



UNIVERSITY OF  
**WATERLOO**

**IQC**

Institute for  
Quantum  
Computing

# QUANTUM GRAD PROGRAMS & LABS

for interdisciplinary study

JOHN DONOHUE

INSTITUTE FOR QUANTUM COMPUTING

UNIVERSITY OF WATERLOO



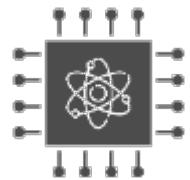
# IQC @ UWaterloo

*The Institute for Quantum Computing*

Founded in 2002

30 faculty members from 7 departments

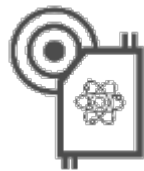
20+ startups founded by members



Computing  
+  
Simulation



Communication  
+  
Security



Sensing  
+  
Metrology



Materials  
+  
Fabrication

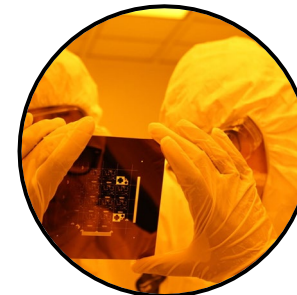
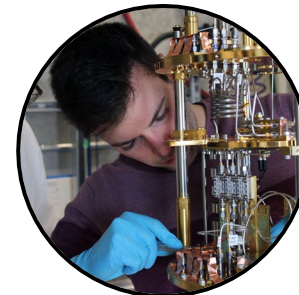
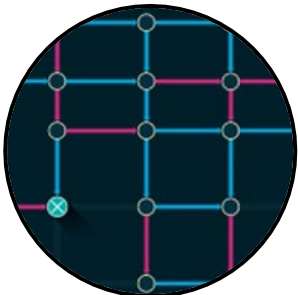
The Mike and Ophelia Lazaridis  
Quantum-Nano Centre

Research Advancement  
Centre



# Research Areas

- Trapped Atoms and Ions
- Computational Complexity
- Quantum Error Correction
- Hybrid Quantum Computing
- Nanofabricated Devices
- Neutron Interferometry
- Electron Spin Resonance
- Nuclear Magnetic Resonance
- Quantum Simulation
- Quantum-safe Cryptography
- Quantum Algorithms
- Optics and Photonics
- Superconducting Circuits
- Quantum Chemistry
- Quantum Key Distribution
- Quantum Communication
- Quantum Games
- Spintronics



Check [uwaterloo.ca/iqc/programs/graduate-studies/supervisors](https://uwaterloo.ca/iqc/programs/graduate-studies/supervisors) for details



### Strong R&D Capacity, Talent Development

Leading foundational and applied research institutions

Distinct pipeline of quantum talent



### Business & Startup Ecosystem

Quantum business, university researchers, solo investors, venture capitalists

Quantum ecosystem, including startups, resulted from IQC's activity and support

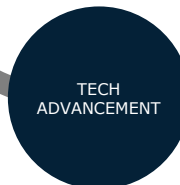
### Regional Institutional Support

Active business outreach

### World-class Infrastructure

Translating research into real world solutions

Leading physical and state of the art infrastructure

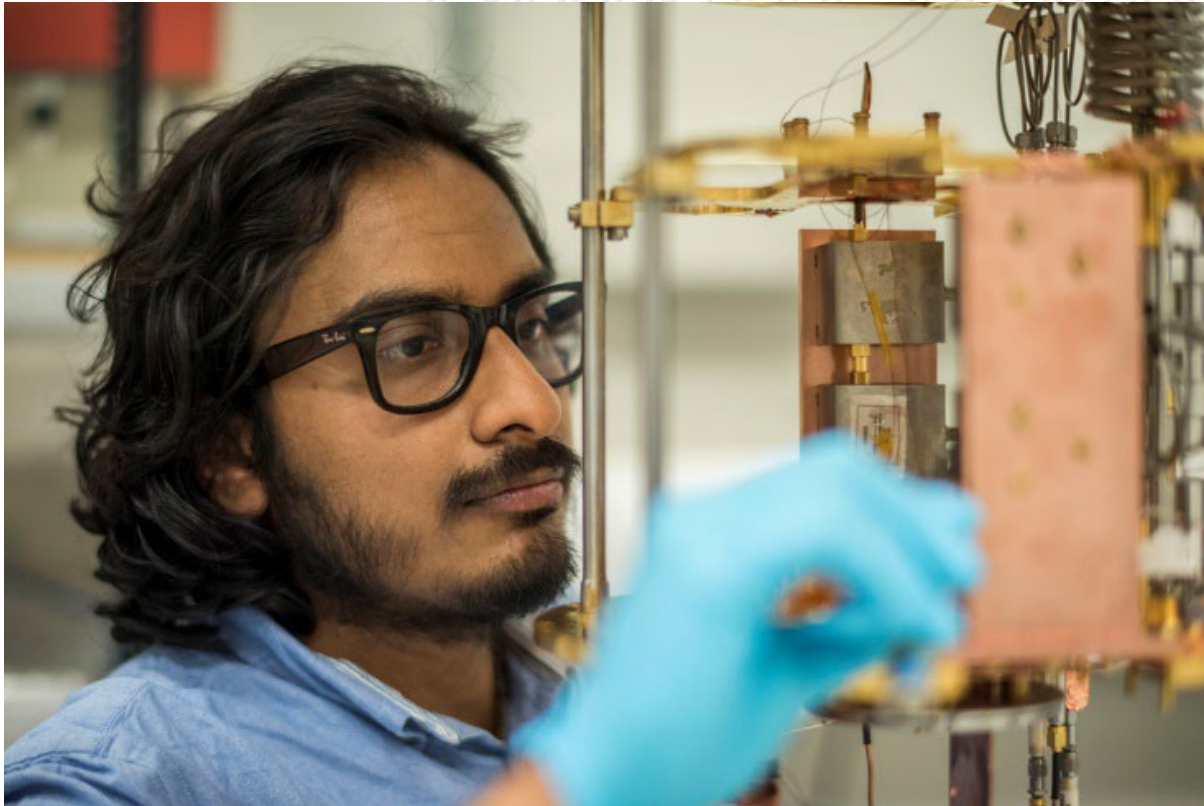


### Regional Institutional Support

Active business outreach



# Graduate Studies in Quantum Information

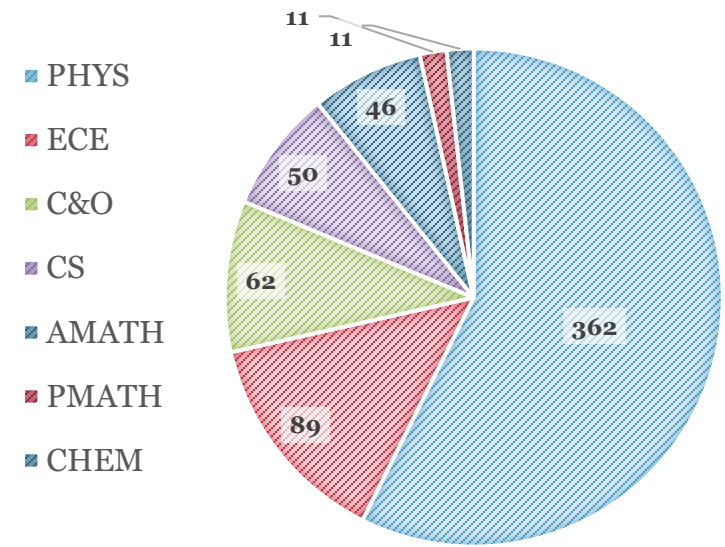


- 168 current graduate students (107 PhD, 61 Masters)
- 380 graduate-level alumni (147 PhD, 243 Masters)

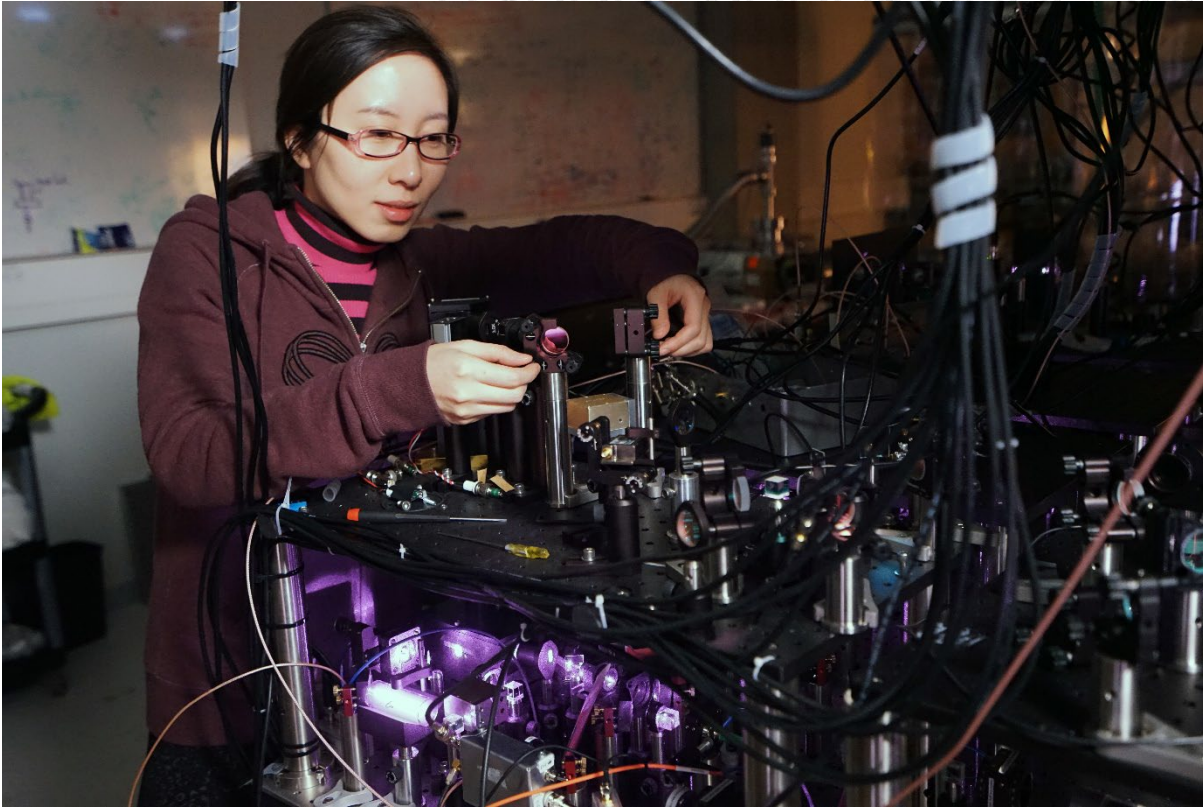
# Collaborative Quantum Information Program

- QI specialization launched in 2010
- Available in seven departments:
  - Electrical & Computer Engineering (MAsc, PhD)
  - Applied Mathematics (MMath, PhD)
  - Pure Mathematics (MMath, PhD)
  - Combinatorics & Optimization (MMath, PhD)
  - Computer Science (MMath, PhD)
  - Chemistry (MSc, PhD)
  - Physics & Astronomy (MSc, PhD)

**IQC ENROLLMENTS  
BY DEPARTMENT**  
(CUMULATIVE, S-2023)



# Collaborative QI Program Requirements



- Option chosen by ~80% of IQC students
- Degree requirements principally set by home department
- Additional seminar requirement
- Additional requisite courses in Quantum Information
  - Two core courses: theory and implementations
  - Two more specialized courses of choice for PhD

# Graduate Courses

Two core courses:

- **Q. Information Processing**
- **QI Processing Devices**

Other regular courses:

- Theory of Quantum Info.
- Quantum Algorithms
- Open Quantum Systems
- Nanoelectronics for QIP
- Q. Electronics and Photonics

Over **50** Special Topics courses, including:

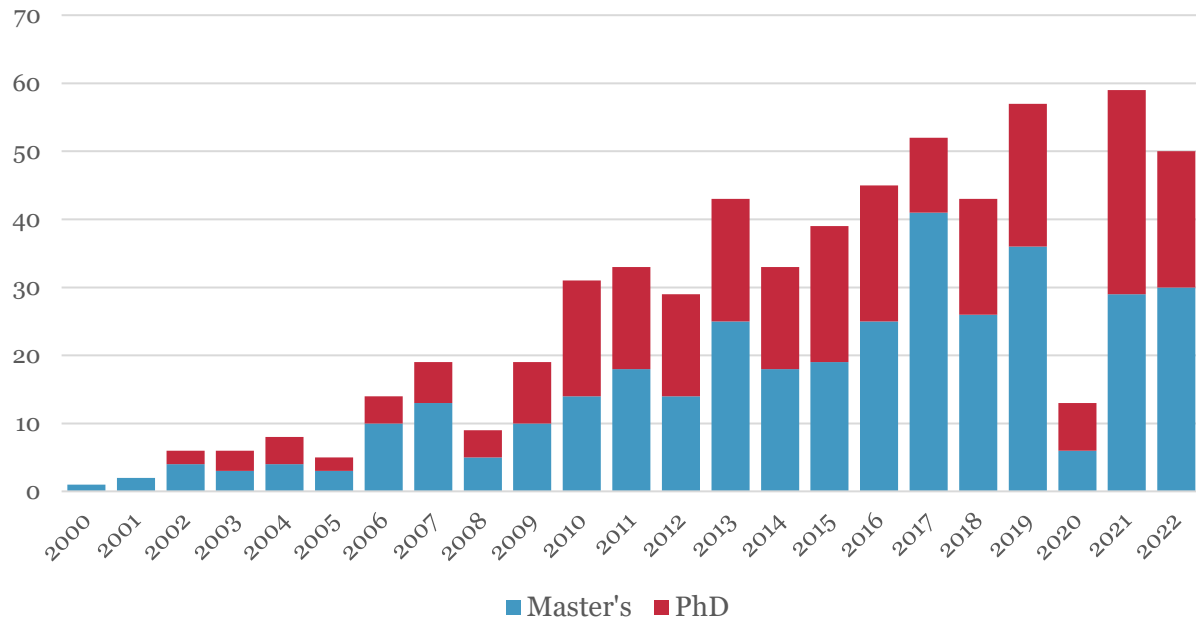
- Semidefinite programming in QI
- Quantum Optics & Nanophotonics
- Post-Quantum Cryptography
- Quantum Error Correction
- Programming Quantum Computers
- QI and Machine Learning
- Relativistic Q. Information
- Design in Quantum Systems



# QI Program Statistics

Student body grows quite fast, but eventually levels off as faculty capacity saturates

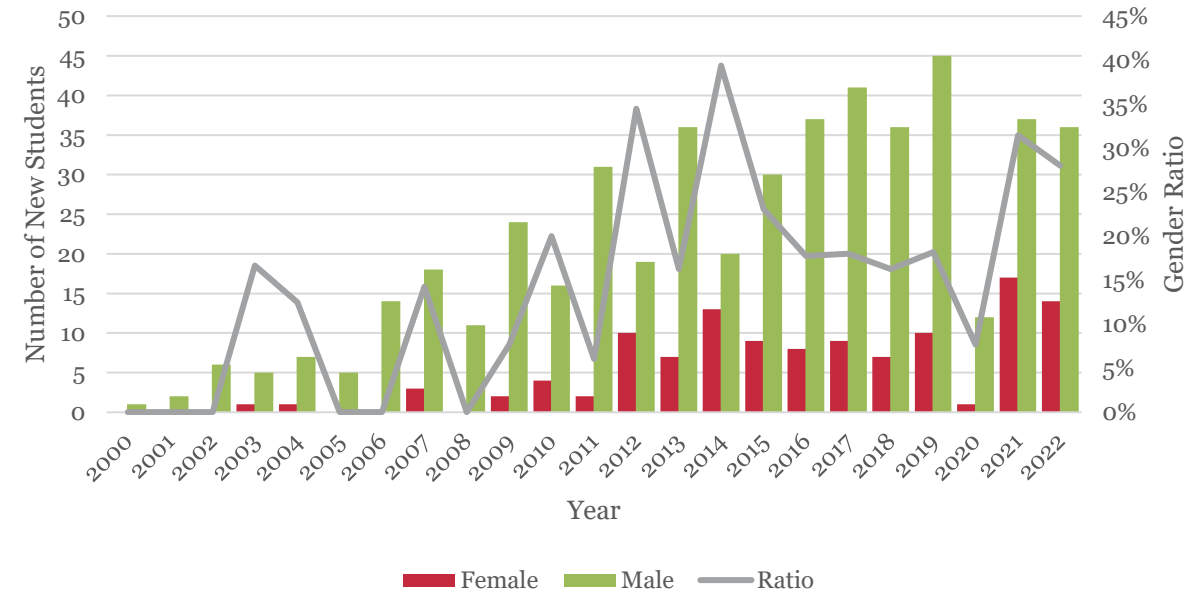
Incoming IQC Students by Degree Type



Gender equity trends are very very noisy

IQC Incoming Graduate Students by Gender

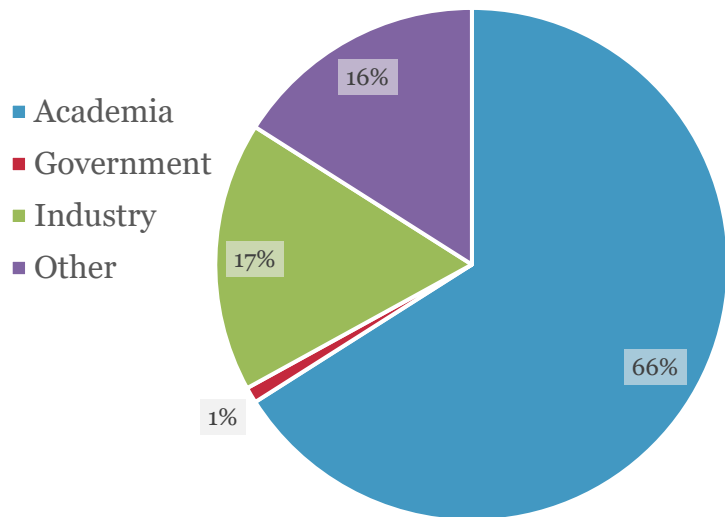
\*limited to those who self-identify as male or female



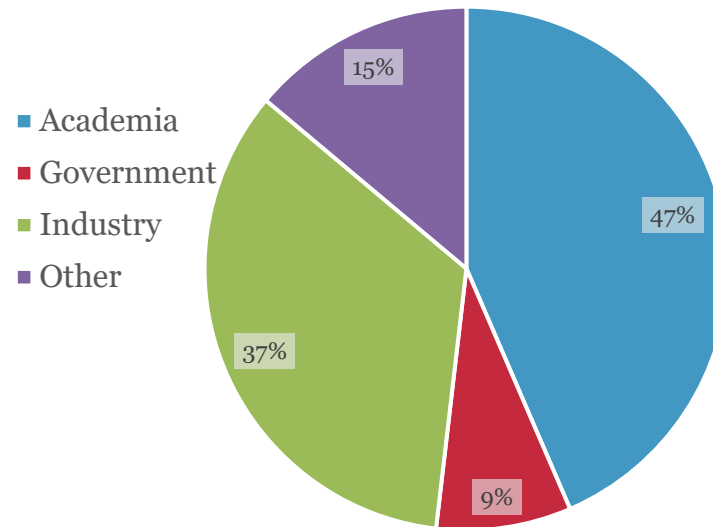
# Where do graduates go?

Students are going to graduate school with industry intentions

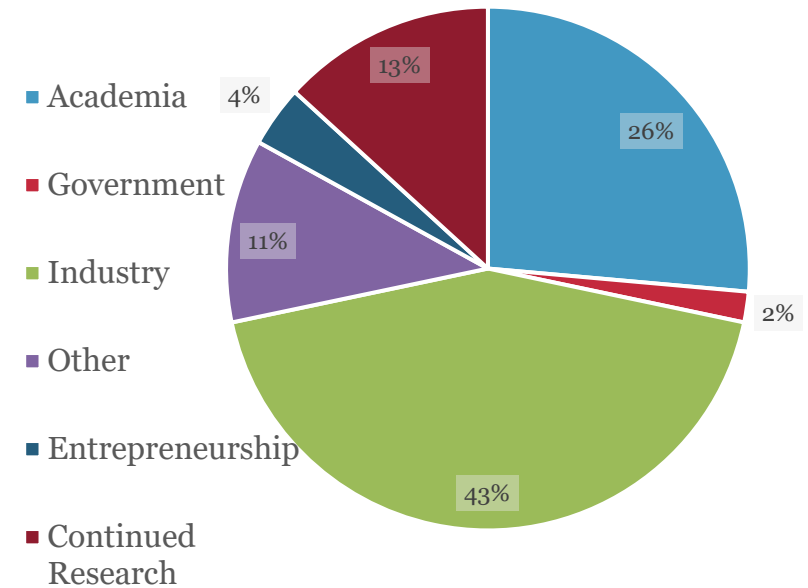
Alumni Sectors - 2017



Alumni Sectors - 2023



Student Intentions - 2022 Survey



# Masters' in Quantum Technologies



UNIVERSITY OF  
**WATERLOO**

Department of  
Physics and Astronomy



Institute for  
**Quantum**  
Computing



Transformative  
**Quantum**  
Technologies

- Course-based Physics MSc in Quantum Technologies
- 5 QI courses + 3 lab courses
- Opened in Sept 2021
  - 4 graduates in 2021/2022
  - 7 exp. grads in 2022/2023

# Lab Courses in Quantum Technologies



QIC860 / PHY760  
Lab on Control of Q. Technology  
Prof. David Cory

- Nuclear magnetic resonance with 2-qubit samples
- Pulse programming and gates
- Decoherence and decoupling
- Nitrogen-vacancy centres
- Randomized benchmarking

# Lab Courses in Quantum Technologies



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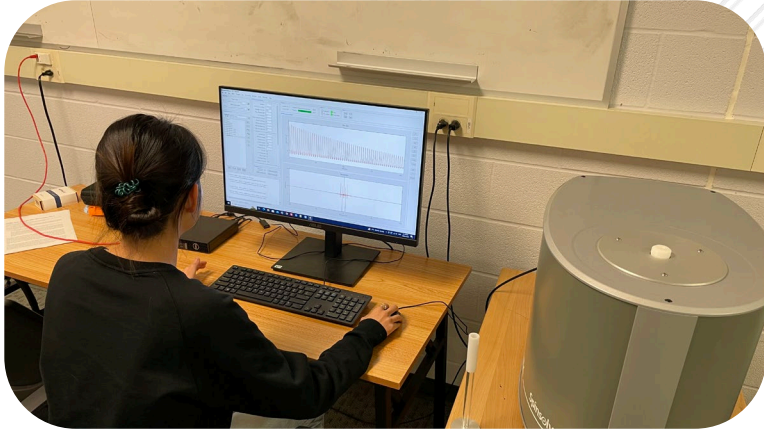
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**QIC861 / PHY761**  
**Lab on Photonic Q. Technology**  
**Prof. Kevin Resch**

- Quantum state tomography
- Photon counting and statistics
- The Bell-CHSH inequality
- Hong-Ou-Mandel interference
- Phase super-resolution
- Quantum eraser

# Lab Courses in Quantum Technologies



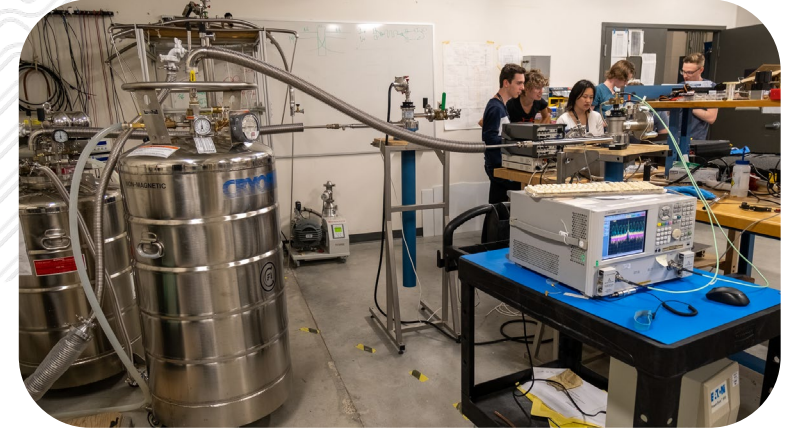
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**QIC862 / PHY762**  
**Lab on Low-T. Q. Tech. & Nanofab.**  
**Prof. Chris Wilson**

- Superconducting transitions
- Low-temp. thermometry
- Josephson junctions
- Cryostats and dil. fridges
- Vector network analyzers
- Nanofabrication techniques

# USEQIP

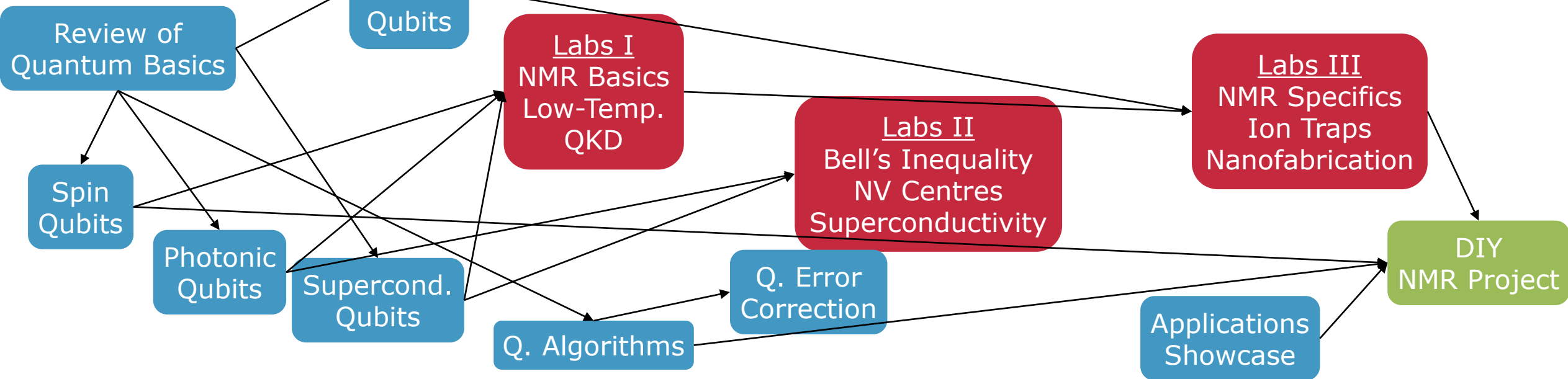
*Undergraduate School on Experimental Quantum Information Processing*



- Two-week intensive summer school for third-year undergraduates
- Held annually since 2009 with up to 30 students per year
- 360 program alumni, 33 returned for graduate studies at IQC
- Undergraduate research awards for students to stay for the summer
  - Student stipends are covered 50/50 by institutional and faculty funds

# USEQIP

*Undergraduate School on Experimental Quantum Information Processing*





# USEQIP

## *Undergraduate School on Experimental Quantum Information Processing*



### Feedback from 2022

*It was a really fun experience! I got to learn a lot of cool theory and had the chance to see some of it in action by doing fun labs.*

*USEQIP provides a very nice introduction to quantum computing from a theoretical and experimental perspective. The labs and lectures are intellectually stimulating and engaging and motivate students to know more about various domains in quantum computing.*

*It gives a great perspective on experimental work done in quantum information and computing. Also amazing opportunity to meet other passionate undergrads and great professors and researchers.*

[uwaterloo.ca/iqc/useqip](https://uwaterloo.ca/iqc/useqip)

# Thank you!

How do we teach these ideas to young students?  
Visit DPE V (Thursday 10:30-12:00)  
***Quantum Information Labs for High-School Students***



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|                              |                      |  |
|------------------------------|----------------------|--|
| Graduate Program Director    | Prof. Jonathan Baugh | <a href="mailto:baugh@uwaterloo.ca">baugh@uwaterloo.ca</a>               |
| Graduate Program Manager     | Paula Roser          | <a href="mailto:paula.rosler@uwaterloo.ca">paula.rosler@uwaterloo.ca</a> |
| Scientific Outreach / USEQIP | John Donohue         | <a href="mailto:jdonohue@uwaterloo.ca">jdonohue@uwaterloo.ca</a>         |
| Q. Tech. Lab Coordinator     | Michael Grabowecky   | <a href="mailto:mgrabowecky@uwaterloo.ca">mgrabowecky@uwaterloo.ca</a>   |
| MSc Q. Tech. Lead            | Prof. David Cory     | <a href="mailto:dcory@uwaterloo.ca">dcory@uwaterloo.ca</a>               |