phase Locked Loop

Applications include: ICT (Optical communication, sensing and metrology)

The core part of the design is a group of ring modulators designed for achieving different amplitude tenability. Each of the modulator will be connected to a delay line of specific length. Light will be coupled in and out of this device using grating couplers. The design will be repeated multiple times and for each repetition, the dimensions of the rings will be varied to some extent. This will allow us to experimentally figure out the best modulator dimensions. We will also fabricate a series of straight waveguides of different lengths with grating coupler at each end. These waveguides will be used to estimate the waveguide loss per unit length.

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High Speed Silicon Modulators

Applications include: ICT (Telecommunication)

Novel high-speed silicon modulators and ring modulators.

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Low-voltage 16 Quadrature Amplitude Microring Modulator

Applications include: ICT

The project aims to demonstrate a prototype low-voltage 16 QAM modulator based on multistage microring-loaded Mach-Zehnder interferometers (MR-MZIs). While high-order QAMs have been demonstrated in silicon photonics technology using cascaded MZIs, these devices typically large drive voltage levels and long MZI arms embedded with pn junctions to achieve the required phase shift levels. As a result, they have large footprints and the electrical contacts along the long MZI arms introduce large parasitic resistances and capacitances, which reduce the modulation speed. By exploiting of the large variations in the phase response of a microring resonance spectrum, we can achieve much more compact QAM modulator designs with low drive voltage levels. The compact sizes of the pn-junction microrings also help reduce parasitic impedance, allowing high modulation speeds to be achieved.For this project, we aim to realize a 16-QAM MR-MZI modulator with maximum drive voltage of 1.5 V and modulation speed up to 20 GHz. As our design is scalable, if successfully demonstrated, it be expanded to accommodate higher modulation formats in future work.

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Multi-wavelength Systems at 2-micron

Applications include: ICT (Telecommunications)

Our group has developed a highly novel approach to fabricate light sources on silicon using rare-earth doped thin films deposited via onto silicon photonic chips from foundries, with significant success for devices operating around a 2-micron wavelength. A primary advantage of this approach to on-chip light sources is the ability to fabricate multiple signal lasers of different wavelengths that can all be powered by a single pump laser source, where multiplexing signals of different wavelength is an important part in many optical communication systems. The designs for this run will focus on combining a series of lasing devices onto a single circuit and using on-chip networks to multiplex and demultiplex their resulting signals. This circuits can also employ various currently available active (modulator / detector) and passive (waveguide) photonic circuit elements available in the AMF platform to realize wavelength multiplexed systems that will have potential applications in LIDAR, telecommunications, LIDAR, and microwave photonics.

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On-chip Two Micron Optical Data Links

Applications include: Aerospace, Automotive, Health/Biomedical, ICT

Scalable and cost-effective viable on-chip light emission is an ongoing challenge in silicon photonics. We have recently shown exciting advances using the AMF silicon photonics platform in regards to novel on-chip light sources, especially in the 2 micron wavelength window. We have developed a highly novel approach to light sources on silicon using rare-earth doped thin films deposited via post-processing steps on to the silicon photonic chip. The designs for this run will focus on utilizing these lasing devices in higher order optical circuits/systems, utilizing the various currently available active (modulator, detectors) and passive (waveguides) photonic circuit elements available in the AMF platform, as well investigating novel photonic circuit elements designed for 2-micron wavelengths. Designed circuits will have various potential applications including telecommunications, LIDAR, sensing, and microwave photonics.

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Optical Computing

Applications include: ICT

Designing a large-scale optical computing circuit.

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Optical Logic Gate based on Microring Resonators

Applications include: ICT

A new logic gate element is proposed based on the optical control of optical signals. The premise of this proposal is that the fundamental limit of integrated transistor-logic is not only because of the size of the transistor, but the electrical interconnections between them. Using silicon-photonics based technologies, such as the ring resonator, which have shown high modulation rates, a new structure that uses optical inputs to control optical outputs, based on Boolean functions, can be achieved. The strategic placement of electrical and optoelectronic circuits within the optical-gate itself limits the distances that the electrons must travel, increasing the speed of the device, while using optical inputs, outputs and optical power which can propagate much longer distances.

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Photonic Memory for Artificial Intelligence (AI)

Applications include: ICT

This design consists of various test structures for post-fabrication integration of an all-optical memory for photonic computing. This design contains simple test structures for memory material characterization, optimization of the memory footprint and switching reliability and photonic computing matrix multipliers to demonstrate application for AI computations.

Polytechnique Montréal
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Power Efficient WDM for Satellite Communications

Applications include: ICT

This design will address the need for true time delay in Satellite Communications (SatCom). Specifically, we wish to demonstrate tunable time delay in an integrated circuit using micro-ring resonator (MRR) and Mach-Zehnder (M-Z) filters. We will also integrate high-speed M-Z modulators for RF modulation and photodiodes for RF conversion. In addition, we will integrate wavelength division multiplexing to greatly increase the potential for information transfer. This work involves three McMaster University groups in collaboration with MDA (formerly MacDonald, Dettwiler and Associates), Montreal. The work will generate new knowledge and has a route to technology transfer for the betterment of Canadian industry. The partnership with MDA is ongoing and this new proposal will specifically allow the prototyping of a Wavelength Division Multiplexing architecture with low micro-ring count.

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Programmable Photonic Network Layouts

Applications include: ICT

This research collaboration targets the design, fabrication, and experimental evaluation of photonic chips for neuromorphic computing applications. Two layouts are envisioned, with the main target being the implementation of Programmable Photonic Neural Networks (PPNNs). The proposed layouts successfully combine both wavelength-division multiplexing (WDM) and coherent photonics, empowered with programmable capabilities for implementing various neural layer operational models in the same photonic hardware.

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Silicon Coherent Transceiver

Applications include: ICT

Driven by the growing traffic demand, coherent optical communication systems are being standardized for more transmission distances due to their higher capacity and achievable transmission rates. In that regard, our design aims to build an on-chip coherent transceiver supporting transmission rates of more than 500 Gbps/? at CMOS compatible drive voltages. We intend to migrate our technology and designs that enabled us to set record high transmission rates in Intensity modulation /direct detection (IMDD) experiments to the coherent domain, which possess some challenges; however, it is a significant step that paves the way for the practical deployment of SiP coherent systems.

McGill University
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Silicon Photonics Enabled Broadband Co-Packaged Photonic Transceiver Design

Applications include: ICT

This design will address the need for broadband photonic transceiver. It will include PIC-EIC co-designed wideband MZM for RF signal modulation and others sub-circuits such as narrow band tunable filters, group of delay networks and high-speed photodetectors for back to RF conversion. The proposed chip will also include different higher-order modulation format signal generating optical circuits. All conversion such as OOK to QAM or OOK to BPSK signal generation will be performed in optical domain unlike conventional approaches. This chip will also be co-packaged on same PCB with electronics ICs for MZM drivers and RF amplifiers for integrated PDs using wire bonding technique. In addition to that a large delay network will be an integral part of the design. This work involves three McMaster University groups in collaboration MDA (formerly MacDonald, Dettwiler and Associates), Montreal. The work will generate new knowledge and has a route to technology transfer for the betterment of Canadian industry. The partnership with MDA is ongoing and this new proposal will specifically allow the prototyping of a co-packaged photonic transceiver architecture leveraging mature CMOS technology.

McMaster University
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Silicon Photonics Integrated Simplified Coherent Receiver

Applications include: ICT

We propose to design integrated simplified coherent receivers on silicon-on-insulator (SOI) platform. Compared with traditional coherent detection, these proposed receivers consist of fewer components or consume less power, while maintaining the same level of receiver sensitivity as coherent transmission. This project contains two designs. The first one is a quasi-coherent receiver (QCR) realized on the silicon platform. It includes several active and passive components, and the key design is an integrated reflector based on vernier rings. Working with an external reflective semiconductor optical amplifier (RSOA), the reflector is applied to generate high-Q lasers as local oscillators in the QCR circuit. As for the second design, we propose an all-silicon carrier-assisted self-coherent transceivers. Following our previous design, we extend the functionality of the circuit so it supports wavelength-division multiplexing (WDM) transmission. We also add a silicon IQ Mach-Zehnder modulator to achieve a fully-integrated carrier-assisted self-coherent transceiver.

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Silicon Photonics Laser Stabilizer Circuits

Applications include: ICT (Communication and sensing)

This design includes integrated photonics circuits that through controlling the amplitude, phase, and delay of optical feedbacks achieve laser stability and eliminate the necessity of integrated isolators. We plan to demonstrate laser self injection locking to optical feedback reduces the noise of the laser while making it impervious to parasitic reflections. The proposed circuitry paves the way to isolator-free operation of lasers on SiPh platforms.

University of British Columbia
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Ultrafast CQD-on-Si Photodiode for LiDAR Applications

Applications include: ICT

Integrating PbS CQDs with Si and utilizing mature Si CMOS technology opens doors to various fascinating applications, such as CMOS image sensors and Si photonics-based LiDAR. Here, we aim for integrating PbS CQDs onto a Si photonics chip and developing an on-chip CQD photodetector for LiDAR application.

University of Alberta
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Ultra-high-speed Low-power Optical Resonator Modulator

Applications include: ICT

The objective of this project is to develop an ultra-high-bandwidth (> 70 GHz), low-power optical modulator. The proposed design uses a novel configuration of cascaded resonator modulators. Variations of critical building blocks will also be implemented to optimize the component design and link configuration.

Université Laval
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Silicon Photonics Training

Examples of projects using Silicon Electronic-Photonic Integrated Circuits Fabrication (SiEPICfab) consortium.

Technology: Active Silicon on Insulator

Advanced Micro Foundry (AMF) SOI

- Adiabatic coupling between silicon and silicon nitride
  University Calgary | Designer: Bishnupada Behera | Professor: Paul Barclay
- Bandwidth-tunable microwave photonic filter
  University of Ottawa | Designer: Zhuoran Wang | Professor: Jianping Yao
- Bistable ring resonators by adding nonlinear materials.
  Polytechnique Montréal | Designer: Pierre-Luc Thériault | Professor: Stéphane Kéna-Cohen
- Control circuits in silicon photonics
  McGill University | Designer: Rebecca Rogers | Professor: Odile Liboiron-Ladouceur
- Design and fabrication of subwavelength grating structures for biosensing
  University of British Columbia | Designer: Sheri Jahan Chowdhury | Professor: Lukas Chrostowski
- Design of Si-SiN interlayer transition devices using contact coupling
  University of British Columbia | Designers: Masih Bahrani, Sean Lam | Professor: Lukas Chrostowski
- Development of a propagation loss model for rib waveguides
  University of British Columbia | Designer: Sayantani Podder | Professor: Lukas Chrostowski
- Grating coupler optimization
  University of Toronto | Designer: Liam Dicke | Professor: Joyce Poon
- Mach-Zehnder interferometer-based passive coherent discriminator
  Université Laval
  Designer: Pierre-Olivier Janvier | Professor: Wei Shi
  Designer: Thierry Lapointe-Leclerc | Professor: Sophie LaRochelle
- Neural probe with thermo-optics switch based-on multi-mode interferoment (MMI) for optogenetics application
  Université Laval | Designer: Mohammad Makhdoumi Akram | Professors: Benoit Gosselin, Wei Shi
- Photonic fluid sensor
  University of British Columbia | Designer: Kithmin Wickremasinghe | Professor: Sudip Shekhar
- Photonic wall shear stress sensors
  Western University | Designer: Mackenzie Essington | Professor: Jayshri Sabarinathan
- Polynomial taper optimization for On-chip adiabatic components
  University of Toronto | Designer: Can Ozcan | Professor: J. Stewart Aitchison

- Resonant tuning ring devices by pulse injection
  University of Alberta | Designer: Ruoheng Zhang | Professor: Ying Tsui

- Silicon photonics
  École de technologie supérieure (ÉTS) | Designer: Narges Dalvand | Professor: Frederic Nabki

- Silicon photonics
  University of Ottawa | Designer: Long Huang | Professor: Jianping Yao

- Silicon photonic multimode interferometer
  McMaster University | Designer: Batoul Hashemi | Professor: Jonathan Bradley

- SiNx interleavers and hybrids
  Université Laval | Designer: Farshid Shateri | Professor: Wei Shi

- Thermal tuned directional couplers
  McGill University | Designer: Hasan Hoji| Professor: Odile Liboiron-Ladouceur

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Technology: Passive Silicon on Insulator

Advanced Micro Foundry (AMF) SOI

- A single-hidden layer feedforward network with four (4) hidden neurons
  Queen's University | Designer: Adam Grace | Professor: Bhavin Shastri

- Blass matrix as a beamforming network for multibeam operation
  University of Ottawa | Designer: Long Huang | Professor: Jianping Yao

- Carbon nanotube emission enhancement in silicon photonics resonators
  University of Waterloo | Designer: HeeBong Yang | Professor: Na Young Kim

- Components for quantum photonic integrated circuits
  University of Waterloo | Designer: Sayan Gangopadhyay | Professor: Michael Reimer

- Design and characterization of integrated silicon photonic components for ultrasound detection via refractive index sensing techniques
  University of Toronto | Designer: Matthew Downing | Professor: Ofer Levi

- Design of a long-integrated antenna for a high resolution far-field emission profile
  Université Laval | Designer: Pascal Audet | Professor: Wei Shi

- Grating couplers optimized for sensorless coherent receivers in free-space optical (FSO) applications
  McMaster University | Designer: Alexander Parent | Professor: Rafael Kleiman

- Inertial photonics/MEMS device
  University | Designer: Richard Beaudry | Professor: Dominique Drouin

- Integrated fourier-domain mode-locked optoelectronic oscillator
  University of Ottawa | Designer: Zhuoran Wang | Professor: Jianping Yao

- Micro-ring resonator photon-pair source with reverse-bias enhancement and on-chip filtering
  University of British Columbia | Designer: Phillip Kirwin | Professor: Lukas Chrostowski

- Microring-assisted contra-directional couplers for an on-chip spectrometer
  Polytechnique Montréal
  Designers: Mahmoud Atalla, Cedric Lemieux-Leduc | Professor: Oussama Moutanabbir

- Modelling, design and characterization of on-chip temperature sensors on SOI platform for integrated flow sensing
  University of British Columbia | Designer: Kithmin Wickremasinghe | Professor: Sudip Shekhar

- Multi-wavelength laser systems
  McMaster University | Designer: Arthur Mendez-Rosales | Professor: Jonathan Bradley

- On-chip integration of biosensors for tunable laser diode spectroscopy
  University of British Columbia | Designer: Sheri Jahan Chowdbury | Professor: Lukas Chrostowski

- On-chip quantum state tomography
  University of Waterloo | Designer: Brady Cunard | Professor: Michael Reimer

- Optical activation function based on microring modulator
  University of British Columbia | Designer: Jingxiang Song | Professor: Lukas Chrostowski

- PAM4 modulator and ring assisted optical phased array
  Queen's University | Designer: Mir Mehedi Al Hammadi | Professor: Muhammad Alam

- Photonic RF frequency multiplier
  University of Ottawa | Designer: Gazi Mahamud Hasan | Professor: Trevor Hall

- Reconfigurable high-speed silicon photonic circuits in a harsh environment compatible application
  Université de Sherbrooke | Designer: Redouane Amrar | Professor: Paul Charette

- Reconfigurable Mach-Zehnder interferometer mesh for quantum computing
  Queen's University
  Designers: Jacob Ewaniuk, Adam McCaw | Professor: Bhavin Shastri

- Sensorless coherent receiver for free-space optical (FSO) applications
  McMaster University | Designer: Aydin Amini | Professor: Rafael Kleiman

- Silicon nitride components optimized for 895-nanometer
  University of Waterloo
  Designers: Jack deGooyer, Maeve Wentland | Professor: Michael Reimer

- Silicon PIN photodiode for fluorescence detection applications in visible range
  Université Laval | Designer: Mohammad Makhdoumi Akram | Professor: Wei Shi

- Silicon photonic weightbank
  Queen's University | Professor: Scott Yam

- Small food print silicon nitride interleaver
  Université Laval | Designer: Farshid Shateri | Professor: Wei Shi

- Subwavelength grating-based sensors with high bulk sensitivity for dual polarization operation
  University of Toronto | Designer: Can Ozcan | Professor: J. Stewart Aitchison

- Wide-band silicon nitride interleaver
  Université Laval
  Designers: Rizan Homayoun Nejad, Arman Safarnejadian | Professor: Leslie Rusch

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Applied Nanotools (ANT) SOI

- Microring resonator (MRR) bend loss study
  University of British Columbia | Designer: Ben Cohen | Professor: Lukas Chrostowski
- Nano opto-electro-mechanical sensors
  University of Waterloo | Designer: Samed Kocer | Professor: Eihab Abdel-Rahman
- Nano opto-electro-mechanical sensors
  University of Waterloo | Designers: HeeBone Yang | Professor: Na Young Kim
- SiN broadband directional coupler
  University of British Columbia | Designer: Phillip Kirwin | Professor: Lukas Chrostowski
- Contra wavelength division multiplexing (WDM)
  Polytechnique Montréal | Designer: Thomas Lacasse | Professor: Yves-Alain Peter
- Si Vernier ring investigation
  McMaster University | Designer: Arthur Mendez-Rosales | Professor: Jonathan Bradley
- Coupled resonator
  University of Toronto | Designer: Shahab Ramezanpour | Professor: Amr Helmy
- Opto-mechanical sensor
  Western University | Designer: Lance Siquioco | Professor: Jayshri Sabarinathan
- Hybrid photonic coarse wavelength division multiplexing (CWDM)
  Université de Sherbrooke | Designer: Redouane Amrar | Professor: Paul Charette

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Technology: Compound Semiconductor III-V Epitaxy

FBH EPI

High Powered AlGaAs Bragg Reflection Waveguide Lasers for Quantum State Generation

Applications include: Other (Quantum computing)

AlGaAs Bragg Reflection Waveguide Lasers with nonlinear optical cores will be fabricated to generate entangled quantum states of light on chip. Power will be enhanced for high nonlinear conversion levels with an electron blocking layer and optimized doping profile.

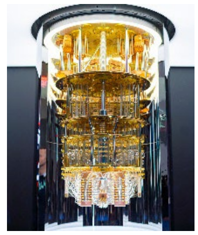
Université de Sherbrooke
Designer: Valentin Daniel | Email: valentin.daniel@usherbrooke.ca
Professor: Abderraouf Boucherif | Email: a.boucherif@usherbrooke.ca

Integration of III-V Materials on Engineered Ge Substrate for Low-Cost High Performance Solar Cells

Applications include: Other (Nanomaterials for energy conversion)

Single and triple junction based solar cells grown on engineered Ge substrate versus standard reference Ge substrate.

University of Toronto
Designer: Trevor Stirling | Email: trevor.stirling@mail.utoronto.ca
Professor: Amr Helmy | Email: a.helmy@utoronto.ca



QUANTUM

Quantum hardware available through CMC includes IBM Quantum Hub at Institut quantique (PINQ²), Université de Sherbrooke, Xanadu Quantum Sandbox, and IonQ via Google Cloud. CMC supports access to quantum computing resources from PasQal, Anyon, and QuEra, and offers technical contract services including quantum coding.
Spotlight on quantum technologies: www.CMC.ca/Quantum

Photo credit: IBM Media Center Gallery

Quantum Training

VTT

Examples of projects using VTT Technical Research Centre of Finland quantum technologies through a 'Build Your Own Superconducting Quantum Device' workshop (sponsored by SIEMENS) on the design, fabrication, and testing of superconducting devices used in quantum computer hardware in collaboration with the Universities of Calgary and Victoria, NSERC CREATE programs Quantum BC and QSciTech, Institut quantique, Institute for Quantum Computing, the Stewart Blusson Quantum Matter Institute, and CMC.

Technology: Niobium SWAPS Junction Process

VTT Nb SWAPS

Parametric amplifier based on a DC-biased Josephson junction coupled to resonators

- **Université de Sherbrooke**
  Designer: Baptiste Monge | Professor: Max Hofheinz

Resonators multiplexed to a transmission line

- To use as benchmark for future designs and to calibrate the fabrication process as well as to test the design-fabrication-simulation-measurement pipeline.
- **CMC Microsystems**
  Designer: Charles Paradis

Resonators terminated by a pair of parallel junctions multiplexed to a transmission line

- **Université de Sherbrooke**
  Professor: Mathieu Juan

RF-SQUID with two measurement methods

- One direct measurement and a measurement method involving an extra DC-SQUID coupled to the RF-SQUID.
- **Simon Fraser University**
  Designer: Mohammad Mostaan | Professor: Paul C. Haljan

Set of Josephson Parametric Amplifiers with varied characteristics for research into quantum-limited amplification

- **University of Waterloo**
  Designer: Rui Yang | Professor: Adrian Lupascu

SQUID to test its potential in magnetic sensing and if the frequency range can be suitable for underwater sensing purposes

- Also includes a parametric amplifier that can be tested separately or connected to the SQUID to act as an on-chip amplifier.
- **University of Dalhousie**
  Professor: Jean-François Bousquet

Superconducting diode made from arrays of Josephson junctions arranged in a set number of arms with a progressively increasing number of junctions

- **University of British Columbia**
  Designers: Oguzhan Can, Rafael Haenel | Professor: Joseph Salfi

The design is an Xmon qubit with a flux line, a drive line and a readout resonator

- **Simon Fraser University**
  Designer: Daniel Julien | Professor: Joseph Salfi

Xmon Qubit with a Readout Resonator

- A flux and a drive line and some variation of the design to test the flux line connection to ground and which layer is best used for this section of the design.
- **Université de Sherbrooke** | Designer: Adham Elshaer | Professor: Dominique Drouin
- **University of Toronto** | Designer: Fadime Bekmambetova | Professor: Piero Triverio
- **University of Waterloo** | Designer: Mohammad Soltani | Professor: Michal Bajcsy

MEMS

Canada's strong MEMS community includes two Teledyne MEMS foundries (Bromont, Quebec and Edmonton, Alberta), centres for pilot fabrication, packaging, system development (INO, C2MI, ACAMP), and several National Research Council (NRC) research centres. Figure four illustrates growth in multi-project wafer (MPW) (173 designs) and university-based nanofabrication (23 designs). **Spotlight on MEMS:** www.CMC.ca/MEMS-nanofabrication-and-integration

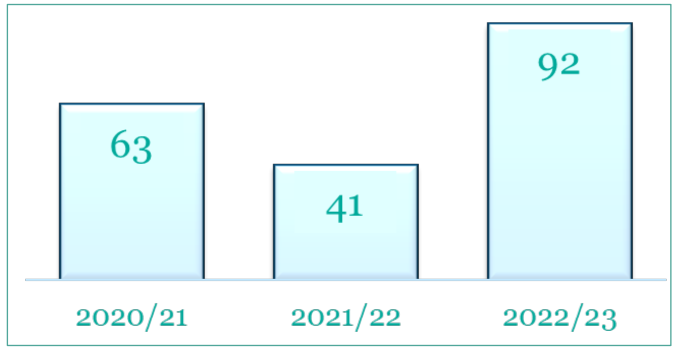


Figure Four: MEMS Designs Fabricated

Technology: MEMS Integrated Design or Inertial Sensors (MiDIS™) Platform

Teledyne DALSA MIDIS™

Accelerometers for Consumer and Industrial Applications (I & II)

Applications include: Aerospace, Automotive, Defence (Safety, Security)

Our goal is to evaluate these designs for high performance inertial sensors and compare them with other existing academic and industrial solutions. These devices will be used to develop workshops for hands-on experience in MEMS design and characterization.

École de technologie supérieure
Designer: Erfan Ghaderi | Email: eghaderi@sfu.ca
Professor: Behraad Bahreyni | Email: behraad_bahreyni@sfu.ca

MEMS Timing Devices

Applications include: Automotive, Natural Resource/Energy

Working toward the improvement of resonators and their applications.
A design has been prototyped using simulation and real-life measurements in the MIDIS technology.

École de technologie supérieure
Designer: Abid Ali | Email: abid.ali@lacime.etsmtl.ca
Professor: Frédéric Nabki | Email: frederic.nabki@etsmtl.ca

Technology: PiezoMUMPs

MEMSCAP PiezoMUMPs

Characterization of Novel AlN-on-Silicon TPoS Resonator

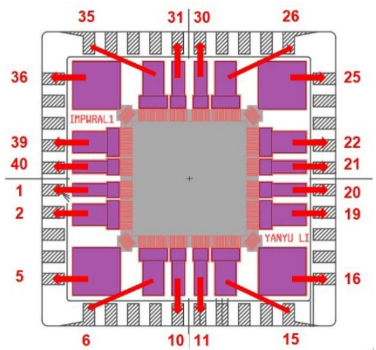
Applications include: ICT (5G applications)

Novel TPoS resonator will be developed for RF filter applications.

University of Waterloo
Designer: Matthew Ou | Email: m3ou@uwaterloo.ca
Professor: Raafat Mansour | Email: rrmansour@uwaterloo.ca

Dual Axis MEMS Accelerometer

Applications include: Automotive



Robust multi-axis MEMS accelerometer with fine-tuned spring support for better sensitivity and stability.

University of Windsor
Designer: Andy Li | Email: li1ip@uwindsor.ca
Professor: Jalal Mohammed Ahamed | Email: jahamed@uwindsor.ca

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Machine Learning Squares

Applications include: Automotive

Working toward the development of a MEMS ultrasonic microphone.

École de technologie supérieure
Designer: Mathieu Gratuze | Email: mathieu.gratuze@etsmtl.ca
Professor: Frédéric Nabki | Email: frederic.nabki@etsmtl.ca

Micro Linear Displacement Sensor (I & II)

Applications include: Aerospace, Automotive

The goal is to optimize a novel type of MEMS displacement sensor that is based on resistive contacts. Gemotric amplification will be used to increase the displacement in different directions. This technique allows a better precision in measurement by reducing the minimal displacement of 2 µm imposed by the technology.

The Si-Si contact model was previously updated with the first generation of MEMS strain sensor. The MEMS device will be integrated with an embedded system to have complete strain sensor system. Different MEMS structures based on contact resistances will be investigated to find the most suitable for strain sensor applications. A post-processing might be done to coat the structures will metal to reduce the overall contact resistance is required. The design will allow to measure displacement from 2 µmto 20 µm.

École de technologie supérieure
Designer: Alberto Prud'homme | Email: alberto.prudhomme@lacime.etsmtl.ca
Professor: Frédéric Nabki | Email: frederic.nabki@etsmtl.ca

MEMS Accelerometer

Applications include: Automotive

MEMS Based environmental robust accelerometer for automotive applications.

University of Windsor
Designer: Ankang Wang | Email: wang119f@uwindsor.ca
Professor: Jalal Mohammed Ahamed | Email: jahamed@uwindsor.ca

MEMS Energy Harvesting System

Applications include: Environment

The design is going to be used as a vibration-based piezoelectric energy harvester, which converts parasitic environmental vibration into the useful electric charges. The proposed structure has an optimized serpentine geometry with the integration of several proof masses at the links for reducing the operational frequency and improving energy conversion efficiency. Thanks to three degrees-of-freedom, the second and the third mode shapes can be located close to each other, providing a wide-band MEMS energy harvester. The model is validated by both analytical modeling and finite element simulation to satisfy expected results.

Memorial University of Newfoundland
Designer: Aylar Abouzarkhanifard | Email: aabouzarkhan@mun.ca
Professor: Mohammad Al Janaideh | Email: maljanaideh@mun.ca

MEMS Magnetic Actuator

Applications include: Health/Biomedical, ICT

Single element magnetic actuator.

École de technologie supérieure
Designer: Mohammadreza Kolahdouz Moghaddam | Email: mohammadreza.kolahdouz-moghaddam.1@ens.etsmtl.ca
Professor: Frédéric Nabki | Email: frederic.nabki@etsmtl.ca

MEMS Rotational Switch

Applications include: ICT

We request resources to fabricate novel MEMS structures that can be integrated with optical waveguides on the same chip with two different designs. This structure includes curved comb drives at both sides of the platform. The device has the ability of in plane rotational motion. This rotation could be clockwise (CW) and counter-clockwise (CCW) to a specific degree concerning the actuated voltage. When the voltage increases, it results in rotation of the platform, and as a consequence, the direction of the light will be modified toward each specified output channel. The next step after testing the device is depositing silicon nitride as a core of the waveguide and silicon dioxide as the top and down cladding of the waveguide. The end facet of the platform will be acting as a mirror.

This structure has two approaches regarding the shape of the springs that the whole structure is connected to them. The first approach is the novel circular spring that can keep the angular displacement stable without translational motion to reduce the insertion loss. The second approach is using two long beams as the spring.

École de technologie supérieure
Designer: Navid Heidari | Email: navid.heidari.1@ens.etsmtl.ca
Professor: Frédéric Nabki | Email: frederic.nabki@etsmtl.ca

MEMS Resonator as Digital Isolator

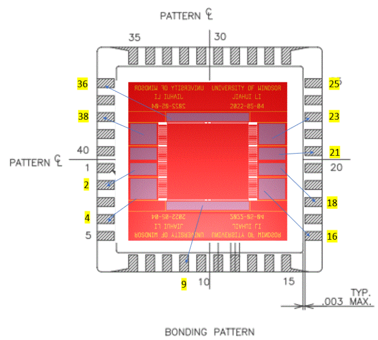
Applications include: Aerospace

MEMS resonator for producing ultrasound waves.

École de technologie supérieure
Designer: Hamid Sadrimanesh | Email: hamid.sadrimanesh.1@ens.etsmtl.ca
Professor: Yves Blaquière | Email: yves.blaquiere@etsmtl.ca
Professor: Frédéric Nabki | Email: frederic.nabki@etsmtl.ca

MEMS Resonator Low Damping

Applications include: Automotive



University of Windsor
Designer: Kevin Li | Email: li195@uwindsor.ca
Professor: Jalal Mohammed Ahamed | Email: jahamed@uwindsor.ca

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MEMS Rotational Switch

Applications include: ICT

We request resources to fabricate novel MEMS structures that can be integrated with optical waveguides on the same chip with two different designs. This structure includes curved comb drives at both sides of the platform. The device has the ability of in plane rotational motion. This rotation could be clockwise (CW) and counter-clockwise (CCW) to a specific degree concerning the actuated voltage. When the voltage increases, it results in rotation of the platform, and as a consequence, the direction of the light will be modified toward each specified output channel. The next step after testing the device is depositing silicon nitride as a core of the waveguide and silicon dioxide as the top and down cladding of the waveguide. The end facet of the platform will be acting as a mirror.

This structure has two approaches regarding the shape of the springs that the whole structure is connected to them. The first approach is the novel circular spring that can keep the angular displacement stable without translational motion to reduce the insertion loss. The second approach is using two long beams as the spring.

École de technologie supérieure
Designer: Navid Heidari | Email: navid.heidari.1@ens.etsmtl.ca
Professor: Frédéric Nabki | Email: frederic.nabki@etsmtl.ca

MEMS Ultrasonic Microphone (I – X)

Applications include: Automotive, Natural Resource/Energy

Working toward the improvement of resonators and their applications. A designs has been prototyped using simulation and real life measurments in the piezomumps technology. Switching to the Polymumps technology will allow improvement of the performances.

École de technologie supérieure
Designer: Abid Ali |Email: abid.ali.1@ens.etsmtl.ca
Professor: Frédéric Nabki | Email: frederic.nabki@etsmtl.ca

MEMS Ultrasonic Microphone

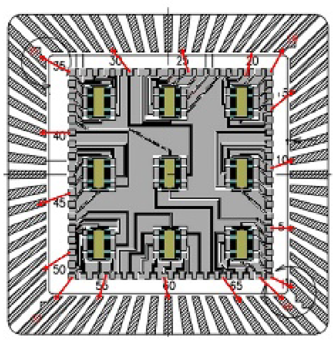
Applications include: Automotive, Entertainment

Working toward the development of a MEMS ultrasonic microphone.

École de technologie supérieure
Designer: Mathieu Gratuze | Email: mathieu.gratuze@etsmtl.ca
Professor: Frédéric Nabki | Email: frederic.nabki@etsmtl.ca

MEMS Temperature Stable Accelerometer

Applications include: Automotive



University of Windsor
Designer: Andy Li | Email: li1ip@uwindsor.ca
Professor: Jalal Mohammed Ahamed | Email: jahamed@uwindsor.ca

MEMS Timing Devices

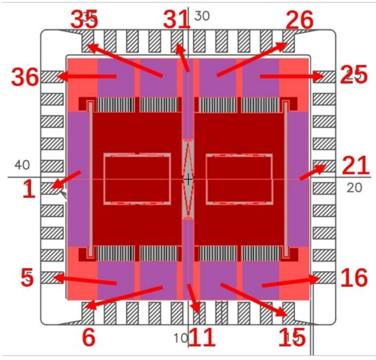
Applications include: Automotive, Natural Resource/Energy

Working toward the improvement of resonators and their applications. Designs have been prototyped using simulation and real-life measurements in the PiezoMUMPs technology.

École de technologie supérieure
Designer: Abid Ali | Email: abid.ali.1@ens.etsmtl.ca
Professor: Frédéric Nabki | Email: frederic.nabki@etsmtl.ca

MEMS Two Mass Gyroscope

Applications include: Automotive



MEMS mode match and precision gyroscope.

University of Windsor
Designer: Huaishen Yan | Email: yan1f@uwindsor.ca
Professor: Jalal Mohammed Ahamed | Email: jahamed@uwindsor.ca

Multi-Resonance Based Ultrasound Array for MV (I – IV)

Applications include: Automotive, Health/Biomedical, ICT

- Flow Measurement Utilizing Ultrasound for Both Flexible and Rigid Plastic Tubing
- Multi-Resonance based PMUT for imaging
- Multi-Resonance based PMUT for vibration sensing
- PMUT for automotive

École de technologie supérieure
Designer: Mohammadreza Kolahdouz Moghaddam | Email: mohammadreza.kolahdouz-moghaddam.1@ens.etsmtl.ca
Professor: Frédéric Nabki | Email: frederic.nabki@etsmtl.ca

Non-Invasive Ultrasonic Flow-Bubble Sensor

Applications include: Automotive, ICT

Non-Invasive Ultrasonic Flow-Bubble Sensor

École de technologie supérieure
Designer: Mohammadreza Kolahdouz Moghaddam | Email: mohammadreza.kolahdouz-moghaddam.1@ens.etsmtl.ca
Professor: Frédéric Nabki | Email: frederic.nabki@etsmtl.ca

PiezoTD2ndside

Applications include: Aerospace

Transducer including transmitters and receivers.

École de technologie supérieure
Designer: Hamid Sadrimanesh | Email: hamid.sadrimanesh.1@ens.etsmtl.ca
Professor: Yves Blaquière Email: yves.blaquiere@etsmtl.ca

pMUT Based Particulate Matter Sensors

Applications include: Entertainment, Health/Biomedical

The goal of the project is to design a particulate matter sensor using MEMS technology. The fabricated Piezoelectric Micromachined Transducers (PMUT) will be used to detect mass of the particulate matter suspended in the ambient air. The resonant frequency of a piezoelectric transducer is a function of the physical dimensions (thickness and area) of the transducer. Hence, any mass loading on the transducer membrane will result in a shift in frequency. The aim of the project is to collect the particles in the ambient air and target them towards the transducer, so that a change in the resonant frequency can indicate the amount of mass collected.

McGill University
Designer: Navpreet Singh | Email: navpreet.singh@mail.mcgill.ca
Professor: Mourad El-Gamal | Email: mourad.el-gamal@mcgill.ca

pMUT Design - Topology Comparison

Applications include: Health/Biomedical

PMUT Design - Topology Comparison #1
PMUT Design - Topology Comparison #2

University of Windsor
Designer: Yumna Birjis | Email: birjis@uwindsor.ca
Professor: Arezoo Emadi | Email: arezoo.emadi@uwindsor.ca

pMUT Resonators for Multiple Sensors Characterization (I & II)

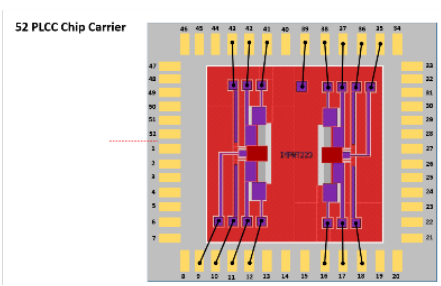
Applications include: Aerospace, Automotive, Environment, Health/Biomedical

Multiple designs of PMUT resonators to be applied as distance, temperature, density and humidity sensors, to be characterized in different conditions and define the best geometry for each kind of sensor. In future work these tests will be applied for the design of real sensors.

École de technologie supérieure
Designer: Alberto Prud'homme | Email: alberto.prudhomme@lacime.etsmtl.ca
Professor: Frédéric Nabki | Email: frederic.nabki@etsmtl.ca

Scanning Micromirror

Applications include: Defence (Safety, Security), Health/Biomedical

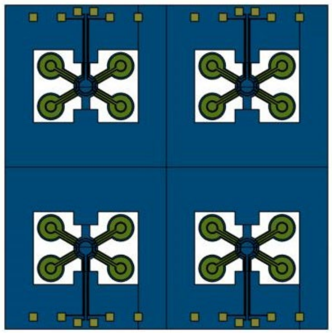


This project introduces a novel design for the actuation of electrostatic scanning micromirrors providing large scanning area. Traditionally, electrostatic scanning mirrors are actuated through applying a potential difference between the mirror and the stationary electrode underneath of it. The presence of the stationary electrode underneath of the mirror, however, limits the rotation angle of the mirror. One way is to increase the initial gap distance between the mirror and the fixed electrode; however, this enhances the power consumption needed to drive the mirror and is not effective. We introduce a novel approach to actuate mirrors using indirect excitation. In this scheme, we are going to benefit from nonlinear “Modal Interaction” phenomenon to excite the rotational mode of the mirror using in-plane excitation creating an energy channel through which the in-plane vibration energy is transferred to the out-of-plane direction. With this in mind, the whole substrate underneath of the mirror can be etched away, providing a large space for the mirror to move through, and consequently, increasing the scanning range covered by the mirror.

University of Waterloo
Designer: Sasan Rahmanian | Email: s223rahm@uwaterloo.ca
Professor: Eihab Abdel-Rahman | Email: eihab@uwaterloo.ca

Temperature Compensation of TPoS MEMS Resonator

Applications include: ICT



Designing the model to reduce/eliminate the frequency drift of a resonator for change in temperatures

University of Windsor
Designer: Gnanesh Nagesh | Email: nagesh@uwindsor.ca
Professor: Jalal Mohammed Ahamed | Email: jahamed@uwindsor.ca

Thermal Actuated DC MEMS Switches

Applications include: Aerospace

The pathway towards a reliable electro-thermal actuated power MEMS switch using this technology requires a systematic approach to mitigate the effect of joule heating. Here, we implement a chevron (V-shaped) actuator design that incorporates isolation stage and heat sink beams in order to mitigate the elevated temperature across the floating contact

École de technologie supérieure
Designer: Abdurrashid Hassan Shuaibu | Email: abdurrashid-hassan.shuaibu.1@ens.etsmtl.ca
Professor: Frédéric Nabki | Email: frederic.nabki@etsmtl.ca

Ultrasound Transducer

Applications include: Health/Biomedical, ICT

Resonator array for imaging purpose.

École de technologie supérieure
Designer: Amir Reza Kolahdouz Moghaddam | Email: amir-reza.kolahdouz-moghaddam.1@ens.etsmtl.ca
Professor: Frédéric Nabki | Email: frederic.nabki@etsmtl.ca

Ultrasound Transducer (I - V)

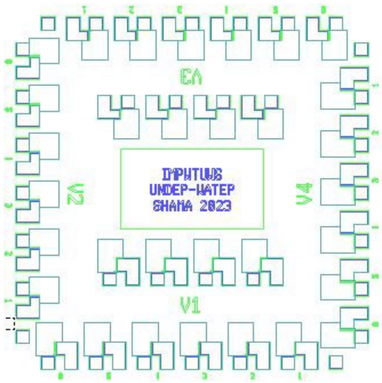
Applications include: Health/Biomedical, ICT

- Array micromirror for the purpose of imaging
- Flow Measurement Utilizing Ultrasound for Both Flexible and Rigid Plastic Tubing (x2)
- Multi-Resonance based PMUT for vibration sensing (x2)
- Single element micromirror for the purpose of imaging

École de technologie supérieure
Designer: Mohammadreza Kolahdouz Moghaddam | Email: mohammadreza.kolahdouz-moghaddam.1@ens.etsmtl.ca
Professor: Frédéric Nabki | Email: frederic.nabki@etsmtl.ca

Underwater MEMS Chemical Sensors

Applications include: Environment



Regarding sensors' design, each sensor on the chip consists of two electrodes. One of these electrodes is fixed, and the other one is a cantilever beam that is free to move. The chip will be back etched underneath each cantilever.

University of Waterloo
Designer: Yasser Sayed Ahmed Abdelaziz Mahrous Shama | Email: ys2shama@uwaterloo.ca
Professor: Eihab Abdel-Rahman | Email: eihab@uwaterloo.ca

Technology: PolyMUMPs

MEMSCAP PolyMUMPs

Capacitive Flow Sensors / Capacitive Flowmeter with High Sensitivity (I - IV)

Applications include: Automotive, Environment, Health/Biomedical, Natural Resource/Energy

Working toward the design of new CMUTS (Capacitive Micromachined Ultrasonic Transducers).

Designs have been prototyped using simulation and real-life measurements. These designs allow a higher displacement and a better control of the resonant frequency. These designs will also allow us the design of compact elements with high resonant frequency (>5MHz). The designs submitted in this area will allow real life measurements.

École de technologie supérieure
Designer: Amirhossein Moshrefi | Email: amirhossein.moshrefi.1@ens.etsmtl.ca
Professor: Frédéric Nabki | Email: frederic.nabki@etsmtl.ca

Chevron (V-shaped) Type Thermal Actuated MEMS Switches

Applications include: Aerospace

The pathway towards a reliable electro-thermal actuated power MEMS switch using this technology requires a systematic approach to mitigate the effect of joule heating. Here, we implement a chevron (V-shaped) actuator design that incorporates isolation stage and heat sink beams in order to mitigate the elevated temperature across the floating contact.

École de technologie supérieure
Designer: Abdurrashid Hassan Shuaibu | Email: abdurrashid-hassan.shuaibu.1@ens.etsmtl.ca
Professor: Frédéric Nabki | Email: frederic.nabki@etsmtl.ca

CMUT vs M3CMUT Performances

Applications include: Health/Biomedical

Performance comparison between CMUt and M3CMUT transducers.

University of Windsor
Designer: Pavithra Munirathinam | Email: muniratp@uwindsor.ca
Professor: Arezoo Emadi | Email: arezoo.emadi@uwindsor.ca

CMUT Optimization (I and II)

Applications include: Health/Biomedical

Design and optimization of Capacitive Micromachined Ultrasonic Transducers (CMUT).

University of Windsor
Designer: Pavithra Munirathinam | Email: muniratp@uwindsor.ca
Professor: Arezoo Emadi | Email: arezoo.emadi@uwindsor.ca

Design and Implementation of Low Voltage Tunable Capacitive Micro-machined Transducers (CMUT) for Portable Applications

Applications include: Health/Biomedical

Capacitive Micromachined Ultrasonic Transducers (CMUT) are MEMS-based transducers which have recently gained interest because of their several advantages over piezoelectric ultrasonic transducers. CMUTs have many advantages, such as their small size, ease of integration with electronics, and fabrication. In this design, the effect of different membrane topologies on displacement, resonant frequency, and the output pressure of the CMUT membrane was investigated in the transmission mode in an air environment. New structural features, a spring arm and a rocker stem are introduced for reduced resonant frequency and pull in voltage.

Université du Québec à Chicoutimi (UQAC)
Designer: Chirag Goel | Email: chirag.goel.1@ens.etsmtl.ca
Professor: Alexandre Robichaud | Email: alexandre_robichaud@uqac.ca

Development of a Linear Thermal MEMS for Mechanical Characterization of Thin Film Material in Situ SEM/TEM

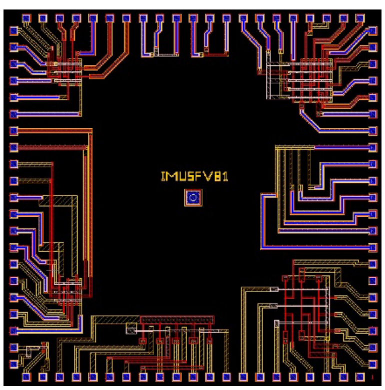
Applications include: Other (Material Science & Engineering)

A thermal MEMS with linear voltage-displacement relationship is developed for mechanical characterization of thin film material in situ SEM/TEM.

McGill University
Designer: Lingzhi Zhang | Email: lingzhi.zhang@mail.mcgill.ca
Professor: Changhong Cao | Email: changhong.cao@mcgill.ca

Development of Unconventional Physical Microprocessors

Applications include: Environment, ICT (Internet of Things)



We aim to submit a chip design that builds upon our recently developed near-sensor, physical processing platforms to equip microsensor systems with built-in microprocessors. We implemented physical processors using off-the-shelf components and proved their computing capability. Now, we plan to build test devices to confirm that the developed microprocessors can process in/near to (1) real-time and (2) are power-efficient compared to the current approaches based on cloud/edge computing.

Simon Fraser University
Designer: Vahideh Shirmohammadli | Email: vshirmoh@sfu.ca
Professor: Behraad Bahreyni | Email: behraad_bahreyni@sfu.ca

MEMS-based Inertial Sensors for Smart Cities

Applications include: Environment

For out-of-plane capacitive accelerometer designed by topology optimization.

Ontario Tech University
Designer: Hossein Rostami Najafabadi | Email: hossein.rostaminajafabadi@ontariotechu.net
Professor: Ahmad Barari | Email: ahmad.barari@ontariotechu.ca

IDE Based Gas Sensors

Applications include: Environment

Array of interdigitated electrode (IDE) Sensors.

University of Windsor
Designer: Gian Carlo | Email: antonyrg@uwindsor.ca
Professor: Arezoo Emadi | Email: arezoo.emadi@uwindsor.ca

MEMS Resonator as Digital isolator

Applications include: Aerospace(Non-Defence)

MEMS resonator for producing ultrasound waves.

École de technologie supérieure
Designer: Hamid Sadrimanesh | Email: hamid.sadrimanesh.1@ens.etsmtl.ca
Professor: Yves Blaquière | Email: yves.blaquiere@etsmtl.ca

MEMS Microphone

Applications include: Health/Biomedical, Other

The purpose of this microphone is to develop an ultrasonic leak detection device as an exceptional alternative to the existing devices or mechanisms. This sensor is mounted on the wall of a room occupied with numerous pressurized pipes with the ultimate goal of real-time inspecting for any possible leakage.

École de technologie supérieure
Designer: Ilgar Jafarsadeghi Pournaki | Email: ilgar.jafarsadeghipournaki.1@ens.etsmtl.ca
Professor: Frédéric Nabki | Email: frederic.nabki@etsmtl.ca

MEMS Ultrasonic Microphone (I and II)

Applications include: Automotive, Natural Resource/Energy

Working toward the improvement of resonators and their applications.

A design has been prototyped using simulation and real-life measurements in the PolyMUMPs technology. Using a vibrometer. Maximum displacement and validation of the Phase comparator and mode shape suppression in the MEMS resonators will be verified using a vibrometer and function generators. The testing plan will include characterization, debugging and test report write-up.

École de technologie supérieure
Designer: Abid Ali | Email: abid.ali.1@ens.etsmtl.ca
Professor: Frédéric Nabki | Email: frederic.nabki@etsmtl.ca

MEMS Ultrasonic Transducers for Space Application (with Cornell and NASA)

Applications include: Aerospace

Air Coupled moving membrane transducers for imaging on MARS in collaboration with Cornell University/ National Aeronautics and Space Administration (NASA).

University of Manitoba
Designer: Mayank Thacker | Email: thacker5@myumanitoba.ca
Professor: Douglas Buchanan | Email: douglas.buchanan@umanitoba.ca

MEMS Capacitive Switch (I and II)

Applications include: ICT (Microwave and RF)

This actuator deflects downward.

University of Waterloo
Designer: Jalaledin Tayebpour | Email: jtayebpo@uwaterloo.ca
Professor: Raafat Mansour | Email: rrmansour@uwaterloo.ca

MEMS Microphone

Applications include: Health/Biomedical, Other (Non-destructive Testing)

The purpose of this microphone is to develop an ultrasonic leak detection device as an exceptional alternative to the existing devices or mechanisms. This sensor is mounted on the wall of a room occupied with numerous pressurized pipes with the ultimate goal of real-time inspecting for any possible leakage.

École de technologie supérieure
Designer: Ilgar Jafarsadeghi Pournaki | Email: ilgar.jafarsadeghipournaki.1@ens.etsmtl.ca
Professor: Frédéric Nabki | Email: frederic.nabki@etsmtl.ca

MNT (Micro-Nano Technology) FABRICATION

Sixty-nine (69) designs benefited from CMC's MNT financial assistance award program in 2022-2023 (Figure 4).

Academic researchers receive an award of 80% of project expenses to reduce the costs of accessing university-based MNT labs.

CMC's MNT Portal includes **40** facilities located at universities across Canada offering custom fabrication - mask generation, etching, materials deposition, lithography, and characterization.
Learn more: www.cmc.ca/MNT

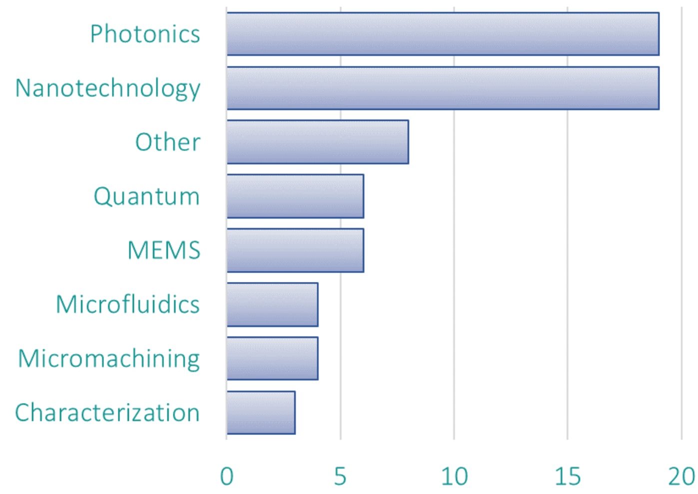


Figure 4 – MNT Designs by Technology, 2022/23

MNT: MEMS, examples

- Design of next-generation Carbon Nanotube (CNT)-Based wafer cleaning device
  MNT: McGill Nanotools Microfab (MNM)
  Application: ICT
  McGill University
  Designer: Lingzhi Zhang | Email: lingzhi.zhang@mail.mcgill.ca
  Professor: Changhong Cao | Email: changhong.cao@mcgill.ca

- Development of an automated additive fabrication process for solid microneedle arrays
  MNT: Microsystems Hub
  Application: Health/Biomedical
  University of Calgary
  Designer: Kazim Haider | Email: syed.haider2@ucalgary.ca
  Professor: Colin Dalton | Email: email

- Fabrication of silicon microwire Arrays through metal-seeded chemical vapor deposition
  MNT: Nano Systems Fabrication Laboratory (NSFL)
  Application: Natural Resource/Energy
  Dalhousie University
  Designer: Patrick Giesbrecht | Email: pgiesbrecht@dal.ca
  Professor: Michael Freund | Email: michael.freund@dal.ca

- New electrode materials for arthroscopic probes
  MNT: GCM Lab
  Application: Health/Biomedical
  Polytechnique Montreal
  Designer: Kathel Cindy Dongnang Ngoula | Email: kathel-cindy.dongnang-ngoula@polymtl.ca
  Professor: Fabio Cicoira | Email: fabio.cicoira@polymtl.ca

MNT: Microfluidics

- ### Automated processing of sexual assault samples to enable rapid DNA analysis
  Application: Health/Biomedical (forensic)
  MNT: Laboratory for Computational Materials Engineering (CME)
  University of Toronto
  Designer: Mohamed Elsayed | Email: mohammed.elsayed@mail.utoronto.ca
  Professor: Aaron Wheeler | Email: aaron.wheeler@utoronto.ca

- ### Decoration of micro/nano-spikes on PDMS with quaternized N-Chloramines for enhanced antibacterial activity
  Application: Health/Biomedical
  MNT: Nano Systems Fabrication Laboratory (NSFL)
  University of Manitoba
  Designer: Mahamuda Sultana | Email: sultana9@myumanitoba.ca
  Professor: Song Liu | Email: song.liu@umanitoba.ca

- ### Fabrication of AC electrothermal microfluidic pumps
  Application: Health/Biomedical
  MNT: Microsystems Hub
  University of Calgary
  Designer: Stirling Cenaiko | Email: stirling.cenaiko@ucalgary.ca
  Professor: Colin Dalton | Email: cdalton@ucalgary.ca

- ### Optoelectronic tweezers for cell sorting
  Application: Health/Biomedical
  MNT: Laboratory for Computational Materials Engineering (CME)
  University of Toronto
  Designer: Mohamed Elsayed | Email: mohammed.elsayed@mail.utoronto.ca
  Professor: Aaron Wheeler | Email: aaron.wheeler@utoronto.ca

MNT: Micromachining

- ### Corrosion of copper under deep geological repository conditions
  Application: Environment, Natural Resource/Energy
  MNT: Western Nanofabrication Facility
  Western University
  Designer: Arthur Situm | Email: asitum@uwo.ca
  Professor: James Noel | Email: jjnoel@uwo.ca

- ### Fabrication of ultra-flexible neural probe with silk shuttle
  Application: Health/Biomedical
  MNT: GCM Lab
  Polytechnique Montreal
  Designer: Jeeyeon Yeu | Email: jee-yeon.yeu@polymtl.ca
  Professor: Fabio Cicoira | Email: fabio.cicoira@polymtl.ca

- ### Fabrication of ultra-flexible neural probe with silk shuttle
  Application: Health/Biomedical
  MNT: GCM Lab
  Polytechnique Montreal
  Designer: Jeeyeon Yeu | Email: jee-yeon.yeu@polymtl.ca
  Professor: Fabio Cicoira | Email: fabio.cicoira@polymtl.ca

- ### Metal-Insulator-Metal Nano Diode Fabrication
  Application: Health/Biomedical, ICT
  MNT: Quantum-Nano Fabrication and Characterization Facility (QNFCF)
  University of Waterloo
  Designer: Dogu Kaan Bugra Ozyigit | Email: dozyigit@uwaterloo.ca
  Professor: Mustafa Yavuz | Email: mustafa.yavuz@uwaterloo.ca

MNT: Nanotechnology, examples:

- ### DMSO treated freestanding Carbon Nanotube (CNT) clusters
  Application: Health/Biomedical (medical imaging, cancer diagnosis), ICT (industrial flaw detection)
  MNT: Quantum-Nano Fabrication and Characterization Facility (QNFCF)
  University of Waterloo
  Designer: Jiayu Alexander Liu | Email: jiayu.alexander.liu@uwaterloo.ca
  Professor: Tze-Wei (John) Yeow | Email: jyeow@uwaterloo.ca

- ### Fiber-based approach to scalable single-protein analysis
  Application: Pharmaceutical (Biopharmaceutical, Chemical)
  MNT: Centre for Advanced Materials and Related Technology (CAMTEC)
  University of Victoria
  Designer: Demelza Wright | Email: demelzawright@uvic.ca
  Professor: Reuven Gordon | Email: rgordon@uvic.ca

- ### Recycling of Lithium Ion Batteries: Charting a sustainable course for separating the coatings and metals at their end of life
  Application: Environment
  MNT: 4D LABS
  Simon Fraser University
  Designer: Gurbinder Kaur | Email: gurbinder_kaur@sfu.ca
  Professor: Byron Gates | Email: bgates@sfu.ca

- ### Tuning heat dissipation of 2D materials
  Application: ICT
  MNT: Toronto Nanofabrication Centre (TNFC)
  York University
  Designer: Shany Oommen | Email: shanym@yorku.ca
  Professor: Simone Pisana | Email: pisana@yorku.ca

MNT: Photonics, examples

- ### AlGaAs Bragg Reflection Waveguide Lasers for Quantum State Generation
  Application: ICT (quantum computing)
  MNT: Quantum-Nano Fabrication and Characterization Facility (QNFCF)
  University of Toronto
  Designer: Trevor Stirling | Email: trevor.stirling@mail.utoronto.ca
  Professor: Amr Helmy | Email: a.helmy@utoronto.ca

- ### Enhanced Evanescent Field waveguide-based Micro-resonator Fabrication for Sensing Application
  Application: Agriculture/Agri-Food; Environment
  MNT: 3IT
  Université de Sherbrooke
  Designer: Pauline Girault | Email: pauline.girault@usherbrooke.ca
  Professor: Paul Charette | Email: paul.g.charette@usherbrooke.ca

- GaN Based UV LEDs for UV Disinfection and Water Purification - Phase II
  Application: Health/Biomedical (cost effective UV related consumer and research products)
  MNT: Quantum-Nano Fabrication and Characterization Facility (QNFCF)
  University of Waterloo
  Designer: Roksana Rashid | Email: roksanarashid@uwaterloo.ca
  Professor: William Wong | Email: wswong@uwaterloo.ca

  Silicon Photonics Integrated Phase-Change Metamaterial Phase and Intensity Modulators for Telecommunications
  Application: ICT
  MNT: NanoFAB
  University of Alberta
  Designer: Yihao Cui | Email: yihao2+cmc@ualberta.ca
  Professor: Behrad Gholipour | Email: bgholipo@ualberta.ca

MNT: Quantum, examples

- Cavity Quantum Electrodynamics with Hole Spin Qubit
  Application: ICT (quantum electronics)
  MNT: Stewart Blusson Quantum Matter Institute
  University of British Columbia
  Designer: Mohammad Khalifa | Email: mkhalifa@ece.ubc.ca
  Professor: Joseph Salfi | Email: jsalfi@ece.ubc.ca

- Fabrication of Quantum Limited Amplication
  Application: Aerospace, Defence (Safety, Security), ICT
  MNT: NanoFAB
  University of Calgary
  Designer: Abdul Mohamed | Email: abdul.mohamed@ucalgary.ca
  Professor: Shabir Barzanjeh | Email: shabir.barzanjeh@ucalgary.ca

- Optomechanical Quantum Transduction
  Application: ICT
  MNT: NanoFAB
  University of Calgary
  Designer: Armin Tabesh | Email: armin.tabesh@ucalgary.ca
  Professor: Shabir Barzanjeh | Email: shabir.barzanjeh@ucalgary.ca

- Quantum Simulation with Spin-based Quantum Bits
  Application: ICT (quantum electronics)
  MNT: Stewart Blusson Quantum Matter Institute
  University of British Columbia
  Designer: Mukhlasur Rahman Tanvir | Email: mukhlasur@ece.ubc.ca
  Professor: Joseph Salfi | Email: jsalfi@ece.ubc.ca

MNT: Other Technologies

III-V High Power Electronics

- Techniques for improving the linearity of lattice-matched InAlN/GaN HFETs
  Application: Automotive, Environment, ICT
  MNT: McGill Nanotools Microfab (MNM)
  Concordia University
  Designer: Yatexu Patel | Email: yatexupatel@gmail.com
  Professor: Pouya Valizadeh | Email: pouya@ece.concordia.ca

Biosensor

- Logic gates for biosensing applications using organic electrochemical transistors
  Application: Health/Biomedical
  MNT: NanoFAB
  University of Alberta
  Designer: Paul Lavryshyn | Email: plavrysh@ualberta.ca
  Professor: Manisha Gupta | Email: mgupta1@ualberta.ca

Characterization

- Analysis of wipe sampling materials to maximize the recovery of anti-neoplastic drugs from surfaces
  MNT: NanoFAB
  Application: Environment
  Simon Fraser University
  Designer: Keyvan Khoroush | Email: keyvan_khoroush@sfu.ca
  Professor: Byron Gates | Email: bgates@sfu.ca

- In-Situ Transmission Electron Microscopy of Memristor behavior under Voltage bias
  MNT: Toronto Nanofabrication Centre (TNFC)
  Application: Defence (Safety, Security)
  University of Toronto
  Designer: Joel Loh | Email: joel.loh@mail.utoronto.ca
  Professor: Nazir Kherani | Email: kherani@ecf.utoronto.ca

- Machine Learning Enable Beyond the Diffraction Limit Imaging
  MNT: NanoFAB
  Application: Agriculture/Agri-Food, Health/Biomedical, ICT, Pharmaceutical, Other (imaging spectroscopy, manufacturing, semiconductors)
  University of Alberta
  Designer: Mahirah Zaini | Email: zaini1@ualberta.ca
  Professor: Behrad Gholipour | Email: bgholipo@ualberta.ca

Microfabrication & Nanofabrication

- Role of ionic liquids on electrostatic doping-induced superconductivity in molybdenum disulfide multilayers
  Application: Natural Resource/Energy, ICT (nano/micro-electronic device engineering)
  MNT: GCM Lab
  Institut national de la recherche scientifique (INRS)
  Designer: Anoir Hamdi | Email: anoir.hamdi@emt.inrs.ca
  Professor: Emanuele Orgiu | Email: emanuele.orgiu@inrs.ca

Organic Electronics

- Fabrication of organic rectifiers based on asymmetric electrodes
  Application: Health/Biomedical
  MNT: GCM Lab
  Polytechnique Montreal
  Designer: Mona Azimi | Email: mona.azimi@polymtl.ca
  Professor: Manisha Gupta | Email: mgupta1@ualberta.ca

- Pressure Sensor utilizing Organic Thin-Film Transistors
  Application: ICT
  MNT: NanoFAB
  University of Alberta
  Designer: Michelle Livojevic | Email: mlivojev@ualberta.ca
  Professor: Paul Barclay | Email: pbarclay@ucalgary.ca

Quantum Photonics / Optomechanics

- Fabrication and Optical Transduction of Diamond Photonic Crystal Nanobeams
  Application: ICT
  MNT: NanoFAB
  University of Alberta
  Designer: Elham Zohari | Email: zohari@ualberta.ca
  Professor: Paul Barclay | Email: pbarclay@ucalgary.ca

Appendix A-1: A Canada-wide Collaboration

CMC lowers barriers to technology adoption by creating and sharing platform technologies including access to state-of-the-art design, manufacturing, and testing capabilities. CMC enables research, development, and the training of highly qualified personnel (HQP), benefitting a network of over 10,000 academic participants and 1,200 companies developing innovations in advanced technologies.

2022/23

- 1 475 connected professors
- 10,435 HQP benefitting
- 785 trained HQP moved to industry in Canada
- 12 new start-ups (recent 5-year average)

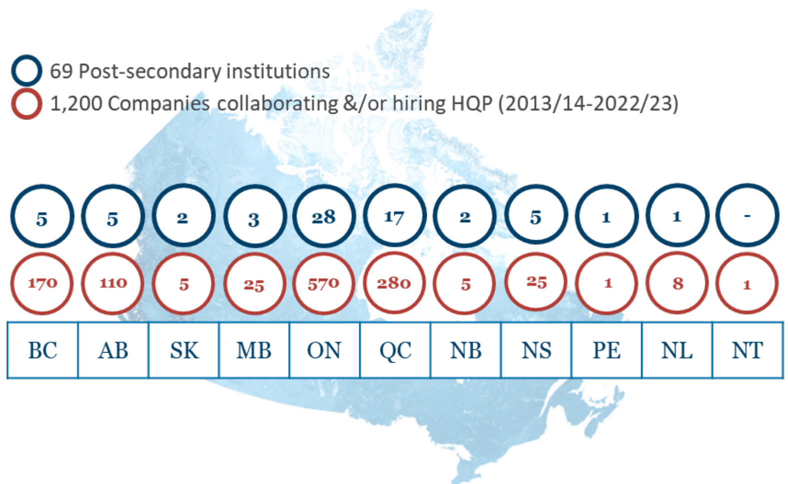
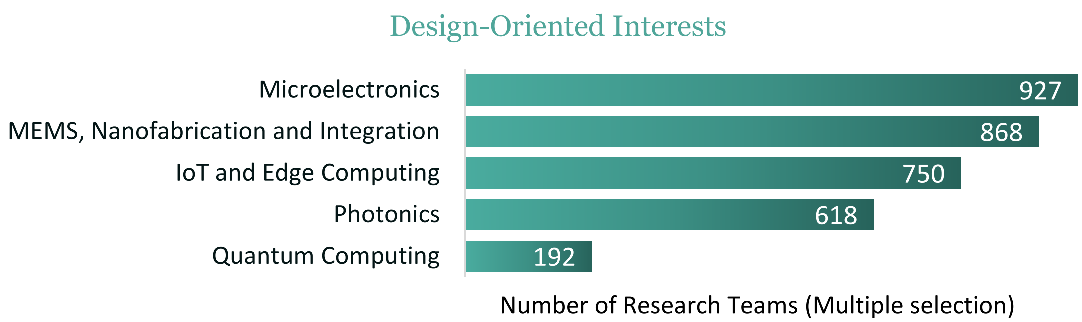


Figure A.1 - CMC Outcomes 2022/23



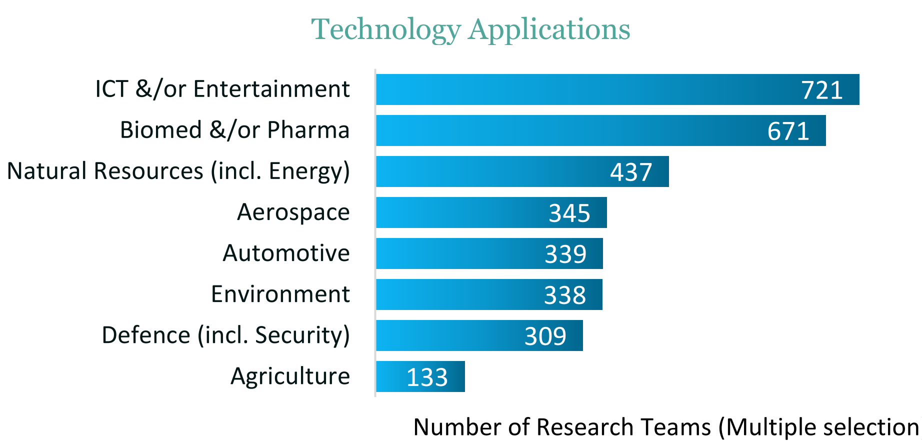
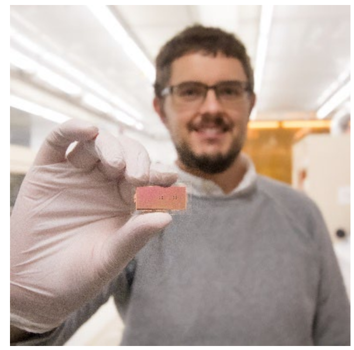


Figure A.2 - CMC Academic Landscape 2022/23

Appendix A-2: Success Stories

Visit www.CMC.ca/SuccessStories to read CMC Success Stories, including the examples listed below.

Greater Bandwidth for Next-Generation Mobile Communications



Thomas Jones, founder, director, and CEO of **Jones Microwave Inc.**, a start-up developing a light-activated switch that controls microwaves at high frequencies, says that could allow cell phones and other devices to access higher bandwidths, speeding up downloads and enabling future applications such as extended reality. Jones began his research as a doctoral student working with **Professor Mojgan Daneshmand**, who led the **Microwave to Millimetre-Wave (M2M) Lab** at the **University of Alberta** and held the Canada Research Chair in Radio Frequency Microsystems for Communication and Sensing. 'This has been a 10-year journey. CMC supported me throughout my PhD and post-doc and now as I build my own company.'

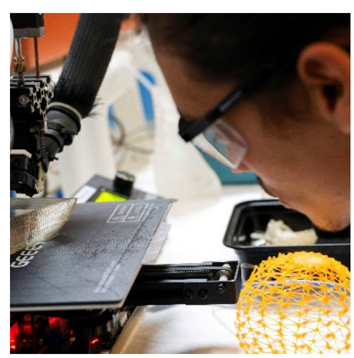
- Published March 2023

Making Better Batteries for the EV Revolution

A **Université de Sherbrooke** start-up **Calogy Solutions** has developed a thin, lightweight thermal management system that can improve battery performance in electric vehicles (EV) and other applications. "We believe there is beauty in simplicity," says **Mahmood Shirazy**, CEO of Calogy Solutions. "There is no motor, and there are no moving parts. There are no electronics. The heat is actually the driving force within it," says Université de Sherbrooke engineering professor **Luc Fréchette**, Chief Technology Officer of the company. Fréchette runs a thermal management lab at Université de Sherbrooke and Shirazy was his PhD student.

- Published January 2023

Game changing 3D industrial printing technology



ZiprPrint, is refining a prototype of the printer system with the help of recent graduate **Luka Morita**. The start-up, brainchild of COO **Mohammad Khondoker**, can print multiple materials, from polymers to metals, and then bond them together using a zipper-like interlocking of parts – a technique that "enhances the bonding strength between dissimilar materials by more than 40 percent" says Khondoker, who began doctoral work in **Dan Sameoto's** research lab at **University of Alberta.** Prof. Sameoto, ZiprPrint's Chief Technology Officer, is working with the **Rehabilitative Research Centre** at the University of Alberta to produce sensor-integrated prosthetics that can improve the quality of life of patients.

- Published December 2022

Appendix B: CMC Roadmap

Technology Roadmap

New and in development prototyping capabilities: CMC plays an enabling role in providing tools, technologies, and expertise to advance Canada's digital economy – where microchip (chip) advanced technologies are critical.

- Microelectronics & Packaging
  - RISC-V with embedded FPGA samples
  - New designs in 12nm FinFET
- IoT and Edge AI
  - Swiftmote Electrochemical Sensing Platform
  - New AI partnerships: Untether, Tenstorrent
- Photonics
  - Photonics library elements for GlobalFoundries®
  - GlobalFoundries®: 45CLO silicon photonics PDK
  - Integrated photonic CWDM filters
- Quantum
  - 29 coding projects completed
  - World's first MPW for Superconducting Qubits
  - In 2020/21, CMC joined the IBM Quantum Hub, making IBM's most powerful (127-bit) quantum computer available in Canada for the first time. Additionally, with Canadian firm Xanadu Quantum Technologies, we launched the Quantum Sandbox.
- Micro Electro-Mechanical Systems (MEMS), Nanofabrication, Integration
  - Strong growth in MEMS & Hybrid fabrication
  - Silicon Interposer TSV process established
  - ESP for novel applications
- CMC Basecamp™ - Fabrication Training Workshops: www.CMC.ca/Basecamp
  - Advanced CMOS Design (FinFET)
  - SiEPIC Passive and Active Photonics – targeting AMF Silicon Photonics and ANT NanoSOI technologies available through CMC Microsystems
  - Superconducting Circuits (device workshop)
  - Silicon Interposers

FABrIC - Canada's Semiconductor Ecosystem, Accelerated

FABrIC is a proposed five-year $200M plus project led by CMC and fourteen other founding organizations to Canada's Federal Government with a start date in 2024, subject to funding, to secure Canada's future in advanced semiconductor (microchip/chip, integrated circuit) manufacturing and design.

FABrIC grows Canada's semiconductor ecosystem, leverages existing chip design and manufacturing facilities, and attracts talent and foreign investment, keeping Canada at the forefront of advanced manufacturing. With FABrIC, business leaders, engineers, scientists, students, and professors work better together and ensure that the Intellectual Property (IP) they create is put to work for Canada.

More: www.CMC.ca/FABrIC

Appendix C: Fabrication Services for Prototypes

Microelectronics

- STMicroelectronics FD SOI 28nm CMOS
- TSMC - options:
  - 65nm GP CMOS, 65nm LP CMOS, 28nm CMOS, 0.13µm CMOS, 0.18µm CMOS BDC, 0.18µm CMOS, 0.35µm CMOS
- AMS 0.35µm CMOS - options:
  - Standard, Opto, High Voltage
- GlobalFoundries® - options:
  - 12LP FinFET, 22FDX FDSOI 22 nm, 45 nm RFE, 90 nm BiCMOS SiGe 9HP, 130 nm BiCMOS SiGe 8XP, 130 nm BCDlite
- XFAB XT018

Photonics & Optoelectronics

- AMF Silicon on Insulator, Passives and Actives
- Applied Nanotools (ANT) NanoSOI - options:
  - Si, SiN
- Azastra III-V epitaxy (GaAs, InGaAs, InGaP) on Germanium substrate
- GlobalFoundries® - CMOS-photonics options:
  - 90WG, 45CLO
- Canadian Photonics Fabrication Centre (NRC-CPFC) III-V Epitaxy on InP Substrates
- FBH-Berlin III-V Epitaxy on GaAs Substrates
- Landmark III-V Epitaxy on GaAs and InP Substrates

Quantum

- VTT Aluminum Junction Process (New)
- VTT Niobium SWAPS Junction Process (New)

Micro Electro-Mechanical Systems (MEMS)

- MEMSCAP PiezoMUMPs
- MEMSCAP PolyMUMPs
- MEMSCAP - Post-processing for PolyMUMPS
- Teledyne DALSA MIDIS™ Platform
- Teledyne Micralyne MicraGEM-Si™
- 3IT Electronic Sensor Platform (ESP)

Micro-Nano Technologies (MNT) Facilities

- 40+ facilities located at universities across Canada

View our FAB schedule online:

www.cmc.ca/FAB

Contact us:

FAB@cmc.ca

LOWERING BARRIERS TO TECHNOLOGY ADOPTION

CMC MICROSYSTEMS

www.CMC.ca