UBC Electrical and Computer Engineering

Towards SiEPIC Integration: Frequency-Entangled Quantum Computing

Team TL083: Davin Birdi, Jessman Jhutty, Manik Dialani – UBC Electrical Engineering Undergraduates
Clients: Mustafa Hammood, & Dr. Lukas Chrostowski – Dream Photonics

Our Client and the Project:

Dream Photonics is a Canadian Semiconductor company looking to prototype **the world's first Frequency-Entangled Quantum Computer.**

Starting with a simple 2-qubit system already proven on in a lab by **Dr. Joseph Lukens**, the scalable approach has yet to be proven on an integrated platform: **Silicon Photonics.**

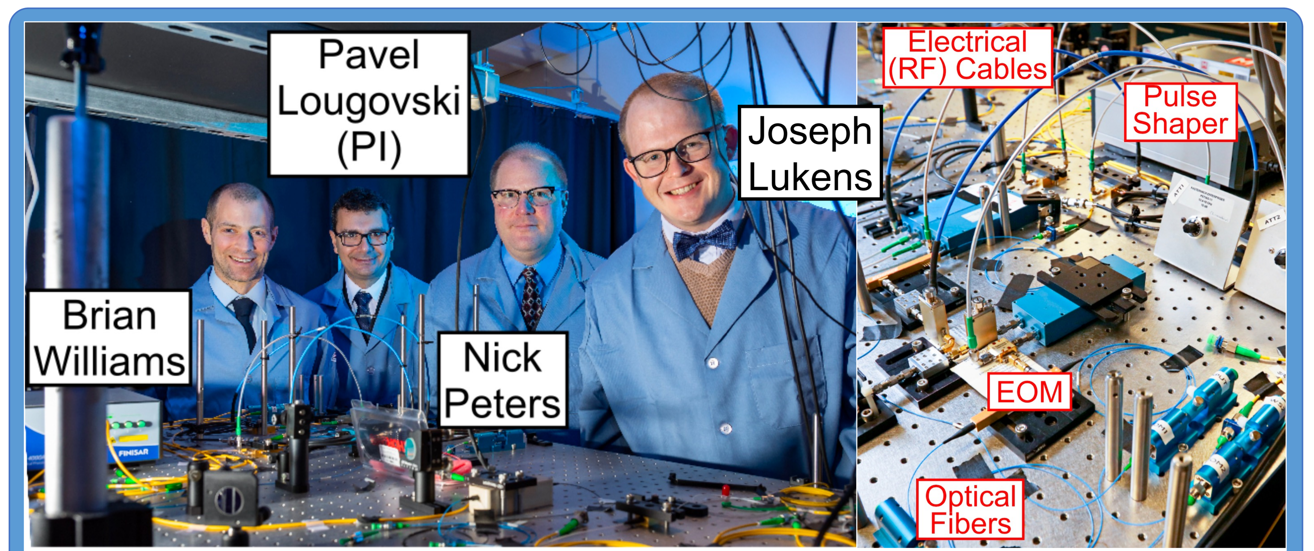
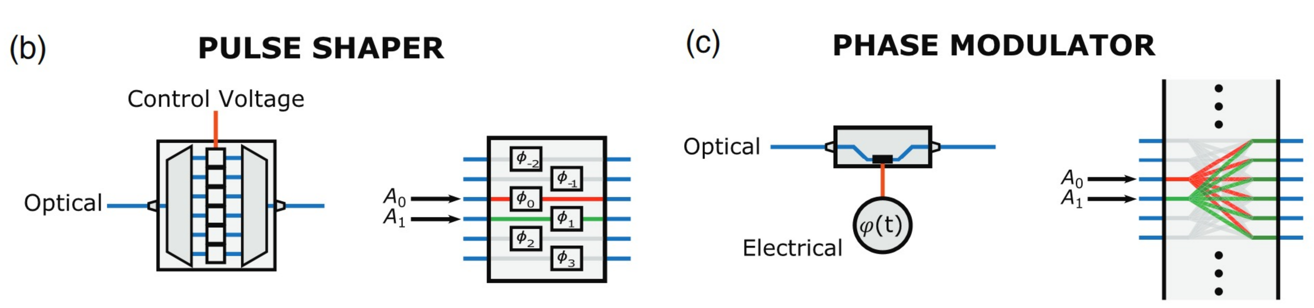


Figure 1: Dr. Lukens and his team, next to their benchtop implementation of a FE-QC

What is Frequency-Entangled Quantum Computing?

Quantum Logic requires its own set of gates like Classical Logic. I.e., instead of AND Gates built of P- and N-type Transistors we have Hadamard Gates built of Pulse Shapers and Phase Modulators.



Using Single Photons, we can encode logical 0 and 1 in its color. As quantum objects, they exist in a probabilistic superposition & can be entangled together

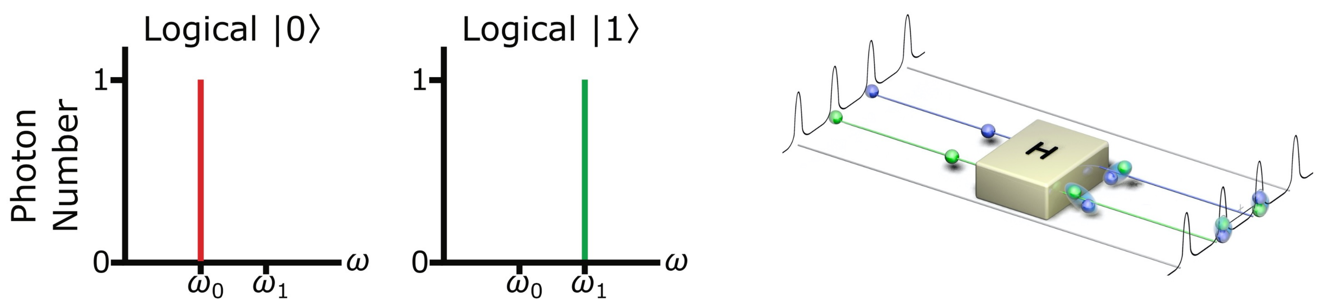


Figure 2: (Top) Functional Schematic for Pulse Shaper and Phase Modulator, (Bottom Left) Mapping of States to Frequency, and (Bottom Right) example of 2-qubit Hadamard Gate.

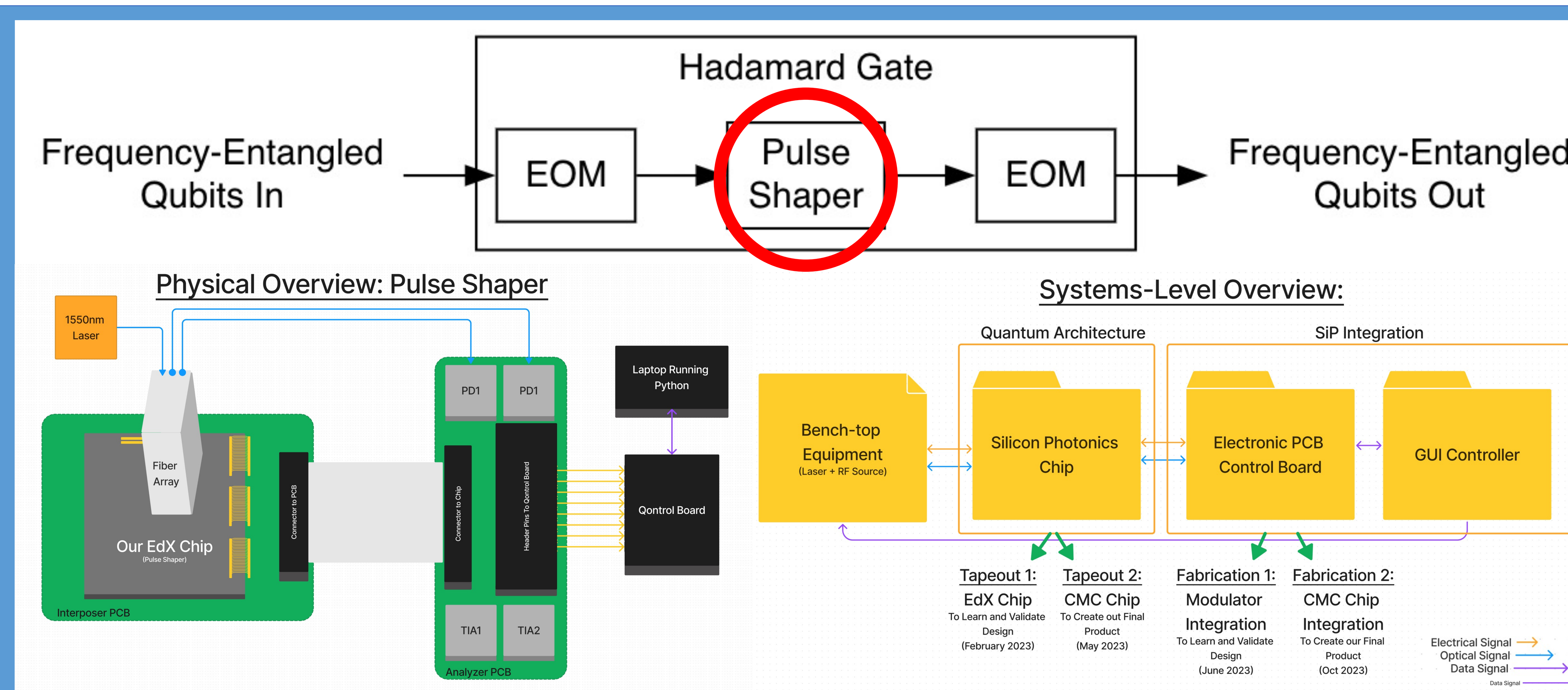


Figure 3: (Top) Schematic for Hadamard Gate and Project Focus, (Left) Physical Representation & connections of Chip, PCB, and Software subsystems, and (right) Schematic Representation and description of subsystems and signal flow.

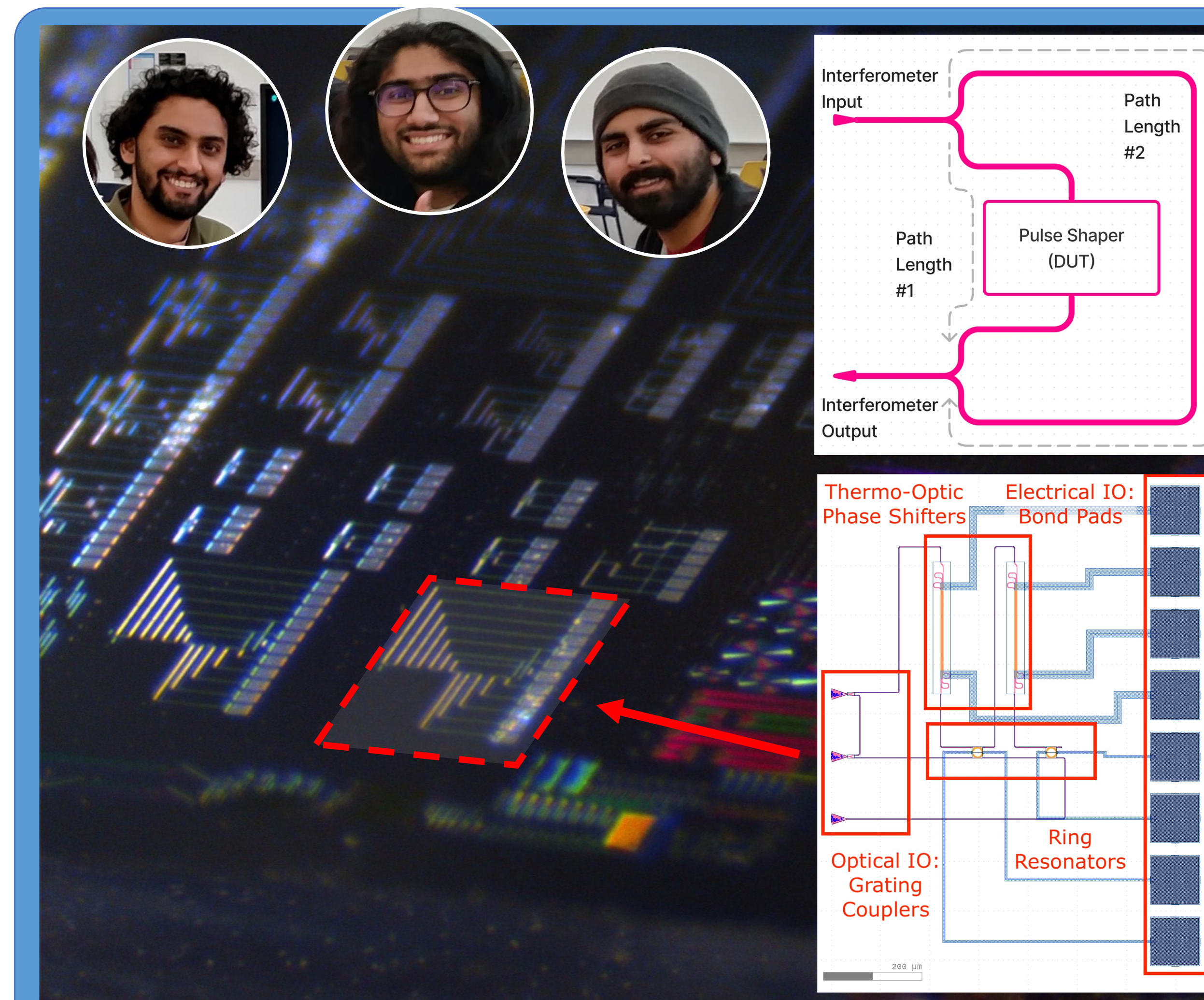
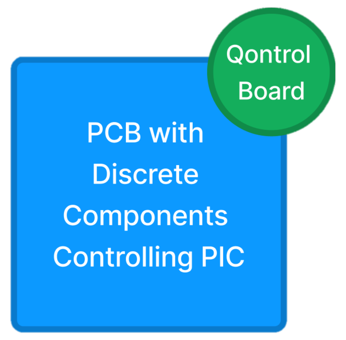


Figure 5: (Background) Microscope Image of PIC, (Top Left) Optical, Electronic, and Software Designers, (Top Right) Schematic Representation of Test Circuit (Bottom Right) Layout of Test Circuit pointed to in Background Image.

Requirements & Goal:

Our Goal is to demonstrate **integrating a photonic system from the chip to the PCB and software level.**

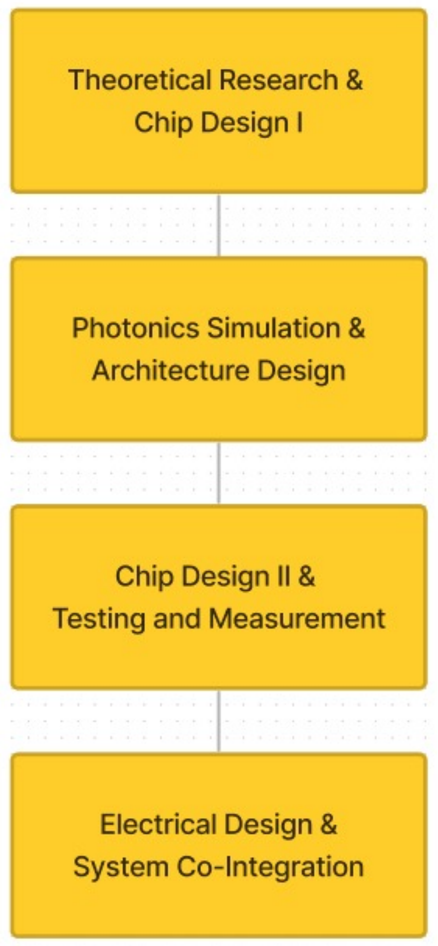


Specifically, design a block of IP that can be substituted in for Benchtop Equipment for use in a FE-QC used for example by Dr. Lukens.

Design Flow:

Starting with understanding Theory of FE-QC, we designed the Pulse Shaper Architecture utilizing the Thermo-Optic Effect for **active tuning** & a **MZI** to capture phase information.

Gaining Lab Experience with custom Optical Probe Stations, we learned to measure and analyze our chip before integrating it with our PCB and Software.



Verification & Validation:

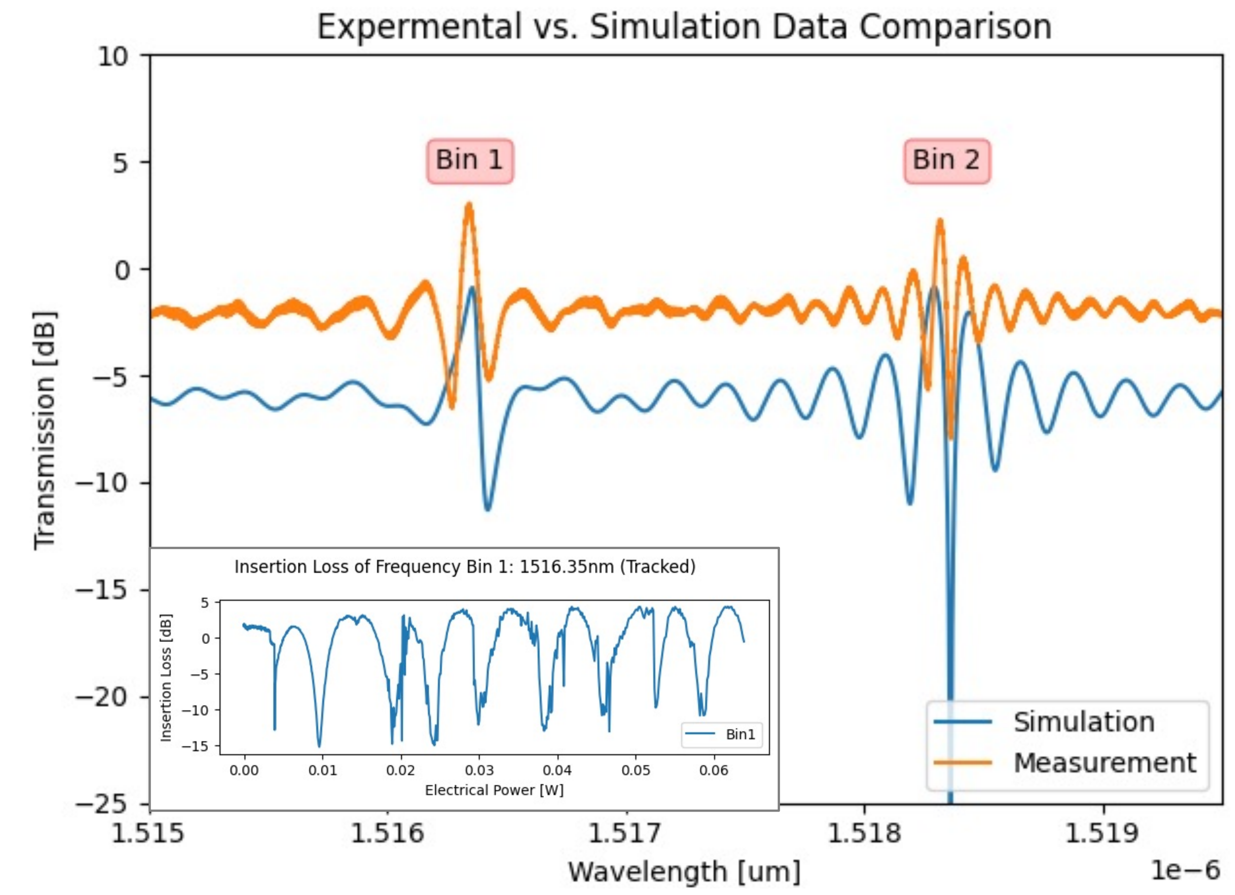


Figure 4: Transmission Spectra of Pulse Shaper Test Circuit calibrated Measurement vs. Simulation. (Inset) Measurement result of Single Wavelength Sweep of Applied Electrical Power, showing Mach-Zehnder Interferometer Spectrum.

Performance and Results:

We use Lumerical INTERCONNECT simulation software to build our devices using idealized primitive components. We compare our experimental vs. simulated results, showing functional agreement.

Our IP Block works with our Measurement GUI, allowing us to drive our simulation as we would our physical circuit in the lab yielding the same results.

Next Steps & Project Future:

We've proven a building block of a FE-QC, the next step is **to optimize the PS design** and **then design the EOM**. When combined, we can validate our Hadamard Gate functionality, and attempt to scale this to build logic circuits with many more qubits.

Main References:

[1] J. M. Lukens and P. Lougovski, **"Frequency-encoded photonic qubits for scalable quantum information processing,"** *Optica*, vol. 4, no. 1, p. 8, Jan. 2017, doi: 10.1364/OPTICA.4.000008.

[2] H.-H. Lu *et al.*, **"Electro-Optic Frequency Beam Splitters and Tritters for High-Fidelity Photonic Quantum Information Processing,"** *Phys. Rev. Lett.*, vol. 120, no. 3, p. 030502, Jan. 2018, doi: 10.1103/PhysRevLett.120.030502.

[3] H.-H. Lu *et al.*, **"Simulations of subatomic many-body physics on a quantum frequency processor,"** *Phys. Rev. A*, vol. 100, no. 1, p. 012320, Jul. 2019, doi: 10.1103/PhysRevA.100.012320.

Acknowledgements:

We express great gratitude to our Clients Mustafa Hammood and Dr. Lukas Chrostowski of Dream Photonics, as well as CMC, NSERC Canada, and Quantum BC. We also thank Applied NanoTools (ANT) for our chip Fabrication.

THE UNIVERSITY OF BRITISH COLUMBIA

Partners

DREAM PHOTONICS · Electrical and Computer Engineering · SiEPIC · QUANTUM BC · CMC