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UNIVERSITY OF WATERLOO | IQC Institute for Quantum Computing

INSTITUTE FOR QUANTUM COMPUTING
FINAL REPORT for 2014 - 2017
ANNUAL REPORT for APRIL 1, 2016 – MARCH 31, 2017

Report for University of Waterloo Board of Governors approval

TO BE SUBMITTED TO:
THE MINISTRY OF INNOVATION, SCIENCE AND ECONOMIC DEVELOPMENT
JULY 30, 2017

FROM THE EXECUTIVE DIRECTOR

Over the past 15 years, I have had the privilege to have a front row seat to the creation of a Canadian success story. The growth and impact of the Institute for Quantum Computing (IQC) displays the power of incredible vision, sustained commitment and collective efforts to build something truly unique right here in Canada. Thanks in large part to the continued support of the Government of Canada, IQC now stands among the top research institutes globally.

Beyond research discoveries, the past year has brought new people, new space and new opportunities to IQC. I am delighted that our Institute continues to grow with 50 new graduate students, twelve new postdoctoral fellows and three new faculty joining this past year. We welcomed new faculty members K. Rajibil Islam from MIT's Center for Ultracold Atoms, Crystal Senko from Harvard University and Jon Yard from Microsoft Research. Major renovations meant an increase of over 2,000 square feet in lab space this year alone, with plans for continued lab expansion. IQC faculty member David Cory leads the largest research grant in the University of Waterloo's history - $76.3 million from the Canada First Research Excellence Fund for the Transformative Quantum Technologies initiative, which will focus on commercializing quantum devices and technologies. This year also marked the launch of the first-ever travelling exhibition on quantum information science and technologies. QUANTUM: The Exhibition celebrates Canada's excellence in quantum information research as part of the Canada 150 celebrations.

As we look to the next year, Canada and IQC are presented with tremendous opportunity. I am excited by the research that continues to emerge from our labs and how quickly new ideas are moving toward commercialization. Together with the Perimeter Institute, the Lazaridis School at Wilfrid Laurier University, Quantum Valley Investments and the many startups emerging from IQC research, the University of Waterloo is playing a critical role in building the Quantum Valley. New IQC members will open up new areas of research and expand our community in exciting and interesting new ways. As well, a new Director will also set a path forward for IQC that will continue to shape and impact our quantum research agenda nationally and internationally.

I am continually humbled by the generous support IQC has received over its lifetime. The Government of Canada, the Province of Ontario, the University of Waterloo, Mike Lazaridis and the many industry and research partners from every

corner of the globe have contributed to IQC's success in immeasurable ways. It is with this continued support, commitment and vision that Waterloo will continue to be a global leader in quantum information research.

Thank you to the Government of Canada and all our supporters for believing in the quantum vision, encouraging excellence in all that we do and for providing me with a front row seat to an incredible journey that has only just begun.

Raymond Laflamme
Executive Director, Institute for Quantum Computing
University of Waterloo

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ABOUT THE INSTITUTE FOR QUANTUM COMPUTING

IQC was created in 2002 to seize the potential of quantum information science for Canada. IQC's vision was bold: position Canada as a leader in research and provide the necessary infrastructure for Canada to emerge as a quantum research powerhouse. Today, IQC stands among the top quantum information research institutes in the world. Leaders in all fields of quantum information science come to IQC to conduct research, share knowledge and encourage the next generation of scientists.

IQC is leading the next great Canadian technological revolution – the quantum revolution. Quantum technologies and applications developed in IQC labs create the foundation for next generation technologies based on quantum information research conducted right here in Canada.

None of this would be possible without the visionary leadership and investments of Mike and Ophelia Lazaridis, the Government of Canada, the Government of Ontario and the University of Waterloo. This strategic private-public partnership has accelerated the advancement of quantum information research and discovery, not only in Canada, but around the globe.

Vision & Mission

IQC's vision is to harness the power of quantum mechanics for transformational technologies that benefit society and become the new engine for economic growth in the 21st century and beyond.

IQC's mission is to develop and advance quantum information science and technology at the highest international level through the collaboration of computer scientists, engineers, mathematicians and physical scientists.

Strategic Objectives

IQC is guided by three strategic objectives developed in partnership with the Ministry of Innovation, Science and Economic Development:

1. To establish Waterloo as a world-class centre for research in quantum technologies and their applications.
2. To become a magnet for highly qualified personnel in the field of quantum information.
3. To be a prime source of insight, analysis and commentary on quantum information.

FUNDING OBJECTIVES 2014-2017

IQC was awarded $15M over three years through the generous support of the Government of Canada. This funding served to support the following five objectives:

A. Increase knowledge in quantum information science and technology (Increase in knowledge in the various fields and sub-fields of quantum information, thereby positioning Canadians at the leading edge of quantum information research and technology).
B. Create new opportunities for students to learn and apply new knowledge to the benefit of Canada, spurring innovation, and investment in R&D activities through highly qualified personnel development.
C. Brand Canada as the destination of choice for conducting research in quantum technologies and attract the best in the world to Canada, creating partnerships with the international quantum information community and promoting world-class excellence in quantum information science and technology.
D. Enhance and expand the Institute's public education and outreach activities to effectively promote science and quantum information science and demonstrate how the research from quantum information science can be applied for the purpose of sustaining and attracting world-class talent.
E. Position Canada to take advantage of economic and social benefits of research through seizing opportunities to commercialize breakthrough research.

Through the activities planned and undertaken with the contribution of the Government of Canada in the past three years, IQC has positioned Canada to take advantage of economic, social, and in some cases, environmental benefits of quantum research.

What follows is a summary of highlighted achievements from 2014-2017 and a more detailed account of progress achieved in the 2016-2017 year.

2014-2017 OVERVIEW

Over the course of the last three years, the Institute for Quantum Computing has made great strides in all five objective areas. The following section provides an overview of achievements from the three-year funding period.

A. Increase knowledge in the various fields and sub-fields of quantum information, thereby positioning Canadians at the leading edge of quantum information research and technology.

Over the past three years, IQC researchers have collectively published 425 articles spanning a wide array of subjects that reflect the breadth and depth of IQC's research agenda. A sample of the contributions made by IQC researchers include:

- **Quantum computing:** Christopher Wilson and his team demonstrated a record-breaking light-matter interaction in superconducting qubits. This new result opens the door for the study and simulation of relevant and important new physical processes, such as exotic quantum materials, high-temperature superconductors and biological processes.
- **Quantum communication:** Nortbert Lütkenhaus and his colleagues developed a software that calculates the theoretical secure key rate of any quantum key distribution protocol. This development will allow researchers to explore protocols that are better suited for implementation given current technological capabilities.
- **Quantum sensors:** An IQC collaboration led by Dmitry Pushin demonstrated that the orbital angular momentum of neutrons can be controlled in a neutron-interferometer. This control can help measure the magnetism, for example, in magnetic materials, as well as enable deeper probes of superconducting and chiral materials.
- **Quantum materials:** Guo-Xing Miao and colleagues measured a very large, local effective magnetic field and generated a spin current in a novel quantum material. Their findings open the way to electronic devices that leverage the spin of electrons – known as spintronics – which are faster and more energy efficient than current electronics. They also have applications to energy harvesting.

IQC researchers have also made important contributions to the fundamental understanding of quantum mechanics as well as developing practical hardware to facilitate the engineering of quantum processors.

With competition for talent increasing each year, a top priority for IQC is attracting and recruiting world-leading talent. Over the last three years, IQC proudly welcomed ten new faculty and research assistant professors:

- Raffi Budakian, from the University of Illinois at Urbana-Campaign
- K. Rajibul Islam, from Harvard University's Center for Ultracold Atoms
- Na Young Kim, from Stanford University

- Eduardo Martin-Martinez (RAP), who received the 2014 John Charles Polanyi Prize for Physics
- Vern Paulsen, from the University of Houston
- Michael Reimer, from the Technical University of Delft
- William Slofstra (RAP), from the University of California
- Crystal Senko, from Harvard University's Center for Ultracold Atoms
- Wei Tsen, from Columbia University
- Jon Yard, from Microsoft Research.

B. Create new opportunities for students to learn and to apply new knowledge to the benefit of Canada, spurring innovation, and investment in R&D activities through highly qualified personnel development.

IQC is currently home to 38 postdoctoral fellows and 128 graduate students. Annual conferences and workshops like Quantum Innovators, USESIP, QCSYS and the biannual Quantum Key Distribution School spur new knowledge and collaborations across the research community.

C. Brand Canada as the destination of choice for conducting research in quantum technologies and attract the best in the world to Canada, creating partnerships with the international quantum information community and promoting world-class excellence in quantum information science and technology.

There are many indicators that point to IQC's position as a world leader in quantum information technology research. Each year faculty members are collectively invited to speak conferences all over the world – in the last years this number collectively reached 369, and an additional 457 scientific visitors travelled to Canada from across the globe to meet, teach and collaborate with researchers at IQC. Each year IQC also organizes conferences that serve to share knowledge and ideas.

D. Enhance and expand the Institute's public education and outreach activities to effectively promote science and quantum information science and demonstrate how the research from quantum information science can be applied for the purpose of sustaining and attracting world-class talent.

Since 2014, IQC's outreach team organized and hosted annual summer schools for Canadian and international undergraduate and high school students (USEQIP and QCSYS) and established a new workshop – Schrödinger's Class – to enable high school teachers to teach quantum in their own classrooms. Public events including open houses and lectures continue each year, and this past year marked the launch of a travelling exhibition on quantum information technologies that is travelling to Canadian science centres throughout 2017.

The communications team continued to produce the award-winning termly magazine, NewBit, and continued to enjoy increased global awareness of IQC and its work through news stories and growth in subscribers to online platforms.

E. Position Canada to take advantage of economic and social benefits of research through seizing opportunities to commercialize breakthrough research.

IQC faculty collectively hold over 50 patents, and start-up companies are being established that bring quantum technologies out of the labs and into the marketplace. Commercial opportunities stemming from quantum research are growing and attracting the attention of the private sector. Mike Lazaridis and Doug Fregin have created the Quantum Valley Investment fund to support commercialization efforts in quantum information research.

2016-2017 ACHIEVMENTS AND RESULTS

Objective A

Increase knowledge in quantum information science and technology (Increase in knowledge in the various fields and sub-fields of quantum information, thereby positioning Canadians at the leading edge of quantum information research and technology).

Expected Outcomes for 2016-2017:

- Continue IQC's aggressive research agenda in quantum computation, quantum communication, quantum sensors and quantum materials.
- Continue to publish research results in world–leading journals.
- Recruit up to two new faculty members.
- Recruit up to one new research assistant professor.
- Continue to outfit labs in the Mike & Ophelia Lazaridis Quantum-Nano Centre as new IQC members are recruited.
- Continue to outfit and maintain the Quantum NanoFab facility to enable fabrication of quantum-enabled technologies.
- Update and maintain lab space in Research Advancement Centre (RAC) buildings.
- Continue effective and relevant relationships with current partners.
- Seek out new partnerships that will advance IQC's mission and strategic objectives.

Progress Achieved in 2016-2017

Continue IQC's aggressive research agenda in quantum computation, quantum communication, quantum sensors and quantum materials.

Each year IQC pursues an aggressive research agenda in quantum computation, quantum communication, quantum sensors, and quantum materials and produces world-leading knowledge in all these areas. In 2016-2017, IQC researchers collectively published 141 papers (a full list of publications can be found in Appendix B. Following are reports on select research findings from this past year:

Frequency and bandwidth conversion of single photons in a room-temperature diamond quantum memory
Published in *Nature Communications* in April 2016
http://www.nature.com/ncomms/2016/160405/ncomms11200/full/ncomms11200.html

Researchers from the Institute for Quantum Computing at the University of Waterloo and the National Research Council of Canada (NRC) have, for the first time, converted the colour and bandwidth of ultrafast single photons using a room-temperature quantum memory in diamond.

Shifting the colour of a photon, or changing its frequency, is necessary to optimally link components in a quantum network. For example, in optical quantum

communication, the best transmission through an optical fibre is near infrared, but many of the sensors that measure them work much better for visible light, which is a higher frequency. Being able to shift the colour of the photon between the fibre and the sensor enables higher performance operation, including bigger data rates.

The research, published in *Nature Communications*, demonstrated small frequency shifts that are useful for a communication protocol known as wavelength division multiplexing. This is used today when a sender needs to transmit large amounts of information through a transmission so the signal is broken into smaller packets of slightly different frequencies and sent through together. The information is then organized at the other end based on those frequencies.

In the experiments conducted at NRC, the researchers demonstrated the conversion of both the frequency and bandwidth of single photons using a room-temperature diamond quantum memory. The diamond quantum memory works by converting the photon into a particular vibration of the carbon atoms in the diamond, called a phonon. This conversion works for many different colours of light allowing for the manipulation of a broad spectrum of light. The energy structure of diamond allows for this to occur at room temperature with very low noise. Researchers used strong laser pulses to store and retrieve the photon. By controlling the colours of these laser pulses, researchers controlled the colour of the retrieved photon.

The integrated platform for photon storage and spectral conversion could be used for frequency multiplexing in quantum communication, as well as build up a very large entangled state – something called a cluster state. Researchers are interested in exploiting cluster states as the resource for quantum computing driven entirely by measurements.

Chiral Quantum Walks

Published in *Physical Review A* in April 2016
http://journals.aps.org/pra/abstract/10.1103/PhysRevA.93.042302

Imagine a movie showing particles in a gas moving and colliding with each other. Then when you play the movie backwards the velocity of the particles will be opposite, but their motion is still governed by the same laws of physics – we could just as well call the backwards film “forward” – there is no fundamental way to distinguish the arrow of time. This is called time-reversal symmetry.

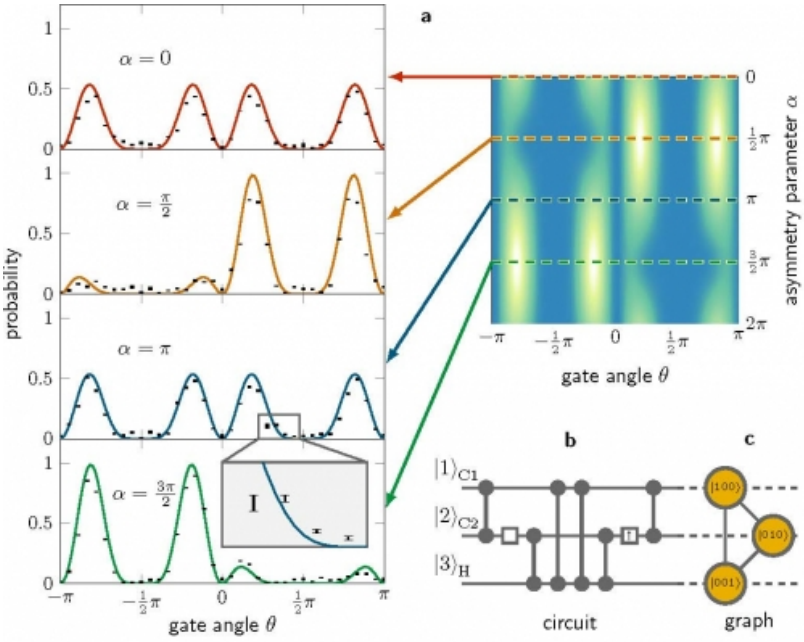
A recent international collaboration including six members from the Institute for Quantum Computing (IQC) have shown how breaking time-reversal symmetry can be used as a resource to control the transport of quantum information.

One of the challenges in developing quantum applications, such as a quantum computer, is controlling how the quantum state evolves. One example is the probability of a particle starting at one physical location and arriving at another at a later time. The standard approach to achieve this requires the application of a sequence of discrete operations call quantum gates. Researchers need to determine

these operations ahead of time and actively manipulate the system. When applied, some of the 'quantumness' of the state is lost because errors arise.

To address this fundamental challenge, the researchers viewed quantum evolution as a 'quantum walk' on a graph. In a quantum walk, once you set up a network a 'single particle quantum walker' moves on a graph and the system evolves on its own.

IQC Postdoctoral fellow Dawei Lu used a liquid-state NMR system to specify the necessary network topologies and simulate this chiral quantum walk. In the joint experimental and theoretical collaboration, breaking time-reversal symmetry was shown to significantly enhance state transport.



a) On the right: The theoretical state-transfer probability, with the lighter color indicating higher probability. On the left we present four constant-α slices of this function. Solid lines are theoretical predictions, and dots represent experimental data. Dot height represents the experimental error (the inset in the bottom plot highlights the error bars for a few data points). (b) Quantum circuit diagram corresponding to the experiment. (c) Graph corresponding to the continuous-time quantum walk (on the single-excitation subspace) simulated by the circuit.

The future applications of time reversal symmetry breaking in quantum information science are ultimately unknown at this time. The results, Chiral Quantum Walks, appeared in *Physical Review A* on April 1, 2016. These ideas are expected to be useful in constructing new quantum algorithms and as a practical tool for implementing quantum control in real systems.

High-Yield Growth and Characterization of ⟨100⟩ InP p-n Diode Nanowires

Published in *Nano Letters* in April 2016
http://pubs.acs.org/doi/abs/10.1021/acs.nanolett.6b00203

Researchers have found a new method to grow high-quality, defect-free material for nanowire p-n junctions, resulting in better electrical contacts for quantum light-emitting diode (LED) devices.

An LED is an electronic semiconductor device that emits light with an injected current. Within the device, two materials, p and n, meet to form the p-n junction. The p side has a positive charge, referred to as an excess of holes or the absence of electrons. The n side is negatively charged with an excess of electrons. When an electrical current is applied across the nanowire, the excess holes and electrons recombine within the p-n junction and emit light.

Nanowires are nanostructures that are grown from gases. Doping agents are used in the growth process to alter the electrical properties of the resulting wire. Previously, nanowire p-n junctions were grown with trimethyl indium and phosphine gases to form indium phosphide (InP), with diethyl-zinc (DEZn) and hydrogen sulfide (H_2S) used as p- and n-doping agents during growth. The tips of these InP nanowires are very narrow – approximately 50 nanometers in diameter (a human hair is about 50,000 nm thick). This makes it extremely difficult to make good electrical contacts with InP nanowire tips for the quantum LED.

In this experiment, the researchers gradually changed the material at the nanowire tip from InP to indium arsenide (InAs). InAs nanowires are known for their ability to make good electrical contacts. This gradual change in the nanowire interface allowed for an improved electrical contact of the p-doped side of the nanowire by two orders of magnitude, resulting in enhanced quantum efficiency. This is also the first time that the effect of the introduction of dopants during this new nanowire growth direction on the wire structure has been investigated. This growth direction, ⟨100⟩, is compatible with current semiconductor technologies.

This research has implications for quantum detectors, solar cells and other energy conversion applications. The improved electrical contact on the p-side leads to lower resistance of energy flow and a more efficient extraction of the electric current required to generate power.

Reimer collaborated with an international team of researchers from Eindhoven University of Technology, Delft University of Technology, Philips Innovation Services Eindhoven, Université de Toulousse and the Royal Institute of Technology. Their results High-Yield Growth and Characterization of ⟨100⟩ InP p-n Diode Nanowires appeared in *Nano Letters* on April 5.

Numerical approach for unstructured quantum key distribution

Published in *Nature Communications* in April 2016
http://www.nature.com/ncomms/2016/160520/ncomms11712/full/ncomms11712.html

Researchers at IQC developed the first available software to evaluate the security of any protocol for Quantum Key Distribution (QKD).

QKD allows two parties, Alice and Bob, to establish a shared secret key by exchanging photons. Photons behave according to the laws of quantum mechanics,

and the laws state that you cannot measure a quantum object without disturbing it. So if an eavesdropper, Eve, intercepts and measures the photons, she will cause a disturbance that is detectable by Alice and Bob. On the other hand, if there is no disturbance, Alice and Bob can guarantee the security of their shared key.

In practice, loss and noise in an implementation always leads to some disturbance, but a small amount of disturbance implies a small amount of information about the key is available to Eve. Characterizing this amount of information allows Alice and Bob to remove it from Eve at the cost of the length of the resulting final key. The main theoretical problem in QKD is how to calculate the allowed length of this final secret key for any given protocol and the experimentally observed disturbance.

A mathematical approach was still needed to perform this difficult calculation. The researchers opted to take a numerical approach, and for practical reasons they transformed the key rate calculation to the dual optimization problem.

The paper, Numerical approach for unstructured quantum key distribution, published in *Nature Communications* presented three findings. First, the researchers tested the software against previous results for known studied protocols. Their results were in perfect agreement. They then studied protocols that had never been studied before. Finally, they developed a framework to inform users how to enter the data using a new protocol into the software.

An experimental test of noncontextuality without unphysical idealizations

Published *Nature Communications* in June 2016
http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4909951/

Theorists from Perimeter and experimentalists from the Institute for Quantum Computing have found a new way to test whether the universe is quantum, a test that will have widespread applicability: they've proven the failure of noncontextuality in the lab.

What does it mean to say the world is quantum? It's a surprisingly difficult question to answer, and most casual discussions on the point are heavy on the hand-waving, with references to cats in boxes.

If we are going to turn the quantum-ness of the universe to our advantage through technologies like quantum computing, our definition of what it means to be quantum – or, more broadly, what it means to be non-classical – needs to be more rigorous. That's one of the aims of the field of quantum foundations, and the point of new joint research carried out by theorists at Perimeter and experimentalists at IQC.

Under quantum theory, two preparations of a system can return identical results in every conceivable test. But researchers run into trouble when they try to define exactly what those systems are doing. It turns out that in quantum mechanics, any model that assigns the systems well-defined properties requires them to be different. That's a violation of the principle of noncontextuality.

To understand what's happening, imagine a yellow box that spits out a mix of polarized photons – half polarized horizontally and half polarized vertically. A different box – imagine it to be orange – spits out a different mix of photons, half polarized diagonally and half polarized anti-diagonally.

Now measure the polarization of the photons from the yellow box and of the photons from the orange box. You can measure any polarization property you like, as much as you like. Because of the way the probabilities add up, the statistics of any measurement performed on photons from the yellow box are going to be identical to the statistics of the same measurement performed on photons from the orange box. In each case, the average polarization is always zero.

Following the principle of noncontextuality, one might think that since the yellow and orange boxes produce indistinguishable mixes of photons, they can be described by the same probability distributions. In a noncontextual world, the fact that the yellow-box photons and orange-box photons are indistinguishable would be explained in the natural way: by the fact that the probability distribution over properties are the same. But the quantum universe resists such explanations – it can be proven mathematically that those two mixtures of photons *cannot* be described by the same distribution of properties. IQC faculty member Kevin Resch set out to experimentally prove this theoretical result.

While previous attempts to test for the predicted failure of noncontextuality have had to resort to assuming things like noiseless measurements that are not achievable in practice, the Perimeter and IQC teams wanted to avoid such unrealistic assumptions. They knew they couldn't eliminate all errors, so they designed an experiment that could make meaningful tests of noncontextuality even in the presence of error.

The result: an experiment that definitively shows the failure of noncontextuality. Like the pioneering work on Bell's theorem, this research clarifies what it means for the world to be non-classical, and confirms that non-classicality experimentally. Importantly, and in contrast to previous tests of contextuality, this experiment renders its verdict without assuming any idealizations, such as noiseless measurements or statistics being exactly the same. This opens a new range of possibilities.

Researchers in several fields are working to find "quantum advantages" – that is, things we can do if we harness the quantum-ness of the world that would not be possible in the classical world. Examples include quantum cryptography and quantum computation. Such advantages are the beams and girders of any future quantum technology we might be able to build. Noncontextuality can help researchers understand these quantum advantages.

Spin-orbit states of neutron wave-packets

Published in *Physical Review A* in July 2016
http://journals.aps.org/pra/abstract/10.1103/PhysRevA.94.013605

Neutrons are massive, subatomic, electrically neutral particles that carry spin and have unique penetrating abilities, properties that make neutrons useful for probing matter and forces. A previous experiment led by IQC Research Assistant Professor Dmitry Pushin demonstrated that Orbital Angular Momentum (OAM) of the incoming neutron can be controlled to any specified value using a macroscopic spiral phase plate cut by a numerical controlled milling machine.

Now, Pushin, together with a team of researchers from IQC, the IBM T.J. Watson Research Center, the Perimeter Institute for Theoretical Physics, the National Institute of Standards and Technology, and the Joint Quantum Institute has proposed a method for preparing an entangled spin-orbit state between the spin and the OAM degrees of freedom of a neutron wave packet.

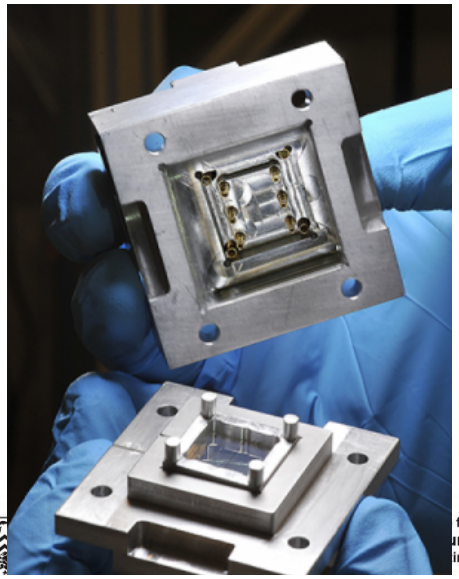
The researchers designed an experimental set-up that passes neutrons through the center of a quadrupole magnetic field, providing a coupling between the neutron's spin and orbital degrees of freedom; this creates the spin-orbit state. The spin-orbit state, in principle, could be used for applications in quantum metrology, such as chiral or helical materials.

Other contributors from IQC included PhD students Joachim Nsofini, Dusan Sarenac, Christopher Wood, faculty member and Canada Excellence Research Chair in Quantum Information Processing David Cory. The paper Spin-orbit states of neutron wave packets appeared in *Physical Review A* on July 13.

Three-Dimensional Wiring for Extensible Quantum Computing: The Quantum Socket

Published in Physical Review Applied in October 2016
http://journals.aps.org/prapplied/abstract/10.1103/PhysRevApplied.6.044010

Researchers from the Institute for Quantum Computing led the development of a new extensible wiring technique capable of controlling superconducting quantum bits, representing a significant step towards to the realization of a scalable quantum computer. One promising implementation of a scalable quantum computing architecture uses a superconducting qubit, which is similar to the electronic circuits currently found in a classical computer, and is characterized by two states, 0 and 1. Quantum mechanics makes it possible to prepare the qubit in superposition states, meaning that the qubit can be in states 0 and 1 at the same time. To initialize the qubit in the 0 state, superconducting qubits are brought down to temperatures close to -273 degrees Celsius inside a cryostat, or dilution refrigerator.



To control and measure superconducting qubits, the researchers use microwave pulses. The pulses are typically sent from dedicated sources and pulse generators through a network of cables connecting the qubits in the cryostat's cold environment to the room-temperature electronics. The network of cables

required to access the qubits inside the cryostat is a complex infrastructure and until recently has presented a barrier to scaling the quantum computing architecture.

The paper, Three-Dimensional Wiring for Extensible Quantum Computing: The Quantum Socket, is a collaborative effort of researchers at INGUN Prüfmittelbau GmbH, Germany, INGUN USA, and Google in the United States, plus the following researchers from IQC and Waterloo: Jeremy Béjanin, Thomas McConkey, John Rinehart, Carolyn Earnest, Corey Rae McRae, Daryoush Shiri, James Bateman, Yousef Rohanizadegan and Matteo Mariantoni.

Ultrastrong coupling of a single artificial atom to an electromagnetic continuum

Published in *Nature Physics* in October 2016
http://www.nature.com/nphys/journal/v13/n1/full/nphys3905.html

Researchers at IQC recorded an interaction between light and matter 10 times larger than previously seen. The strength of the interaction between photons and a qubit was so large that it opens the door to a realm of physics and applications unattainable until now.

The ultrastrong coupling between photons and qubits may lead to the exploration of new physics related to biological processes, exotic materials such as high-temperature superconductors, and even relativistic physics.

To conduct their experiment, the researchers fabricated aluminum circuits in the University of Waterloo's Quantum NanoFab, and then cooled them in dilution refrigerators to a temperature as low as one per cent of a degree above absolute zero. The circuits become superconducting at these cold temperatures, meaning that they can carry a current without resistance or losing energy. These aluminum circuits, known as superconducting qubits, obey the laws of quantum mechanics and can behave as artificial atoms.

This illustration shows a qubit attached to a waveguide where light in the form of microwaves enters and exits.

To control the quantum state of a superconducting circuit, the researchers sent photons using microwave pulses into the superconducting circuit and applied a small magnetic field through a coil inside the dilution refrigerator. By measuring the photon transmission, the researchers could define the resonance of the qubit, indicated by the reflection of the photons off the qubit. Usually, the qubit resonance is centered around a very narrow range of frequencies.

This work was carried out in a collaboration between the Waterloo-based experimental groups of Adrian Lupascu and Christopher Wilson. Both are faculty members in the departments Physics

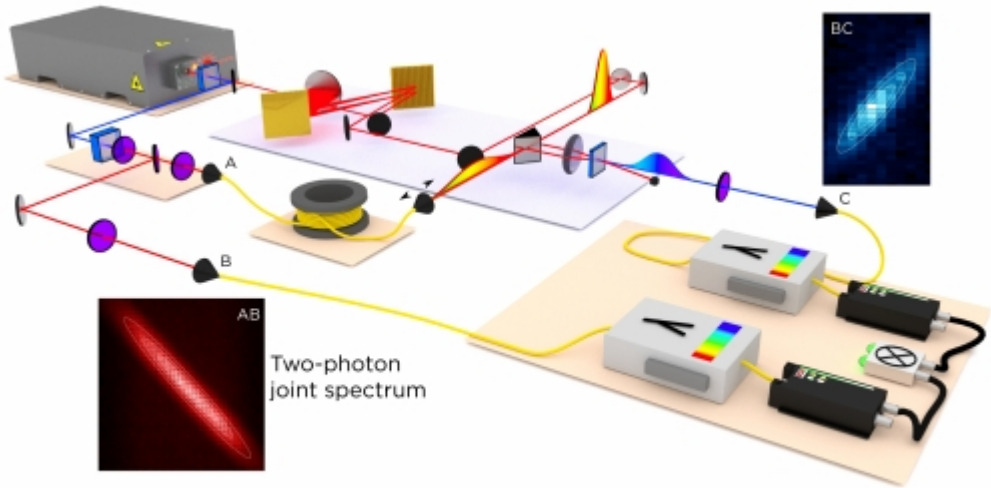
and Astronomy and Electrical and Computer Engineering, as well as IQC. The other authors from IQC of this work are Jean-Luc Orgiazzi, Muhammet Ali Yurtulan, PhD students, and Ron Belyansky, undergraduate research assistant. The project was carried out in collaboration with PhD Juan Jose Garcia-Ripoll from the Instituto de Física Fundamental in Madrid, Spain, and PhD Borja Peropadre from Harvard University.

Spectrally engineering photonic entanglement with a time lens

Published in *Physical Review Letters* in December 2016
http://journals.aps.org/prl/abstract/10.1103/PhysRevLett.117.243602

A team of researchers from IQC have developed a process for reshaping the entanglement of two photons, demonstrating a new set of tools useful for quantum-state engineering.

Information can be encoded in the colour and shape of a photon, or unit of light. A photon's spread of colours makes up its energy spectrum, and also determines its shape as a pulse in time. Processes such as the one demonstrated by the team of IQC researchers can shape the energy correlations of entangled photon pairs by manipulating the photon's spectrum, and may be ued for ultrafast photonic information processing, interfacing different quantum systems, or quantum state engineering and control.



The experimental setup for the photon shaping performed is shown above with the initial two-photon energy correlations in red, and the inverted output two-photon energy correlations in blue.

The researchers created entanglement through a process known as spontaneous parametric down-conversion, where a photon from a bright laser pulse is split in two. Next, one of the two down-converted photons was sent through an optical fiber to spread out its colours in time through a process called dispersion. Dispersion, which describes how different colours of light travel at different speeds in a material, can

cause problems for telecommunications efficiency through optical fibers, however in this case the team used the effect as a tool.

The dispersed photon was then mixed in a nonlinear crystal with a strong laser pulse that had been dispersed in the opposite direction. If the photon and the strong pulse are both in the crystal at the same time, they may combine and produce a photon at a higher energy level through a process called sum-frequency generation. When combined, the researchers could control the transformation between an input photon colour to an output photon colour, allowing for precise re-shaping of the photon's energy spectrum.

Single-photon sensitive spectrometers were used to measure the energy spectrum of the re-shaped photon and its partner from down-conversion simultaneously. The results showed that the dispersion process magnified the spectrum of one photon, similar to how a lens can be used to magnify the shape of a laser beam. The energy spectrum of the initial photon was inverted, showing a flip in the energy and time correlations of the two entangled photons.

The paper, "Spectrally engineering photonic entanglement with a time lens," was published in *Physical Review Letters* on December 6 by Donohue, Resch, and Master's student Morgan Mastrovich. During the experiment, Mastrovich was attending the Undergraduate School on Experimental Quantum Information Processing (USEQIP).

Prospects and limitations of bottom-up fabricated hollow-core waveguides

Published in *Optical Materials Express* in January 2017
https://www.osapublishing.org/ome/fulltext.cfm?uri=ome-7-1-148&id=355962

IQC researchers propose two possible methods for building an optical cavity inside a hollow-core on-chip waveguide, to develop a platform for quantum information processing through photon-photon interactions.

Particles of light, called photons, can carry information over long distances and make excellent qubits for quantum communication. However, photons generally do not "talk" to each other – in other words, photons do not interact with other photons on their own. This makes quantum logic gates, one of the building blocks of a quantum computer, difficult to implement for single photon operation.

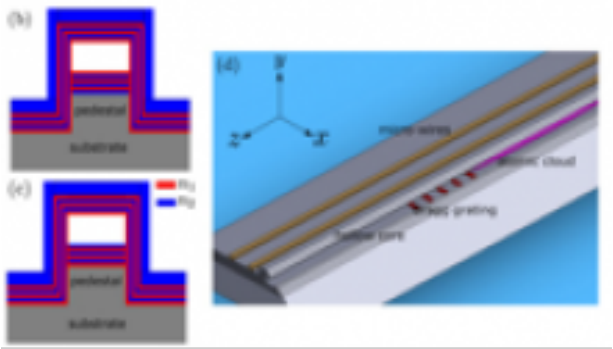
At the same time, atoms and photons do "talk". A photon can change the state of an atom, while an atom can absorb or change the phase of a photon depending on the atom's state. If two photons interact with the same atom, this can result in an effective photon-photon interaction. The technological challenge for scalable quantum information processing or other applications is then creating an environment where controlled light-matter interaction can occur on a chip, which requires simultaneous tight confinement of both photons and atoms.

One approach has been loading and trapping laser-cooled atoms, which are better at interacting with single photons than their room-temperature counterparts, inside

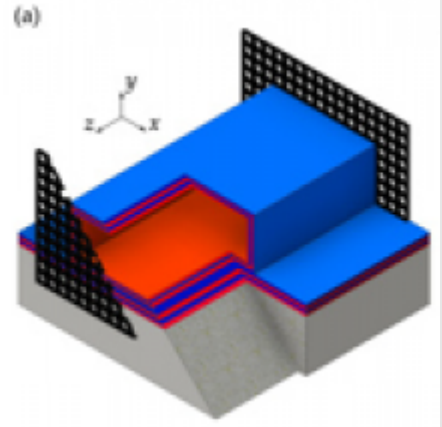
hollow-core waveguides for tight transverse confinement. Integrating a pair of mirrors into the waveguide to form a cavity adds longitudinal confinement for light to this platform.

Forming mirrors inside conventional, solid-core optical waveguides, such as optical fibres, is commonly done by periodically modulating the refractive index of the waveguide's core along its length. When the period of modulation is chosen correctly, this can create highly reflective mirrors. These mirrors operate on a principle similar to anti-reflection coating on glasses or camera lenses, except they act as anti-anti-reflection coatings and can achieve reflectivity as high as 99.999%. However, since the hollow core of the waveguide does not offer any material for modulation, adding mirrors is tricky without clogging up the waveguide.

In their exploratory work recently highlighted by OSA Publishing's Spotlight on Optics, Master's student Golam Bappi, with PhD students Jeremy Flannery, Rubayet Al Maruf and faculty member Michal Bajcsy present two methods for fabricating mirrors in a hollow-core on-chip waveguide to facilitate photon-photon interactions.



In the first design (left), the team of researchers proposed forming mirrors in a rectangular hollow-core waveguide by adding small pieces of dielectric material to the hollow core during the waveguide fabrication. The pieces are arranged in a lateral fashion similar to railroad ties and form the mirror by effectively modulating the overall refractive index of the hollow core waveguide in a periodic fashion while keeping the core open for atoms.



The second design (left) uses a pair of patterned dielectric membranes attached to the ends of the waveguide to create a cavity by acting as reflective metasurfaces. The holes, drilled at the right size and right spacing, make the membrane act as a highly reflective mirror and allow atoms to be loaded in to the cavity. The patterned membranes then trap the light by forcing the photons to bounce back and forth between them.

Bajcsy's Nano-Photonics and Quantum Optics Lab has already started the fabrication of the proposed structures. The next steps will be to evaluate their performance in an experimental set-up where cold atoms are prepared and loaded in to the waveguide, and photons are sent in for interaction.

In addition to the development of quantum logic gates operated with single photons, other potential applications of these structures include optical transistors in which

the flow of light is controlled by a single photon and precision lasers, called superradiant lasers, useful in precision metrology.

The paper, “Prospects and limitations of bottom-up fabricated hollow-core waveguides” appeared in *Optical Materials Express* in January.

Experimental violation of the Leggett–Garg inequality in a three-level system

Published in *New Journal of Physics* in February 2017
http://iopscience.iop.org/article/10.1088/1367-2630/aa5c51/meta;jsessionid=CC23C0436E5005F8479180DCDDA23820.c1.iopscience.cld.iop.org

IQC PhD student Hemant Katiyar led the first experiment to violate the Leggett-Garg inequality on a three-level quantum system, demonstrating the possibility of larger violations than previously thought possible.

The Leggett-Garg (LG) test is meant to demonstrate a violation of macrorealism, the idea that macroscopic objects (like cats and tables) cannot exist in superpositions of classically observable states (like dead or alive, here or there), given a certain set of reasonable assumptions. It uses dichotomic, non-invasive measurements to calculate a function with a fixed upper bound for a macrorealistic system and a higher upper bound for a quantum system.

This upper bound is 1 for a macroscopic system, and has long been believed to be 1.5 for a quantum system. However, a recent discovery revealed that this quantum upper bound can be increased up to a maximum of 3 by testing higher dimensional systems than the standard two-level system of the original LG test. The levels of a system are determined by the number of states of the system; for example, a three-level quantum system (qutrit) can exist in three possible states.

Katiyar, along with former IQC postdoctoral fellow Aharon Brodutch (now at the University of Toronto), postdoctoral fellow Dawei Lu, and Executive Director and Canada Research Chair in Quantum Information Raymond Laflamme performed the LG test using nuclear magnetic resonance (NMR). They first created a qutrit out of a macroscopic-sized sample of molecules, chose three distinct times to perform measurements on the system and then performed three independent experiments, starting the system in the same state every time. To accurately estimate the probabilities of the qutrit being in different possible states, they repeated these three experiments many times.

To assure that the violation of the LG inequality is legitimate and not a result of errors, the test requires that the measurements do not disturb the system. Borrowing from IQC associate Sir Anthony Leggett himself, the group assumed there were two boxes. The boxes are closed, and there is a ball in either one of them. Now, open one of the boxes and the ball is not there, so one knows it is in the other box. So, in a way, the ball is measured without interacting with the ball.

The box-ball analogy describes negative result measurement, a method of non-invasive measurement. Even using this method, the researchers had to contend with experimental limitations which disturbed the quantum system. Fortunately, after performing calculations to account for these errors, the violations of the inequality achieved were still greater than the previous theoretical limit.

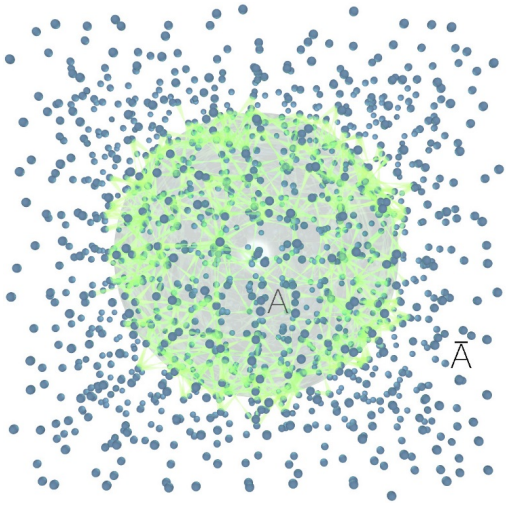
Katiyar is quick to elaborate that their results are not a definitive proof that macroscopic realism is false. Though their sample size was macroscopic, it was made up of microscopic molecules, and so a violation of the LG inequality is not unexpected. The importance of their results lies in the use of a three-level system to expand the upper bound beyond what has ever been experimentally achieved, giving a larger buffer for noise and experimental error. Their improvement in the methods of performing an LG test brings researchers one small step closer to violating the inequality with a truly macroscopic object.

The results were published as “Experimental violation of the Leggett-Garg inequality in a 3-level system” in the *New Journal of Physics*.

Entanglement area law in superfluid ^{4}He

Published in *Nature Physics* in March 2017
http://www.nature.com/nphys/journal/vaop/ncurrent/full/nphys4075.html

When condensed helium is cooled to approximately two degrees Kelvin, it becomes a quantum phase of matter called a superfluid. In this state, the helium atoms move without friction and could flow without ever stopping, in principle. While entanglement is often thought of as occurring between two particles, here the researchers were studying a many-body system, meaning they had to measure entanglement between particle-filled regions of space. The researchers took a cubic box of superfluid helium-4 and divided it into a spherical sub-region and its complement. They then measured the entanglement entropy between the two regions at different system densities.



Consider a classical box filled with encrypted documents. Intuitively, it is clear that if you doubled the size of the box, you could fit twice the number of documents inside, and therefore twice the information. Quantum mechanics, however, flouts intuition. Theoretical physicists Stephen Hawking and Jacob Bekenstein found out decades ago that the entropy of a black hole, a quantum box in our scenario, does not increase with volume, but rather with surface area. To double the amount our quantum box holds, we would need to double its surface area. This is the area law scaling of entropy, and it turns out that it applies to the entanglement entropy of quantum phases of matter as well, as shown in this computational experiment with superfluid helium.

In the past, the area law scaling of entanglement entropy in matter has only been studied either in simplified qualitative models that do not predict or precisely describe experiments, or more recently, in experimental implementations that use artificially created systems. IQC faculty member Rajibul Islam and his team were one of the first groups to experimentally measure entanglement entropy in a many-body system, which they achieved using an artificial system in 2015.

After years of adapting and developing numerical methods to quantitatively study superfluid helium and entanglement entropy, Herdman and his collaborators, IQC affiliates and University of Waterloo faculty members Pierre-Nicholas Roy, Department of Chemistry, Roger Melko, Department of Physics and Astronomy and Perimeter Institute for Theoretical Physics, as well as Adrian Del Maestro, Department of Physics, University of Vermont, demonstrated the area law in a real, natural system for the first time. The paper Entanglement area law in superfluid 4He published in Nature Physics March 13, showed that entanglement between the sphere and complement of superfluid helium was dominated by an area law (like our quantum box), not a volume law (like our classical box). The researchers also demonstrated that they could control entanglement between the sub-regions by changing the pressure of the system, a simple variable for experimentalists to control.

Recruiting New Researchers

Recruit up to two new faculty members and one research assistant professor

IQC successfully recruited three new faculty members this year and is proud to welcome K. Rajibul Islam, Crystal Senko and Jon Yard, whose appointments bring the total number of current faculty to 26, positioning IQC on the way to reaching its goal of 33 members. A full list of current faculty members can be found in Appendix C.

K. Rajibul Islam, Assistant Professor, joined IQC in November of 2016. He is jointly appointed with the Department of Physics and Astronomy in the Faculty of Science, and is the Principal Investigator of the Laboratory for Quantum Information with Trapped Ions. Islam completed his Bachelor's and Master's degrees in India, focusing on the theory of statistical physics, quantum magnetism and the interaction of spins in frustrated systems. Motivated by the possibility of studying physical systems in a lab, Islam shifted to experimental research with laser-cooled trapped ions and moved to the University of Maryland, College Park to earn his PhD under the supervision of Christopher Monroe. His thesis, "Quantum Simulation of Interacting Spin Models with Trapped Ions," was recognized by the University of Maryland's Distinguished Dissertation Award in 2013. In his first three years as a postdoctoral fellow with Harvard University at the Center for Ultracold Atoms (CUA), Islam studied entanglement in ultra-cold neutral bosonic atoms in optical potentials with Markus Greiner's group. Returning his research focus to ions, this time in optical potentials

created in a high quality optical resonator, Islam joined MIT as a postdoctoral researcher in Vladan Vuletic's group at CUA. At IQC, Islam's experimental research will address fundamental physics questions, concentrating on encoding and manipulating quantum information in a quantum many-body system using trapped ions.

Crystal Senko, Assistant Professor, joined IQC in November of 2016. She is jointly appointed with the Department of Physics and Astronomy in the Faculty of Science at the University of Waterloo. During her doctoral research in quantum information, Senko used trapped ions to simulate a quantum computational module and to create a spin chain experiment for manipulation in the lab. She earned her PhD under the supervision of Christopher Monroe at the University of Maryland. At the Center for Ultracold Atoms (CUA) as a postdoctoral fellow with Harvard University, Senko worked on the development of a photonic crystal waveguide that, when atoms are placed next to it, creates an interesting system for information transfer between atoms by the photons flowing through the photonic crystal. Senko's research at IQC focuses on using trapped ions for quantum simulations and quantum computing applications. Her work also explores qudits and how to improve the efficiency of encoding a logical unit of information using the multiple levels of a qudit.

Jon Yard, Associate Professor, joined IQC in September 2016. He is jointly appointed with the Department of Combinatorics and Optimization in the Faculty of Mathematics and as an Associate Faculty member with the Perimeter Institute for Theoretical Physics (PI). Yard earned his doctorate under the supervision of information theorist Thomas Cover at Stanford University, where his theoretical research was focused on core questions in quantum information theory such as determining the capacities of noisy quantum channels and networks for distributing quantum information. Gradually shifting his attention towards quantum computing, Yard moved on to postdoctoral positions at McGill University, Caltech and Los Alamos National Laboratory. At Los Alamos, Yard was awarded the Richard P. Feynman Fellowship for his work in quantum communication theory. As part of Microsoft's Research Station Q team, Yard pursued connections between algebraic number theory and quantum computing, and also looked at the classification of topological states of matter. At IQC, Yard will tackle complex mathematical problems and look for new solutions to existing problems by combining approaches from mathematics, physics, engineering and computer science.

Continue to publish research results in world-leading journals.

Publications and Citations

One measure of research output taking place at IQC are the papers published each year. In 2016-2017, IQC's researchers published 141 papers, reaching international

audiences, and several were published in prominent scientific publications including *Nature Physics, Nature Communications* and *Physical Review Letters.* Below is a summary of IQC research published in prominent journals since fiscal 2012. A full list of papers published this year can be found in Appendix B.

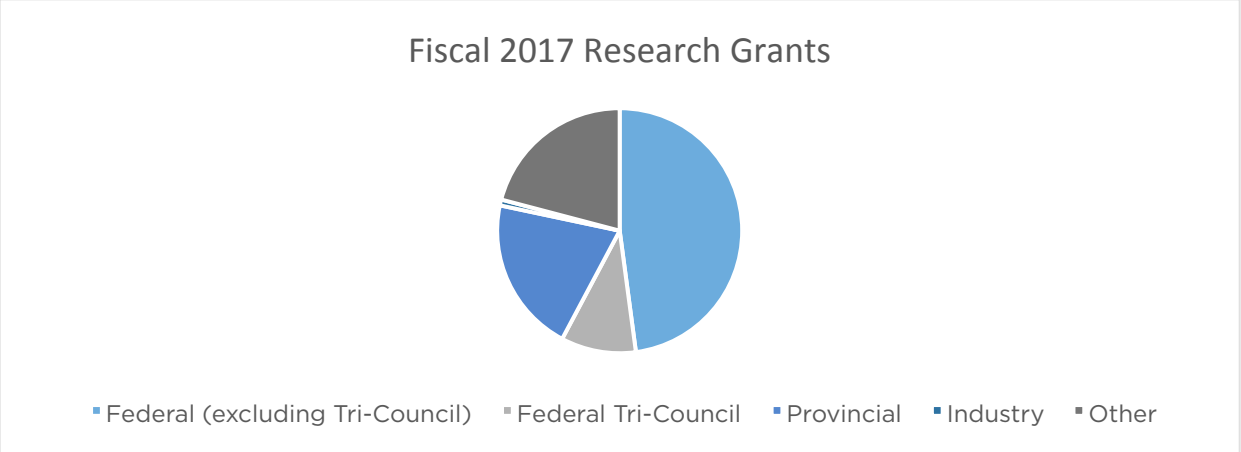
Publication	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17
Nature	1	1		2	1	
Nature Photonics	1		3	2	1	2
Nature Physics	3	2	3		2	1
Nature Communications	1	1	1	5	3	4
Physical Review Letters	17	14	14	16	17	11
Science	2	1	1	3		
Journal of Mathematical Physics	4	6	4	4	6	2

In addition to being published in notable journals, the number of citations IQC papers garner is a testament to the quality of research conducted. Since IQC was established and began producing research in 2002, papers published have been cited by other researchers in papers a total of 25,426 times (as of March 31, 2017). In the past year, this number grew by approximately 1,000 citations per quarter. Below is a chart demonstrating this growth year over year.

Note: *Source for Publications and Citations: Thomson Reuters' Web of Science on April 3, 2017. Data compiled using an address search for Institute for Quantum Computing (inst* quantum comp*). Citations are cumulative for all IQC publications for all years.*

Research Grants

Over the previous fiscal year, IQC researchers were collectively awarded $25,770,938 in research funding. Funding sources are diverse and include research chair awards, funding from the Province of Ontario, the Government of Canada, the Canada Foundation for Innovation (CFI), industry partners and others.



Note: *Information on research grants is aligned with the University of Waterloo fiscal year, which falls May 1 – April 30.*

Faculty Awards

Success of IQC's faculty has also been recognized by external agencies through awards. In 2016-2017, faculty members received the following awards:

- Raymond Laflamme, IQC's Executive Director and a faculty member in the Department of Physics and Astronomy, received a Discovery grant for his theoretical and experimental work in the field of quantum error correction;
- Kevin Resch, IQC's Deputy Director, Academic and the Canada Research Chair in Optical Quantum Technologies was awarded an NSERC Research Tools and Instruments (RTI) grant;
- Debbie Leung, an IQC faculty member in the Department of Combinatorics and Optimization, received a Discovery grant for her research studying the quantum effects in quantum communications and entanglement manipulation;
- Vern Paulsen, a faculty member in the pure mathematics department, received a Discovery grant for his research in operator algebras and quantum information;
- Michael Reimer of the Department of Electrical and Computer Engineering also received a Discovery grant for his work with nanoscale photonic devices to store, process and transfer quantum information.

IQC is also home to the following research chairs:

- Raymond Laflamme, Canada Research Chair (Tier 1) in Quantum Information (renewed in 2016);
- Debbie Leung, University Research Chair, University of Waterloo (2015);
- Raffi Budakian, WIN Endowed Chair in Superconductivity (2014);
- Kevin Resch, Canada Research Chair (Tier 2) in Optical Quantum Technologies (2013);
- Michele Mosca, University Research Chair, University of Waterloo (2012);
- David Cory, Canada Excellence Research Chair in Quantum Information Processing (2010);
- Richard Cleve, IQC Research Chair (2004).

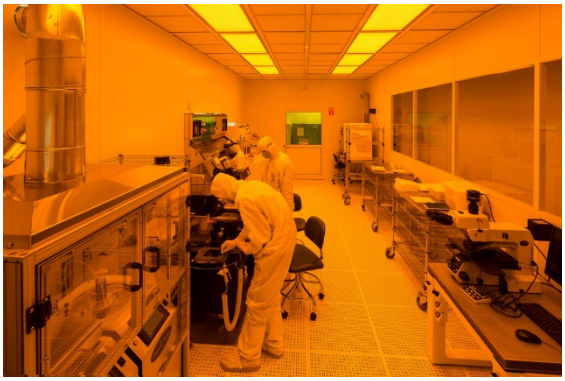
Continue to outfit labs in the Mike & Ophelia Lazaridis Quantum-Nano Centre as new IQC members are recruited.

As of March 2017, there are 14 operational research labs in the Lazaridis Centre, with an additional four research labs currently being designed for experiments by three of IQC's more recently recruited faculty members: Rajibul Islam, Michael Reimer and Crystal Senko. In addition, there are four services labs (operational or in a design phase) which include an electronics shop, a chemical preparation lab, a staging lab and an educational outreach lab.

Active research labs include:

Quantum Photonics Laboratory
Satellite Quantum Key Distribution Laboratory
Integrated Quantum Optoelectronics Laboratory
Quantum Verification Laboratory
Laboratory for Digital Quantum Matter
Quantum Optics and Quantum Information Group Laboratory
Engineered Quantum Systems Laboratory
Integrated Nano Electronics
Ultracold Quantum Matter and Light

Continue to outfit and maintain the Quantum NanoFab facility to enable fabrication of quantum-enabled technologies.



At the end of the previous fiscal year the Quantum NanoFab facility acquired a new JEOL JBX-6300FS 100kV e-beam lithography system. Since this acquisition, and in the most recent fiscal, the system was installed and is fully operational. In March of 2017, IQC entered into four year service contract agreement with JEOL Canada Inc. for ongoing routine maintenance and system repair.

With the announcement of funding by the Canada First Research Excellence Fund in the fall of 2016, the Quantum NanoFab facility was able to order a Critical Point Dryer system - to be used for damage-free release of delicate, freestanding structures in MEMS-type nanofabrication process technologies – and published a public tender for a new Scanning Electron Microscope (SEM). Expansion of Quantum NanoFab cleanroom is also underway with a lab adjacent to the cleanroom being converted to an ISO 6 cleanroom, which will house new characterization equipment.

In addition, the Quantum NanoFab team continues to grow to accommodate updates. In the fall of 2016, Lino Eugene, PhD, joined the IQC in the role of *Electron Beam Lithography Senior Scientist* to manage the nanofabrication process technology development and maintenance for all lab equipment within the Quantum NanoFab. In March, an additional role was added - a *Nanofabrication Process & Characterization Engineering Manager* position approved in February and filled in March 2017 by an existing team member whose current position will be filled in the coming year.

Update and maintain lab space in Research Advancement Centre (RAC) buildings.

In 2016-2017, IQC completed a major renovation and upgrade to lab facilities in RAC I. This resulted in the renovation and upgrading of five existing experimental labs plus the conversion of space to create four new specialized labs. This conversion increased the lab space in RAC I by 2,218 square feet. Further additions or extensions the central services of the building included chilled water, central exhaust, nitrogen distribution, deionized water distribution, humidification, vacuum, pressurized air, local temperature control and electrical and lighting upgrades, as required.

In RAC II, the installation of a new chemistry lab for device cleaning, including two new chemical hoods, was completed this past year as was a large diameter tube furnace for device annealing. RAC II's quiet labs have been outfitted with low vibration stands to allow low temperature scanning probe studies, and construction of an extension to the building to house a dilution refrigerator with a 20 T magnet has begun, with an anticipated completion date of June 2017.

Continue effective and relevant relationships with current partners. Seek out new partnerships that will advance IQC's mission and strategic objectives.

The IQC research community values opportunities for collaboration, both with other research groups and universities as well as with government, non-profits and private organizations. In the 2016-2017 year, IQC faculty members collectively reported 94 active collaborations with 73 unique organizations that span the globe. The following list of organizations includes examples of such organizations and includes universities, research institutes, private corporations and government.

Cambridge University, USA
Canadian Institute for Advanced Research (CIFAR) - Quantum Information Program, Canada
Canadian Space Agency, Canada
Centre for Quantum Technologies (CQT), NUS, Singapore
Communication Security Establishment, Canada
Department of Defence, Canada
European Telecommunications Standards Institute (ETSI), France
Hefei National Laboratory for Physical Sciences at the Microscale, University of Science and Technology of China, China
McGill University, Canada
National Institute of Optics (INO), Canada
National Institute of Standards and Technology (NIST), USA
National Research Council, Canada Natural Sciences and Engineering Research Council of Canada (NSERC), Canada
Ontario Centres of Excellence, Canada
Perimeter Institute for Theoretical Physics, Canada
Shanghai Center for Complex Physics, China
Swiss Federal institute of Technology in Zurich (ETHZ), Switzerland
Technion University, Israel
University of Innsbruck, Austria
University of Maryland, USA
University of Sydney, Australia
University of Torun, Poland
University of Vienna, Austria

Seeking New Strategic Partnerships

In addition to maintaining and growing established relationships, IQC's stakeholder groups continuously seek new partnerships to support strategic objectives. In 2016-2017, IQC explored or initiated the following:

- In May, IQC established a memorandum of understanding with the Beijing Computational Science Research Center in China with the intent to promote possibilities for cooperation in education by conducting joint research and exchanging postdoctoral fellows.
- On June 14th and December 8th IQC hosted Cybersecurity Symposia in Ottawa. These symposia brought together leaders from industry, academia and government to discuss the issues and opportunities for Canada's cybersecurity environment and to explore potential collaborative partnerships in a quantum world.
- The Canada First Research Excellence Fund (CFREF) awarded IQC faculty member and Canada Excellence Research Chair, David Cory, a total of $76.3 million to launch a new program: Transformative Quantum Technologies (TQT). This new program will explore three challenges in quantum research: to develop a universal quantum processor, quantum sensors and long-distance quantum communications. Under the direction of Professor Cory, TQT will aim to connect academic research with industry applications in a variety of fields.
- On December 1st, a six-member delegation of the European Union's Quantum Technologies Flagship High Level Steering Committee (HLSC) visited IQC to meet with several faculty members. Attendees included: Prof. Dr. Jürgen Mlynek, Chairman of the HLSC; academic members of the HLSC, Prof. Dr. Vladimir Buzek, Prof. Dr. Tommaso Calarco, Prof. Dr. Wim van Saarloos; Ms. Freeke Heijman of the Ministry of Economic Affairs, the Netherlands and Mr. Benedikt Weiler, Federal Ministry of Education and Research, Germany.
- In January, Norbert Lütkenhaus, IQC faculty member, represented the University of Waterloo and IQC as part of the government of Ontario's Cybersecurity Mission to *Cybertech Israel 2017.* Cybertech is the most significant conference and exhibition of cyber technologies outside of the United States and provides attendees with a unique and special opportunity to get acquainted with the latest innovations and solutions featured by the international cyber community.

Objective B

Create new opportunities for students to learn and apply new knowledge to the benefit of Canada, spurring innovation, and investment in R&D activities through highly qualified personnel development.

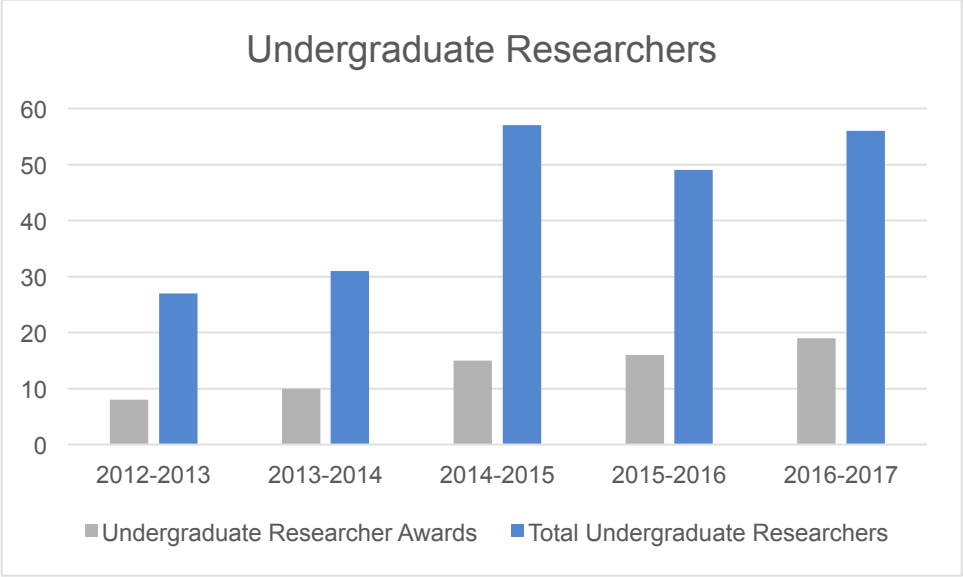
Expected Outcomes for 2016-2017

- Continue to grow and attract the best talent to IQC's graduate program
    - Field at least 200 applications to the University of Waterloo/IQC graduate studies program
    - Attend at least four graduate fairs to connect with prospective students
    - Expand connections made with undergraduate programs at Ontario and Canadian universities
    - Take part in at least two international recruitment events
- Continue to host timely, focused conferences, workshops, seminars and courses
    - Host two major conferences
    - Hold up to 10 workshops and seminars
    - Jointly sponsor up to 10 workshops and conferences with national and international partner organizations

Progress Achieved for 2016-2017

Attracting Talent and Connections to IQC

Each year IQC uses programs like USEQIP (the Undergraduate School for Experimental Quantum Information Processing) to attract the best and brightest undergraduate students from around the world to consider IQC for graduate school. Aside from hosting tours and programs like USEQIP, IQC also offers competitive Undergraduate Researcher Awards (URA) each year which gives the opportunity for undergraduates to complete work terms conduct research at IQC. This past year, 296 students applied to USEQIP, a URA or a combination of both. A total of 19 students from around the world were awarded a URA and over 50 undergraduates were hired for research work terms by faculty members.



Postdoctoral Fellows

In the 2016-2017 fiscal, IQC recruited twelve new postdoctoral fellows from a total of 65 applications. The following postdoctoral fellows joined IQC:

Razieh Annabestani
Hilary Carteret
Javad Doliskani
Michael Epping
Sara Hosseini
Hyun Ho Kim
Jun Li
Zhe Liu
Zhihuang Luo
Hao Qin
Peter Tysowski
Pan Zeng

These researchers were recruited from institutions from the University of Waterloo, the University of Western Ontario, the University of Florida, Pohang University of Science and Technology, Télécom ParisTech, University of Science and Technology - China, the Australian National University and the Heinrich-Heine University of Düsseldorf.

Postdoctoral Profile

Theoretical researcher Patrick Coles studies quantum cryptography. While earning his Master's in Biochemistry as a Churchill Scholar at University of Cambridge, a biography of Richard Feynman planted the idea of becoming a theoretical physicist in his mind.

He focused on physics-oriented courses while earning his PhD in Chemical Engineering at the University of California, Berkeley. He became a theoretical physicist like Feynman when he returned home to Pittsburgh as a postdoctoral fellow under Robert Griffiths at Carnegie-Mellon. He continued his research under Stephanie Wehner at Singapore's Centre for

Quantum Technologies, before reaching out to IQC faculty member Nobert Lütkenhaus.

“I chose IQC because it’s one of the best places in the world for quantum cryptography. In Norbert’s group, we do very practical theory, and yet at the same time, we are also developing elegant tools that are applicable to many situations,” said Coles.

The most recent of those tools is a MATLAB-based software that enables researchers to evaluate the performance of any conceivable Quantum Key Distribution (QKD) protocol. Coles and his team were able to develop a quick and reliable numeric way to calculate the key rate for any given QKD protocol. They tested their method on protocols with known key rates to confirm its validity, and then began investigating unstudied protocols. A year after they submitted their findings to Nature Communications, they completed the software that is now freely available on Lütkenhaus’ research group website.

A full list of current postdoctoral fellows can be found in Appendix E.

Graduate Students

Since the spring of 2016, 288 students applied to IQC graduate programs, surpassing the annual goal of 200. This number includes applications directly to the collaborative program and to other programs spanning Computer Science, Applied Math, Combinatorics and Optimization, Electrical and Computer Engineering, Physics or Chemistry and indicated an interest in quantum computing or quantum information.

As of March 31 a total of 128 students – 46 Masters and 82 PhD – were currently enrolled.

A full list of students for the fiscal year can be found in Appendix F.

Graduate Student Profile

A naturally curious Nayeli Azucena Rodriguez Briones always wanted to pursue post-graduate studies. She earned her Bachelor of Science in Physics degree at the Autonomous University of Zacatecas (UAZ) in Mexico, her home country and she is now a PhD student studying physics and quantum information at IQC with Executive Director Raymond Laflamme, Research Assistant Professor Eduardo Martin-Martinez and IQC associate member Achim Kempf from the Department of Applied Mathematics.

Studying quantum information piqued her interest because she could investigate fundamental problems while creating new technologies at the same time. Although her research is theoretical, the results are at the core of experimental implementation in quantum information processing. “It’s exciting to see fundamental discoveries of our universe lead to innovative technologies,” says Rodriguez Briones. “It’s like a

game, you are trying to find out how the universe works and at the same time, you are crafting new technologies. It's fun and it's useful."

Rodriguez Briones is currently developing a purification method for qubits to prepare them for use in a quantum computational device. Controlled preparation of nearly pure quantum states allows the user to initialize the quantum system before doing any kind of quantum computation. Pure qubits are useful for processing quantum information, running algorithms or performing quantum-error correction.

Student Awards

IQC is able to attract students from around and accepts the highest quality researchers. Below is a list of awards earned by IQC graduate students this year.

Graduate Students	Award
Matthew Amy	NSERC Alexander Graham Bell Canada Graduate Scholarship - Doctoral President's Graduate Scholarship
Vadiraj Ananthapadmanabha Rao	IQC Entrance Award
Elena Anisimova	Provost Doctoral Entrance Award for Women
Juan Miguel Arrazola	IQC David Johnston Award for Scientific Outreach
Eduardo Barrera Ramirez	IQC Entrance Award Ontario Graduate Scholarship President's Graduate Scholarship
Stefanie Beale	NSERC Alexander Graham Bell Canada Graduate Scholarship - Masters President's Graduate Scholarship
Kristine Boone	NSERC Alexander Graham Bell Canada Graduate Scholarship - Masters Ontario Graduate Scholarship President's Graduate Scholarship
Matthew Brown	QEII-Graduate Scholarship in Science and Technology
Brandon Buonacorsi	Institute for Quantum Computing Entrance Award
Arnaud Carignan-Dugas	IQC Entrance Award NSERC Alexander Graham Bell Canada Graduate Scholarship - Masters NSERC Postgraduate Scholarship - Doctoral President's Graduate Scholarship
Christopher Chamberland	President's Graduate Scholarship QEII-Graduate Scholarship in Science and Technology
Paulina Corona Ugalde	Provost Doctoral Entrance Award for Women
Alessandro Cosentino	David R. Cheriton Graduate Scholarship
Stephaney Daley	IQC Entrance Award
Hillary Dawkins	IQC Achievement Award IQC Entrance Award NSERC Alexander Graham Bell Canada Graduate Scholarship - Masters Ontario Graduate Scholarship President's Graduate Scholarship
Olivia Di Matteo	IQC Entrance Award NSERC Alexander Graham Bell Canada Graduate Scholarship - Doctoral President's Graduate Scholarship
John Donohue	NSERC Alexander Graham Bell Canada Graduate Scholarship - Doctoral President's Graduate Scholarship

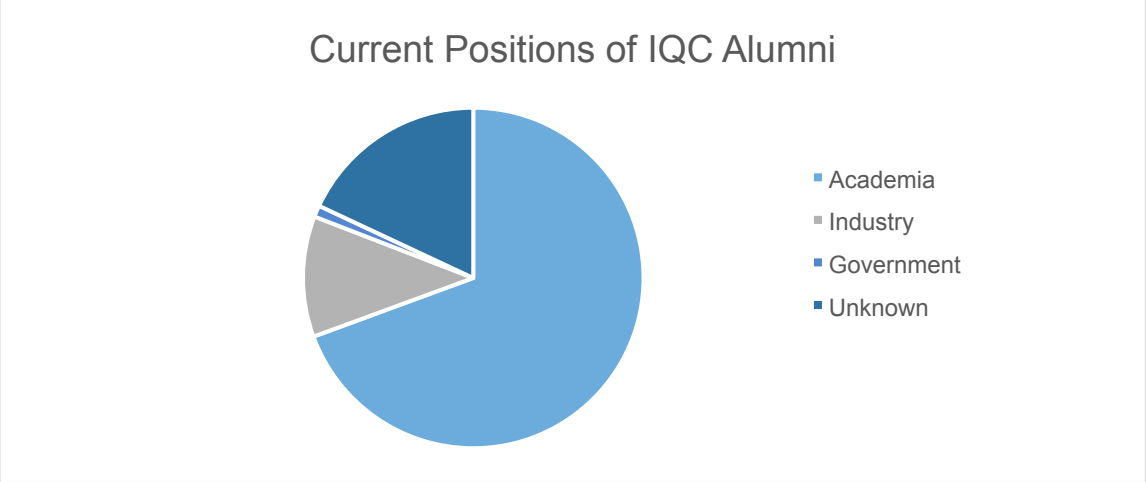
Graduate Students	Award
Carolyn Earnest	IQC David Johnston Award for Scientific Outreach Provost Doctoral Entrance Award for Women
Jennifer Fernick	IQC Entrance Award Provost Doctoral Entrance Award for Women
Kent Fisher	NSERC Vanier Canada Graduate Scholarship Ontario Graduate Scholarship President's Graduate Scholarship
Jeremy Flannery	Ontario Graduate Scholarship President's Graduate Scholarship
Honghao Fu	NSERC Alexander Graham Bell Canada Graduate Scholarship - Masters Ontario Graduate Scholarship President's Graduate Scholarship
Nicholas Funai	Mike and Ophelia Lazaridis Fellowships - PhD
Kaveh Gharavi	Ontario Graduate Scholarship
Matthew Graydon	IQC Entrance Award NSERC Alexander Graham Bell Canada Graduate Scholarship - Doctoral Ontario Graduate Scholarship President's Graduate Scholarship
Aimee Gunther	IQC David Johnston Award for Scientific Outreach NSERC Postgraduate Scholarship - Doctoral Ontario Graduate Scholarship President's Graduate Scholarship Provost Master's Entrance Award for Women
Holger Haas	IQC Entrance Award
Laura Henderson	NSERC Alexander Graham Bell Canada Graduate Scholarship - Masters President's Graduate Scholarship Provost Master's Entrance Award for Women
Gregory Holloway	IQC Achievement Award NSERC Postgraduate Scholarship - Doctoral Ontario Graduate Scholarship President's Graduate Scholarship
Taylor Hornby	David R. Cheriton Graduate Scholarship Ontario Graduate Scholarship President's Graduate Scholarship
Anqi Huang	Provost Doctoral Entrance Award for Women
Vinay Iyer	IQC Entrance Award
Tomas Jochym-O'Connor	NSERC Vanier Canada Graduate Scholarship
Sarah Kaiser	IQC David Johnston Award for Scientific Outreach Mike and Ophelia Lazaridis Fellowship
Shitikanth Kashyap	Mike and Ophelia Lazaridis Fellowship
Sumeet Khatri	NSERC Alexander Graham Bell Canada Graduate Scholarship - Masters Ontario Graduate Scholarship President's Graduate Scholarship
Maria Kieferova	Mike and Ophelia Lazaridis Fellowships - PhD Provost Doctoral Entrance Award for Women
Hyeran Kong	IQC Entrance Award
	NSERC Alexander Graham Bell Canada Graduate Scholarship - Masters

Graduate Students	Award
David Layden	Ontario Graduate Scholarship President's Graduate Scholarship
Youn Seok Lee	Mike and Ophelia Lazaridis Fellowships - Masters
Jason LeGrow	NSERC Alexander Graham Bell Canada Graduate Scholarship - Doctoral NSERC Alexander Graham Bell Canada Graduate Scholarship - Masters Ontario Graduate Scholarship President's Graduate Scholarship
Li Liu	David R. Cheriton Graduate Scholarship Mike and Ophelia Lazaridis Fellowships
Xingliang Lou	Ontario Graduate Scholarship President's Graduate Scholarship
Benjamin Lovitz	IQC Entrance Award
Jean-Philippe Maclean	NSERC Vanier Canada Graduate Scholarship
Christian Mastromattei	Ontario Graduate Scholarship President's Graduate Scholarship
Morgan Mastrovich	Mike and Ophelia Lazaridis Fellowships - Masters
Michael Mazurek	IQC Achievement Award NSERC Alexander Graham Bell Canada Graduate Scholarship - Doctoral NSERC Alexander Graham Bell Canada Graduate Scholarship - Masters Ontario Graduate Scholarship President's Graduate Scholarship
Corey McRae	IQC Achievement Award
Clifford Plesha	IQC Entrance Award
Christopher Pugh	IQC David Johnston Award for Scientific Outreach IQC Entrance Award NSERC Alexander Graham Bell Canada Graduate Scholarship - Doctoral NSERC Alexander Graham Bell Canada Graduate Scholarship - Masters Ontario Graduate Scholarship President's Graduate Scholarship
Daniel Puzzuoli	IQC Entrance Award Ontario Graduate Scholarship President's Graduate Scholarship
Jason Pye	NSERC Alexander Graham Bell Canada Graduate Scholarship - Doctoral NSERC Alexander Graham Bell Canada Graduate Scholarship - Masters Ontario Graduate Scholarship President's Graduate Scholarship
Hammam Qassim	Mike and Ophelia Lazaridis Fellowships - PhD
John Rinehart	IQC Entrance Award
Nayeli Azucena Rodriguez Briones	Institute for Quantum Computing Entrance Award Mike and Ophelia Lazaridis Fellowships - PhD Provost Doctoral Entrance Award for Women
Vincent Russo	David R. Cheriton Graduate Scholarship IQC Entrance Award
Shihan Sajeed	IQC Achievement Award
Jeffrey Salvail	IQC Entrance Award NSERC Alexander Graham Bell Canada Graduate Scholarship - Doctoral President's Graduate Scholarship
John Schanck	IQC Entrance Award
Sumit Sijher	Mike and Ophelia Lazaridis Fellowships - PhD
Yongchao Tang	Mike and Ophelia Lazaridis Fellowships - PhD

Graduate Students	Award
Guillaume Verdon-Akzam	IQC Entrance Award
Dhinakaran Vinayagamurthy	David R. Cheriton Graduate Scholarship IQC Entrance Award
Sean Walker	NSERC Alexander Graham Bell Canada Graduate Scholarship - Doctoral NSERC Alexander Graham Bell Canada Graduate Scholarship - Masters Ontario Graduate Scholarship President's Graduate Scholarship
Chunhao Wang	NSERC Alexander Graham Bell Canada Graduate Scholarship - Doctoral Ontario Graduate Scholarship President's Graduate Scholarship
Kyle Willick	NSERC Alexander Graham Bell Canada Graduate Scholarship - Doctoral President's Graduate Scholarship
Joshua Young	Ontario Graduate Scholarship President's Graduate Scholarship

Alumni

This year, IQC granted degrees to eleven Masters students and ten PhD students, bringing the total of IQC student alumni to 180 cumulatively. These researchers have chosen to pursue careers in various fields - from academia to industry to government – both within Ontario and around the world. The chart below indicates the distribution of IQC alumni current positions:



Continue to host timely, focused conferences, workshops, seminars and courses

Part of recruiting and retaining talent relies on building a strong and stimulating research community. As a leading institute, IQC is proud to be part of many national and international conferences, workshops and seminars held by and for researchers. This past year, IQC was host to three major conferences, two workshops, 48 seminars, 23 colloquia and jointly sponsored an additional 10 conferences held at partner organizations across the globe. Below are highlights of major conferences

hosted and sponsored this year. A full list of seminars and colloquia can be found in Appendix H.

Major Conferences

Relativistic Quantum Information North

From June 21-24, the Relativistic Quantum Information North (RQI-North) Conference brought together an interdisciplinary community of researchers at the interface of quantum information science and relativity. Approximately 80 researchers attended the conference, which was organized by IQC Associates Achim Kempf and Robert Mann and IQC Research Assistant Professor, Eduardo Martin-Martinez.

Quantum-Safe Cryptography

IQC hosted the 4th ETSI/IQC Workshop on Quantum-Safe Cryptography in Toronto September 19-21. This workshop brought together diverse players in the quantum-safe cybersecurity community to facilitate the knowledge exchange and collaboration required to transition cyber infrastructures and business practices to make them safe in an era with quantum computers. Participants came from across Canada, the United States, Europe and Asia and representation spanned industry, academia, government and financial institutions.

Quantum Innovators

From October 24-26, IQC hosted its annual Quantum Innovators workshop for a total of 26 participants. The workshop, held each year, brings the most promising researchers exploring the frontiers of quantum physics and engineering to IQC. Following this year's workshop, two alumni attendees – Rajibul Islam and Crystal Senko - joined IQC as faculty members in early November.

In addition to hosting these conferences, IQC faculty collectively were invited to speak at 145 other conferences around the world this year. A full list of faculty-attended conferences and invited talks can be found in Appendix G.

Workshops, Seminars and Colloquia

Workshops

Semi-Quantum Computing Workshop

This workshop, which took place at IQC August 16-17, brought together some of the pioneers of this field and covered a number of semi (or sub-universal) quantum computing models including DQC1, Linear Optics and sub-universal quantum simulators/annealers.

Schrödinger's Class

Previously titled Teaching Quantum Technologies, Schrödinger's Class is annual workshop for high school teachers. Presented this year on November 25-26, participants attended lectures and engaged in hands-on activities focused on the integration of quantum technology into the current teaching curriculum.

Sponsored Conferences

The following chart highlights the fourteen national and international conferences hosted by partners and sponsored in part by IQC between April 1, 2016 and March 31, 2017.

Date	Name	Location
Jun 6-11	Quantum Physics and Logic	University of Strathclyde
Jun 11-12	Information Theoretic Interpretations of Quantum Mechanics	University of Western Ontario
Jun 19-24	International Symposium on Symbolic and Algebraic Computation	Wilfrid Laurier University, Waterloo, Canada
Jul 27-29	Women in Physics Canada	University of Saskatchewan
Aug 22-25	Workshop on Representation Theory in Quantum Information	University of Guelph, Canada
Sep 12-16	6th International Conference on Quantum Cryptography	Washington D.C.
Sep 19-21	Ultra-Strong Light Matter	University of the Basque Country
Sep 27-29	Theory of Quantum Computation	University of Berlin
Jan 8-10	Canadian Conference for Undergraduate Women in Physics	McMaster University
Jan 13-15	Physics Games	Université Laval

Objective C

Brand Canada as the destination of choice for conducting research in quantum technologies and attract the best in the world to Canada, creating partnerships with the international quantum information community and promoting a world-class excellence in quantum information science and technology.

Expected Outcomes for 2016-2017

- Be a catalyst for collaborations of quantum information scientists through networks such as the Canadian Institute for Advanced Research (CIFAR) Quantum Information program, and the Natural Sciences and Engineering Research Council of Canada (NSERC) Strategic Networks
- Promote collaborations through participation in national and international conferences
- Produce internationally recognized, high-calibre publications co-authored by IQC researchers
- Organize at least four conferences that involve multidisciplinary participants
- Continue, enhance and increase visits to IQC by international scientists and academics from around the world

Progress Achieved for 2016-2017

Be a catalyst for collaborations of quantum information scientists through networks such as the Canadian Institute for Advanced Research (CIFAR) Quantum Information program, and the Natural Sciences and Engineering Research Council of Canada (NSERC) Strategic Networks

CIFAR

CIFAR's Quantum Information Science program is fundamentally committed to leading-edge multidisciplinary research and IQC is very well represented within this network. Currently, the program consists of 30 fellows, 8 of which are faculty members at IQC, as is one of four advisors to the program. IQC's Executive Director, Raymond Laflamme is the program director.

Promote collaborations through participation in national and international conferences

IQC's researchers are often invited to present at conferences around the world. Over the past year, faculty members collectively travelled to attend and participate at 149 conferences around the world. Photonics North, the 47th Annual Meeting of the APS Division of Atomic, Molecular and Optical Physics, the CERC Summit, QCRYPT 2016, and the 20th Conference on Quantum Information Processing are among the conferences IQC faculty members were invited to speak at. Appendix G provides a full list of all these conferences by faculty member.

Produce internationally recognized, high-calibre publications co-authored by IQC researchers

Researchers at IQC regularly collaborate with other researchers and scientists around the world in an effort to create scientific networks that produce the highest standard of research. This year, for example, faculty members collaborated with other Canadian researchers, both from IQC's home community and across Canada, as well as with researchers from universities from around the world. Research institutes and universities include the Perimeter Institute for Theoretical Physics in Waterloo Canada, the National Institute of Optics in Canada, University of Calgary, McGill University, the University of Maryland, the European Telecommunications Standards Institute in France, the University of Vienna and the National Institute of Standards and Technology. In addition, partnerships with government agencies and private sector companies have also continued throughout the year. These include, but are not limited to the Department of Defense in Canada, the Canadian Communication Security Establishment, the Canadian Space Agency, the Natural Sciences and Engineering Research Council of Canada and Quantum Valley Investments.

Organize at least four conferences that involve multidisciplinary participants

The following four conferences were organized and presented by IQC last this year:

Relativistic Quantum Information North

From June 21-24, the Relativistic Quantum Information North (RQI-North) Conference brought together an interdisciplinary community of researchers at the interface of quantum information science and relativity. Approximately 80 researchers attended the conference, which was organized by IQC Associates Achim Kempf and Robert Mann and IQC Research Assistant Professor, Eduardo Martin-Martinez.

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IQC hosted the 4th ETSI/IQC Workshop on Quantum-Safe Cryptography in Toronto September 19-21. This workshop brought together diverse players in the quantum-safe cybersecurity community to facilitate the knowledge exchange and collaboration required to transition cyber infrastructures and business practices to make them safe in an era with quantum computers. Participants came from across Canada, the United States, Europe and Asia and representation spanned industry, academia, government and financial institutions.

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Quantum Innovators

From October 24-26, IQC hosted its annual Quantum Innovators workshop for a total of 26 participants. The workshop, held each year, brings the most promising researchers exploring the frontiers of quantum physics and engineering to IQC. Following this year's workshop, two alumni attendees – Rajibul Islam and Crystal Senko - joined IQC as faculty members in early November.

Continue, enhance and increase visits to IQC by international scientists and academics from around the world

As an interdisciplinary organization focused on collaboration, IQC hosts dozens of scientific visitors from across the globe each year. The time spent at IQC by visitors serves to further and enhance collaborative relationships with researchers in all fields. In 2016-2017, IQC hosted 146 scientific visitors. These visitors collectively represent 106 unique research institutions or universities from across Canada and from countries across the world including China, India, Australia, Poland, South Africa, Singapore, the United States, the United Kingdom, Spain, Austria, South Korea and Israel. A full list of scientific visitors can be found in Appendix I.

Tours

In addition to scientific visitors, IQC hosts other tours for leaders of government, industry and academia. A full list of all group tours lead by IQC can be found in Appendix I.

Objective D

Enhance and expand the Institute's public education and outreach activities to effectively promote science and quantum information science and demonstrate how the research from quantum information science can be applied for the purpose of sustaining and attracting world-class talent.

Expected Outcomes for 2016-2017

- Host two major undergraduate and high school summer schools
- Host three Quantum Frontiers Distinguished Lectures
- Host an Open House event in fall 2016
- Premiere an exhibition on quantum information at THEMUSEUM in Kitchener
- Establish relationships with key strategic partners to further share IQC's research discoveries
- Host the second annual teacher workshop
- Continue to share IQC's research through publications, web and social media outlets

Progress Achieved in 2016-2017

Host two major undergraduate and high school summer schools

From May 30 through June 10, IQC hosted its annual summer school, the **Undergraduate School on Experimental Quantum Information Processing** (USEQIP). USEQIP is a two-week program on the theoretical and experimental study of quantum information aimed primarily at students one year away from completing their undergraduate studies. This year's program attracted 204 applications from around the world. Ultimately, 25 participants were chosen. Of these, eight were female and 16 were male, and collectively they represented Canada, the United States, Germany, Colombia, Poland, India, Serbia and Japan. Nineteen of the 25 participants stayed at IQC for a summer Undergraduate Researcher Award (URA).

From August 5th through 12th IQC hosted its annual Quantum Cryptography School for Young Students (QCSYS). Forty-four students participated in this year's program and students came from across Canada, the United States, Brazil, Ecuador, India, Mexico, Poland, China, Tunisia and the United Arab Emirates.

Host three Public Lectures

Throughout 2016-2017, IQC hosted a series consisting of three lectures and film screenings:

- On June 22, Bill Unruh of the University of British Columbia spoke to an audience of over 150 about the detection of gravitational waves on earth. It was a review of what gravitational radiation is, how it is detected, the incredible sensitivity of the detectors, what was detected, and how quantum limits and their evasion lie at the heart of these detectors.
- On November 15, IQC hosted Charles W. Clark of NIST to give a public lecture for 90 attendees. The lecture titled, *Over the Rainbow: The Other World Seen by Animals,* discussed that, although much of what we understand about the world comes from our eyes (which sense the colours from red to violet that are expressed in the rainbow), this patch of colours is just a small island in the vast electromagnetic spectrum. Two invisible regions of great importance to us are those just over and just under the rainbow - the infrared and ultraviolet, respectively. The lecture explored these regions and how a variety of animals live in a visual world totally unfamiliar to us.
- On February 23, as part of a partnership the Centre for Quantum Technologies in Singapore, IQC hosted a festival for quantum-inspired films. The screening of the top 10 short films was followed by a lecture by Senior Manager, Scientific Outreach, Martin Laforest about the applications of quantum devices. Laforest explored what researchers know quantum devices will be used for and where researchers are hoping they will be used in the future.

In addition to public lectures held onsite, IQC's outreach team also held public talks at THEMUSEUM in Kitchener as part of programs surrounding QUANTUM: The Exhibition.

- On November 9, Martin Laforest presented a talk, *Everyday Quantum: From Environment to Healthcare*, which provided attendees context around future applications of quantum research that stand to affect daily life.
- On November 16, Electra Eleftheriadou, IQC's Scientific Outreach Officer presented *Quantum Security and Cryptography,* which was an exploration of how information technology and information security will be impacted by advances in quantum research.

Open House

IQC hosted an Open House event on Saturday, September 17, in conjunction with Waterloo Region's community-wide Doors Open event. IQC welcomed 750 members of the community through its doors for guided and self-guided tours of the Mike and Ophelia Lazaridis Quantum-Nano Centre building and its labs. The Open House also featured giveaways, large interactive screens for children to play Quantum Cats and the unveiling of IQC's recently awarded GUINNESS WORLD RECORDS Smallest National Flag, which was fabricated by the Quantum NanoFab team.

QUANTUM: The Exhibition

After close to two years of preparation, QUANTUM: The Exhibition opened at THEMUSEUM in downtown Kitchener on October 13, 2016. The premiere event was attended by approximately 300 people - including two federal ministers - and featured video greetings from University of Waterloo President Feridun Hamdullahpur, the Right Honourable Justin Trudeau and Professor Stephen Hawking. Following the opening, IQC worked collaboratively with THEMUSEUM to ensure a rich public programming schedule was executed to engage a wide audience while the exhibition was on display at THEMUSEUM. These programs and events, which also included programming by other partners, helped make up an Innovation150 Festival for Waterloo Region, and included a speaker series (The Quantum Dialogues) featuring talks by members of IQC's outreach team, an appearance by Steve Spangler, weekend science shows for families, a Beer + Science evening event and a Girl Guide Science Sleepover. In addition, IQC commissioned THEMUSEUM (through their Teacher-in-Residence program) to develop curriculum-based education programs for school groups. The exhibition was on display at THEMUSEUM through January 1, 2017 and attracted 16,526 visitors in this time.

Following this run, IQC launched a national-tour for the exhibition as part of the Canada 150 celebrations. On January 19, the exhibition opened at Science World of British Columbia in Vancouver. On display through February 26, it attracted over 64,000 visitors while in Vancouver. Currently, the exhibition is on display at the Western Development Museum in Saskatoon and will continue to travel to other

science centres in Calgary, Halifax and Ottawa in the 2017-2018 year.

Establish relationships with key strategic partners to further share IQC's research discoveries

INNOVATION150

Through a grant awarded by the Department of Canadian Heritage, IQC has established a partnership with four other leading Canadian science outreach organizations – the Perimeter Institute for Theoretical Physics, Actua, the Canadian Association of Science Centres and the Canada Science and Technology Museum – to create INNOVATION150, which will be used to promote Canadian scientific innovation throughout 2017. This relationship is expanding and IQC is establishing additional relevant relationships, including those with science centres across the country and with research institutes in Iqaluit.

In an effort to raise awareness about IQC, its research and outreach activities, including the quantum exhibition and Canada 150 celebrations, IQC worked with members of the Quantum NanoFab team to design and create a tiny Canadian flag. This flag, measuring under two microns in length, was awarded the title of Smallest National Flag by GUINNESS WORLD RECORDS in September which garnered significant media attention.

AAAS

On February 19, IQC faculty member, Michele Mosca, participated in a panel at the American Association for the Advancement of Science (AAAS) in Washington D.C. Titled Quantum Computing and Post-Quantum Cryptography, the session was organized by Charles Clark of the Joint Quantum Institute and explored how a computational perspective on quantum mechanics is revolutionizing diverse fields of study. Mosca presented *Cybersecurity in an Era with Quantum Computers: Will We Be Ready?* Other panellists included Scott Aaronson of the Massachusetts Institute of Technology and Dorit Aharonov of Hebrew University.

Outreach Lab

This year saw the continued development of a dedicated Outreach Lab at IQC in the Lazaridis Centre (QNC). Martin Laforest, Senior Manager of Scientific Outreach has established this lab to host more youth programs through the year. To date, Martin has secured an optics table and various components and equipment for running optics and superconductivity experiments. The space has been designed around three independent islands and will be equipped with soundproof curtains to allow for up to three separate groups at a given time. Continued updates will be made to the lab throughout the next year.

Host the Second Annual Teacher Workshop

The Teaching Quantum Technologies teacher workshop has been renamed to Schrödinger's Class. On November 25-27, IQC ran the second annual workshop for 26 attendees from across Canada, the United States and Germany. Participants, all high school teachers, attended lectures and engaged in hands-on activities focused on the integration of quantum technology into the current teaching curriculum. The objective of this free program is to give educators a deeper understanding of quantum mechanics, the ability to teach quantum mechanics beyond the basics and the ability to discuss cutting-edge advances in the field with their students.

Continue to share IQC's research through publications, web and social media outlets

The communications team at IQC ensures that the researchers and their work are recognized worldwide through publications, media releases and online platforms.

Publications

NewBit, IQC's external magazine highlights research results and includes feature articles and stories on faculty projects, outreach initiatives, conferences, events and other announcements. Approximately 2,000 copies are printed and distributed to researchers, staff, board members, alumni and partners from academia, industry and government. It is also made available online in both an accessible PDF format and Flipbook format for download.

Earned Media

IQC garners national and international media attention on varying activities resulting in thousands of impressions this fiscal year. A full list of earned media can be found in Appendix J and the chart below outlines the highlights from this year.

Date	News Outlet	Title of Article
04-05-2016	Phys.org	Changing the colour of single photons in a diamond quantum memory
04-15-2016	Macleans.ca	Justin Trudeau's quantum leap
04-15-2016	Globe and Mail	'Don't get me started': Trudeau gives quick quantum computing lesson
05-04-2016	Phys.org	Researchers find new way to control quantum systems
09-06-2016	CBC.ca	University of Waterloo gets $76 million for quantum research
09-23-2016	National Post	Quantum computing will cripple encryption methods within decade, spy agency chief warns
10-18-2016	Science Daily	New 3-D wiring technique brings scalable quantum computers closer to reality
10-24-2016	Global News Connect	Move Over, Lasers: Scientists Can Now Create Holograms from Neutrons, Too
10-25-2016	TVO	Ontario Innovators: A quantum leap in computer technology
10-26-2016	Wall Street Journal	Meet the Man Fighting to Protect Your Secrets
12-20-2016	Globe and Mail	Canadians solve key puzzle for future of encryption

Online Activity

Social Media

Throughout last year IQC enjoyed steady growth across all its social media platforms. IQC launched an Instagram account, as well as two accounts (Twitter and Instagram) dedicated to QUANTUM: The Exhibition. Below are some highlights of social media performance from April 1, 2016 to March 31, 2017.

IQC's YouTube channel added over 2,000 subscribers for a second year in a row. While the total number of views remained steady at over 200,000 year to year, engagement increased. Likes were up 19%, shares were up 47% and 21.5% more videos were added to user's playlists than in the previous year. IQC's Facebook page enjoyed 345 likes last year, bringing its total to 3,857, and reached almost twice as many people through high quality posts, causing engagement to increase by almost 40%. On Twitter, IQC experienced a 27% increase in followers (56% when including the exhibition handle).

The chart below summarizes results from social channels. The numbers for Twitter and Instagram reflect numbers for both IQC's as well as the exhibition's handles.

New Followers	Total Current Followers	Reach	Engagement

YouTube	2,072	9,660	222,275 views	1,962 likes / 1,347 shares 1,628,019 minutes watched
Facebook	345	3,867	398,857	13,166
Twitter	2,326	8,118	1,739,329 impressions	23,277
Instagram	265	265	-	2,314 likes

Website

IQC's website continues to be a popular source for people to find out more about what happens at IQC. Each month our website received an average of over 15,000 sessions, each lasting for close to 2 minutes. This translates to 188,477 sessions by 112,989 unique users over the course of the year.

Objective E

Position Canada to take advantage of economic and social benefits of research through seizing opportunities to commercialize breakthrough research.

Expected Outcomes for 2016-2017

- Host commercialization workshops for IQC researchers
- Continue development of an industry affiliate program
- Promote opportunities for IQC researchers to connect with Waterloo's entrepreneurial ecosystem through networking and formal events in partnership with the broader startup networks in Waterloo Region

Progress Achieved in 2016-2017

As of 2017, IQC faculty collectively hold over 50 patents, and start-up companies are being established that bring quantum technologies out of the labs and into the marketplace. To date, the following seven spinoffs companies have emerged from IQC research:

- HighQ
- Neutron Optics
- Universal Quantum Devices
- Qspin
- evolutionQ
- QuantumLaf Inc.
- Quantum Benchmarking Inc.

Note: *In the past, researchers were not required to report on patents or commercialization activities. With this in mind, the actual number of patents and or licenses is not known and may be higher.*

Commercial opportunities from quantum research are growing and attracting the attention of the private sector. Mike Lazaridis and Doug Fregin have created the Quantum Valley Investment fund to support commercialization efforts in quantum information research. This $100 million fund invests in breakthroughs in quantum information science that have the potential to lead to technologies and applications with commercial potential. IQC is also in regular contact with other potential investors and with leading companies including IBM, Microsoft and Fujitsu. These firms have considerable interest in our discoveries, people, and even location in Canada as a potential site for their own work.

The critical mass of research and commercialization opportunities happening at IQC will also leverage a wider, stronger network of funding and support from the innovation ecosystem in the Waterloo Region. From Quantum Valley Investments to the Accelerator Centre to the Communitech Hub, IQC researchers have a network of

support unmatched anywhere in the world. IQC is uniquely positioned to leverage these relationships, support structures and funding opportunities.

APPENDICES

A. Risk Assessment & Mitigation Strategies

		LIKELIHOOD		
		LOW	MED	HIGH
IMPACT	HIGH	6	8	9
	MED	3	5	7
	LOW	1	2	4

Risk Factor	Impact Score	Likelihood Score	Risk Rating	Explanation of Score	Mitigation Measures
IQC may not be able to attract high quality researchers	High	Medium	8	The market for world-class researchers is increasingly competitive with many countries making significant investments.	Pursue recruits from a wide breadth of areas of research. Offer competitive job offers/ package. Adequately promote the world-class researchers and the cutting-edge facilities/ equipment at IQC. Further invest in cutting edge laboratory facilities.
Transformational technologies may render current research less relevant	High	Low	6	If IQC research is rendered less relevant, HQP and data seekers will go elsewhere	Ensure a wide breadth of research to investigate (this would differentiate IQC from its competitors). Continue applications for research funds to support leading-edge equipment.
IQC may not be able to recruit enough HQPs	High	Low	6	Many international HQPs come from potentially politically unstable countries (top three are Iran, China, India)	Promote IQC sufficiently. Ensure excellent research. Diversify markets/ countries from which students are recruited.
Operating constraints limit IQC's efforts to brand itself	High	Low	6	Operating constraints include limited resources (including staff), degree of flexibility	Recruit the right people/talents/skills. Develop and deliver a branding project plan. Foster close working relationships with appropriate units within the university.

B. Publications

Publications April 1, 2016-March 31, 2017

Anderson, Jonas T.; Jochym-O'Connor, Tomas (2016) Classification of transversal gates in qubit stabilizer codes. QUANTUM INFORMATION & COMPUTATION, 16, 32 pages

Arrazola, Juan Miguel; Karasamanis, Markos; Lutkenhaus, Norbert (2016) Practical quantum retrieval games. PHYSICAL REVIEW A, 93(6), 9 pages

Arrazola, Juan Miguel; Wallden, Petros; Andersson, Erika (2016) Multiparty quantum signature schemes. QUANTUM INFORMATION & COMPUTATION, 16, 30 pages

Ashenfelter, J.; Balantekin, A. B.; Band, H. R.; Barclay, G.; Bass, C. D.; Berish, D.; Bignell, L.; Bowden, N. S.; Bowes, A.; Brodsky, J. P.; Bryan, C. D.; Cherwinka, J. J.; Chu, R.; Classen, T.; Commeford, K.; Conant, A. J.; Davee, D.; Dean, D.; Deichert, G.; Diwan, M. V.; Dolinski, M. J.; Dolph, J.; DuVernois, M.; Erikson, A. S.; Febbraro, M. T.; Gaison, J. K.; Galindo-Uribarri, A.; Gilje, K.; Glenn, A.; Goddard, B. W.; Green, M.; Hackett, B. T.; Han, K.; Hans, S.; Heeger, K. M.; Heffron, B.; Insler, J.; Jaffe, D. E.; Jones, D.; Langford, T. J.; Littlejohn, B. R.; Caicedo, D. A. Martinez; Matta, J. T.; McKeown, R. D.; Mendenhall, M. P.; Mueller, P. E.; Mumm, H. P.; Napolitano, J.; Neilson, R.; Nikkel, J. A.; Norcini, D.; Pushin, D.; Qian, X.; Romero, E.; Rosero, R.; Seilhan, B. S.; Sharma, R.; Sheets, S.; Surukuchi, P. T.; Trinh, C.; Varner, R. L.; Viren, B.; Wang, W.; White, B.; White, C.; Wilhelmi, J.; Williams, C.; Wise, T.; Yao, H.; Yeh, M.; Yen, Y-R; Zangakis, G. Z.; Zhang, C.; Zhang, X. (2016) The PROSPECT physics program. JOURNAL OF PHYSICS G-NUCLEAR AND PARTICLE PHYSICS, 43(11), 30 pages

Basiri-Esfahani, Sahar; Myers, Casey R.; Combes, Joshua; Milburn, G. J. (2016) Quantum and classical control of single photon states via a mechanical resonator. NEW JOURNAL OF PHYSICS, 18, 21 pages

Bejanin, J. H.; McConkey, T. G.; Rinehart, J. R.; Earnest, C. T.; Mcrae, C. R. H.; Shiri, D.; Bateman, J. D.; Rohanizadegan, Y.; Penava, B.; Breul, P.; Royak, S.; Zapatka, M.; Fowler, A. G.; Mariantoni, M. (2016) Three-Dimensional Wiring for Extensible Quantum Computing: The Quantum Socket. PHYSICAL REVIEW APPLIED, 6(4), 29 pages

Belenchia, Alessio; Benincasa, Dionigi M. T.; Martin-Martinez, Eduardo; Saravani, Mehdi (2016) Low energy signatures of nonlocal field theories. PHYSICAL REVIEW D, 94(6), 6 pages

Brenna, W. G.; Mann, Robert B.; Martin-Martinez, Eduardo (2016) Anti-Unruh phenomena. PHYSICS LETTERS B, 757, 5 pages

Brod, Daniel J.; Combes, Joshua (2016) Passive CPHASE Gate via Cross-Kerr Nonlinearities.PHYSICAL REVIEW LETTERS, 117(8), 6 pages

Brod, Daniel J.; Combes, Joshua; Gea-Banacloche, Julio (2016) Two photons co- and counterpropagating through N cross-Kerr sites. PHYSICAL REVIEW A, 94(2), 21 pages

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C. Faculty Members and Research Assistant Professors

Faculty Members

Michal Bajcsy
Jonathan Baugh
Raffi Budakian
Kyung Soo Choi
Richard Cleve
David Cory
Joseph Emerson
Kazi Rajibul Islam
Thomas Jennewein
Na Young Kim
Raymond Laflamme
Debbie Leung
Adrian Lupascu
Norbert Lutkenhaus
Matteo Mariantoni
Guo-Xing Miao
Michele Mosca
Ashwin Nayak
Vern Paulsen
Michael Reimer
Kevin Resch
Crystal Senko
Adam Wei Tsen
John Watrous
Christopher Wilson
Jon Yard

Research Assistant Professors

Dmitry Pushin
William Slofstra

D. Postdoctoral Fellows

Current postdoctoral fellows at IQC:

Razieh Annabestani	Dawei Lu
Jean-Philippe Bourgoin	Zhihuang Luo
Hilary Carteret	Filippo Miatto
Franklin Cho	Muhammad Mustafa
Patrick Coles	George Nichols
Javad Doliskani	Ibrahim Nsanzineza
Ying Dong	Geovandro Pereira
Michael Epping	Michele Piscitelli
Guanru Feng	Mahmood Sabooni
Denis Gagnon	Dave Touchette
Vlad Gheorghiu	Peter Tysowski
Sandra Gibson	Joel Wallman
Christopher Herdman	Ben Yager
Brendon Higgins	Taehyun Yoon
Sara Hosseini	Hui Zhang
Jeongwan Jin	Pan Zeng
Hyun Kim	
Katanya Kuntz	
Sangil Kwon	
Jun Li	
Chang Liu	
Zhe Liu	

E. Graduate Students

The following are graduate students part of the IQC community as of March 31, 2017.

PhD Students

Sascha Agne
Arash Ahmadi
Omar Alshehri
Matthew Amy
Vadiraj Ananthapadmanabha Rao
Elena Anisimova
Jeremy Bejanin
Marian Berek
Nayeli Azucena Rodriguez Briones
Brandon Buonacorsi
Poompong Chaiwongkhot
Christopher Chamberland
Chung Wai Sandbo Chang
Rahul Deshpande
Olivia Di Matteo
Arnaud Dugas
Carolyn Earnest
Jennifer Katherine Fernick
Jeremy Flannery
Nicolas Funai
Kaveh Gharavi
Aimee Gunther
Holger Haas
Shima Hadiashar
Laura Henderson
Ian Hincks
Anqi Huang
Shitikanth Kashyap Hemant Katiyar
Maria Kieferova
Feyruz Kitapli
Joel Klassen
Meenu Kumari
Han Le
Jason LeGrow
Lin Li
Madelaine Liddy
Piers Lillystone
Li Liu
Dmitri Louchtchenko
Jean-Philippe MacLean
Rubayet Al Maruf
Mike Mazurek
Thomas George McConkey
Corey Rae McRae
Arthur Mehta
Maryam Mirkamali
Abel Molina
Mike Nelson
Mohamad Niknam
Joachim Nsofini
Jean-Luc Orgiazzi
Satish Pandey
Tarun Patel
Jitendra Prakash
Christopher Pugh
Daniel Puzzuoli
Jason Pye
Hammam Qassim
Eduardo Barrera Ramirez
John Rinehart
Vincent Russo
Shihan Sajeed
Dusan Sarenac
John Schanck
David Schmid
Ala Shayeghi
Sumit Sijher
Nigar Sultana
Huichen Sun
Yongchao Tang
Arcahana Tiwari
Paulina Corona Ugalde
Guillaume Verdon-Akzam
Sebastian Verschoor
Cameron Vickers
Dhinakaran Vinayagamurthy
Sean Walker
Chunhao Wang
Kyle Willick
Muhammet Yurtalan
Mohd Zeeshan

Masters Students

Shahab Akmal
Thomas Alexander
Stephanie Beale
Emma Bergeron
Julia Amoros Binefa
Kristine Boone
Matthew Brown
Jiahui Chen
Stephaney Daley
Ian Dsouza
Daniel Grimmer
Guiyang Han
Taylor Hornby
Jaron Huq
Tyler Jackson
David Jepson
Hyeran Kong
Youn-Seok Lee
Jin Gyu Lim
Jie Lin
Jun An Lin

Ray (Ruo Peng) Liu
Xudong (Michael) Liu
Guofei (Philip) Long
Benjamin Lovitz
Shayan Majidy
Nicolas Manor
Christian Mastromattei
Morgan Mastrovich
Somendu Maurya
Emma McKay
Denis Melanson
Sainath Motlakunta
Maria Papageorgiou
Helen Percival
Clifford Plesha
Mats Powlowski
Romain Ruhlmann
Allison Sachs
Ramy Tannous
Theerapat Tansuwannont
Sai Sreesh Venuturumilli
Zimeng Wang
Christopher Warren
Yihang (Young) Yang
Shazhou (Joey) Zhong

F. Invited Talks and Conference Participation

Faculty	Title/Subject	Institution/Conference
Michal Bajcsy	Cavities, waveguides, and metasurfaces: Enhancing atom-photon interactions with photonic crystals	University of Toronto
	Laser-cooled cesium atoms confined in a fiber-guided magic-wavelength dipole trap	47th Annual Meeting of the APS Division of Atomic, Molecular, and Optical Physics (DAMOP)
	On-chip splicer for coupling light between photonic-crystal and solid-core fibers	Photonics North
	Bragg mirrors and cavities in a hollow core photonics-crystal fiber	
	Dielectric metasurfaces as mirrors for Fabry-Perot cavities integrated into hollow-core waveguides	OSA's Advanced Photonics Congress
	Laser-cooled cesium atoms loaded into a hollow-core photonic-crystal fiber with a magic-wavelength optical dipole trap	25th International Conference on Atomic Physics
	High efficiency superconducting single-photon detectors evanescently coupled to laser written waveguides	Frontiers in Optics
	Estimation of atom loading efficiency into a hollow core fiber	Frontiers in Optics
Jonathan Baugh	Semiconductor nanostructure devices for quantum information applications	Amherst College Physics Colloquium
	Semiconductor nanostructure devices for quantum information applications	Dartmouth College Physics Colloquium
	Incoherence of error in the quantum control of an electron spin qubit	Canada Institute for Advanced Research workshop
	Superconductivity in semiconductor nanowires	University of Maryland
Kyung Soo Choi	Building synthetic quantum systems with atoms and photons – From waveguide QED with neutral atoms to many-body physics with Rydberg-dressed lattice gases	OpenKIST QIP Workshop
	Building synthetic quantum systems with atoms and photons – From waveguide QED with neutral atoms to many-body physics with Rydberg-dressed lattice gases	McMaster University
	Quantum information processing with cold atoms	KIAS Sumer School on QIS (ICAP Satellite)
David Cory	Quantum materials, characterization and devices	Conference on Topological Orders and Emergent Spacetime on Quantum Simulators

Faculty	Title/Subject	Institution/Conference
	Future quantum devices	CERC Summit
	Collective spin interactions	57th Experimental Nuclear Magnetic Resonance Conference
	Quantum devices, future of quantum technologies	Lincoln Labs
	Quantum characterization of materials	University of Delaware - Materials Characterization Workshop
	Quantum characterization of materials	Quantum Information and Computing for Chemistry Workshop
	Future directions of quantum information	US Government
	Spin/Orbit states of neutrons	Workshop on Matter-Wave Interferometry
	60 Years of Innovation: uWaterloo and quantum computing	University of Waterloo Anniversary Event
	Quantum sensors	US Department of Defence
Joseph Emerson	How quantum science is re-shaping information technology	2016 Internet2 Global Summit
		Laboratory for Physical Sciences
		Simon Fraser University - Physics Department
		University of British Columbia - Physics Department
Kazi Rajibul Islam	Measuring entanglement entropy	Bose-Einstein Condensation Conference
	Controlling quantum many-body systems at the level of a single particle	University of California at Berkeley
	Measuring entanglement entropy	Indian Association for the Cultivation of Science
	Measuring entanglement entropy	MIT iQuISe Seminar
Thomas Jennewein	Implementing free-space QKD systems between moving platforms: polarization vs. time-bin encoding	QCRYPT 2016
	Schrodinger's cat and the quantum internet	Jet Propulsion Laboratory
	Satellite based quantum communications links	York University - UK Quantum Hub Satellite Workshop
Raymond Laflamme	Emerging Innovators: The job of growing new Bbsinesses in Canada	Government of Canada Public Policy Forum - Canada Growth Summit 2016 (panels)
	Invited speaker to Symposium	Government of Canada - Canadian Association for Security and Intelligence

Faculty	Title/Subject	Institution/Conference
		Studies
	Algorithmic cooling (Workshop on quantum stochastic differential equations for the quantum simulation of physical systems)	University of Tennesee - Army Research Laboratory
	Experimental quantum error correction	Technion - Quantum Science, Matter and Engineering Symposium
Debbie Leung	Embezzlement of entanglement, conservation laws, and nonlocal games	Georgia Tech - QMATH13: Mathematical Results in Quantum Physics
	Embezzlement of entanglement and approximate violation of conservation laws	Carleton University - Theory Canada 11
	When does a quantum channel have quantum capacity?	Stanford University - Yamamoto Reunion 2016
	Embezzlement of entanglement, conservation laws, and nonlocal games	University of Illinois at Urbana-Champaign - Great Plains Operator Theory Symposium
	On quantum channel capacities	UW and DEI: Education and Research - Indo-Canadian Research Colloquium
	On the complementary quantum capacity of the depolarizing channel	University of Maryland - CIFAR Quantum Information Processing program meeting
	Embezzlement of entanglement, conservation laws, and nonlocal games	University of Hong Kong - CS Department
	Embezzlement of entanglement, conservation laws, and nonlocal games	University of Ottawa - Quantum Information Seminar
	Entanglement can improve zero-error communication capacities over classical channels	Stanford University - Quantum information research seminar
	Quantum Entanglement Embezzlement	Andaz/SpaceX/Caltech - Physics of the Universe Summit 2017
	From embezzlement (of entanglement) to break any (conservation) law	University of Colorado
Adrian Lupascu	Ultrasound coupling of a single artificial atom to electromagnetic fields	Topological orders, quantum information, and emergent spacetime on quantum simulators
	Ultrasound coupling of a single artificial atom to an electromagnetic continuum	International Conference on Quantum Coherent Phenomena at Nanoscale

Faculty	Title/Subject	Institution/Conference
	Superconducting flux qubits – prospects for relativistic quantum information experiments	Relativistic Quantum Information North
	Artificial atoms driven by strong periodic fields	Phys 10 in 10 undergraduate seminar series
Norbert Lutkenhaus	KACST's International Conference on Cybersecurity 2016	KACST Headquarters
	SIPQNP	Raytheon BBN Technologies
	Talk at CLEO Conference	Conference on Lasers and Electro-Optics (CLEO)
	Quantum key distribution standardization workshop	Shandong Institute of Quantum Science and Technology
	Unstructured quantum key distribution - Lecture	Tsinghua University
	Protection of Long-Lived Systems (PLLS)	Technische Universität Darmstadt
	Beyond IDD information theory 4	
	SPIE 2016 – Optics and Photonics	
	4th Annual ETSI quantum-safe cryptography workshop in partnership with IQC	ETSI/ Institute for Quantum Computing (IQC)
	Frontiers in Optics/Laser Science Conference	
	ETSI QKD ISG	ETSI
	Workshop on quantum communications	European Commission on Quantum Communication
	UK Communication Hub	
	Relativistic quantum information north conference	University of Waterloo
	QCMC	National University of Singapore
	DOQS 2016 Workshop	University of Strathclyde
	Qcrypt	Joint Center for Quantum Information and Computer Science, University of Maryland
	Theory of quantum computation, communication and cryptography - TQC 2016	Freie Universitat Berlin
	International conference for young quantum information scientists (YQIS)	
	UK Communication Hub	
	ETSI QKD ISG	ETSI

Faculty	Title/Subject	Institution/Conference
	Low energy quantum gravity	University of Queensland
Eduardo Martin-Martinez (RAP Oct 2015-June 2016) IQC associate from July 2016	Selling the vacuum for profit: Quantum energy teleportation, entanglement harvesting and spacetime curvature	Instituto de Estructura de la Materia (CSIC)
	Entanglement Harvesting and Huygens principle violations in cosmology	SISSA - International School for Advanced Studies
Guo-Xing Miao	Proximity enhanced superconductor superlattices for resonators	Southern University of Science and Technology of China
	Materials for solid-state information processing	East China Jiaotong University
	Spin-polarized transport in magnetic tunnel junctions	Qingdao University
	Spin-polarized transport in magnetic tunnel junctions	Shandong University
Michele Mosca	Cybersecurity in an Era with Quantum Computers: Will We Be Ready?	AAAS 2017 meeting
	Panelist: Post-Quantum Crypto	RSA Conference
	If X and Y are bigger than Z, you're in trouble	Executive Summit
	Quantum information	University of Waterloo - Teachers' Workshop
	Keynote speaker: Quantum computing	BSA| The Software Alliance
	Compiling quantum algorithms	University of Waterloo - Tutte Colloquium
	Panelist: Quantum-Safe Strategy for Canada	GTEC
	Panelist: Disruptive technologies, people, policy and program	Canadian Science policy Conference 2016
	Lunch and round table host: The quantum threat to cybersecurity	WSJDLive
	Cybersecurity in an era with quantum computers: will we be ready	Security Education Conference
	As we enter a new quantum era	Perimeter Institute - Public Lecture Series
	Cryptography and cybersecurity in the quantum era	Qcrypt 2016
	The quantum threat to cryptography	AWACS 2016
	Panelist: Community involvement, rigidity, trusting the standards, biodiversity, quantum-safe standards	AWACS 2016
	Is quantum computing actually the biggest threat to payment and banking?	Cardware 2016

Faculty	Title/Subject	Institution/Conference
	The current state of cryptography and how quantum computing will change everything...again!	Ontario Connections 2016
	Update on the quantum threat, mitigation, and relevant timelines	ICMC 2016 International Cryptographic Module Conference
	Quantum security	Global Risk in Financial Institute - Lunch Seminar
	Quantum computer science workshop	Banff International Research Station for Mathematical Innovation and Discovery
	Forth ETSI workshop on quantum-safe cryptography in partnership with IQC	SK Telecom
Ashwin Nayak	Semi-definite programming and applications	Institute for Mathematical Sciences - 2nd IMSc School on Quantum Information
	CIFAR Quantum information science program	CIFAR
	CIFAR Quantum information science program	CIFAR
	Eric Allender and Mike Saks are 60- DIMACS Workshop on E+M=C^2	Rutgers University
	Communication complexity and applications, II	BIRS Workshop
Vern Paulsen	Plenary Speaker	University of Illinois, GPOTS
Dmitry Pushin	Neutron limit on the strongly-coupled chameleon field	APS April Meeting
	Phase-grating interferometer for thermal and cold neutron	American Conference on Neutron Scattering
	Twisting neutron wave	Informal Workshop on Matter-Wave Interferometry
	The quantum neutron	The Johns Hopkins University - Applied Physics Laboratory
	The quantum neutron	Texas A&M University
	The quantum neutron	Tulane Univeristy
Kevin Resch	Chirped-pulse quantum nonlinear optics	OSA Laser Congress
	Temporal imaging of entangled photons with an upconversion time lens	Spectral and Spatial Engineering of Quantum Light (SSEQL)
	Entangled photon triplets: cascaded down-conversion and quantum nonlocality	Trent University - Physics Colloquium
	Spectral manipulation of entangled photons with an upconversion time lens (Delivered by M. Mastrovich and J. Donohue)	IQC - SAC Poster Session

Faculty	Title/Subject	Institution/Conference
	Storing single photons using a room temperature quantum memory (Delivered by J.P. Maclean)	IQC - SAC Poster Session
	Ultrafast single-photon manipulation with an upconversion time lens (Delivered by J. Donohue)	University of Toronto - CQIQC Seminar
	Experimental implementation of quantum coherent mixtures of causal relations (Delivered by J.P. Maclean and R. Spekkens)	Perimeter Institute - Experimental Quantum Foundations Workshop,
	Experimental reconstruction of the Bloch sphere (Delivered by M. Mazurek and M. Pusey)	Perimeter Institute - Experimental Quantum Foundations Workshop
	Storage and retrieval of THz-bandwidth single photons using a room-temperature diamond quantum memory (Delivered by J.P. Maclean)	Photonics North 2016
Crystal Senko	Bottom-up approaches to quantum many-body physics with cold trapped atoms	DAMOP 2016
William Slofstra	Planary talk: Tsirelsons problem and an embedding theorem for groups arising from non-local games	QIP 2017-20th conference on Quantum Information Processing
	Smooth Schubert varieties of affine type	Séminaire de Combinatoire et d'Informatique Mathématique, LaCIM, Université de Québec à Montréal
	Colloquium: Tsirelsons problem and linear system games	University of Waterloo, Pure Math Dept.
	Tsirelsons problem and linear system games	CIFAR Quantum Information Science Program Meeting
	Tsirelsons problem and linear system games	Quantum Foundations Seminar Series- Perimeter Institute for Theoretical Physics
	Tsirelsons problem and linear system games	QMath13: Mathematical Results in Quantum Physics, Georgia Tech
	Smooth Schubert varieties of affine type	Algebra seminar, University of Ottawa
	Tsirelsons problem and linear system games	LMS Research School on "Combinatorics and Operators in Quantum Information Theory," Queen's University Belfast
	Local formality of inversion hyperplane arrangements	Summer Conference on Hyperplane Arrangements (SCHA) in Sapporo, University Hokkaido

Faculty	Title/Subject	Institution/Conference
	Local formality of inversion hyperplane arrangements	Conference on Group Actions and Algebraic Combinatorics
	Poster: Parabolic double cosets in Coxeter groups	The 28th International Conference on Formal Power Series and Algebraic Combinatorics (FPSAC)
	Talk: Staircase diagrams and the enumeration of smooth Schubert varieties	The 28th International Conference on Formal Power Series and Algebraic Combinatorics (FPSAC)
Adam Wei Tsen	Superconductivity and charge density waves in the clean 2D limit	Pennsylvania State University - Department of Physics Condensed Matter Seminar
	Superconductivity and charge density waves in the clean 2D limit	University of Guelph - Department of Chemistry Seminar
	Superconductivity and charge density waves in the clean 2D limit	University of Toronto - Department of Physics Condensed Matter Seminar
	Superconductivity and charge density waves in the clean 2D limit	Perimeter Institute - 4-Corners Condensed Matter Symposium
	Superconductivity and charge density waves in the clean 2D limit	International Research School: Electronic States and Phases Induced by Electric or Optical Impacts
John Watrous	Quantum interactive proofs and semidefinite programming (two lectures)	Conference on Quantum Information Processing tutorial program
	Quantum information basics	Perimeter Institute: IT From Qubit Summer School
	Semidefinite programming, cone programming, and quantum state discrimination	Canadian Mathematical Society: Optimization Techniques in Quantum Information Theory session
Christopher Wilson	Quantum electrodynamics in 1D using a superconducting artificial atom	Relativistic Quantum Information
Jon Yard	SIC-POVMs and algebraic number theory	Bowdoin College
	Quadratic forms on hermitian matrices	University of Guelph

G. Seminars and Colloquia

Date Seminars	Speaker	Topics
21-Apr-16	Cheng Guo	Tensor Rank and Entanglement Transformation between Multipartite Pure States
06-May-16	Alexei Bylinksii	Friction under microscope in a trapped-ion optical-lattice emulator
12-May-16	Bruno Huttner	Quantum Technologies for Cyber Security: from threats to solutions
16-May-16	Robert Johnson	Increasing the Efficiency of Thermal Reactions by Providing Heat on a Molecularly Relevant Scale via the Photothermal Effect
17-Jun-16	Nina Bindel	Towards Practical Lattice-Based Signature Schemes
17-Jun-16	Bhaskaran Muralidharan	Two quantum resistors: Next generation explorations
23-Jun-16	Apoorva Patel	Optimisation of Quantum Hamiltonian Evolution: From Two Projection Operators to Local Hamiltonians
24-Jun-16	Bhaskaran Muralidharan	The role of dual-nuclear baths on a singlet-triplet dynamics in a double quantum dot
28-Jun-16	Tom Stace	Correlated decay in driven quantum systems
12-Jul-16	Jonathan Oppenheim	quantum thermodynamics - a review
02-Aug-16	Carlos Perez Delgado	Secure Quantum Computation: Optimality and Beyond
02-Aug-16	Stephanie Simmons	A photonic link for donor spin qubits in silicon
04-Aug-16	Marco Piani	Should entanglement measures be monogamous or faithful?
15-Aug-16	Hugo Cable	Towards Integrated Photonics for Quantum Computation
18-Aug-16	Rotem Liss	On the geometry of entanglement
08-Sep-16	Dmitry Pushin	The Quantum Neutron
20-Sep-16	Sacha Schwarz	Nonlocal Correlations between Frequency Engtangled Two-Qudit States
22-Sep-16	Lorenzo Procopio	Single-photon implementation of an indefinite causal order
23-Sep-16	Imran Khan	Continuous-variable quantum quantum communication activities in Erlangen, Germany
26-Sep-16	Joseph Choi	Superchiral Field, Phase Modulation, Optical Cloaking
24-Oct-16	Christoph Marquardt	Practical continous variable quantum communication in fibre and free space systems
10-Nov-16	Juan Bermejo Vega	Contextuality as a resource for quantum computation
15-Nov-16	Charles W. Clark	Twisting the neutron wavefunction
17-Nov-16	Franco Wong	Generation and Spectral Characterization of High-Purity Biphotons
22-Nov-16	Mark McArdle	Cybersecurity is Hard. Up for a Challenge?
29-Nov-16	Stephen K. Gray	Entanglement and Purcell Effects in Systems for Quantum Information and Sensing
30-Nov-16	Fereshteh Rajabi	Dicke's Superradiance in Astrophysics
02-Dec-16	Karol Zyczkowski	Structured Hadamard matrices and quantum information Abstract

Date	Speaker	Topics
Seminars		
13-Dec-16	Sara Hosseini	Experimental demonstration of Gaussian protocols for one-sided device-independent quantum key distribution
10-Jan-17	Alexander Ling	Making polarization-entangled photon-pair sources for nanosatellites: Size, Weight and Power Considerations
24-Jan-17	Milena Grifoni	Join Fem Phys and Women in Science for an informal conversation with Dr. Milena Grifon
25-Jan-17	Christine Muschik	Real-time dynamics of lattice gauge theories with a few-qubit quantum computer
03-Feb-17	Peter Goltenbort	Research with very cold and ultra-cold neutrons at the Institut Laue Langevin in Grenoble
03-Feb-17	Justin Bohnet	Entanglement in a synthetic quantum magnet made of hundreds of trapped ions
06-Feb-17	Simon Gröblacher	Quantum experiments exploiting the radiation pressure interaction between light and matter
08-Feb-17	Beni Yoshida	Quantum error-correction in black holes
10-Feb-17	Onur Hosten	Quantum entanglement for precision sensing with atoms and light
13-Feb-17	William Slofstra	The mathematics of non-local games
15-Feb-17	Mehran Vahdani	Carbon nanotube forest from energy conversion to MEMS devices and a laser based single sub 10nm particle analyzer: new developments in nanot
27-Feb-17	Laura Mancinska	Harnessing quantum entanglement
27-Feb-17	Torsten Karzig	Progress and challenges in designing a universal Majorana quantum computer
02-Mar-17	Penghui Yao	Expected communication cost of distributed quantum tasks
02-Mar-17	Zhexuan Gong	Harnessing quantum systems with long-range interactions
09-Mar-17	Shalev Ben-David	The Power of Randomized and Quantum Computation
13-Mar-17	Dave Touchette	Quantum information complexity
14-Mar-17	Leena Aggarwal	Tip induced superconductivity at mesoscopic point contacts on topological semimetals
22-Mar-17	Dr. Mohammad Ansari	Entropy measurement in quantum systems
24-Mar-17	Félix Marsault	Optical manipulation of polariton in semiconductor microstructures
Colloquia		
18-Apr-16	Lidia del Rio	Finding non-signalling agents and subsystems in global theories
16-May-16	Shunlong Luo	Two Spins: Parallel vs. Antiparallel
30-May-16	Peter D. Johnson	Monogamy of entanglement, no-cloning, and dissipative quantum state preparation
06-Jun-16	Tzu-Chieh Wei	Novel resource states for universal quantum computation by local measurement
20-Jun-16	Volkher Scholz	Entanglement in Quantum Field theories: an operational approach
27-Jun-16	Robert Myers	Information, Holography and Gravity
11-Jul-16	Jess Riedel	Where are the branches in a many-body

Date Seminars	Speaker	Topics
		wavefunction?
18-Jul-16	Michael Walter	Quantum Information in tensor networks
25-Jul-16	Xiaobo Zhu	On resonance quantum switch by longitudinal control field and demonstration of Solving Linear Equations by Superconducting Quantum Circuits
04-Aug-16	Sophie Laplante	Robust Bell inequalities from communication complexity
08-Aug-16	Ken Brown	Error Models and Error Thresholds
12-Sep-16	Cheol-Joo Kim	Chiral Atomically Thin Films
31-Oct-16	Martin Suchara	Efficient Fault-Tolerant Quantum Computing
07-Nov-16	William Oliver	Quantum Engineering of Superconducting Qubits
14-Nov-16	Douglas Stebila	Post-Quantum Key Exchange for the Internet and the Open Quantum Safe Project
28-Nov-16	Jose Aumentado	Graphs and Multi-mode Coupling: How to build a programmable, directional parametric amplifier
12-Dec-16	Carlos Silva	Two-dimensional coherent photocurrent excitation spectroscopy of a hybrid lead-halide perovskite solar cell
09-Jan-17	Yidun Wan	Ground State Degeneracies of Topological Orders on Open Surfaces via Anyon Condensation
23-Jan-17	Milena Grifoni	Probing light-matter entanglement in the non-perturbative regime of a strongly driven spin-boson system
13-Feb-17	Liuyan Zhao	An inversion-symmetry-broken order inside the pseudogap region of a cuprate revealed by optical second harmonic generation
06-Mar-17	Pravesh Kothari	Quantum Entanglement, Sum-of-Squares and the Log-Rank Conjecture
13-Mar-17	David Allcock	Trapped-ion quantum logic with near-field microwave-driven gates
20-Mar-17	Rakesh Tiwari	Robust quantum optimizer with full connectivity

H. Scientific Visitors and Tours

Scientific Visitors

Visitor	Visitor Affiliation
Alexei Bylinskii	Massachusetts Institute of Technology, USA
Shunlong Luo	Academy of Mathematics and Systems Science, Chinese Academy of Sciences, China
Arpita Maitra	Indian Institute of Management Calcutta, India
Francois Sfigakis	University of Cambridge, UK
Gaurav Bhole	The University of Queensland, St. Lucia
Juan Carlos Gracia Escartin	Universidad de Valladolid, Spain
Natsumi Komatsu	Rice University, USA
Bruno Huttner	ID Quantique, Switzerland
Dariusz Lasecki	Adam Mickiewicz University, Poland
Robert Johnson	Pennsylvania State University, USA
Jacob Marks	Yale University, USA
Zachary Pagel	Tufts University, USA
Dominique Pouliot	University of Illinois at Urbana-Champaign, USA
Ivana Rilak	University of Belgrade, Serbia
Jean Lapointe	National Research Council, Canada
Jason Herrmann	Harvard University, USA
Matt Hodel	Massachusetts Institute of Technology, USA
Amir Karamlou	Massachusetts Institute of Technology, USA
Dennis Feng	University of California - Berkeley, USA
Noah Dylan Johnson	University of Wisconsin - Madison, USA
Michael Wolfe	University of Maryland, USA
Daniela Angulo Murcillo	National University of Columbia, Colombia
Milena Crnogorcevic	Middlebury College, USA
Peter D. Johnson	Dartmouth College, USA
Yiruo Lin	University of Illinois at Urbana-Champaign, USA
Crystal Senko	Harvard University, USA
Bhaskaran Muralidharan	Indian Institute of Technology Bombay, India
Mahrud Sayrafi	University of California - Berkeley, USA
Tzu-Chieh Wei	University of British Columbia, Canada
Karolina Sedziak	Nicolaus Copernicus University, Poland
Nina Bindel	Technische Universität Darmstadt, Germany
Serge-Olivier Paquette	Université de Montréal, Canada

Visitor	Visitor Affiliation
Apoorva Patel	Indian Institute of Science, Centre for High Energy Physics Bangalore, India
Volkher Scholz	Ghent University, Belgium
Nachiket Sherlekar	University of Waterloo, Canada
Valentina Bacetti	Macquarie University, Australia
Rebecca Lapointe	Université de Montréal, Canada
Robert Myers	Perimeter Institute, Canada
Tom Stace	The University of Queensland, Australia
Bowen Yang	Nankai University, China
Yu Zheng	Nankai University, China
Luis Garay	Universidad Complutense Madrid, Spain
Miriam Gauntlett	University of Cambridge, UK
Zidu Liu	University of Science and Technology of China, China
Dongsheng Wang	University of Calgary, Canada
Angela Karanjai	The University of Sydney, Australia
Jonathan Oppenheim	University College London, UK
Jess Riedel	Perimeter Institute, Canada
Yonuk Chong	Korea Research Institute of Standards and Science, South Korea
Michael Walter	Stanford University, USA
Lino Eugene	McGill University, Canada
Xiaobo Zhu	University of Science and Technology of China, China
Thomas Kauten	University of Innsbruck, Austria
Sophie Laplante	Université Paris Diderot, France
Carlos Perez Delgado	Singapore University of Technology and Design, Singapore
Marco Piani	University of Strathclyde, Scotland, UK
Xionfeng Ma	Tsinghua University, China
Xiongfeng Ma	Tsinghua University, China
Stephanie Simmons	Simon Fraser University, Canada
Akihiro Mizutani	Osaka University, Graduate School, Japan
Urbasi Sinha	Raman Research Institute, India
Nai-Hui Chia	Pennsylvania State University, USA
Todd Pittman	University of Maryland, USA
Michael Bremner	University of Technology, Australia
Hugo Cable	University of Bristol, UK
Animesh Datta	The University of Warwick, UK
Rotem Liss	Technion – Israel Institute of Technology, Israel
Tal Mor	Technion – Israel Institute of Technology, Israel
Hengyan Wang	University of Science and Technology of China, China
Michael Lynch	Acadia University, Canada
Yoon-Seok Lee	Pusan National University, South Korea
Haining Pan	Nanjing University, China

Visitor	Visitor Affiliation
Hugo Woerdeman	Drexel University, USA
Dmitry Pushin	National Institute for Science and Technology Centre for Neutron Research (NCNR), USA
Cheol-Joo Kim	Cornell University, USA
Hong Chiang	Chongqing University, China
Atmn Patel	Kingsville District High School, Canada
Sacha Schwarz	University of Bern, Switzerland
Imran Khan	Max Planck Institute for the Science of Light, Germany
Lorenzo Procopio	University of Vienna, Austria
Joseph Choi	University of Rochester, USA
Rolf Horn	Quspin Technologies, Canada
Henry De Valence	Eindhoven University of Technology, The Netherlands
Andreas Fognini	Delft University of Technology, The Netherlands
Youn-Chang Jeong	Agency for Defense Development (ADD), South Korea
Yoon-Ho Kim	Pohang University of Science and Technology (POSTECH), South Korea
Heedeuk Shin	Pohang University of Science and Technology (POSTECH), South Korea
Christoph Marquardt	Max Planck Institute for the Science of Light, Germany
Shihai Sun	National University of Defence Technology, China
Laura Garcia-Alvarez	University of the Basque Country, Spain
K. Rajibul Islam	Massachusetts Institute of Technology, MIT-Harvard Center for Ultracold Atoms, USA
Martin Suchara	AT&T Labs Research, USA
Mike Kobierski	McGill University, Canada
William Oliver	Massachusetts Institute of Technology, USA
Juan Bermejo Vega	Perimeter Institute, Canada
Douglas Stebila	McMaster University, Canada
Dapeng Yu	South University of Science and Technology of China, China
Manhong Yung	South University of Science and Technology of China, China
Charles W. Clark	National Institute of Standards and Technology (NIST), USA
Franco Wong	Massachusetts Institute of Technology, USA
Mark McArdle	eSentire, Canada
Jose Aumentado	National Institute of Standards and Technology (NIST), USA

Visitor	Visitor Affiliation
Stephen K. Gray	Argonne National Laboratory, USA
Fereshteh Rajabi	University of Western Ontario, Canada
Karol Zyczkowski	Jagiellonian University, Poland
Harry Buhrman	University of Amsterdam, The Netherlands
Tony Leggett	University of Illinois at Urbana-Champaign, USA
Christopher Monroe	University of Maryland, USA
Carlos Silva	Université de Montréal, Canada
Sara Hosseini	Australian National University, Australia
Xiaodong Ma	University of Science and Technology of China, China
Alexander Ling	Centre for Quantum Technologies, National University of Singapore, Singapore
Yidun Wan	Fudan University , China
Jorma Louko	The University of Nottingham, UK
Andrew Cameron	University of Prince Edward Island, Canada
Milena Grifoni	University of Regensburg, Germany
Christine Muschik	University of Innsbruck, Austria
Mathieu Lauriere	New York University Shanghai, China
Justin Bohnet	National Institute of Standards and Technology, Boulder
Bienvenu Irenge Ndagano	University of the Witwatersrand, South Africa
Peter Geltenbort	Institut Laue-Langevin
Simon Gröblacher	Delft University of Technology
Beni Yoshida	Perimeter Institute
Onur Hosten	Stanford University
Liuyan Zhao	University of Michigan
Henry Yuen	University of California, Berkeley
Fereshteh Rajabi	University of Western Ontario
Mehran Vahdani	The University of British Columbia
Penghui Yao	University of Maryland, Baltimore
Ryan Wilson	College of new Jersey
Torsten Karzig	Microsoft Research Station Q, Santa Barbara, CA
Laura Mancinska	University of Bristol, UK
Shilling Huang	Tsinghua University
Zhexuan Gong	University of Maryland, College Park
Andy Ding	Illinois Wesleyan
Pravesh Kothari	Princeton University
Christian Prosko	University of Alberta
Brendan Bramman	Hastings College
Matthew Taylor	Dallahouise University
Shalev Ben-David	Massachusetts Institute of Technology

Visitor	Visitor Affiliation
David Allcock	National Institute of Standards and Technology, Boulder
Leena Aggarwal	Indian Institute of Science Education and Research, Pune
Sam Slezak	Pumbloldt State University
William Rose	University of Illinois
Rakesh Tiwari	McGill University
Evan Peters	Oregon State University

Tours – Industry, Government and Academic

Group	Date	# of Visitors
Academic		
Prof. Dr. Marcelo Knobel, Universidade Estadual de Campinas (Unicamp)	May 10, 2016	1
Dr. Sylvie Albert, Dean, Faculty of Business & Economics at University of Winnipeg; Ryan Mounsey, Manager of Expansion & Retention Services, Economic Development at the City of Waterloo	May 18, 2016	2
Dr. Mark Dockstator, President of First Nations University of Canada	July 13, 2016	1
PI Visitors	August 30, 2016	
Arthur McDonald	April 13, 2016	1
Bill Unruh	June 22, 2016	1
PI: RJ Taylor, Josie Bird	May 24, 2016	2
Larry Simon (CS Alumnus)	March 30, 2017	2
Industry		
ISARA	May 4, 2016	15
Nokia visit	May 12, 2016	
Mr. Herman Lam, CEO, Hong Kong Cyberport Management Company Limited; Ms. Shero Yip, Manager, Partners Team Chief Rep. of Shanghai and Guangzhou Rep. Office, Hong Kong Cyberport Management Company Limited; Mr. Juwan Lee, CEO & Founder, Nexchange (FinTech), a Cyberport Incubate; Mr. Patrick Lam, CEO, PaynPaid (FinTech), a Cyberport Incubate; Ms. Sin Wai Yi Ada, COO, Appus Technology Limited (Open Data), a Cyberport Incubate; Dr. George Dixon, Vice-President, Office of Research; Bob Lemieux, Dean, Faculty of Science; David Timms, Director Advancement, Faculty of Science; Marc Gibson, Science Lead, Velocity Science; Joani Gerber, Director, Operations, Accelerator Centre; Carrie Schultz, Program Coordinator, Client Services, Accelerator Centre	May 13, 2016	11
Tour for Stantec Researchers	June 7, 2016	

Group	Date	# of Visitors
Tustpoint Innovation: Desh Sharma, Kevin Henry, Paul Bottinelli; Royal Bank: Kevin DesRues, Robert Heckman, Jack Sullivan, Hady Abi-Nader; Amazon: Ken Beer; BMO: Dino Palazzo; Evolutionq: John Mulholland; Infosec Global: David Maxwell; CIBC: Mojgan Mallakin, Robert Plaenk	June 21, 2016	13
Microsoft Canada	August 4, 2016	10
Nokia	August 5, 2016	5
Postech: Dr. Doh-Yeon Kim, President; Professor Woo-Jin Song, Vice President, External Relations; Ms. Hyoeun Park, Director, International Relations	August 9, 2016	3
Wistron	August 16, 2016	7
ACE Group	August 17, 2016	
ACE Group	September 28, 2016	
Kate Lunau, Editor at VICE Media	September 28, 2016	1
FairVentures	October 13, 2016	20
Thomson Reuters tour of IQC	October 14, 2016	
McKinsey & Group: Andrew Pickersgill, Senior Partner; Marcos Tarnowski, Partner	October 26, 2016	2
Sandy Eix, Vancouver Sciene Centre	November 14, 2016	1
Craig Daniels, Scientific Writer and Editor	November 18, 2016	1
Vancouver Science Centre: Mila Cotic; Jesse Brydle	November 21, 2016	2
Robert Watson, CEO of Information Technology of Canada	November 21, 2016	1
Jeff McCarron, Discovery Centre Halifax	November 23, 2016	1
FedDev President	November 29, 2016	1
Creative Destruction Lab: Rachel Harris; Joshua Gans; Mara Lederman; Kristina McElheran; Avi Goldfarb; Alberto Galasso; Dan Trefler; Kevin Bryan; Ajay Agrawal	November 30, 2016	9
YPO (Young Presidents' Organization)	December 5, 2016	10
Crestview	January 23, 2017	5
RBC: Aaron Kim, Director - Innovation Research, Architecture and Digital Collaboration, RBC Financial Group; Kory Fong - Research Development Lead, RBC Research	March 30, 2017	2
Continental - Interior Division (Auto tech): Mathias Dehm, Head of Security and Privacy Research for Digital Services (Germany); Michael Scheffel, Strategic Business Development & Business Partner for Security – M&A, Competitive Intelligence, Investment (Germany); Peter Himmler, Director Strategic Projects at Elektrobit Automotive GmbH, Elektrobit (Acquired by Continental) (Germany); Roland Bock, Director Product Management, Continental Automotive GmbH, Infotainment & Connectivity (Regensburg, Germany); Brett Stark, Senior Product Manager, Continental (Chicago); Philip Chapin, Senior Engineering Manager at Continental (Greater Detroit Area); Ward Randall, Mangaer- Sales & Portfolio at Continental Corporation (Greater Detroit Area); Erin D'Alessandro, Director of Business Development and Client Services, Waterloo EDC; Sherryl Petricevic, Senior Business Development Officer, Waterloo EDC	March 27, 2017	9

Group	Date	# of Visitors
Government		
Portia Maier, Australian Consul-General	April 1, 2016	1
David Ewart	May 31, 2016	3
Bruce Heyman, US Ambassador to Canada	May 4, 2016	3
Stephen Thompson, Industry Canada	September 29, 2016	1
RCAF	November 15, 2016	10
Kolinda Grabar-Kitarović, President of Croatia (with group)	November 21, 2016	15
James Meddings, Federal Economic Development Agency for Southern Ontario	November 29, 2016	1
EU Flagship	December 1, 2016	10
Army Research Office	December 1, 2016	20
Simon Kennedy, Deputy Minister - Health	January 10, 2017	1
Anne Kari Ovind, Ambassador of Norway	January 17, 2017	1
ISED Innovation Networks and Clusters Branch: Jennifer Miller, Director General; Anna MacKay, Innovation Analyst	January 18, 2017	2
Embassy of France: Brigitte Pourcelle, Cultural and Science Councellor; Antoine Rauzy, University Cooperation Attache & Scientific Attache	January 23, 2017	1
Ontario Ministry of Research, Innovation and Science	January 30, 2017	
Julie Nero, Policy Analyst - Program Coordination Branch	February 1, 2017	1
Ambassador of Belgium	February 9, 2017	1
Chris Cooper, Canadian Ambassador to Turkey	March 1, 2017	2
CSA/ISED visit	March 8, 2017	5

I. Earned Media

Date	Publication	Title
04-05-2016	University of Waterloo News	Changing the colour of single photons in a diamond quantum memory
04-05-2016	EurekAlert!	Changing the colour of single photons in a diamond quantum memory
04-05-2016	Opli	CHANGING THE COLOUR OF SINGLE PHOTONS IN A DIAMOND QUANTUM MEMORY
04-05-2016	nextBIG Future	Storage and retrieval of terahertz-bandwidth single photons via a quantum memory in room-temperature bulk diamond
04-05-2016	sci24h.com	Storage and retrieval of terahertz-bandwidth single photons via a quantum memory in room-temperature bulk diamond
04-05-2016	Phys.org	Changing the colour of single photons in a diamond quantum memory
04-06-2016	newswise	Changing the colour of single photons in a diamond quantum memory
04-07-2016	Nanotechnology Now	Changing the colour of single photons in a diamond quantum memory
04-08-2016	Weekendavisen	Kvantedalen
04-08-2016	Haptic	Quantum frequency conversion in a diamond quantum memory
04-13-2016	Space Daily	Changing the color of single photons in a diamond quantum memory
04-15-2016	CBC News | Kitchener-Waterloo	Prime Minister Justin Trudeau affirms $50M for physics think-tank in Waterloo, Ont.
04-15-2016	CBC Player	PM has fun explaining quantum computing
04-15-2016	Global News	PM Justin Trudeau gives reporter quick lesson on quantum computing during visit to Waterloo
04-15-2016	Huffington Post	Justin Trudeau Drops Quantum Computing Answer To Question About ISIS
04-15-2016	The Verge	Canadian prime minister schools journalist in how quantum computing works
04-15-2016	CTV Kitchener	Trudeau 1-on-1: Talking Waterloo Region, Saudi arms deal and refugees
04-15-2016	Macleans.ca	Justin Trudeau's quantum leap
04-15-2016	Globe and Mail	'Don't get me started': Trudeau gives quick quantum computing lesson
04-15-2016	Business Insider	Justin Trudeau gave a sarcastic reporter a quick lesson in quantum computing
04-15-2016	Gossip Monthly Magazine	PM Justin Trudeau gives reporter quick lesson on quantum computing during visit to Waterloo
04-15-2016	WCCFTech	Handsome Canadian Prime Minister Justin Trudeau Reveals His Inner Computer Geek
04-15-2016	Refinery29	Justin Trudeau Knows About Quantum Computing, Don't Test Him
04-15-2016	Ask Men	Canadian Prime Minister Justin Trudeau Explains Quantum Computing
04-15-2016	HackRead	Justin Trudeau owns reporter on sarcastic question about quantum computing

Date	Publication	Title
04-15-2016	The Register	Canny Canadian PM schools snarky hack on quantum computing
04-15-2016	RCI	PM at the Perimeter Institute
04-15-2016	Popular Scioence	Canada's Prime Minister Knows A Thing Or Two About Quantum Computers
04-15-2016	Kicker	Justin Trudeau effortlessly explained quantum computing
04-15-2016	CJAD	Trudeau gives quantum computing lesson
04-15-2016	Fusion	A reporter tried to stump Justin Trudeau with a question about quantum computing, and got royally Trud-owned
04-15-2016	Times of Malta	Canadian Prime Minister Justin Trudeau nerds out over quantum theory
04-15-2016	The Quint	Justin Trudeau Silences a Reporter With Quantum Computing Gyaan
04-15-2016	imgur	Justin Trudeau correctly answered a question about quantum computing
04-15-2016	Reuters video	Trudeau nerds out over quantum theory
04-16-2016	The Express Tribune	Canada's PM stuns audiences with knowledge of Quantum computing
04-15-2016	National Post	'Don't get me started:' Trudeau delivers impromptu quantum computing lesson
04-15-2016	Toronto Star	PM shows off knowledge of quantum computing
04-15-2016	Slate - XXfactor	Handsome Canadian Prime Minister Justin Trudeau Gives Passable Off-the-Cuff Lecture on Quantum Computing
04-15-2016	Mashable	Justin Trudeau explains quantum computing like a boss
04-15-2016	Indian Express	Canadian PM Justin Trudeau impresses everyone with his knowledge on quantum computing
04-15-2016	Time	Watch Justin Trudeau Explain Quantum Computing to a Sarcastic Reporter
04-15-2016	Mother Jones	Maybe Quantum Physics Can Explain How An Object Can Be So Hot and Cool at the Same Time
04-15-2016	betakit	Prime Minister Justin Trudeau announces $50 million investment in Waterloo's Perimeter Institute
04-15-2016	Talking Cloud	Video: Watch Canadian PM Explain Quantum Computing
04-15-2016	engadget	Canada's prime minister schools reporter on quantum computing
04-15-2016	mic.com	Journalist Challenges Justin Trudeau to Explain Quantum Computing, Trudeau Nails It
04-15-2016	Huffpost Good News	Justin Trudeau Gives Snarky Reporter A Lesson In Quantum Computing
04-16-2016	Vanity Fair	Man of Your Dreams Justin Trudeau Casually Drops Quantum Computing Lecture in Press Conference
04-16-2016	Scoop Whoop	A Sarcastic Journalist Asked Justin Trudeau A Question On Quantum Computing. Here's How He Shut Him Up
04-16-2016	The Tech News	See Justin Trudeau Prime Minister of Canada Explaining Quantum Computing
04-16-2016	Pedestrian TV	WATCH: Justin Trudeau Explains Quantum Computing Like It's No Big Deal
04-16-2016	news.com.au	Canadian PM was jokingly asked about quantum computing and gives perfect answer
04-16-2016	Washington Post	Watch Canadian Prime Minister Justin Trudeau's charming quantum computing lesson

Date	Publication	Title
04-16-2016	Metro	Justin Trudeau just proved he's a quantum computing badass
04-16-2016	Gizmodo	Everyone Should Be Able To Explain Quantum Computing Like Justin Trudeau
04-16-2016	Daily News and Analysis	Ladies breathe easy: When Justin Trudeau gave a class in quantum computing to a journalist
04-16-2016	India Today	Justin Trudeau turns professor, gives quick lesson in quantum computing
04-16-2016	The Guardian	The reaction to Justin Trudeau's explanation of Quantum Computers shows we should raise our expectations
04-16-2016	9news	Canadian PM Justin Trudeau flawlessly explains quantum computing
04-16-2016	The Virginian Pilot	Trudeau Shows Geek Side in Video Gone Viral
04-16-2016	Epoch Times	Canadian Prime Minister Explains Quantum Computing
04-16-2016	Pulse Headlines	Canada's PM, Justin Trudeau, amazed the world while explaining quantum computers
04-16-2016	UPI.com	Canadian PM Justin Trudeau shows off quantum computing knowledge
04-16-2016	Esquire.com	Canadian Prime Minister Justin Trudeau Casually Explained Quantum Computing Like a Boss
04-16-2016	Canada Journal	Justin Trudeau explains quantum computing like a boss (Video)
04-16-2016	Next Big Future	Canada has a technology geek Prime Minister
04-16-2016	World News Day	Canada PM Justin Trudeau impresses all with his knowledge on quantum computing
04-16-2016	Best Techie	This Politician Understands Quantum Computing Better Than Most People
04-16-2016	Story Pick	Watch How Justin Trudeau Silenced A Reporter With His Awesome Speech On Quantum Computing
04-16-2016	UPROXX	Justin Trudeau Delivers A Lecture In Quantum Computing, So Everyone Can Feel Inadequate Now
04-16-2016	Tech Times	Canada's Justin Trudeau: Feminist, Yogi, And Apparently Quantum Computing Whiz Too
04-16-2016	Balochistan Express	Canada's PM stuns audiences with knowledge of Quantum computing
04-16-2016	The Daily Heights	Canada's PM stuns audiences with believe of Quantum computing
04-16-2016	MSN.com	Justin's Quantum Leap
04-16-2016	Canoe.com	Internet abuzz after quantum computing lesson by Justin Trudeau
04-16-2016	New York Post	Hunky Justin Trudeau shuts reporter down on quantum computing
04-16-2016	The Irish Times	Justin Trudeau explains quantum computing to stunned reporters
04-17-2016	Irish Examiner	Canadian PM Justin Trudeau's quantum computing explanation goes viral
04-17-2016	Daily Star	Canada's Trudeau explains quantum computing in viral video
04-17-2016	Al Arabiya	Watch: Canada's Trudeau shows geek side in video gone viral
04-17-2016	ABC Online	Justin Trudeau: Canadian PM gives impromptu quantum

Date	Publication	Title
		computing explanation, gets standing ovation
04-17-2016	Fortune	Justin Trudeau Explains Quantum Computing, And the Crowd Goes Wild
04-17-2016	Herald Scotland	Canadian PM Justin Trudeau's quantum computing explanation goes viral
04-17-2016	Times India	Is Justin Trudeau the smartest leader the world has seen?
04-17-2016	The Independent	Justin Trudeau shuts down sarcastic reporter with impromptu quantum computing explanation
04-17-2016	The Hindu	Canadian PM can explain quantum computing. Can you?
04-17-2016	The Times of India	Canadian PM Trudeau shows geek side in video
04-17-2016	Today Online	Canada PM lights up Internet explaining quantum computing
04-17-2016	Daily Mail	Not just a pretty face then? Justin Trudeau stuns room full of reporters and scientists with perfect answer to complex quantum computing question
04-17-2016	Pink News	Justin Trudeau just totally schooled a room full of journalists about quantum computing
04-17-2016	Inquisitr	Canada's Prime Minister Justin Trudeau explains quantum computing, goes viral
04-17-2016	Interrobang	Justin Trudeau Explains Quantum Computing
04-17-2016	Newser	Go Ahead, Ask Justin Trudeau About Quantum Computing
04-17-2016	Tech News Plus	Justin Trudeau Gives Quantum Computing Lecture to Journalist
04-17-2016	Parent Herald	Canadian Prime Minister Justin Trudeau Gives Impressive Explanation Of Quantum Computing
04-17-2016	Catch News	Canadian PM Justin Trudeau talks about Quantum Computing & the internet cannot handle it
04-17-2016	Malay Mail Online	Justin Trudeau takes on question on quantum computing and Twitter goes nuts
04-17-2016	Carbonated TV	Canadian PM's Impromptu Quantum Computing Lecture Is Gold
04-17-2016	ITV News	Canadian PM gives impromptu quantum computing lesson
04-17-2016	The American Spectator	Why I'm Not Impressed With Justin Trudeau's Answer on Quantum Computing
04-17-2016	Enstarz	Justin Trudeau Update: Prime Minister Schools Reporter For Asking A Flip Question [VIDEO]
04-17-2016	Tweaktown	PM explains quantum computing to a reporter, like a boss
04-17-2016	Newshub	Canadian PM floors room with quantum computing knowledge
04-17-2016	Motherboard	We Asked Some Experts to Score Justin Trudeau's Explanation of Quantum Computing
04-17-2016	CBS New York	VIDEO: Internet Freaking Out Over Justin Trudeau's Quantum Computing Explanation
04-17-2016	tvnz	Showing his geek side - Canadian PM wows crowd with quantum computing knowledge
04-17-2016	Daily Caller	Here's The True Story Behind Trudeau's 'Explanation' Of Quantum Computing
04-17-2016	Telegraph	Canadian prime minister Justin Trudeau expertly explains quantum computing in viral video
04-17-2016	Shtetl-Optimized	Grading Trudeau on quantum Computing
04-17-2016	Irish Independent	Canadian PM Justin Trudeau's quantum computing

Date	Publication	Title
		explanation goes viral
04-17-2016	Kansas City Star	Canada's Justin Trudeau explains quantum computing in viral video
04-17-2016	NBC News	Internet Abuzz After Quantum Computing Lesson by Canadian PM Trudeau
04-18-2016	The Star Online	Canada PM lights up Internet explaining quantum computing
04-18-2016	GMA News Online	Internet abuzz after quantum computing lesson by Canada's Trudeau
04-18-2016	The Nation	Canadian PM drops quantum computer knowledge
04-18-2016	Strait Times	Quantum leap in Trudeau's popularity
04-18-2016	Express Tribune	Canada's PM stuns audiences with knowledge of Quantum computing
04-18-2016	CBC News	Google, NASA put big money on D-Wave's quantum computer
04-18-2016	Gawker	Justin Trudeau's Quantum Computing Explanation Was Likely Staged for Publicity
04-18-2016	Mail Online	Trudeau never fails to impress and explains quantum theory
04-18-2016	News18.com	Watch: Canadian PM Explains Quantum Computing in Under 1 Minute
04-18-2016	The China Post	Canada PM lights up Internet explaining quantum computing
04-18-2016	IFL Science	Watch Canadian Prime Minister Justin Trudeau Perfectly Explain Quantum Computers
04-18-2016	Macleans.ca	When a Prime Minister scrums (Or: why democracy isn't dead)
04-18-2016	Toronto Sun	Media at Justin Trudeau's feet
04-18-2016	Washington Post	Actually, Justin Trudeau doesn't get quantum computing
04-18-2016	BGR	Canadian PM's amazing quantum computing answer was too good to be true
04-18-2016	GOOD Magazine	Canada's Prime Minister Justin Trudeau Nails Question On Quantum Computing
04-18-2016	National Post	'I'm really hoping people ask me how quantum computing works': Trudeau's 'geek' lecture not so off-the-cuff
04-18-2016	Weasel Zippers	Canadian Prime Minister Stages Question And Answer On Quantum Computing For Publicity…
04-19-2016	WCBM	Canadian Prime Minister Stages Question And Answer On Quantum Computing For Publicity
04-19-2016	Macleans.ca	Trudeau versus the experts: Quantum computing in 35 seconds
04-19-2016	Waterloo Free Press	Conservatives Use Trudeau's Quantum Computing Answer In Attack Ad
04-20-2016	The Star Online	Canada's spies closely watching quantum tech developments
04-20-2016	Huffington Post	Conservatives Use Trudeau's Quantum Computing Answer In Attack Ad
04-20-2016	KernGoldenEmpire.com	Canadian PM shows off knowledge of quantum computing
04-20-2016	Ottawa Citizen	Ashby: Trudeau on quantum computing obscures the real issue
04-20-2016	FactsCan	Justin Trudeau: "What quantum states allow for is much

Date	Publication	Title
		more complex information to be encoded into a single bit."
04-20-2016	Waterloo Region Record	Canada's spies closely watching quantum tech developments
04-20-2016	PopSugar	Thie Video Shows Justin Trudeaue Geeking Out About Quantum Computing
04-21-2016	Telegiz	Canadian PM Justin Trudeau explains quantum computing in half a minute
04-22-2016	Redland City Bulletin	Quantum computing leaps: Sydney University and UNSW as the best of frenemies
04-22-2016	University of Waterloo News	Waterloo physicist honoured for early-career achievement
04-22-2016	CBC News Blog	Politicians need science awareness: Bob McDonald
04-23-2016	The Sydney Morning Herald	Quantum computing leaps: Sydney University and UNSW as the best of frenemies
04-26-2016	The New York Times	Justin Trudeau, Politician and Star of Hif Own Viral Universe
04-30-2016	The Economist	More particle than wave
05-04-2016	International Business Times	IBM surges ahead of Google in quantum computing
05-04-2016	Fortune	IBM Just Made A Powerful Research Tool Available To Everyone For Free
05-04-2016	Wired	IBM Is Now Letting Anyone Play With Its Quantum Computer
05-04-2016	MIT Technology Review	IBM Inches Ahead of Google in Race for Quantum Computing Power
05-04-2016	The USB Port	IBM makes Quantum-Computing available to the public IBM quantum processor
05-04-2016	Phys.org	Researchers find new way to control quantum systems
05-04-2016	HNGN	IBM's Quantum Computer Now Available To Anyone As Cloud Service
05-04-2016	University of Waterloo News	Waterloo researchers find new way to control quantum systems
05-05-2016	TIME	IBM Just Made a Powerful Research Tool Available to Everyone for Free
05-05-2016	Daily Exhange	Waterloo researchers find new way to control quantum systems
05-05-2016	Daily Bulletin	Take that, Uncertainty Principle: bringing reliability to quantum experiments
05-05-2016	Sinema Blaze	IBM surges ahead of Google in quantum computing Sinema Blaze http://cinemablaze.com/2016/05/04/ibm-surges-ahead-of-google-in-quantum-computing.html
05-05-2016	TechWorm	IBM streams ahead of Google in quantum computing
05-05-2016	Morning Post Exchange	Waterloo researchers find new way to control quantum systems
05-06-2016	Globe and Mail	Trudeau apologizes, but no sign of when electoral reform will begin
05-06-2016	TechTarget	Can IBM fast-track quantum computing via the crowd?
05-05-2016	ScienceRecorder.com	IBM opens quantum computing to public
05-11-2016	Waterloo Stories	Learning to speak quantum like Prime Minister Trudeau
05-11-2016	CBC News | Kitchener-Waterloo	New University of Waterloo course teaching basics of quantum
05-13-2016	Maple Ridge & Pitt	A question of physics

Date	Publication	Title
	Meadows The News	
05-17-2016	newswise	Quantum Technologies a National Priority for Canada
05-18-2016	University Affiars	Meet Laurier's Quantum Woman: Shohini Ghose
05-18-2016	University of Waterloo Magazine	The trend toward playing with purpose
05-19-2016	KRTV.com	Did Justin Trudeau just lose his halo
05-20-2016	University of Waterloo News	Computing a secret, unbreakable key
05-21-2016	Lifeboat blog	Computing a secret, unbreakable key
05-25-2017	The Guardian	Has the age of quantum computing arrived?
06-01-2016	The Hill Times	Nurturing the next BlackBerry
06-15-2016	Waterloo Chronicle	UW grad ready for next test in future mission to Mars
06-18-2016	Military Embedded Systems	Paving the way for fast, secure quantum communications
06-29-2016	The Record	Will quantum computing be BlackBerry's Waterloo?
07-10-2016	Forbes	The Very Strange -- And Fascinating -- Ideas Behind IBM's Quantum Computer
07-19-2016	Daily Exchange	Laurier to host international computer algebra conference
07-26-2016	Inside Toronto.com	Top 4 grads from Toronto Catholic District School Board comes from Etobicoke
07-26-2016	FQXi Community	Untangling Quantum Causation
07-27-2016	Nature	Chinese satellite is one giant step for the quantum internet
07-27-2016	Scientific American	Chinese satellite is one giant step for the quantum internet
08-16-2016	South China Morning Post	How quantum satellite launch is helping China develop a communications system that 'cannot be hacked'
08-18-2016	CBC News London	China launches quantum satellite
08-18-2016	Motherboard	Why China's Quantum Satellite Is Incredible—And Will Surely Be Overhyped
08-29-2016	physicsworld.com	Nonlinear optical quantum-computing scheme makes a comeback
09-01-2016	ComputerWorld Hong Kong	Quantum computing threatens encryption security
09-02-2016	US Politics Today	Media Advisory: Government of Canada Announces Recipients of the Canada First Research Excellence Fund
09-05-2016	Toronto Star	Top students chill after stellar school year
09-06-2016	Canadian Insider	Quantum Computing: A New Threat to Cybersecurity
09-06-2016	Edmonton Journal	Quantum Computing: A New Threat to Cybersecurity
09-06-2016	Market Wired	Government of Canada Invests $900 Million to Transform University Research
09-06-2016	BetaKit	Global Risk Institute calls emerging quantum computing teechnology major threat to cybersecurity systems
09-06-2016	National Post	Liberals hand out $900M in research grants to universities with Science Minister front-and-centre
09-06-2016	CBC News | Kitchener-Waterloo	University of Waterloo gets $76 million for quantum research
09-06-2016	CTV Kitchener	Waterloo, Guelph research programs get major federal funding
09-06-2016	Canadian Manufacturing	Quantum computing threatens the most sophisticated cybersecurity, says report
09-06-2016	MyInforms.Com	Carleton, U of O benefit little from $900M in federal research funding

Date	Publication	Title
09-06-2016	Ottawa Sun	Carleton, U of O benefit little from $900M in federal research funding
09-06-2016	Ottawa Citizen	Carleton, U of O benefit little from $900M in federal research funding
09-06-2016	Canada.com	Carleton, U of O benefit little from $900M in federal research funding
09-06-2016	The Star Phoenix	Liberals hand U of S $77.8 million for massive water research program
09-06-2016	New Hamburg Independent	UW getting $76 million for quantum computing research
09-06-2016	KitchenerPost.ca	UW getting $76 million for quantum computing research
09-06-2016	Waterloo Chronicle	UW getting $76 million for quantum computing research
09-06-2016	MyInforms.Com	UW getting $76 million for quantum computing research
09-06-2016	TheRecord.com	UW getting $76 million for quantum computing research
09-06-2016	Video - The Loop	Funding for quantum tech
09-06-2016	NationTalk	U of S awarded $77.8M to lead “Global Water Futures” research program
09-06-2016	MyInforms.Com	University of Waterloo gets $76 million for quantum research
09-06-2016	CBC.ca	University of Waterloo gets $76 million for quantum research
09-06-2016	New Hamburg Independent	UW getting $76M for quantum computing research
09-06-2016	TheRecord.com	UW getting $76M for quantum computing research
09-06-2016	MyInforms.Com	UW getting $76M for quantum computing research
09-06-2016	MyInforms.Com	Ottawa unveils research fund winners
09-06-2016	MyWebMemo.com	Ottawa unveils research fund winners
09-06-2016	Dotemirates[EN]	Ottawa unveils research fund winners
09-06-2016	The Globe and Mail	Ottawa unveils research fund winners
09-06-2016	MyWebMemo.com	Liberals hand out $900M in research grants to universities with Science Minister front-and-centre
09-06-2016	Ottawa Citizen	Liberals hand out $900M in research grants to universities with Science Minister front-and-centre
09-06-2016	MyInforms.Com	Liberals hand out $900M in research grants to universities with Science Minister front-and-centre
09-06-2016	The Windsor Star	Liberals hand out $900M in research grants to universities with Science Minister front-and-centre
09-06-2016	Edmonton Journal	Liberals hand out $900M in research grants to universities with Science Minister front-and-centre
09-06-2016	National Post	Liberals hand out $900M in research grants to universities with Science Minister front-and-centre
09-06-2016	Calgary Herald	Liberals hand out $900M in research grants to universities with Science Minister front-and-centre
09-06-2016	Regina Leader-Post	Liberals hand out $900M in research grants to universities with Science Minister front-and-centre
09-06-2016	The Star Phoenix	Liberals hand out $900M in research grants to universities with Science Minister front-and-centre
09-06-2016	Montreal Gazette	Liberals hand out $900M in research grants to universities with Science Minister front-and-centre
09-06-2016	Vancouver Sun	Liberals hand out $900M in research grants to universities with Science Minister front-and-centre

Date	Publication	Title
09-06-2016	Canada.com	Liberals hand out $900M in research grants to universities with Science Minister front-and-centre
09-06-2016	Bullfax.com	Liberals hand out $900M in research grants to universities with Science Minister front-and-centre
09-06-2016	MyInforms.Com	UW getting $73 million for quantum computing research
09-06-2016	KitchenerPost.ca	UW getting $73 million for quantum computing research
09-06-2016	New Hamburg Independent	UW getting $73 million for quantum computing research
09-06-2016	Waterloo Chronicle	UW getting $73 million for quantum computing research
09-06-2016	TheRecord.com	UW getting $73 million for quantum computing research
09-06-2016	Water Canada	$78M to go Canadian Cold Regions Water Science Research
09-06-2016	Canada.com	Southern Alberta flood leads to 'largest university-led water project in the world'
09-06-2016	570News	UW receives $91-million in funding; $76-million for quantum research
09-06-2016	MyInforms.Com	UW receives $91-million in funding; $76-million for quantum research
09-06-2016	Ottawa Citizen	@Kady's Watchlist for Sept. 6 - Keep an eye out for cabinet ministers on campus, kids!
09-06-2016	Canada.com	@Kady's Watchlist for Sept. 6 – Keep an eye out for cabinet ministers on campus, kids!
09-06-2016	Perimeter Institute for Theoretical Physics	Canada invests in leading-edge physics and more
09-07-2016	MobileSyrup	Global Risk Institute calls emerging quantum computing teechnology major threat to cybersecurity systems
09-07-2016	The Chronicle Herald	NATIONAL AFFAIRS: Everyday science still starving for money
09-07-2016	MyInforms.Com	National Column: Everyday science still starving for money
09-07-2016	The Morinville News	National Column: Everyday science still starving for money
09-07-2016	MyWebMemo.com	Canada's everyday science researchers still starved for funds: Paul Wells
09-07-2016	Thestar.com	Canada's everyday science researchers still starved for funds: Paul Wells
09-07-2016	MyInforms.Com	Canada's everyday science researchers still starved for funds: Paul Wells
09-07-2016	Waterloo Stories	Research with "potential to change the world"
09-07-2016	University Affairs	Universities get a big boost in federal research funding
09-07-2016	Toronto Star Replica Edition	Everyday science still starving for money
09-07-2016	CasualPC	Why quantum computing has the cybersecurity world white-knuckled
09-07-2016	CIFAR	CIFAR congratulates Government of Canada for landmark investment in Canadian research
09-07-2016	CIO	Why quantum computing has the cybersecurity world white-knuckled
09-07-2016	ComputerWorld	Why quantum computing has the cybersecurity world white-knuckled
09-08-2016	PCWorld	Why quantum computing has the cybersecurity world white-knuckled
09-08-2016	InfoWorld	Why quantum computing has the cybersecurity world white-knuckled

Date	Publication	Title
09-08-2016	BetaKit	Canadian Government dedicates $900 million to helping universities become world-leading research centres
09-08-2016	SummNews	Quantum computing has the cybersecurity world white-knuckled – ComputerWorld
09-09-2016	Waterloo alumni e-newsletter	Waterloo-led research projects get $91M in funding
09-11-2016	Future Wave Tech Info blog	Trudeau versus the experts: Quantum computing in 35 seconds
09-14-2016	Waterloo Chronicle	UW gets $91 million in federal funding
09-14-2016	Cambridge Times	Science, technology sites focus of Doors Open Waterloo Region this Saturday
09-16-2016	TheRecord.com	Canada leading due to innovation, says minister
09-16-2016	Future Wave Tech Info blog	Institute for Quantum Computing
09-16-2016	govloop	Don't Kill Passwords: Build a Secure Infrastructure!
09-16-2016	University of Waterloo News	Workshop tackles challenges of protecting businesses and governments from a quantum threat
09-18-2016	South China Morning Post	Global expert urges Hong Kong companies to adopt quantum cryptography to improve security
09-19-2016	CBC News | Kitchener-Waterloo	University of Waterloo's Institute for Quantum Computing earns Guinness record with microscopic Canadian flag
09-19-2016	Maritimes	Microscopic maple leaf made by quantum computer is smallest-ever, says Guinness World Records
09-19-2016	University of Waterloo News	Nano-scale Canadian flag sets world record in lead-up to nation's 150th birthday
09-19-2016	CTV Kitchener	Waterloo engineers create world's smallest Canadian flag
09-19-2016	Phys.org	Nano-scale Canadian flag sets world record in lead-up to nation's 150th birthday
09-19-2016	Waterloo Region Record	UW sets world record for tiniest flag
09-19-2016	Yahoo Finance	ISARA Corportaion Readies Security Measures for the Quantum Age
09-19-2016	Latest Canada	University of Waterloo's Institute for Quantum Computing earns Guinness record with microscopic Canadian flag
09-19-2016	Eastern Ontario Network Television	University of Waterloo's Institute for Quantum Computing earns Guinness record with microscopic Canadian flag
09-19-2016	FrogHeart	Smallest national flag record achieved to celebrate Canada's 150th birthday
09-29-2016	Montreal Gazette	ISARA Corporation Readies Security Measures for the Quantum Age
09-20-2016	570News	UW's Institute for Quantum Computing creates world's smallest national flag
09-20-2016	Motherboard	Scientists set a new distance record for quantum teleportation
09-20-2016	IT World Canada	Prepare for threat of quantum computing to encrypted data, Canadian conference told
09-20-2016	MyInforms.Com	University of Waterloo's Institute for Quantum Computing earns Guinness record with microscopic Canadian flag
09-20-2016	Cemag	O, Canada, What a small flag you have!
09-20-2016	Darpan	Nano-Scale Canadian Flag Sets Guinness World Record
09-20-2016	Future Wave Tech Info	Nano-Scale Canadian Flag Sets Guinness World Record

Date	Publication	Title
09-20-2016	Nanowerk	Nanoscale Canadian flag sets world record in lead-up to nation's 150th birthday
09-21-2016	The Hindu	Setting a new standard: Nano-scale Canadian flag creates Guinness world record
09-22-2016	Daily Bulletin	IQC shows a little partiotism goes a long way
09-23-2016	National Post	Quantum computing will cripple encryption methods within decade, spy agency chief warns
09-24-2016	eweek	Scientists Demonstrate Long Distance Quantum Communication
09-26-2016	The New Yorker	Hacking, Cryptography, and the Countdown to Quantum Computing
09-26-2016	NewsWise	Live webcast: What to expect from the coming quantum era
09-27-2016	Compute Scotland	Quantum: technology impact?
09-27-2016	Officially Amazing	Canadian engineers create world's smallest flag
10-01-2016	Future Wave Tech Info	Hacking, Cryptography, and the Countdown to Quantum Computing …
10-03-2016	Globe and Mail	B.C. quantum computing firm D-Wave Systems raises $21-million
10-03-2016	Market Wired	Canada Concludes Successful Sixth Americas Competitiveness Exchange
10-03-2016	Orillia Packet.com	Accolades piling up for local teen
10-04-2016	Waterloo Chronicle	Space for startups
10-04-2016	Wired	The quantum clock is ticking on encryption – and your data is under threat
10-04-2016	Wired	The quantum clock is ticking on encryption – and your data is under threat
10-04-2016	CISCO blogs	ETSI/IQC's 4th Workshop on Quantum-Safe Cryptography
10-04-2016	IT Security News	ETSI/IQC's 4th Workshop on Quantum-Safe Cryptography
10-05-2016	Scientific American	How Quantum Computing Could Change Cybersecurity Forever
10-05-2016	Motherboard	Watch a Quantum Computing Expert Describe How the World's About to Change
10-05-2016	Seeker	How Quantum Computing Will Change Your Life
10-05-2016	Cosmos	Public lecture livestream: 'As we enter the new quantum era'
10-06-2016	StartIrtech	New article: Vanity in advance or post-quantum cryptography secrets
10-06-2016	Cantech letter	Listen to an expert explain how quantum computing is going to change our lives
10-06-2016	SC Magazine UK	IP Expo: Quantum computing is really cool, no really
10-06-2016	Headlines News	How Quantum Computing Could Change Cybersecurity Forever Video
10-10-2016	CSIC Consejo Superior de Investigaciones Cientificas	Un experimento internacional logra aumentar la energía de interacción entre la luz y la materia
10-11-2016	TheRecord.com	Quantum exhibit shows that 'the world is not as it seems'
10-12-2016	University of Waterloo News	Waterloo-led experiment achieves the strongest coupling between light and matter (University of Waterloo)
10-12-2016	EurekAlert	Waterloo-led experiment achieves the strongest coupling between light and matter (University of Waterloo)

Date	Publication	Title
10-13-2016	University of Waterloo News	UWaterloo exhibition sparks curiosity in quantum science
10-13-2016	Engineering Specifier	Strongest coupling ever between light and matter
10-13-2016	Photonics Online	UWaterloo Exhibition Sparks Curiosity In Quantum Science
10-13-2016	eeDesignIt	Photon and qubit interaction strength opens doors
10-17-2016	World News.com	Waterloo-led experiment achieves the strongest coupling between light and matter (University of Waterloo)
10-18-2016	University of Waterloo News	New 3-D wiring technique brings scalable quantum computers closer to reality
10-18-2016	Phys.org	New 3-D wiring technique brings scalable quantum computers closer to reality
10-18-2016	Science Daily	New 3-D wiring technique brings scalable quantum computers closer to reality
10-18-2016	Tom's Hardware	Dressed Qubits' With 10X Better Stability Bring Us Closer To Practical Quantum Computers
10-18-2016	The Register	SHA3-256 is quantum-proof, should last BEELLIONS of years, say boffins
10-18-2016	Open Nanofabrication	New 3-D wiring technique brings scalable quantum computers closer to reality
10-19-2016	The Kitchener Post	QUANTUM: The Exhibition
10-19-2016	Waterloo Chronicle	QUANTUM: The Exhibition
10-19-2016	Innovations Report	New 3-D wiring technique brings scalable quantum computers closer to reality
10-19-2016	The Science Explorer	New 3D Wiring Technique Brings Quantum Computers Closer to Being Scalable
10-19-2016	Women's toolbox	New 3D Wiring Technique Brings Quantum Computers Closer to Being Scalable
10-20-2016	Future Wave Tech Info blog	Institute for Quantum Computing
10-20-2016	Exchange Magazine	New 3-D wiring technique brings scalable quantum computers closer to reality
10-20-2016	Communitech News	Hard problem, huge market: ISARA Corporation takes quantum cryptography to market
10-20-2016	Next Big Future	3-D wiring technique is progress to scalable quantum computers
10-21-2016	Hacked	Breathe Easy Bitcoiners, Quantum Computing No Match For Sha-2 Encryption
10-22-2016	The Record	Waterloo startup focuses on security for the quantum age
10-24-2016	Global News Connect	Move Over, Lasers: Scientists Can Now Create Holograms from Neutrons, Too
10-25-2016	Latest Technology	Move Over, Lasers: Scientists Can Now Create Holograms from Neutrons, Too
10-25-2016	TVO	Ontario Innovators: A quantum leap in computer technology
10-25-2016	Exchange Morning Post	Christie projectors light up QUANTUM: The Exhibition at THEMUSEUM in downtown Kitchener
10-25-2016	AV Technology	Christie Projectors Light Up Science Exhibition in Kitchener, Ontario
10-25-2016	NCdjs	Christie Projectors Light Up Science Exhibition in Kitchener, Ontario
10-25-2016	Semiconductor	System Bits: Oct. 25

Date	Publication	Title
	Engineering	
10-25-2016	Imprint	Anyone can learn a little quantum
10-26-2016	Wall Street Journal	Meet the Man Fighting to Protect Your Secrets
10-26-2016	Nature.com	Quantum bits wired up
10-26-2016	IEEE Spectrum	China's 2,000-km Quantum Link Is Almost Complete
10-26-2016	Optics and Photonics	Making Neutron Holograms
28/10/2016	Benzinga	Christie Projectors Light Up Science Exhibition in Kitchener, Ontario
10-28-2016	Erie News Now	Christie projectors light up QUANTUM: The Exhibition at THEMUSEUM in downtown Kitchener
10-31-2016	CBC News | Kitchener-Waterloo	Quantum exhibit at THEMUSEUM
10-31-2016	Wall Street Daily	Can Quantum Computing Produce a Hack-Proof Network?
10-31-2016	CBC News | Kitchener-Waterloo	Confused about quantum? New exhibit at The Museum explains it for people of all ages
10-31-2016	News4Security	Does quantum computing bring security promise?
10-31-2016	Future Wave Tech Info blog	Hacking, Cryptography, and the Countdown to Quantum Computing …
11-01-2016	Exchange Magazine	Watercooler: TWO GLOBALLY GROUNDBREAKING RESEARCH INITIATIVES
11-01-2016	WireService.ca	Media Release: Economic Development Corporation introduces new brand identity: "Waterloo EDC - inventing the future."
11-01-2016	physicsworld.com	Neutron holograms image the interiors of objects
11-02-2016	InsightAAAS	Quantum Valley the next frontier
11-01-2016	GCN	Promises and perils of quantum computing
10-31-2016	FCW	Does quantum computing bring security promise?
11-01-2016	snapd	Invitation Only Premiere of QUANTUM
11-09-2016	Government of Canada	Minister Bains visits India's "Silicon Valley"
10/11/2016	@UWaterloo alumni	Quantum: The Exhibtion
11-11-2016	Lifeboat blog	Bitcoin users relax: Quantum computing no match for SHA-2 encryption
11-11-2016	Future Wave Tech Info blog	, 2016Research by IQC postdoctoral fellow recognized for excellence
11-14-2016	Wall Street Daily	Trump Administration: Has The Donald Gone Legit?
11-21-2016	CTV Kitchener	President of Croatia
11-21-2016	TheRecord.com	President of Croatia
28/11/2016	CPAC	Conference Canada 2020
11-30-2016	CASI Toronto Flyer	IQC Researchers Successfully Conduct Airborne Demonstration of Quantum Key Distribution
04/12/2016	Communitech News	President of Croatia
04/12/2016	TheRecord.com	Girls Matter at UW physics event
05/12/2016	Daily Trust	Microsoft speeding up its quantum computing effo
09/12/2016	The Community edition	Quantum Exhibition Informs, Is All Over the Place
09/12/2016	@UWaterloo	Waterloo welcomes President of Croatia, Kolinda Grabar-Kitarovic to Campus
12-12-2016	Market Research Report Store	New 3-D wiring technique brings scalable quantum computers closer to reality
12-14-2016	Waterloo Region Record	Snowden speaking by video conference at UW 60th anniversary event
12-20-2016	Globe and Mail	Canadians solve key puzzle for future of encryption

Date	Publication	Title
12-21-2016	TheRecord.com	Waterloo team pulls off encryption breakthrough
12-21-2016	St. Thomas/Elgin Weekly News	Waterloo team pulls off encryption breakthrough
12-23-2016	CAP News	CAP Member Chris Pugh featured in Globe and Mail
12-27-2016	Future Wave Tech Info blog	Hacking, Cryptography, and the Countdown to Quantum Computing
12-28-2016	TheRecord.com	Quantum exhibit soon leaves Kitchener for nationwide tour
12-30-2016	Lifeboat blog	Quantum Computing and why we need to replace the Internet
12-30-2016	Science Nordic	Quantum Computing and why we need to replace the Internet
01-01-2017	FrogHeart	2016 thoughts and 2017 hopes from FrogHeart
01-04-2017	University Herald	The Year 2017 Could Be The Start Of Quantum Computers
01-05-2017	Daily Bulletin	Celebrating Canada's 150th
01-01-2017	Daily Bulletin	Beyond 60 lecture kicks off anniversary year
01-17-2017	The Province	GE and Actua host digital technology event for "Generation Now"
01-19-2017	Daily Bulletin	Vancouver hosts anniversary reception, launch of QUANTUM: The Exhibition
01-19-2017	Government of Canada	Government of Canada celebrates science as part of Canada 150
01-19-2017	Government of Canada	Le gouvernement du Canada fait honneur aux sciences dans le cadre du 150e anniversaire du Canada
01-23-2017	New Scientist	Exotic black holes caught turning into a superfluid
01-24-2017	Daily Bulletin	Vancouver hosts 60th anniversary reception, launch of QUANTUM: The Exhibition
01-25-2017	CBC News	New Canadian quantum computer called twice as powerful as last one, but what does that mean?
01-27-2017	Wired	Quantum Computers Versus Hackers, Round One. Fight!
01-30-2017	MIT Technology Review	Quantum Computing Paranoia Creates a New Industry
02-01-2017	Quartz	The most complex problem in physics could be solved by machines with brains
02-02-2017	Wired	Physicists, Lasers, and an Airplane: Taking Aim at Quantum Cryptography
02-03-2017	IT World Canada	In a troubled economy, an ICT strategy can be a positive force
02-13-2017	Globe and Mail	A century and a half of Northern telecom innovations
02-11-2017	The Record	Kik's millionaire founder aims to leave his mark on the region
02-13-2017	The Wall Street Transcript	BlackBerry Ltd.: BlackBerry Partners with ISARA to Secure the Quantum Future
22/02/2017	Info Risk Today	Post-Quantum Crypto: Don't Do Anything
02/03/2017	thestar.com	Prime Minister Justin Trudeau preaches patience: Paul Wells
06/03/2017	IBM	IBM Building First Universal Quantum Computers for Business and Science
06/03/2017	News on 6 (via PR Newswire)	IBM Building First Universal Quantum Computers for Business and Science
15/03/2017	CTV Saskatoon	at 12:59
15/03/2017	Global Saskatoon	Western Development Museum explores quantum science in new exhibit

Date	Publication	Title
16/03/2017	Science News	Superfluid helium behaves like black holes

J. Governance

Below is a biography for individuals currently servicing on IQC's Executive Committee, Advisory Board and Scientific Advisory Committee.

Executive Committee

George Dixon, Vice President, Chair, University Research, University of Waterloo

George Dixon is Vice-President, University Research and Professor of Biology at the University of Waterloo. Professor Dixon has received both the Award for Excellence in Research and the Distinguished Teaching Award from the university. He has over 25 years experience in aquatic toxicology and environmental risk assessment and management. He maintains an active research program, which is focused methods for environmental effects monitoring, methods of assessing the environmental risks associated with exposure of aquatic organisms to metal mixtures, and on the aquatic environmental effects of oil sands extraction in Alberta. He is Associate Editor of three scientific journals, including the Canadian Journal of Fisheries and Aquatic Sciences.

Stephen Watt, Dean, Faculty of Mathematics, University of Waterloo

Stephen M. Watt is Dean of the Faculty of Mathematics and Professor in the David R. Cheriton School of Computer Science at the University of Waterloo. He previously held the title of Distinguished University Professor at Western University where he served for periods as Chair of the Department of Computer Science and Director of the Ontario Research Centre for Computer Algebra. Prior to this, he held positions at the IBM T.J. Watson Research Center in Yorktown Heights (USA) and INRIA and the University of Nice (France). Professor Watt's areas of research include algorithms and systems for computer algebra, programming languages and compilers, mathematical handwriting recognition and document analysis. He was one of the original authors of the Maple and Axiom computer algebra systems, principal architect of the Aldor programming language and its compiler at IBM Research, and is co-author of the MathML and InkML W3C standards. Watt was a co-founder of Maplesoft in 1988 and served on its board of directors from 1998 to 2009. He served on the board of directors of the Descartes Systems Group from 2001 to 2015, including two periods as Board Chair. He presently serves on the boards of Waste Diversion Ontario, which oversees the management of all Ontario's recycling programs, and of the McMichael Canadian Art Foundation. Professor Watt is the recipient of numerous distinctions, including Doctor Honoris Causa from the University of the West (Romania), the J.W. Graham Medal in Computing and Innovation (Waterloo) and the Outstanding Innovation Award (IBM).

Raymond Laflamme, Executive Director, Institute for Quantum Computing

Raymond Laflamme was born in Quebec City and did his undergraduate studies in Physics at Universite Laval. He then moved to Cambridge, England, where he survived Part III of Mathematical Tripos before earning his PhD in the Department of

Applied Mathematics and Theoretical Physics (DAMTP) under the direction of Stephen Hawking. Laflamme and Don Page are responsible for having changed Hawking's mind on the direction of time in a contracting Universe (as described in Hawking's best-seller "A Brief History of Time"). After his PhD, Laflamme became a Killam post-doctoral fellow at the University of British Columbia, where he met his future wife Janice Gregson. He moved back to Cambridge in 1990 as a Research Fellow at Peterhouse. He finally settled down for nine years at Los Alamos National Laboratory. He arrived as a postdoctoral fellow, then became an Oppenheimer Fellow in 1994, just after the birth of his son Patrick. His daughter Jocelyne was born in 1995. In 2001 he joined the Perimeter Institute for Theoretical Physics as a founding member. He has founded the Institute for Quantum Computing with Michele Mosca and has been its Executive Director since 2002.

Bob Lemieux, Dean of Science, University of Waterloo

Dr. Bob Lemieux joined Waterloo as the Dean of Science starting July 1, 2015. Previous to his appointment here, he was a professor in the Department of Chemistry and served as Associate Dean (Research) in the Faculty of Arts and Science at Queen's University. Bob Lemieux came with proven experience as an administrator, researcher, mentor and teacher. His passion for teamwork and collaboration has helped him create a culture of synergistic partnerships across academic units and faculties. Lemieux has been a faculty member of Department of Chemistry at Queen's University since 1992. His multi-disciplinary research into designing advanced liquid crystal materials found in high-performance microdisplays has earned him several international recognitions, including the 2012 Samsung Mid-Career Award and the Ontario Premier's Research Excellence Award. He is co-investigator on a CREATE grant. Lemieux received the Chemistry departmental teaching award twice as well as the W.J. Barnes Teaching Excellence Award from the Queen's Arts and Science Undergraduate Society. Lemieux was Head of the Chemistry Department for five years and Associate Dean (Research) in the Faculty of Arts and Science at Queen's University, and has also been involved in the recruitment of a Canada Excellence Research Chair.

Wayne J. Parker, Acting Dean, Faculty of Engineering, University of Waterloo

Dr. Wayne J. Parker is a professor in the Civil and Environmental Engineering Department at the University of Waterloo, and is cross appointed Director of Centre for Control of Emerging Contaminants (CCEC). Currently, he is the Acting Dean for the Faculty of Engineering. Dr. Parker holds a Ph.D. in Civil Engineering from the University of Waterloo. Some of his research interests are Anaerobic membrane bioreactors for wastewater and sludge treatment; fate of emerging contaminants in wastewater systems; pretreatment of sludges for enhanced digestion; advanced sludge digestion processes; nutrient recovery from wastewater. Before coming to Waterloo, Dr. Parker was an Associate Professor at Carleton University.

Robert Crow, Executive in Residence, Institute for Quantum Computing

Robert E. (Bob) Crow is an experienced public policy and technology industry leader, currently serving as Executive in Residence at the Institute for Quantum Computing (IQC), University of Waterloo.

Bob's career includes lengthy service in the private, Non Governmental Organization (NGO), and university sectors as an executive, consultant and teacher. He is especially known as a strategic thinker and builder of organizational capacity in settings where technology and public policy intersect. A frequent speaker, Bob is an informed and articulate advocate for his organizations and their missions. Bob is the former Vice-President for Industry, Government and University Relations at Research In Motion Limited (RIM), where he built and led RIM's global programs in government relations, community relations, corporate responsibility, market intelligence and university research. Bob's teams supported RIM's rapid international expansion from 2001 – 2011 and were especially noted for their ability to create and defend access to foreign markets, often under challenging circumstances. Prior to joining RIM in July 2001, Bob was Vice-President Policy at the Information Technology Association of Canada (ITAC) where he successfully positioned ITAC as a business association of credibility and influence in the Canadian policy milieu. Prior to this, he served from 1975 – 1998 at Ryerson University in Toronto as both professor of planning and senior administrator in a wide variety of roles including Information and Communication Technology strategy development, establishment of a technology centre, and leader of Ryerson's advancement activities.

Bob holds a bachelor's degree in engineering from Cornell University and master's degrees in planning and economics from the University of North Carolina at Chapel Hill and the University of Toronto, respectively. He also studied engineering and public policy at Carnegie Mellon University at the advanced graduate level.

Kevin Resch, Deputy Director, Academic, Institute for Quantum Computing

Kevin Resch received the BSc (Hon.) degree in Chemical Physics from Queen's University, Kingston, Canada, in 1997. He received the MSc and PhD degrees in Physics from the University of Toronto, Canada, in 1998 and 2002 respectively. His Masters and Doctoral theses were based on experimental quantum optics and completed under the supervision of Aephraim Steinberg. Subsequently, Kevin held a Natural Sciences and Engineering Research Council of Canada (NSERC) Postdoctoral Fellowship with Anton Zeilinger's group at the University of Vienna, Austria and a Research Fellow position with Andrew White's Quantum Technology Laboratory at the University of Queensland, Brisbane, Australia. He joined the University of Waterloo's physics department and the Institute for Quantum Computing (IQC) in 2006.

Advisory Board

Mike Lazaridis (Board Chair) Co-founder and Managing Partner, Quantum Valley Investments

Mike Lazaridis is the founder of telecommunications company Blackberry (formerly Research In Motion). He served as Vice Chair of the company's Board, and Chair of the Board's new Innovation Committee. IQC was launched in 2002 thanks to the vision and incredible philanthropy of Lazaridis, who has given more than $105 million to the institute since inception. He is also the founder of Waterloo's Perimeter Institute for Theoretical Physics.

Tom Brzustowski, RBC Professor, Telfer School of Management, University of Ottawa

Tom Brzustowski graduated with a B.A.Sc. in Engineering Physics from the University of Toronto in 1958, and a PhD in Aeronautical Engineering from Princeton in 1963. He was a professor in the Department of Mechanical Engineering at the University of Waterloo from 1962 to 1987. He served as Chair of Mechanical Engineering from 1967 to 1970 and as Vice President, Academic of the university from 1975 to 1987. He served as deputy minister in the Government of Ontario from 1987 to 1995. He was appointed President of NSERC in October 1995, and reappointed in 2000. He is an Officer of the Order of Canada and a fellow of the Canadian Academy of Engineering and of the Royal Society of Canada.

George Dixon, Vice President, Chair, University Research, University of Waterloo

Complete biography listed under Executive Committee.

Raymond Laflamme (ex-officio), Executive Director, Institute for Quantum Computing

Complete biography listed under Executive Committee.

Robert Crow, Executive in Residence, Institute for Quantum Computing

Complete biography listed under Executive Committee.

Robert Dunlop, Retired, Industry Canada

Robert recently retired from Industry Canada where he was the assistant deputy minister responsible for science and innovation. He held this position between 2009 and 2014, and before that he served at the assistant deputy minister level at Finance Canada where he co-managed the Economic Development and Corporate Finance Branch. Over his career he had responsibilities in a number of areas including program management, policy development and supporting ministers.

Robert is a native Montrealer where he studied economics and finance at McGill University. He now lives in Toronto.

Cosimo Fiorenza, VP and General Counsel, Quantum Valley Investments

Cosimo Fiorenza is the Vice-President and General Counsel of the Quantum Valley Investments and the Quantum Valley Investment Fund. He is actively involved at several public and private non-profit and charitable institutions in addition to

Institute for Quantum Computing, including the Perimeter Institute, the Law Society of Upper Canada, the Centre for International Governance Innovation, and several private family foundations. Mr. Fiorenza holds a degree in Business Administration from Lakehead University and a law degree from the University of Ottawa.

Mark Pecen, CEO, Approach Infinity Inc.

Mark Pecen serves as CEO of Approach Infinity, Inc., providing advisory services to firms requiring technology due diligence and management consulting in the areas of wireless communication and emerging technologies, rapidly growing technology companies and their venture capital funding partners. The firm comprises a network of senior executives and experts in the management of technology, innovation, research and development, marketing, sales, global standards, patents, technology entrepreneurship, and individuals with specific technical disciplines such as information theory, radio frequency systems, wireless system protocols, cryptography and others. Pecen retired as Sr. Vice President, Research and Advanced Technology and technology advisor to the CEO of BlackBerry, maker of wireless smart phones. He was responsible for the creation and management of BlackBerry's Advanced Technology Research Centre and a significant portion of BlackBerry's wireless patent portfolio. A past Distinguished Innovator and member of the Science Advisory Board at Motorola, Pecen also managed consultation work for clients in North America and Europe.

Peter Hackett, Professor, University of Alberta

Peter Hackett has been President and CEO of Alberta Ingenuity since October 2004. He is the former Vice-President Research at the National Research Council of Canada where he led NRC corporate strategies emphasizing emerging technologies, entrepreneurship and technology clusters. He was the lead NRC executive behind the creation and design of the National Institute for Nanotechnology at the University of Alberta. He is a member of the Institute Advisory Board Institute of Genetics, the Canadian Institute of Health Research, a board member of Genome Alberta and a founding member of the Alberta Advisory Committee on the Bio-economy. He was honoured recently by a Specially Elected Fellow of the Royal Society of Canada (RSC).

David Fransen, Former Consul General Canadian Consulate in Los Angeles

David Fransen worked from 1985 to 1988 at the Privy Council Office, where he provided policy advice related to such developments as the Green Plan in 1990, the drafting of the Canadian Environmental Assessment Act and the Canadian Environmental Protection Act, and the creation of the Canadian Environmental Assessment Agency. He then became Director of Economic Framework Policies in the Strategic Policy Branch of Industry Canada. In 1999, David became the Director General of the Centre for Healthy Human Development at Health Canada. He became Assistant Deputy Minister of the Industry Sector in 2003, where he was primarily

responsible for providing policy advice and delivering programs related to some of Canada's key economic sectors. He became a member of the board of the Institute for Quantum Computing in 2006. He was most recently the Consul General, Canadian Consulate General in Los Angeles.

Peter E. Brown, Senior Practice Partner, Deloitte Canada

Peter E. Brown, CPA CA, ICD.D., is a Senior Practice Partner in Deloitte Canada. Peter has close to 30 years' experience in public accounting, serving clients in both the public and private sectors. He has gained significant international experience in assurance and advisory services and has extensive experience with business advisory services. Peter served as Managing Partner for Deloitte's Atlantic Practice until 2008 when Peter relocated to Toronto to assume the role of Managing Partner and National Leader for Private Company Services. In 2011, Peter's responsibilities were expanded to include the entire middle market for Deloitte Canada. In 2013 Peter relinquished these responsibilities and was appointed to Deloitte Canada's Client Cabinet which is comprised of senior leaders with firm wide market responsibilities. Peter is the co-author of The Power of The Best, published in September 2012, the sequel to Building the Best - Inside Canada's Best Managed Companies. Peter is a frequent speaker on topics of entrepreneurship and what makes Best Managed companies unique. Peter has also served on the Board of Directors for Deloitte Canada. Peter has a broad range of expertise in issues unique to entrepreneurs in privately held companies and to globally oriented mid-market companies. He also has extensive experience in leadership, strategic planning, mergers and acquisitions, and succession planning. His clients ranged from family owned businesses to global organizations in various industries, including transportation, consumer business, technology, real estate, professional services, and mining services. Peter's current portfolio of clients includes Fortis, Hatch, Stikeman Elliott LLP, Smart Centres, Spin Master and Major Drilling Group International Inc. Peter has been involved in United Way both in the Atlantic Region and Toronto, in Chambers of Commerce throughout Atlantic Canada, and is a member of the Advisory Board for the Sobeys School of Business. Peter is also involved in Habitat for Humanity and served as part of a Deloitte Humanitarian Team that travelled to Brazil in October of 2011 to build homes and meet with local business leaders. Peter is a graduate of St. Mary's University and is a member of the Canadian and Ontario Institutes of Chartered Accountants and a CPA (Illinois). Peter is a graduate of the Directors Education Program offered by the Institute of Corporate Directors and Rotman School of Management.

Scientific Advisory Committee

Prof. Harry Buhrman, Centrum voor Wiskunde en Informatica (CWI)

Harry Buhrman is head of the research group 'Algorithms and Complexity' at the Centrum Wiskunde & Informatica, which he joined in 1994. Since 2000 he also has a joint appointment as full professor of computer science at the University of Amsterdam. Buhrman's research focuses on quantum computing, algorithms, complexity theory, and computational biology. One of the highlights in the work of Buhrman is the article co-authored with Richard Cleve (University of Waterloo,

Canada) ‘Quantum Entanglement and Communication Complexity’. They demonstrated that with quantum entanglement certain communication tasks can be solved more efficiently. He also co-developed a general method to establish the limitations of quantum computers. He has written more than 100 scientific publications.

Prof. Anthony Leggett, University of Illinois at Urbana-Champaign

Anthony J. Leggett, the John D. and Catherine T. MacArthur Professor and Center for Advanced Study Professor of Physics, has been a faculty member at Illinois since 1983. He was a co-winner of the 2003 Nobel Prize in Physics for pioneering work on superfluidity. He is a member of the National Academy of Sciences, the American Philosophical Society, the American Academy of Arts and Sciences, the Russian Academy of Sciences (foreign member), and is a Fellow of the Royal Society (U.K.), the American Physical Society, and the American Institute of Physics. He is an Honorary Fellow of the Institute of Physics (U.K.). He was knighted (KBE) by Queen Elizabeth II in 2004 "for services to physics." He is also a Mike and Ophelia Lazaridis Distinguished Research Chair.

Prof. Chris Monroe, University of Maryland

Christopher Monroe is an experimental atomic, molecular and optical physicist. Monroe obtained his PhD at the University of Colorado in 1992. From 1992-2000, Monroe was a postdoc and staff physicist in the Ion Storage Group of David Wineland at the National Institute of Standards and Technology in Boulder, CO. In 2000, Monroe moved to the University of Michigan, where he introduced the use of single photons to couple quantum information between atomic ions. In 2006, he became Director of the FOCUS Center at the University of Michigan. In 2007, Monroe became the Bice Sechi-Zorn Professor of Physics at the University of Maryland and a Fellow of the new Joint Quantum Institute between Maryland and NIST. In 2007-2008, Monroe's group succeeded in producing quantum entanglement between two widely separated atoms and teleported quantum information between atoms separated by a large distance.

Umesh Vazirani, University of California

Umesh Vazirani is a professor in the Computer Science Division of the Department of Electrical Engineering and Computer Sciences at the University of California, Berkeley. Professor Vazirani is a Director of the Berkeley Quantum Information and Computation Center (BQIC). He received an NSF Presidential Young Investigator Award in 1987 and the Friedman Mathematics Prize in 1985. Professor Vazirani wrote the book, “An Introduction to Computational Learning Theory" with Michael Kearns and currently is at the forefront of research in the area of quantum computing.

Prof. Anton Zeilinger, University of Vienna

Anton Zeilinger is a professor of physics at the University of Vienna (previously Innsbruck). Professor Zeilinger is known for multiple experiments in the realm of quantum interferometry and the demonstration of quantum teleportation. His work

influenced the experimental progress in a new sub-field of physics, quantum information theory. He has contributed to theoretical physics and the foundations of quantum mechanics — he has showed an amplification of the Einstein-Podolsky-Rosen paradox, where one considers three, instead of just two, entangled particles.

Prof. Wojciech Zurek, Los Alamos National Laboratory

Wojciech Hubert Zurek is a Laboratory Fellow at Los Alamos National Laboratory (LANL). He is a leading authority on a number of physics topics, including quantum theory, and particularly, decoherence. His work also has great potential benefit to the emerging field of quantum computing. He was educated in Krakow, Poland (M.Sc. 1974) and Austin, Texas (PhD 1979). He spent two years at Caltech as a Tolman Fellow, and began his appointment at LANL as a J. Oppenheimer Fellow. He was the leader of the Theoretical Astrophysics Group at LANL from 1991 until he was made a Laboratory Fellow in the Theory Division in 1996. Zurek is currently a foreign associate of the Cosmology Program of the Canadian Institute for Advanced Research.

K. Administrative Staff

IQC Administrative Staff as of March 31, 2017:

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Erica Boland
Mai Brit
Christine Chris
Steven Chuqi
Sara Clark
Matt Cooper
Robert (Bob) Crow
Andrew Dale
Monica Day
Tobi Day-Hamilton
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L. Financial Information – Auditor's Report