Report to Industry Canada

2013/14 Annual Report and
Final Report for 2008-2014 Granting Period

Institute for Quantum Computing
University of Waterloo
June 2014

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From the Executive Director

The next great technological revolution – the quantum age

> "There is a second quantum revolution coming – which will be responsible for most of the key physical technological advances for the 21st Century."
>
> Gerard J. Milburn, Director, Centre for Engineered Quantum Systems, University of Queensland - 2002

There is no doubt now that the next great era in humanity's history will be the quantum age.

IQC was created in 2002 to seize the potential of quantum information science for Canada. IQC's vision was bold, positioning Canada as a leader in research and providing the necessary infrastructure for Canada to emerge as a quantum industry 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 participate in our research, share their knowledge and encourage the next generation of scientists to continue on this incredible journey. We are living the reality of a great technological revolution with quantum technologies and applications already emerging from our labs.

The holy grail of quantum information research is the development of a general purpose quantum computer. Research teams at IQC are aggressively working towards the goal of creating such a machine and great progress continues to be made in our labs. In addition, we have discovered that there are other substantial outcomes of quantum information research. These include ultra-precise sensors, unbreakable quantum cryptography and novel materials to harness and maximize the unusual properties of the quantum world. Each of these areas of inquiry has emerged from research towards a general purpose quantum computer. And while important to that end, these research areas will have significant societal impacts in their own rights – perhaps even more in total than the quantum computer itself.

Recent and future advances are due in no small part to the visionary leadership and investments from 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 allowed IQC to recruit the best and brightest faculty and students from around the globe, including:

- David Cory, recruited in 2008 from MIT, whose work towards a 100 qubit quantum processor involves a team of nearly 30 graduate students.
- Thomas Jennewein, recruited in 2009 from Austria, who leads a team of researchers exploring global quantum communications via satellites.
- Christopher Wilson, recruited in 2013 from Sweden, who is creating superconducting qubits to harness the power of the quantum world on a chip.
- Kyung Soo Choi, recruited in 2014 from South Korea, who completed his PhD at CalTech with a 4.0 grade point average and is now working on the intersection of experimental quantum optics, atomic physics, and condensed matter physics.

These individuals along with eighteen other faculty members, thirty-five research professors and fellows and 114 graduate students have joined IQC because of the vision of our benefactors and their commitment to research excellence.

Together, this partnership has created an innovation ecosystem like no other. My colleagues from around the globe envy the commitments and investments made by our government, our university and our benefactors. Their investments enable IQC to strive for excellence in all our activities and advance into the quantum age at the front of the pack. Their investments allow IQC researchers to endeavour into the quantum world and harness the power of the very small for large societal benefit. Their investments and the passionate work of my colleagues have created one of the leading research and innovation centres in the world.

As I look to the future, I see IQC continuing to make strategic contributions to Canada's research and innovation agenda. I see breakthrough technologies continuing to emerge from our labs. I see quantum technologies that will have broad and deep impacts into Canadian society. To realize this future, we must continue our path of excellence as the world has woken up to the "quantum opportunity." Major investments are being made in the UK (£270M over five years), Singapore ($36.9M over four years), the Netherlands, China, the US and other countries. New research institutes are emerging that will compete for talent and strive to lead the world in bringing quantum technologies to reality. To continue our contributions, we must, as partners, forge this path together.

IQC and Canada have a unique opportunity - the opportunity to continue to make strategic investments and take full advantage of our leadership position in the quantum race and to further build the Quantum Valley. Our private-public partnership has created the right environment and we are well on our way to seizing this opportunity. I look forward to continuing on this incredible journey with all of our partners and realizing our bold vision for generations to come.

Raymond Laflamme
Executive Director
Institute for Quantum Computing
University of Waterloo

Executive Summary

The road to Quantum Valley

The Institute for Quantum Computing'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.

IQC is regarded as one of the leading quantum information research institutes in the world attracting world-class researchers, conducting excellence in research and training the next generation of quantum technologists. This success is due in no small part to the collaborative private-public partnership behind IQC – the University of Waterloo, Mike and Ophelia Lazaridis, the Province of Ontario and the Government of Canada.

Over the past five years, the Government of Canada's investment in IQC has helped to accelerate the institute's growth, enhance its research infrastructure, draw international research talent to IQC, and share the results of our research with the world.

Highlights from 2008-2014 include:

Creating an innovation ecosystem like no other

The Waterloo ecosystem is known for its innovative spirit and drive for entrepreneurship and commercialization success. Building on this base of excellence, IQC, the University of Waterloo and our benefactors have created an innovation ecosystem that harnesses the power of the quantum world. From the theoretical research into the darkest depths of our universe at the Perimeter Institute to utilizing the unique quantum properties of the smallest building blocks of our world at IQC to supporting the commercialization of technology built upon this knowledge through Quantum Valley Investments, Waterloo Region has become one of the best places in the world to participate in the next great technological revolution – the quantum age.

Research at IQC drives this innovation chain forward. Our theoretical and experimental explorations of the quantum world are leading to new innovations that will have significant impact on society. IQC research spans quantum computation, quantum communication, quantum sensors and quantum materials. Since 2008, research at IQC has advanced to compete at the highest international levels. Our 22 faculty have been recruited from around the globe, our postdoctoral fellowship program attracts the best and brightest talent to IQC and our rapidly growing collaborative graduate program is preparing the next generation of quantum information specialists.

Today's Waterloo innovation ecosystem – the Quantum Valley – will drive technological innovation for the benefit of Canada, and the world.

Construction of the Mike & Ophelia Lazaridis Quantum-Nano Centre

IQC's headquarters, the Mike & Ophelia Lazaridis Quantum-Nano Centre, is a state-of-the-art building featuring 285,000 square feet of laboratory, office and collaboration space along with a fabrication facility (cleanroom). Designed to meet the highest scientific standards for temperature, vibration, humidity and electromagnetic radiation control, the Lazaridis Centre provides the ideal environment for interaction and collaboration of the top researchers and students from around the world. IQC's overall research footprint has expanded by 350% to include the new Lazaridis Centre and the Research Advancement Centres (I and II) to a total of 53,943 sq. ft. of laboratory space on the University of Waterloo campus.

Recruiting the best talent

Over the past five years, IQC's faculty complement has grown to 22 faculty with both senior and young researchers joining our ecosystem. IQC continues to recruit the best and brightest minds, including:

- David Cory, recruited in 2008 from MIT and now Canada Excellence Research Chair (CERC) in Quantum Information, whose work towards a 100 qubit quantum processor involves a team of nearly 30 graduate students.
- Thomas Jennewein, recruited in 2009 from Australia, who leads a team of researchers exploring global quantum communications via satellites.
- Christopher Wilson, recruited in 2013 from Sweden, who is creating superconducting qubits to harness the power of the quantum world on a chip.
- Raffi Budakian, recruited in 2014 from Univeristy of Illinois at Urbana-Champagne, joins IQC as WIN Endowed Chair in Superconductivity.
- Kyung Soo Choi, recruited in 2014 from South Korea, who completed his PhD at CalTech with a 4.0 grade point average and is now working on the intersection of experimental quantum optics, atomic physics, and condensed matter physics.
- Sir Anthony Leggett, Nobel Laureate in Physics, recruited as an associate and spends each summer participating in research and teaching at IQC.
- Amir Yacoby, professor at Harvard University, recruited as Distinguished Research Chair in Condensed Matter at IQC in September 2013.
- Steve MacLean, former head of the Canadian Space Agency, recruited to IQC associate position in September 2013.

Additionally, IQC's graduate programs have seen a 170% increase – from 42 students in 2009 to 114 in 2014. IQC will continue to grow to meet our full complement of 33 faculty, 55 postdoctoral fellow and 165 graduate students. These students have garnered national and international awards, scholarships and fellowships including NSERC awards, Banting Fellowships, Vanier Fellowships and many others.

Creating a global hub for quantum research collaboration

IQC has quickly become a global hub for quantum information research and collaboration. From 2008/09-2013/14, IQC hosted 26 scientific conferences with researchers from around the globe on topics ranging from the fundamentals of quantum theory to experimentation of quantum devices. Addiitonally, IQC's visitor program promotes collaboration and exchange of research with institutions across the globe. Over the past five years, IQC hosted 923 scientific visitors from leading institutions, 185 industry visitors and 163 government representatives, including:

- Stephen Hawking
- Serge Haroche, Collège de France, co-recipient of the 2012 Nobel Prize in Physics

- David Wineland, National Institute of Standards and Technology, co-recipient of the 2012 Nobel Prize in Physics
- Charles Bennett, IBM Research, co-founder of quantum cryptography
- John Preskill, invented a powerful method, derived from entanglement theory, for proving the security of quantum protocols with Peter Shor

Bringing quantum science to the world

IQC's outreach activities bring the quantum world out of the lab and into the minds of young and old alike. IQC's outreach activities have spanned the globe through a variety of activities including graduate fairs and public open houses, the quantum symphony and Nobel Laureate lectures.

Through open houses, tours, presentations, science shows and more, IQC has reached out across the country to raise awareness and educate young people on the importance of quantum information science. Whether individuals or groups, IQC has welcomed high school to graduate students, teachers, government representatives, industry partners and the general public through its doors to experience the quantum world first hand.

Educating the next generation of quantum scientists and technologists

Unique to IQC, our collaborative graduate program educates the next generation of scientists, computer scientists, mathematicians, and engineers. In partnership with Waterloo's Faculties of Science, Mathematics and Engineering, the quantum information collaborative graduate program has grown by 170% since 2008 - now at 114 students. Additionally, IQC's postdoctoral fellowships have seen a 500% increase with 48 current postdoctoral fellows.

These activities have positioned IQC as one of the preeminent research institutions in the world and have branded Canada as a global leader in quantum information research. As IQC continues its rapid growth and advances the understanding of the quantum world, Waterloo Region's reputation as the Quantum Valley will continue to be solidified.

The Institute for Quantum Computing

Vision, Mission and Strategic Objectives

At the foundation of IQC is the **vision** that harnessing quantum mechanics will lead to transformational technologies that will benefit society and become a new engine of economic growth in the 21st century.

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.

To fulfill its mission, IQC is guided by three strategic objectives:

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 establish IQC as the **authoritative source of insight, analysis and commentary** on quantum information.

Budget & Financial Statement ($000s)

The following table outlines the Industry Canada funding spend by IQC over the term of the agreement.

	2010	2011	2012	2013	2014	Total
Building	12,615	12,385	-	-	-	25,000
Equipment	938	1,062	1,309	529	1,162	5,000
People and Operations	2,947	3,553	3,691	5,164	4,645	20,000
Total	16,500	17,000	5,000	5,693	5,807	50,000

Strategic Objectives

Over the last five years, IQC's achievements and results are guided by our strategic objectives and the strategic framework developed in consultation with Industry Canada.

IQC strategic objectives:

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 establish IQC as the **authoritative source of insight, analysis and commentary** on quantum information.

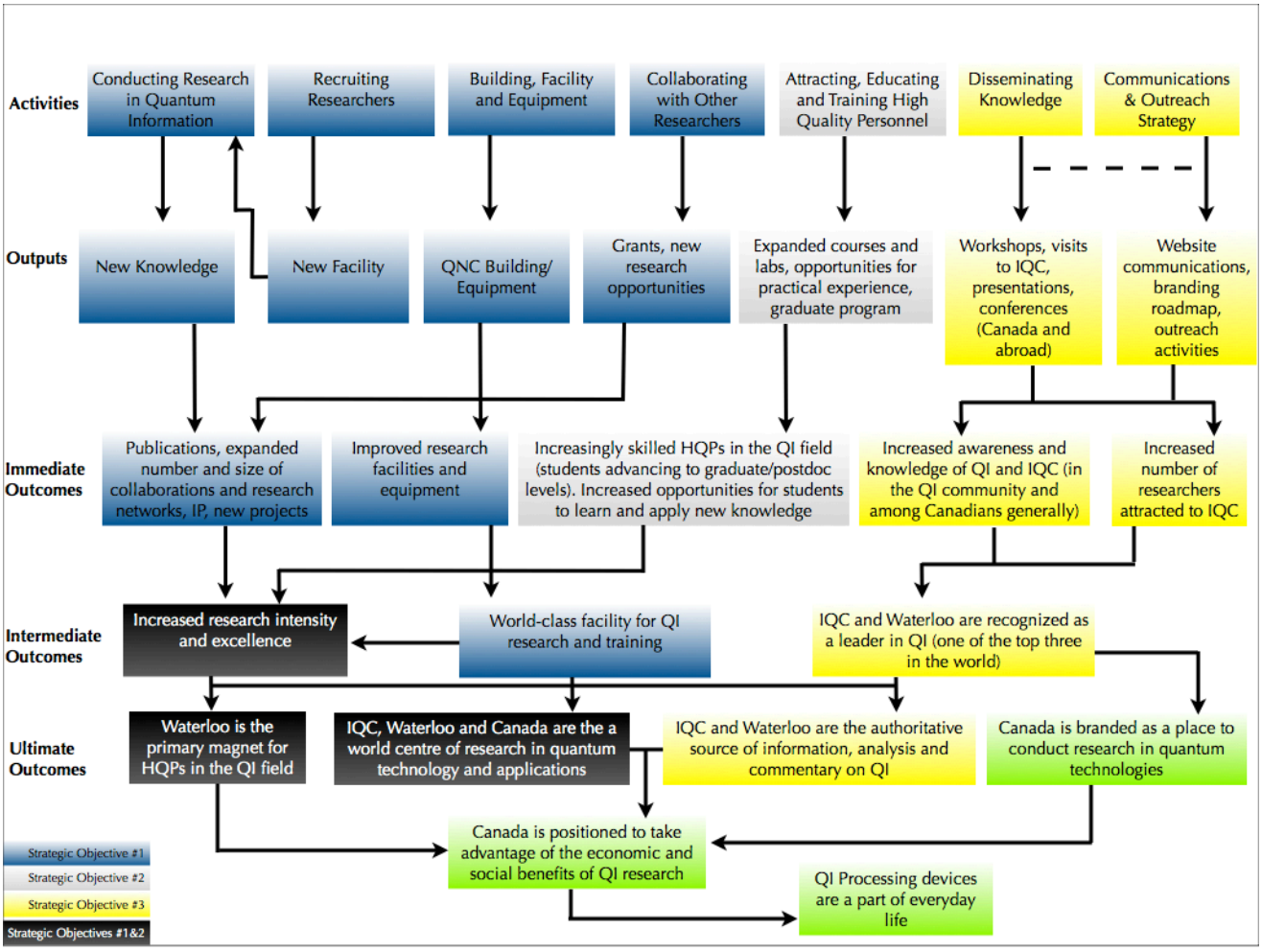


Figure 1: IQC Strategic Framework

2008-2014 Overview

Over the course of the Industry Canada 2008-2014 funding period, the Institute for Quantum Computing has undergone significant growth and development. The investments made into IQC have positioned the Institute as one of the leading research institutes in quantum information in the world.

IQC OBJECTIVES 2008-2014

1. Construction of the Mike & Ophelia Lazaridis Quantum-Nano Centre
2. Establish research infrastructure
3. Host scientific conferences and lectures
4. Disseminate and exchange research results
5. Promote science awareness to the public
6. Support domestic and international students, postdoctoral fellows and visiting professors
7. General administration and operation of the facility (including administrative staff and technical support)

1. Construction of the Mike & Ophelia Lazaridis Quantum-Nano Centre

The Mike & Ophelia Lazaridis Quantum-Nano Centre is the new, state-of-the-art headquarters of the Institute for Quantum Computing. The Lazaridis Centre officially opened on September 21, 2012 and is the home to IQC and the Waterloo Institute for Nanotechnology (WIN). It features 285,000 square feet of lab, office and collaboration space along with a fabrication facility (cleanroom). Designed to meet the highest scientific standards for temperature, vibration, humidity and electromagnetic radiation control, the Lazaridis Centre provides the ideal environment for interaction and collaboration of the top researchers and students from around the world.

Building highlights:

- 285,000 square feet, shared between IQC and WIN
- Meets the highest scientific standards for control of vibration, humidity, electromagnetic radiation and temperature
- Shared cleanroom/fabrication facility (6,700 sq. ft.) enables design of structures billionths of a metre in size
- Labs constructed underground to minimize electromagnetic interference and vibration
- Highly convertible seminar space accommodates conferences, public lectures and more

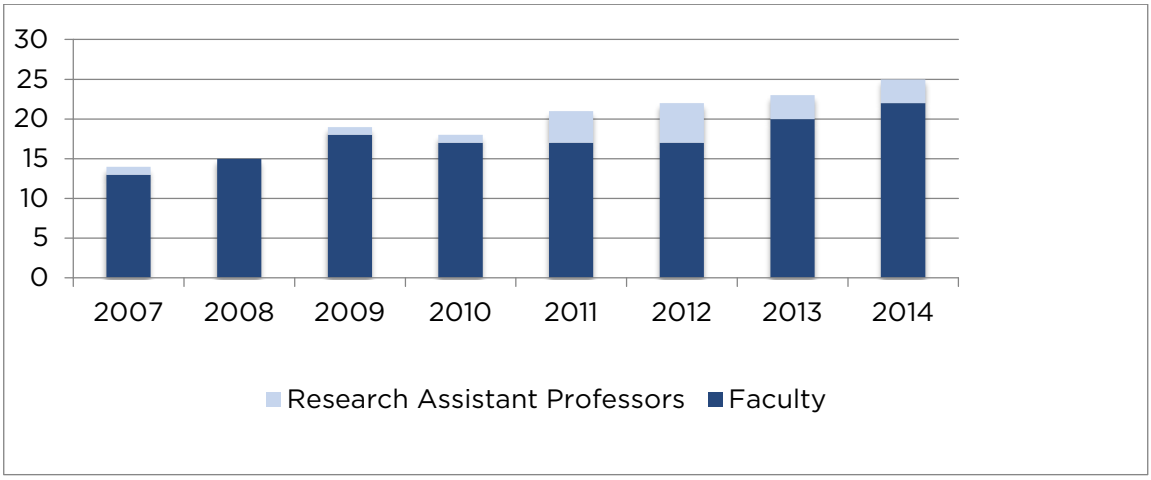
- Auditorium with multi-tiered retractable seating splits into two or four rooms to accommodate up to 220 people
- Six-storey atrium with floating staircase provides common ground for scientists of all disciplines to meet and collaborate
- An architectural marvel at the heart of campus
- Vertical windows of varying reflectivity/transparency on IQC metaphorically signify quantum superposition; honeycomb pattern on WIN side represents strong natural nanostructures

Currently, the building construction is 100% complete with all staff moved into the space. Sixteen lab spaces are in use with remaining labs slated for new faculty hires in the coming years.

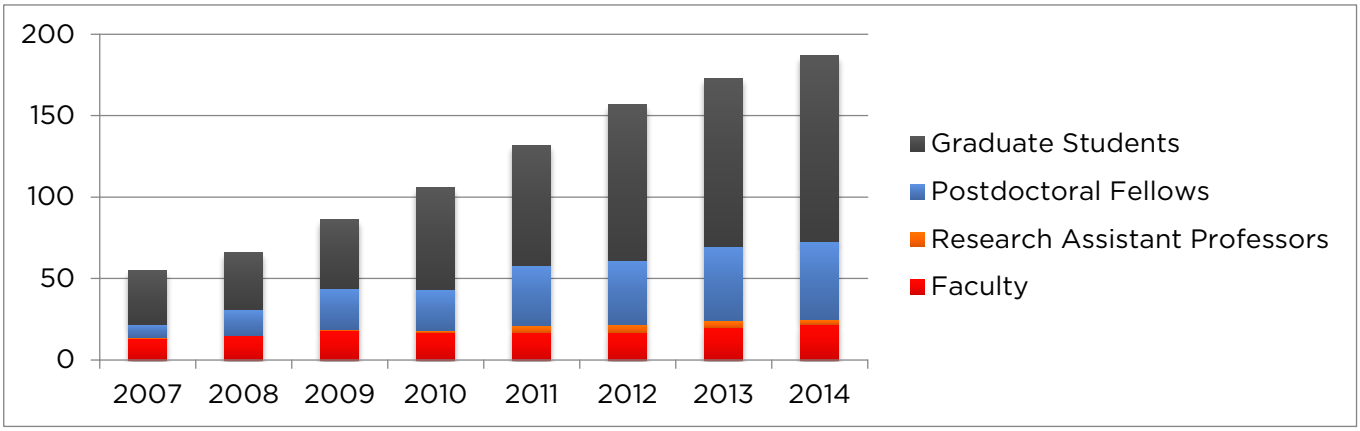
2. Establish research infrastructure

Over the past five years, IQC's research faculty complement has grown to 22 faculty, along with a 170% increase in the number of students (from 42 students in 2009 to 114 in 2014). In turn, IQC's overall research footprint has expanded to include the new Lazaridis Centre and the Research Advancement Centres (I and II).

IQC Faculty & Research Assistant Professors from 2007 to Present



IQC Membership from 2007 to Present



RESEARCH LABS

The Industry Canada funding over this period has allowed IQC to rapidly grow its research infrastructure to accommodate the increased space and researcher requirements. From 2008-2014, **IQC grew its lab space by 350%** to a total lab space of **53,943 sq. ft**.

Square Footage: IQC Lab Space by Year

Time Period	Buildings	Square Footage
2001 - 2004	Physics and Chemistry	2,625 sq. ft.
2004 - 2008	195 Columbia St., Physics and Chemistry	6,694 sq. ft.
2008 - 2010	RACI, Chemistry	11,983 sq. ft.
2010 - 2012	RACI, RACII and Chemistry	25,132 sq. ft.
2012 - 2013	RACI, RACII, Chemistry and Lazaridis Centre	51,832 sq. ft.
2013 - 2014	RACI, RACII, Chemistry and Lazaridis Centre	53,943 sq. ft

IQC labs are outfitted to specific researcher needs and include equipment required for their area of research. Examples of labs outfitted during the funding period include:

- Quantum Photonics Laboratory
  A key goal pursued in this lab is to develop technologies that enable applications of quantum information and communication on a global scale. Researchers are developing technologies for quantum cryptography systems through optical fibres and free space to satellites. They are also engineering novel and high-quality states of entangled photons (particles of light) and applying them to quantum communication protocols and fundamental quantum physics experiments.
- Quantum Optics & Quantum Information Laboratory
  Photons generated using lasers can be used as qubits for quantum computation. Because photons interact very little with their surrounding environment, they are resistant to decoherence. Research in this lab focuses on experimental quantum optics, nonlinear optics, state reconstruction and measurement, and interferometry.
- Quantum Verification Lab
  The Quantum Verification Lab aims to identify weaknesses and vulnerabilities in commercial quantum cryptography systems. Although quantum cryptography is perfectly secure in principle, hardware implementations of it — such as commercially available quantum key distribution (QKD) setups — can have unforeseen loopholes. Research in the Quantum Verification Lab ensures these loopholes are discovered and remedied in future hardware systems.

In addition to the laboratory space, IQC shares a fabrication facility with the Waterloo Institute for Nanotechnology (WIN). Temporary fabrication facilities were available in RAC1.

A permanent fabrication facility is now located in the Lazaridis Centre and is nearing outfit completion. The Quantum NanoFab in the Lazaridis Centre expects to be in full operation by summer 2014.

Over the last five years, numerous research activities have resulted in fabricated devices. Sample devices fabricated at IQC include:

Coherent Spintronics Group – Jonathan Baugh's Group

The SEM image (right) shows an indium arsenide (InAs) nanowire across a series of bottom gates (25nm wide with a 60nm pitch). The colourscale plot shows device resistance versus gate voltage where the dark blue region in the middle corresponds to nearly zero resistance, due to proximity effect superconductivity in the nanowire channel. The critical current of this Josephson junction, seen as the red line at the boundary of this region, is modulated by the local gate. The successful observation of proximity superconductivity in this device opens up many new doors, including the ability to search for Majorana fermions, exotic quasiparticle states that have been proposed for fault tolerant quantum computing.

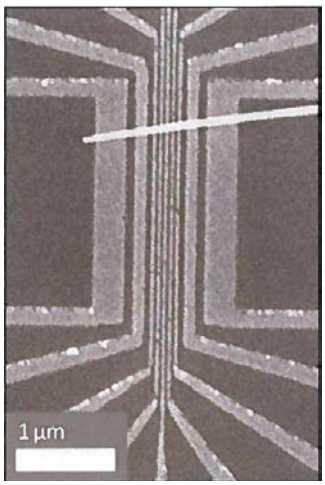


Figure 3: InAs nanowire

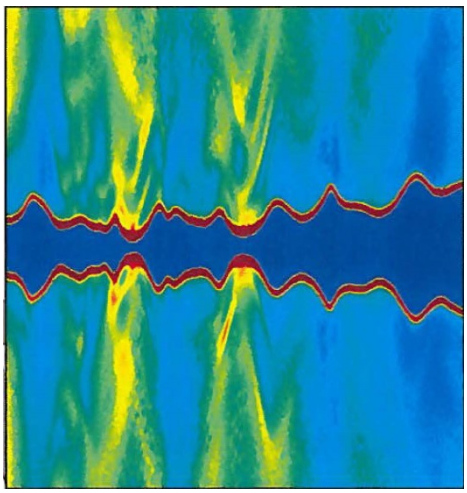


Figure 3: Plot showing device resistance vs. gate voltage

Spin-based quantum processing - David Cory's Group

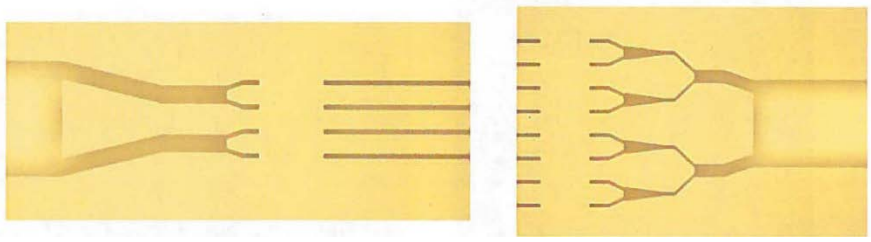


Figure 4: Superconducting microstrip resonators - niobium (Nb) on sapphire

These novel superconducting quantum devices are arrays of high-quality microstrip resonators made of niobium on a sapphire wafer. When excited with microwaves, these resonators are specifically designed to generate a planar magnetic field directly above the device. Such a magnetic field profile allows for electron spin resonance experiments on thin film, which is a key ingredient for David Cory's 96 qubit project. Moreover, these resonators can also be used to couple electron-spins to other quantum systems, such as superconducting qubits, to move towards scalable hybrid systems for quantum information processing.

Superconducting Quantum Devices - Adrian Lupascu's Group

The image below shows a qubit-based magnetometer designed by IQC faculty member Adrian Lupascu and his research group. The sensor relies on the use of a superconductlng flux qubit. The qublt is a ring Interrupted by Josephson junctions, operated at temperatures in the tens of milliKelvin range, and controlled using microwave pulses. The magnetometer is useful for detection in the range from tens of kHz to tens of MHz, and it surpasses in sensitivity of other detection methods. The sensitivity reaches 3.3 pT/rt(Hz) for an operation frequency of 10 MHz. (Publication: *Nature Communications*, 3, 1324, 2012)

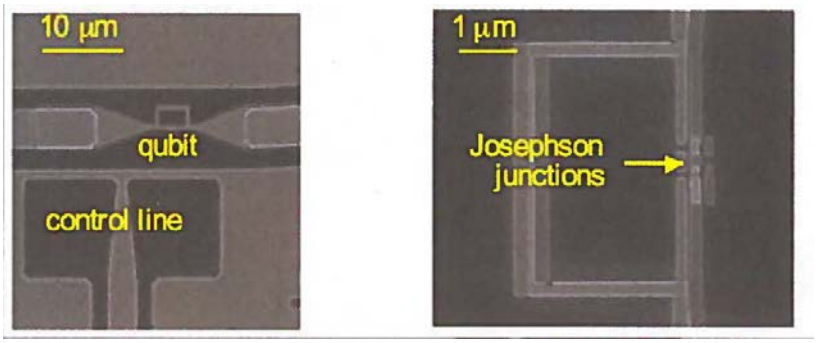


Figure 5: Qubit-based magnetometer

3. Host scientific conferences and lectures

From 2008/09-2013/14, IQC hosted **26 scientific conferences** with researchers from around the globe on topics ranging from the fundamentals of quantum theory to experimentation of quantum devices. Examples of scientific conferences held at IQC include:

- **Quantum Foundation and Quantum Information Conference - "Decoherence and Friends"** May 20 – 23, 2013

  Over the past 30 years Wojciech Zurek led the development of the theory of decoherence and studied its implications for the foundations of quantum physics and its consequences for quantum information science and technology. This conference brought together Zurek's colleagues from around the world to celebrate the anniversary of his seminal work. Some of the most notable attendees included:

  - Serge Haroche, Collège de France, co-recipient of the 2012 Nobel Prize in Physics
  - David Wineland, National Institute of Standards and Technology, co-recipient of the 2012 Nobel Prize in Physics
  - Charles Bennett, IBM Research, co-founder of quantum cryptography
  - Bill Wootters, Williams College, proved the no cloning theorem, a cornerstone in quantum information research, in a joint paper with Zurek
  - Ben Schumacher, Kenyon College, discovered a method for interpreting quantum states as information and invented a way of compressing the information in a state, and storing the information in a smaller number of states - known as Schumacher compression. He also coined the term qubit.

- Seth Lloyd, a leading pioneer in the field of quantum computation and quantum communications who proposed the first technologically feasible design for a quantum computer

- QCrypt - 3rd International Conference on Quantum Cryptography
  August 5 – 9, 2013

  The annual conference on quantum cryptography (QCrypt) is a conference for students and researchers working on all aspects of quantum cryptography. The main goals of the conference are to represent the previous year's best results and to support the building of a research community in quantum cryptography. Notable attendees included:

  - Sir Anthony Leggett, University of Illinois at Urbana–Champaign, 2003 Nobel Prize in Physics
  - Charles Bennett, IBM Research, co-founder of quantum cryptography
  - John Preskill, invented a powerful method, derived from entanglement theory, for proving the security of quantum protocols with Peter Shor

- Quantum Information Processing with Spins and Superconductors
  May 17-19, 2010

  This scientific workshop brought together worldwide leaders in the field of quantum information processing with solid-state systems, in particular with superconducting systems and electron spins. The goal of this workshop was to discuss recent progress, unanswered questions, and future directions for building a solid-state quantum-information processor. Notable attendees included:

  - Leonardo DiVincenzo, Yale University
  - Andrew Briggs, University of Oxford
  - Daniel Loss, University of Basel
  - John Martinis, Univeristy of California, Santa Barbara

- Theory and Realisation of Practical Quantum Key Distribution
  June 14 – 17, 2010

  This workshop was devoted to all aspects of practical Quantum Key Distribution (QKD), arguably the most advanced application of quantum information science.

  - Renato Renner, Head of Institute for Theoretical Physics at ETH Zurich
  - Nicolas Gisin, co-founder of ID Quantique
  - Gregoire Ribordy, co-founder and CEO of ID Quantique
  - Wolfgang Tittle, Alberta Innovates Technology Futures Industrial Research Chair

4. Disseminate and exchange research results

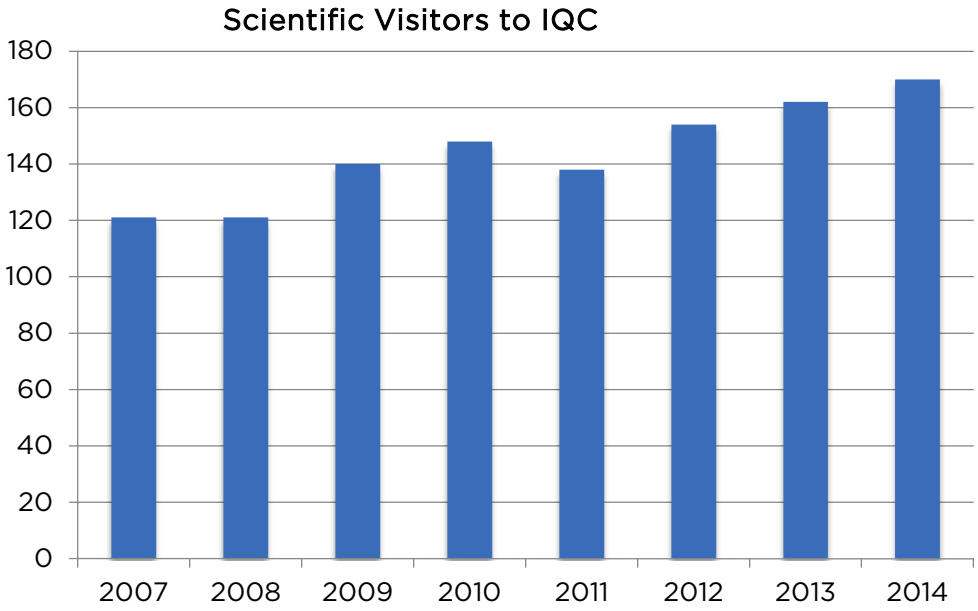
IQC's visitor program promotes the dissemination and exchange of research with institutions across the globe. Over the past five years, IQC hosted **923 scientific visitors** from leading institutions, **185 industry visitors** and **163 government representatives**. Additionally, IQC has hosted the world's leading researchers including:

- **Stephen Hawking** (right)
- Three Nobel Prize recipients:
    - **Sir Anthony Leggett** (2003 Nobel Prize in Physics)
    - **Serge Haroche** (co-recipient of 2012 Nobel Prize in Physics)
    - **David Wineland** (co- recipient of 2012 Nobel Prize in Physics)
- **Freeman Dyson** - best known for demonstrating the equivalence of two then-current formulations of quantum electrodynamics—Richard Feynman's diagrams and the operator method developed by Julian Schwinger and Sin-Itiro Tomonaga

Figure 6: Professor Stephen Hawking visting IQC September 2012

- **Charles Bennett** - considered one of the founding fathers of modern quantum information theory (Bennett's four laws of quantum information)
- **Gilles Brassard** – invented the BB84 protocol for quantum cryptography along with Charles Bennett
- **John Preskill** - invented a powerful method, derived from entanglement theory, for proving the security of quantum protocols with Peter Shor
- **Anton Zeilinger** – highly recognized for his pioneering conceptual and experimental contributions to the foundations of quantum physics, which have become the cornerstone for the field of quantum information
- **Seth Lloyd** - a leading pioneer in the field of quantum computation and quantum communications who proposed the first technologically feasible design for a quantum computer
- **Don Eigler** – recipient of the 2010 Kavli Prize in Nanoscience for his breakthroughs: the first to use a scanning tunneling microscope tip to arrange individual atoms on a surface and the creation of the first quantum corrals
- **Paul Kwiat** - a primary inventor of the world's first two sources of polarization-entangled photons from down-conversion, which have been used for quantum cryptography, dense-coding, quantum teleportation, entanglement distillation, and most recently, optical quantum gates

The chart below shows the trend in IQC's academic visitors over the past seven years. For a full list of visitors and their institutions, see Visitors on page 77.



5. Promote science awareness to the public

IQC's outreach activities have touched **over 10,000 people** through a variety of activities including graduate fairs and public open houses, from the quantum symphony to Nobel Laureate lectures. Outreach activities are aimed to bring IQC's research out of the labs and into the hands and minds of various audiences including potential graduate and undergraduate students, high school students and the general public. Examples of IQC's outreach activities include:

IQC Open Houses

IQC has hosted four open houses in five years showcasing the science of quantum information, research facilities, faculty and students. Each open house featured scientific experiments for all ages, scientific lectures and tours of the facilities. Through our open houses, IQC has had over 2,500 guests through our facilities in five years.

Figure 7: A budding scientist at IQC's open house in 2013

Open houses have included tours of the Research Advancement Centre labs, scientific displays, parnterships with the Faculties of Science and Engineering on campus and stops on the annual local Doors Open tours, along with open houses in the new Lazaridis Centre.

Quantum Frontiers Distinguished Lecture Series

The Quantum Frontiers Distinguished Lecture series brings quantum information researchers from around the world to IQC to share their knowledge and raise awareness about the impact of quantum information technologies. Guest lecturers have included:

- Don Eigler, Fellow, IBM Almaden Research Centre (2011)

  IQC launched the Quantum Frontiers Distinguished Lecture Series in April 2011, with a filled-to-capacity talk by nanotechnology pioneer Don Eigler. A fellow at the IBM Almaden Research Centre, Eigler is widely known for having spelled out I-B-M using 35 individual atoms of xenon. Eigler's lecture explored how researchers are working to build and operate atomic-scale logic circuits that perform computation using only the spin degree of freedom.

- Ralph Merkle, Institute for Molecular Manufacturing (2011)

  Ralph Merkle is a pioneer in molecular nanotechnology and delivered the second installment of the Quantum Frontiers Distinguished Lecture Series in June 2011. Merkle, who is based at Singularity University and the Institute for Molecular Manufacturing, focused his talk on an intriguing question: if you could arrange atoms exactly as you wanted, how would you arrange them? The answers proved a fascinating glimpse into nanotechnology research.

- David Wineland, NIST (2012)

  David Wineland participated in the Quantum Frontiers Distinguished Lecture series at IQC in January 2012. Wineland, a physicist at the U.S. Department of Commerce's National Institute of Standards and Technology (NIST), delivered a lecture on atomic clocks and trapped ions. Wineland was awarded the Nobel Prize in Physics later that year with co-recipient, Serge Haroche.

- Chip Elliot, Raytheon BBN Technologies (2012)

  Chip Elliott is the Chief Engineer at BBN Technologies and Project Director for the Global Environment for Network Innovations. Dr. Elliott led the creation of the world's first quantum cryptography network, and he holds many patents on communication and quantum technology. He delivered an instalment of the Quantum Frontiers Distinguished Lecture series on "Can we speak – privately? Quantum cryptography in a broader context."

- John Kirtley, Stanford University (2014)

  A fellow of both the American Physics Society and the American Association for the Advancement of Sciences, John R. Kirtley is known for developing novel techniques based on scanning Superconducting QUantum Interference Device (SQUID) microscopy. A condensed matter physicist, he is the Consulting Professor at the Center for Probing the Nanoscale in the Department of Applied Physics at Stanford University. Kirtley shared the 1998 Oliver E. Buckley Prize in condensed matter physics, was the Alexander von Humboldt Foundation Forschungspreis winner at the University of Augsbert (Germany) in 2007 and holds a Chaire d'Excellence from the NanoSciences Foundation in Grenoble, France. Kirtley delivered the latest instalment of the Quantum Frontier Distinguished Lecture Series at IQC on March 20, 2014.

Tours and Visits

Faculty, students and staff at IQC have reached out to schools across the country to raise awareness and educate young people on the importance of quantum information science. Whether individuals or groups, IQC has welcomed high school to graduate students, teachers, government representatives, industry partners and the general public through its doors to experience the quantum world first hand. Additionally, IQC has travelled across Canada and around the world to share our research.

Figure 8: Finance Minister Jim Flaherty visted IQC in 2010

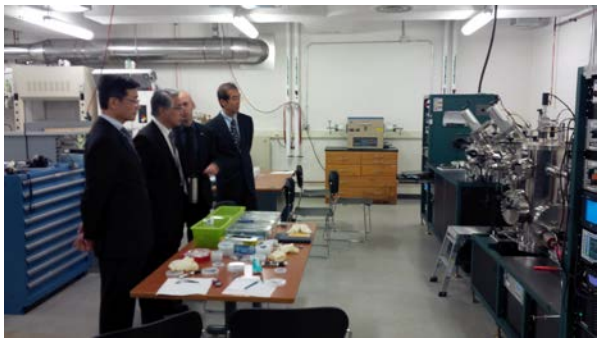
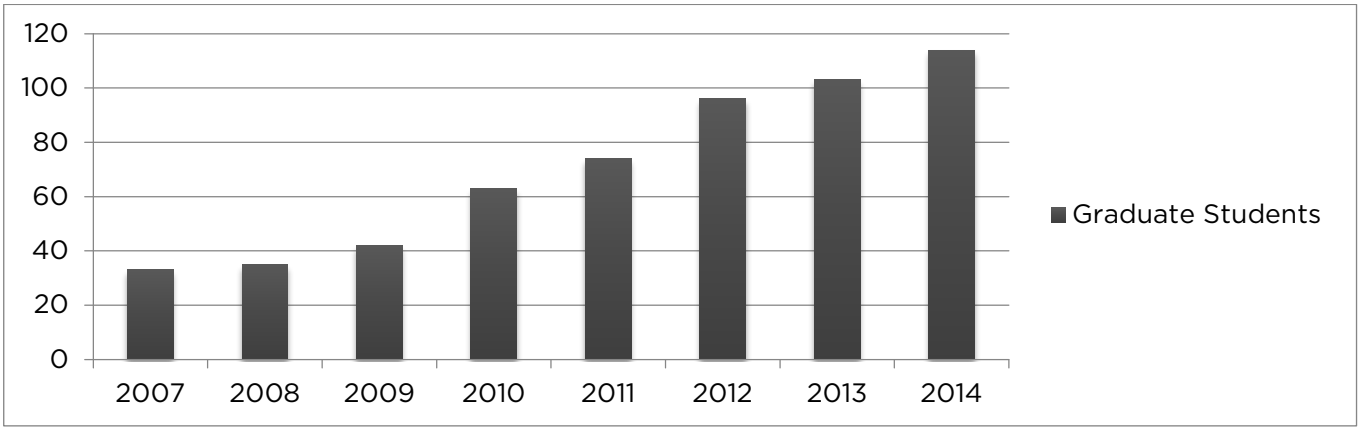


Figure 9: Fujitsu visit to IQC 2013

6. Support domestic and international students, postdoctoral fellows and visiting professors

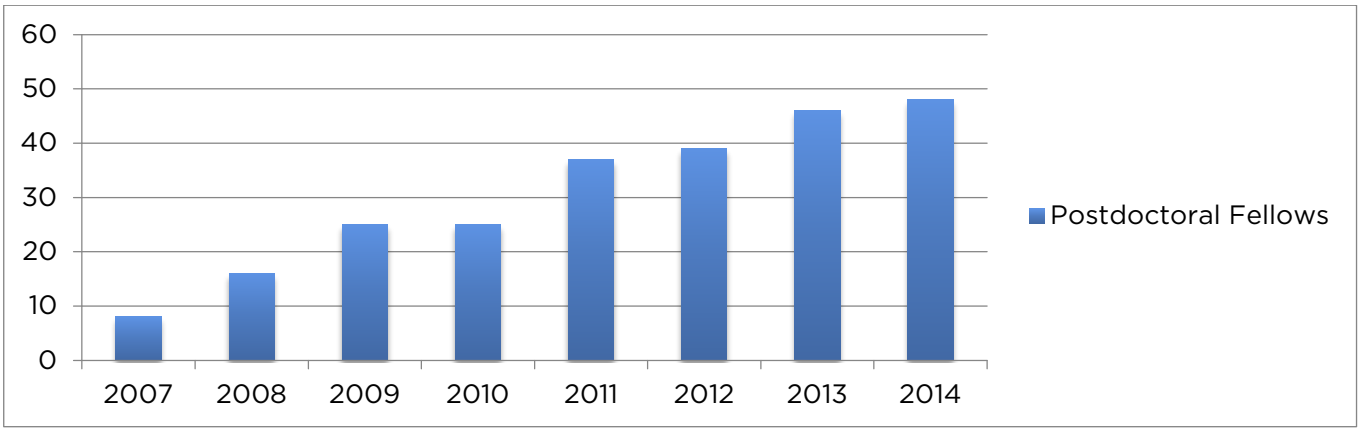
From 2008-2014, IQC's student complement has seen a **170% increase** - 42 students in 2009 to 114 students in 2014.

IQC Graduate Students from 2007 to present



IQC has also seen a **500% increase** in postdoctoral fellows as shown in the graph below.

IQC Postdoctoral Fellows from 2007 to present



IQC has welcomed students and postdoctoral fellows from all over the world. The chart below illustrates IQC's international student body from 2010 to present (timeframe when international student data was collected).

International students to IQC 2010 - present

	2010	2011	2012	2013	2014
Postdoctoral Fellows	20	26	29	31	32
Graduate Students	27	42	43	38	56

Students and postdoctoral fellows attend from a variety of countries including: Australia, Bangladesh, Cameroon, Canada, China, France, Ireland, India, Iran, Italy, Japan, Norway, Singapore, Spain, the Netherlands, the UK and the U.S.

7. General administration and operation of the facility (including administrative staff and technical support)

Over the past five years, IQC has adapted its adminstrative and technical support structure to the complex nature of its growing research activities. Quantum information research varies from theoretical to experimental requiring a diverse level of both administrative and technical support. IQC's support infrastructure includes the following teams:

Laboratories

A team of specialized staff works in the facilities and research labs at IQC. This group builds and operates the world-class Quantum NanoFabrication facility, for the combined benefit of the University of Waterloo's stakeholders, researchers and collaborators. The group maintains infrastructure and ensures that key lab equipment performs optimally and consistently. Technical laboratory support is critical to the ongoing continuity of experimental research at IQC and to fulfill its strategic objectives — in particular the first objective of performing world-class research. The team includes: the Director of Operations; a Process Engineer; two Equipment Technologists; and a Cleanroom Certification and Inventory Specialist.

External Relations and Outreach

IQC understands that great science should not and cannot happen in isolation. It is vital to share the results and discoveries of IQC's research with the scientific community, with the governments that support it, and with the public that will benefit from it. IQC's External Relations and Outreach team plays a crucial role in developing the international reputation of the institute by showcasing its researchers and their work. This is done through a strategy that includes publications, media relations, the IQC website, government relations, events and conferences, e-communications and social media, video production and more. Such activities raise IQC's visibility and international renown, aiding in the recruitment of top faculty, postdoctoral fellows, students and visiting researchers. IQC's External Relations and Outreach team includes: the Associate Director, Communications & Outreach; the Senior Manager, Scientific Outreach; the Senior Communications Manager; a Communications Officer; a Research Development Officer; and a Coordinator, Events, Outreach and Communication.

Information Technology

Information technology is integral to IQC's success and its support ranges from enabling administrative functions to supporting scientific research and online outreach. IQC's information technology strategy encompasses infrastructure, information/transaction management and stakeholder support. An information management repository provides intuitive retrieval and administration of the institute's business, including practices and procedures, financial reports, performance indicators, governance framework (e.g., committee terms of reference), and other information that facilitates the successful operation of the institute. IQC's Information Technology team includes an Associate Director, Information Technology; a Computing Support Specialist; and a Client Support Specialist.

Finance and Administration

The fundamental function of IQC's administrative team is to provide IQC researchers and students with the professional support needed to pursue leading-edge research in quantum information. They work collaboratively with the University of Waterloo's central finance administration office and the many departments throughout campus. IQC's current 11-member Finance and Administration team is made up of the following roles: the Assistant Director, Administration; a Financial Officer; an Administrative Officer; a Visitor Coordinator; a Graduate Program Coordinator and Recruitment Assistant; an Administrative Coordinator/Financial Assistant; two Administrative Assistants; an Administrative Assistant/Receptionist; and Administrative Support.

2013/14 Annual Report Highlights

Conducting Research in Quantum Information – 2013/14 Highlights

IQC conducts research in quantum information at the highest international level. Our research produces new knowledge that leads to publications, presentations at conferences and commercialization opportunities.

OBJECTIVES FOR FISCAL 2013/14

- Continue leading-edge investigation of theoretical approaches to quantum information processing in order to better understand the impact of quantum mechanics for information processing, develop control methods for quantum processors and investigate new potential applications.
- Continue developing approaches to quantum information using photonic, nuclear and electron spins, quantum dots, superconducting technologies and proceed with studying the requirements needed to design earth-to-satellite quantum communications systems.
- Expand the development of commercialization opportunities, in particular in quantum sensors which are showing incredible promise and significant societal impact.

HIGHLIGHTED RESULTS FROM FISCAL 2013/14

- The development of a new quantum algorithm that efficiently simulates the dynamics of sparse Hamiltonians. The new algorithm's efficiency significantly improves upon previous algorithms, in particular in the cost required to attain the outcome within a given level of precision.
- The demonstration of the distribution of three entangled photons at three different locations several hundreds of metres apart proving quantum nonlocality. By separating the entangled photons in a way that did not allow for a signal to coordinate the behaviour of the photons, the researchers developed a stringent test of quantum nonlocality. The distribution of three entangled particles can eventually lead to more than pairwise communication where only one party can communicate with another. It opens the possibility for multipartite quantum communication protocols, including Quantum Key Distribution (QKD), third man cryptography and quantum secret sharing.
- The demonstration that quantum cryptography can protect people doing business with others they may not know or trust. The experiment deployed quantum-entangled photons in such a way that one party (Alice) could share information with a second party (Bob) while meeting stringent restrictions. The protocol, known as 1-2 random oblivious transfer (ROT) is a starting point for more complicated schemes that have applications, for example, in secure identification – a situation encountered on the internet or at a bank's ATM.

Exponential improvement in precision for simulating sparse Hamiltonians

IQC researchers **Andrew Childs**, **Richard Cleve**, and **Robin Kothari** (PhD student), along with colleagues Dominic Berry (Macquarie University) and Rolando Somma (Los Alamos National Laboratory) have developed a new quantum algorithm that efficiently simulates the dynamics of sparse Hamiltonians. The paper *Exponential improvement in precision for simulating sparse Hamiltonians* was accepted to appear in the 46th Annual Symposium on the Theory of Computing (STOC 2014), one of the most prestigious conferences in theoretical computer science.

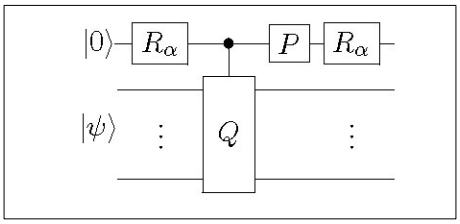


Figure 10: Fractional query gadget

The history of this simulation problem goes back to 1982, when Richard Feynman proposed the concept of a quantum computer for the specific purpose of such simulations. In 1996, Seth Lloyd described the first specific algorithm in the quantum computing framework, and this has been refined by several researchers over the years.

The new algorithm's efficiency is significantly better than previous algorithms in several parameters – most notably in the cost required to attain the outcome within a given level of precision (where the improvement in exponential over previous algorithms). The methodology combines algorithmic methods that were developed by some of the authors in a different context with new ideas for preventing certain faults from occurring. (In the previous work, these faults could arise and were corrected by a complicated procedure).

The final algorithm is rather simple, and appears to make the prospect of simulating interesting Hamiltonian dynamics feasible on even small-scale quantum computers of 100 qubits. This could help predict the behaviour of quantum physical systems, which is of interest to physicists working to determine the properties of quantum physics. It would also serve as a proof of principle demonstrating that

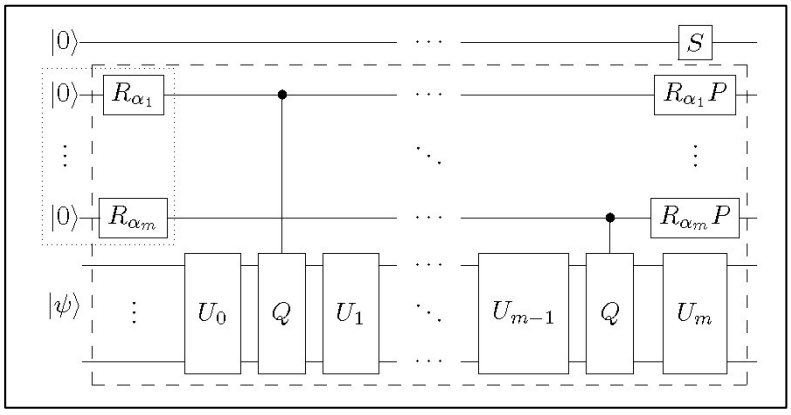


Figure 11: A segment

"small" quantum computers can do interesting things that classical computers cannot do in a reasonable amount of time.

Article Abstract: We provide a quantum algorithm for simulating the dynamics of sparse Hamiltonians with complexity sublogarithmic in the inverse error, an exponential improvement over previous methods. Specifically, we show that a d-sparse Hamiltonian H can be simulated for time t with precision ϵ using $O(\tau\log(\tau/\epsilon)\mathrm{loglog}(\tau/\epsilon))$ queries and $O(\tau\log 2(\tau/\epsilon)\mathrm{loglog}(\tau/\epsilon))$ additional 2-qubit gates, where τ=d2‖H‖maxt. Unlike previous approaches based on product formulas, the query complexity is independent of the number of qubits acted on, and for time-varying Hamiltonians, the gate complexity is logarithmic in the norm of the derivative of the Hamiltonian. Our algorithm is based on a

significantly improved simulation of the continuous- and fractional-query models using discrete quantum queries, showing that the former models are not much more powerful than the discrete model even for very small error. We also significantly simplify the analysis of this conversion, avoiding the need for a complex fault correction procedure. Our simplification relies on a new form of "oblivious amplitude amplification" that can be applied even though the reflection about the input state is unavailable. Finally, we prove new lower bounds showing that our algorithms are optimal as a function of the error.

Demonstrating quantum nonlocality

A team of IQC researchers demonstrated the distribution of three entangled photons at three different locations several hundreds of metres apart demonstrating quantum nonlocality. The team lead by Associate Professor **Kevin Resch** included Associate Professor **Thomas Jennewein**, Professor **Raymond Laflamme**, PhD students **Chris Erven**, **Evan Meyer-Scott**, **Kent Fisher**, **Jonathan Lavoie**, **Christopher Pugh**, **Jean-Philippe Bourgoin**, master's student **Nickolay Gigov**, undergraduate research assistant **Laura Richards**, postdoctoral fellow **Brendon Higgins**, and former IQC postdoctoral fellows Robert Prevedel (now at Max F. Perutz Laboratories and the Institute for Molecular Pathology), Zhizhong Yan (Macquarie University), Krister Shalm (National Institute of Standards and Technology) and former faculty member Gregor Weihs (University of Innsbruck). The results of the experiment, *Experimental Three-Particle Quantum Nonlocality under Strict Locality Conditions*, were published in Nature Photonics in March.

Figure 12: Photons generated in the lab were beamed to separate trailers in field on the experiment proved quantum nonlocality

The project team studied the correlations of three photons in a Greenberger-Horne-Zeilinger (GHZ) state – a type of entangled quantum state involving at least three particles. First, photon triplets were generated. Then, the first photon was delayed in a 580m optical fibre in the lab while the two other photons travelled up 85m of optical fibre to the rooftop where they were sent through two telescopes to two trailers about 700m away from the source and from each other.

Each trailer contained detectors, time-tagging devices and quantum random number generators. To ensure the locality loophole was closed, the random number generators determined how the photon at each trailer would be measured independently. The UQD (a local start-up by IQC researcher Thomas Jennewein) time tagging devices also ensured the measurements happened in a very small time window (three nanoseconds), meaning that no information could possibly be transmitted from one location to the other during the measurement period. By separating the entangled photons in a way that did not allow for a signal to coordinate the behaviour of the photons, the researchers developed a stringent test of quantum nonlocality.

The experiment demonstrated the distribution of three entangled particles, which can eventually be used to do more than pairwise communication where only one party can communicate with another. It opens the possibility for multipartite quantum communication protocols, including Quantum Key Distribution (QKD), third man cryptography and quantum secret sharing.

Article Abstract: Quantum correlations, often observed as violations of Bell inequalities, are critical to our understanding of the quantum world, with far-reaching technological and fundamental impact. Many tests of Bell inequalities have studied pairs of correlated particles. However, interest in multi-particle quantum correlations is driving the experimental frontier to test larger systems. All violations to date require supplementary assumptions that open results to loopholes, the closing of which is one of the most important challenges in quantum science. Seminal experiments have closed some loopholes, but no experiment has closed locality loopholes with three or more particles. Here, we close both the locality and freedom-of-choice loopholes by distributing three-photon Greenberger–Horne–Zeilinger entangled states to independent observers. We measured a violation of Mermin's inequality with parameter 2.77 ± 0.08, violating its classical bound by nine standard deviations. These results are a milestone in multi-party quantum communication and a significant advancement of the foundations of quantum mechanics.

Quantum physics secures new cryptography scheme

IQC researchers **Chris Erven** (postdoctoral fellow), under the supervision of **Raymond Laflamme** and former faculty member Gregor Weihs (now at University of Innsbruck) collaborated with colleagues from the Centre for Quantum Technologies (CQT) at the National University of Singapore to demonstrate a form of quantum cryptography that can protect people doing business with others they may not know or trust.

In cryptography, the problem of providing a secure way for two mutually distrustful parties to interact is known as 'two-party secure computation'. *An Experimental Implementation of Oblivious Transfer in the Noisy Storage Model*, published in *Nature Communications* in March, describes the implementation using quantum technology of an important building block for such schemes. The experiments performed at IQC deployed quantum-entangled photons in such a way that one party, dubbed Alice, could share information with a second party, dubbed Bob, while meeting stringent restrictions. Specifically, Alice has two sets of information. Bob requests access to one or the other, and Alice must be able to send it to him without knowing which set he's asked for. Bob must also learn nothing about the unrequested set. This is a protocol known as 1-2 random oblivious transfer.

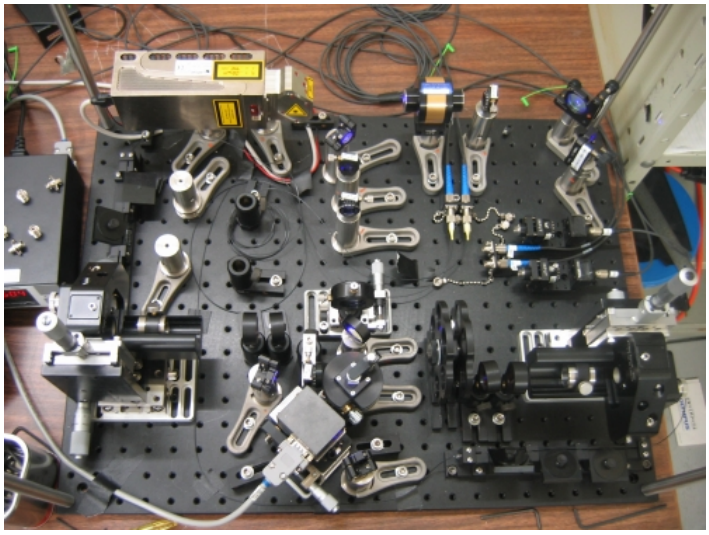


Figure 13: The experiment's Alice and Bob communicated with entangled photons produced in this setup. Such apparatus could be miniaturised using techniques from integrated optics so that people might carry hand-held quantum devices.

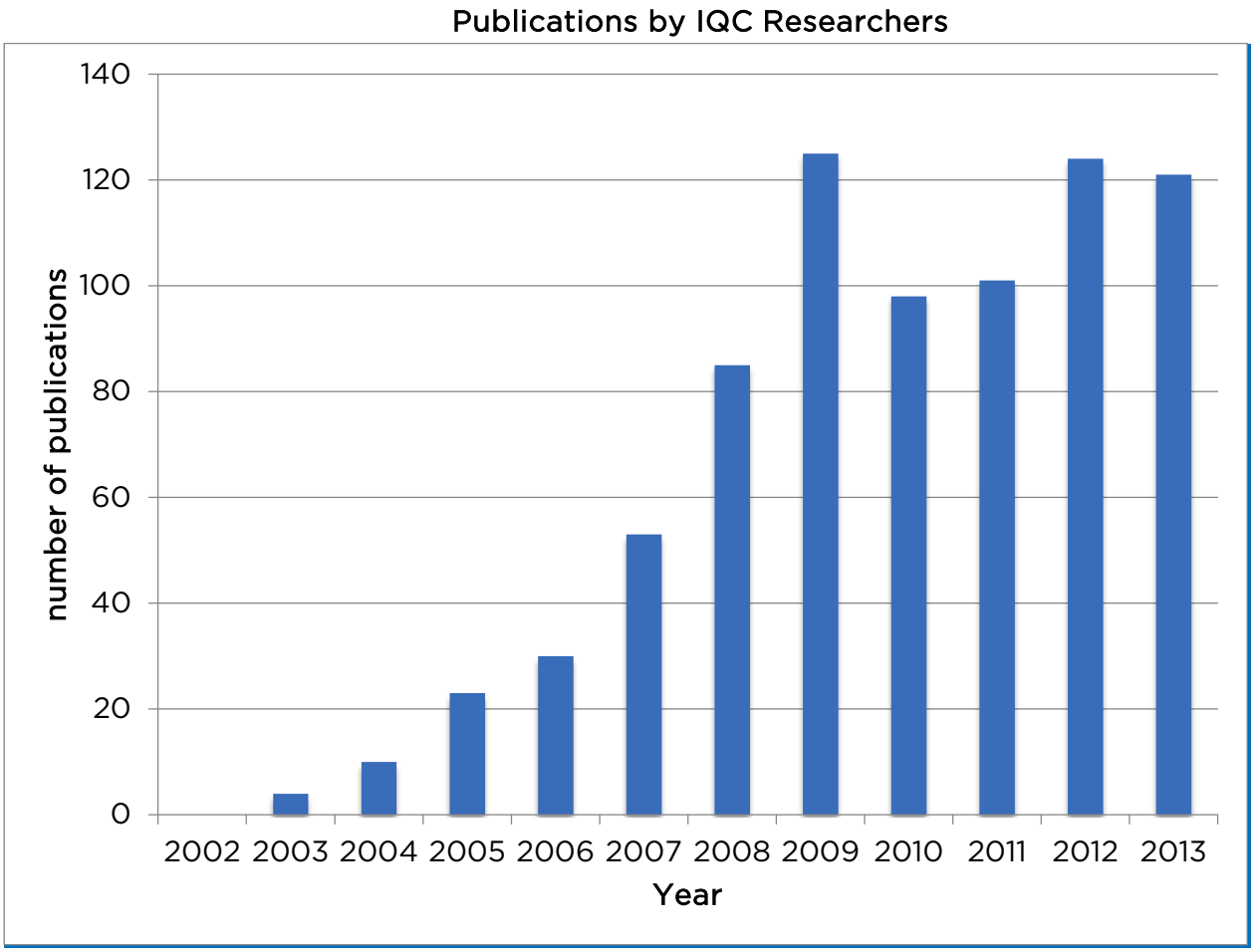
Random oblivious transfer is a starting point for more complicated schemes that have applications, for example, in secure identification – a situation encountered on the Internet or at a bank's ATM.

Article Abstract: Cryptography's importance in our everyday lives continues to grow in our increasingly digital world. Oblivious transfer (OT) has long been a fundamental and important cryptographic primitive since it is known that general two-party cryptographic tasks can be built from this basic building block. Here we show the experimental implementation of a 1-2 random oblivious transfer protocol by performing measurements on polarization-entangled photon pairs in a modified entangled quantum key distribution system, followed by all of the necessary classical post-processing including one-way error correction. We successfully exchange a 1,366 bits random oblivious transfer string in ~3 min and include a full security analysis under the noisy storage model, accounting for all experimental error rates and finite size effects. This demonstrates the feasibility of using today's quantum technologies to implement secure two-party protocols.

PUBLICATIONS BY IQC RESEARCHERS

IQC researchers publish in world-leading journals. Publications are one of several indicators of research output. In 2013/14, there were 120 publications by IQC researchers. For a list of publications, see Publications on page 99.

The chart below displays the number of peer-reviewed publications by IQC researchers since 2002 as found in ISI Web of Science database. [1]



[1] The search was done in May 2014 and used was through the affiliation with a search string that includes the IQC address, i.e. ad = Inst Quantum Comp. The search does not include preprint and might miss some papers in conferences proceedings that computer scientists, engineers and others use. http://apps.webofknowledge.com.proxy.lib.uwaterloo.ca/

IQC Research Published in Prominent Journals Since 2007[2]

Publication	2007	2008	2009	2010	2011	2012	2013
Nature	3	2	1	3	1	1	
Nature Photonics			1	1	1		3
Nature Physics	1	1	5	5	3	2*	3
Nature Communications					1	1	1
Physical Review Letters	10	7	16	14	17	14	14
Science	2	1	1	1	2	1	1
STOC	1	2	1	2			
FOCS			3		1	1	
Journal of Mathematical Physics		1	2	2	4	6	4

**One publication previously not reported*

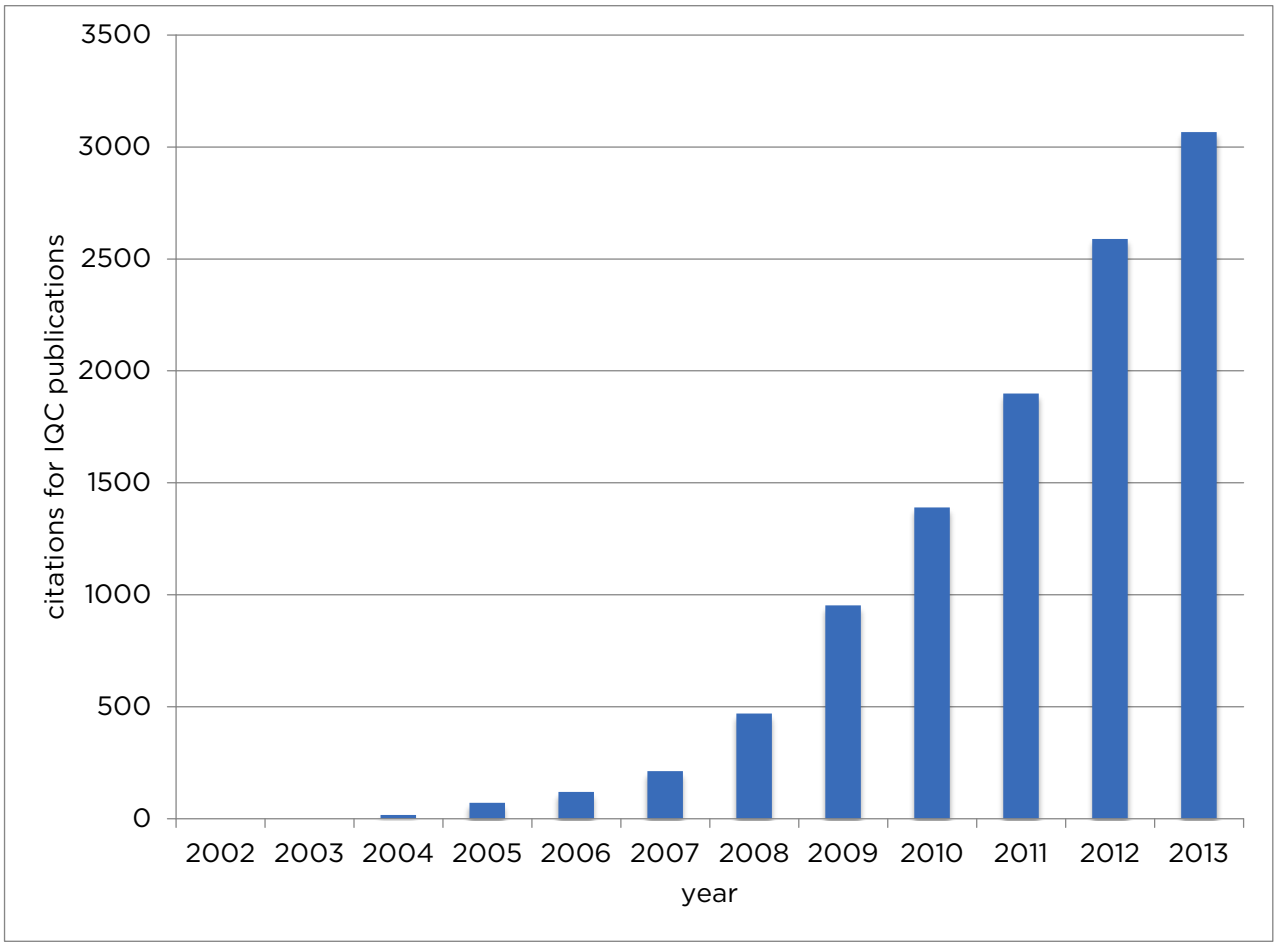
For a list of IQC publications in the 2013/14 fiscal year, see Publications on page 99 or visit pubs.iqc.uwaterloo.ca to explore the institute's electronic database, the Quantum Library. The online repository stores, shares and searches all of the institute's digital research material.

2 Thomson Reuters' ISI Web of Knowledge data was acquired using the InCites tool. A simultaneous search was made for IQC as an address and year of publication. Web of Knowledge provides additional search options based on those results, including source journal.

CITATIONS

Citations are another of the several indicators that IQC uses to demonstrate the authority of its research output. These trends should be interpreted alongside other indicators that show IQC advancing research in quantum technology. As of 2013/14, there have been 11,846 cumulative citations for all publications described in the previous page. The data came, again, from the citation report of ISI Web of Science.

Cumulative Citations of IQC Researchers[3]



3: 2012 IQC reporting on citations relied on data from Google Scholar. The algorithm Google Scholar uses to compile its information is not known but includes non-peer reviewed sources. This year's data includes only data from ISI Web of Science.

RESEARCH GRANTS

IQC researchers garnered $7,328,844[4] in research funding in the term May 1, 2013 to April 30, 2014. These grants included $5,410,753 in government funding and $1,918,091 from industry partners and other funders.

Fiscal Year	08/09	09/10	10/11	11/12	12/13	13/14	Total
Research Grants Received	$11,114,153	$11,944,390	$12,551,733	$8,350,363	$10,712,425	$7,328,844	$62,001,908

For a detailed breakdown of grants received since 2013/14, see Summary of Other Grants and Gifts on page 94.

FACULTY AWARDS

IQC faculty members have continued to set a global standard for excellence in quantum information research. The calibre of these scientists and their research is reinforced by the many awards and acknowledgements given to faculty members. In the 2013/14 fiscal year, IQC researcher **Kevin Resch was named Canada Research Chair in Optical Quantum Technologies**.

IQC faculty received the following awards in 2013/14:

- Raymond Laflamme: Queen Elizabeth II Diamond Jubilee Medal
- Michele Mosca: Queen Elizabeth II Diamond Jubilee Medal
- Matteo Mariantoni: Early Researcher Award
- Christopher Wilson: Early Researcher Award
- Andrew Childs: University of Waterloo Outstanding Performance Award

IQC is also home to the following research chairs:

- Kevin Resch, Canada Research Chair in Optical Quantum Technologies (2013)
- Michele Mosca, University Research Chair, University of Waterloo (2013)
- David Cory, Canada Excellence Research Chair in Quantum Information Processing (2010)
- Raymond Laflamme, Canada Research Chair in Quantum Information (2009)
- Debbie Leung, Canada Research Chair in Quantum Communications (2005)
- Richard Cleve, IQC Research Chair (2004)

4 Data provided by University of Waterloo Office of Research

Recruiting New Researchers – 2013/14 Highlights

IQC continues to recruit world-leading theoretical and experimental researchers in a range of disciplines from computer science to engineering, from mathematics to physics.

OBJECTIVES AND RESULTS IN FISCAL 2013/14

- Recruit up to five new faculty members
- Recruit up to one new research assistant professor
- Recruit up to five new postdoctoral fellows

HIGHLIGHTED RESULTS FROM FISCAL 2013/14

Recruiting and retaining the world's top researchers is a high priority for IQC. During 2013/14, IQC was home to 22 faculty members, 3 research assistant professors, 48 postdoctoral fellows, 114 graduate students, and 34 long-term visitors.

Two new supervising faculty members were added to IQC in 2013/14 bringing our total faculty complement to 22. As well, two new associates were recruited to IQC: Amir Yacoby and Steve MacLean.

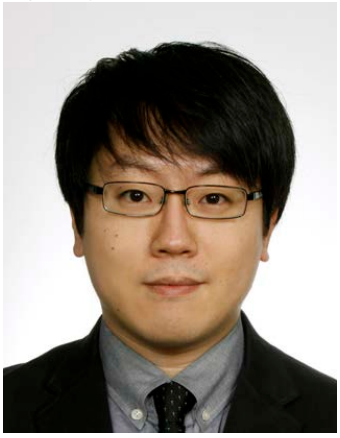
NEW IQC FACULTY MEMBERS

Michal Bajcsy

Assistant Professor **Michal Bajcsy** joined IQC and the Department of Electrical Engineering in January after completing a postdoctoral fellowship at Ginzton Laboratory at Stanford University. Bajcsy received both his BSc and PhD from Harvard University's School of Engineering and Applied Science and spent several years as a visiting student at the Massachusetts Institute of Technology.

At IQC, Bajcsy's research focuses on scalable photonic devices and quantum optics experimental platforms based on quantum emitters such as cooled atoms, quantum dots and colour centers, coupled to nanophotonic structures.

Kyung Choi



Assistant Professor Kyung Choi joined IQC and the Department of Physics and Astronomy from the Korea Institute of Science and Technology where he has been a senior scientist and group leader since 2011. He completed his PhD and a postdoctoral fellowship at the California Institute of Technology.

He currently holds the Presidential Early Career Award for Scientist and Engineers from the Republic of Korea. His research will focus on the development and application of advanced techniques in cold atom physics and quantum optics to probe the fundamental nature of the quantum world.

NEW IQC ASSOCIATE MEMBERS

Amir Yacoby

Amir Yacoby, a renowned experimental condensed matter physicist, has been appointed as an IQC associate and the Distinguished Research Chair in Condensed Matter.

A professor of condensed matter physics at Harvard University, Yacoby will spend three months each year as a visiting professor in Waterloo participating in research at IQC. His lab will focus on implementing quantum information processing in condensed matter systems.

Steve MacLean

Before Steve MacLean was a Canadian astronaut and the president of the Canadian Space Agency, he was a physicist researching electro-optics, laser-induced fluorescence of particles and crystals and multi-photon laser spectroscopy.

His research at IQC will focus on the development of attosecond lasers. This type of laser would produce shorter and more powerful pulses of light to allow for images as precise as the space between atoms to be captured.

RECRUITMENT HISTORY AND GOALS

	Researchers Recruited in 2011	Researchers Recruited in 2012	Researchers Recruited in 2013	Goal to Recruit in 2014	Researchers Recruited in 2014
Faculty	1 - Canada Excellence Research Chair	2	4	Up to 5	2
Research Assistant Professors	3	3	0	Up to 2	0
Postdoctoral Fellows	18	10	9	Up to 10	14
Graduate Students	20	31	25	Up to 30	31

DOMESTIC V. INTERNATIONAL RESEARCHERS

IQC's global makeup is displayed in the table below.

	Canadian	Dual Citizenship	International
Faculty	6	6	10
Research Assistant Professors	--	--	3
Postdoctoral Fellows	16	--	32
Graduate Students	58	--	56

Students came to IQC from 13 different countries: Australia, Bangladesh, Cameroon, Canada, China, France, India, Iran, Italy, Norway, Singapore, the UK and the U.S.

Postdoctoral fellows came to IQC from 13 different countries: Australia, Austria, Canada, China, France, Ireland, Japan, Poland, Singapore, Spain, the Netherlands, the UK and the U.S.

Collaborating with Other Researchers – 2013/14 Highlights

Quantum science is inherently collaborative – particularly at IQC where researchers from a variety of disciplines come together to form the institute. Moreover, research in this field is enhanced by collaboration between researchers in a variety of fields and from a variety of institutions.

OBJECTIVES FOR FISCAL 2013/14

- Be a catalyst for collaborations of quantum information scientists though networks such as the NSERC Nano-Qubits Network (NNQ), 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.

COLLABORATIVE RESEARCH PROJECTS

In 2013/14, IQC collaborated with researchers from **99 institutions in more than 20 countries** around the globe including:

- Harvard University
- Massachusetts Institute of Technology
- University of California, Santa Barbara
- University of Queensland
- University of Bristol
- Austrian Academy of Science
- Tsinghua University
- University of Innsbruck
- Macquarie University
- Institute for Theoretical Physics, ETH Zurich
- University of Vienna
- Stockholm University
- Los Alamos National Laboratory

For a complete review of IQC's 2012 collaborations see Collaborations on page 104.

RESEARCH NETWORKS

IQC continues to manage and participate in a variety of research networks across Canada.

CIFAR (Canadian Institute for Advanced Research) - Quantum Information Program

IQC's Executive Director, Raymond Laflamme, has served as the director of CIFAR's Quantum Information Processing research program since 2002. CIFAR (Canadian Institute for Advanced Research) aims to lead the world in framing and answering complex questions at the frontiers of understanding. Their vision is to create knowledge that enriches human life, improves understanding of the world, and advances the research community in Canada. The Quantum Information Processing program was founded in 2002 and renewed in 2007 and 2012. There are 35 members total - 10 of which are IQC researchers. CIFAR's QIP program has representatives from computer science, mathematics, and theoretical and experimental quantum physics.
WEBSITE: http://www.cifar.ca/quantum-information-science

CryptoWorks21

The NSERC CREATE Training Program in Building a Workforce for the Cryptographic Infrastructure of the 21st Century (CryptoWorks21) is a supplementary program for graduate students and postdoctoral fellows who would like to develop next-generation cryptographic tools. It is a collaborative program lead by IQC with colleagues from University of Calgary, Université de Montréal and INTRIQ. CryptoWorks21 has a network of partners and collaborators in research centres worldwide focusing on cryptography and quantum information. The network provides a collection of expertise, mentorship and training opportunities, and experimental facilities across Canada and abroad.

The CryptoWorks21 program:

- Prepares a new generation of researchers to create quantum-safe tools for the 21st century
- Provides professional knowledge and technical skills for all researchers
- Fosters collaboration between young scientists and experts in quantum and cryptographic research
- Enables students to build relationships with cryptographic communities in academia, industry and government
- Encourages collaboration between students and partners in mathematics, computer science, physics and engineering
- Designed for students seeking Masters or PhD degrees, and postdoctoral fellowships.

Research opportunities for graduate students include the opportunity to investigate challenges and applications for quantum-safe cryptography and participate in workshops, conferences, specialized short courses and mentorship programs.
WEBSITE: https://cryptoworks21.ca/

CREATE Program on Neutron Science and Engineering of Functional Materials

The NSERC CREATE Program on Neutron Science and Engineering of Functional Materials trains graduate students, postdoctoral fellows and undergraduates in the use and development of Quantum Information Processing (QIP) and neutron methods. The program is lead by Canada Excellence Research Chair and IQC Professor, David Cory.

Neutrons are exquisite probes of functional materials because they are light, have no electric charge, and have a magnetic moment. These properties make them wonderful probes of magnetism and structure in materials, material science, chemistry, biophysics, and fundamental physics. Neutron optics and particularly neutron interferometry are excellent examples of macroscopic coherent quantum systems. That is why neutron interferometry can serve not only to study materials, but also as a test-bed for quantum information processing methods.

This program creates a cohort of young, uniquely skilled, multidisciplinary researchers who are experts in both of these areas. This training program combines Canada's historical strength in neutron science at McMaster University's Brockhouse Institute with its established leadership in quantum information science at the University of Waterloo's Institute for Quantum Computing (IQC). These centres of expertise will be linked with international leaders via the National Institute of Standards and Technology (NIST).
WEBSITE: https://uwaterloo.ca/institute-for-quantum-computing/programs/neutron-create

MEMORANDA OF UNDERSTANDING

IQC has increased its international collaborations to a total of nine official agreements to date. These agreements facilitate collaborative research projects, joint research and the pursuit of common scientific interests. These official relationships offer scientists at both organizations a chance to visit, exchange ideas and collaborate with a new circle of researchers.

- Technion – Israel Institute of Technology - Memorandum of Understanding (March 2014)
- Universitat des Saarlandes, Germany – Memorandum of Understanding (January 2014)
- European Programme, France/Germany/Austria/Canada/Latvia (July 2013)
- Raman Research Institute, India - Memorandum of Understanding (July 2012)
- Tsinghua University, China - Memorandum of Understanding (July 2012)
- USTC (Heifei), China - Memorandum of Understanding (November 2012)
- National University of Singapore - Memorandum of Understanding (March, 2010)
- National Science Council of Taiwan - Statement of Understanding (December, 2009)
- Institut National de Recherche Scientifique (INRS) - Memorandum of Understanding
- INTRIQ (L'Institut Transdiciplinaire D'Information Quantique) - Memorandum of Understanding

OTHER IMPORTANT STRATEGIC RELATIONSHIPS

IQC has established important strategic relationships with a number of organizations that can help support its strategic objectives.

Perimeter Institute for Theoretical Physics

The Perimeter Institute (PI) in Waterloo is an independent, resident-based research institute devoted to foundational issues in theoretical physics. PI was instrumental in the creation and early development of IQC, and was essential in bringing IQC's Executive Director, Raymond Laflamme, back to Canada. PI also played a crucial role in the recruitment of Professors Ashwin Nayak, Richard Cleve and David Cory, Canada Excellence Research Chair in Quantum Information Processing. PI and IQC have collaborated on many scientific, outreach and recruitment efforts.

University of Guelph

IQC has developed a relationship with the University of Guelph – in particular with the mathematics department. Two faculty members at Guelph are Associates at IQC – David Kribs, head of the department researching algebra and operator theory, and Bei Zeng who conducts research in the area of quantum error correction. The collaboration has also resulted in interactions with postdoctoral fellows and students.

COM DEV, Canadian Space Agency & Institut National d'Optique

These three organizations are part of a multi-institutional collaboration working with researchers at IQC to create international quantum communications networks. COM DEV is an Ontario-based designer and manufacturer of space-qualified equipment, and is committed to the prospective Quantum Encryption and Science Satellite (QEYSSAT) project. The Institut National d'Optique (INO) is a technological design and development firm for optic and photons solutions, working with IQC on technology for the prospective QEYSSAT mission. The Canadian Space Agency (CSA) is committed to the logistical operations of launching the prospective mission.

European Commission's Directorate General for Education and Culture and Human Resources and Social Development Canada (HDRC)

IQC is a participating institution in a program called "The Collaborative Student Training in Quantum Information Processing Project" - a part of the EU-Canada Programme for Cooperation in Higher Education, Training and Youth. The project is aimed at giving graduate students in Canada and the EU opportunities to study areas of Quantum Information Processing (QIP) that lie outside of the expertise of their local research groups. Ashwin Nayak, Raymond Laflamme and Norbert Lütkenhaus lead IQC's participation in the program.

National Institute for Science & Technology (NIST), U.S.

IQC faculty member David Cory and research assistant professor Dmitry Pushin maintain a laboratory at NIST in Gaithersburg, MD, to perform experiments in neutron interferometry and sensing. Lab funding, and support for students and postdoctoral fellows carrying out research there, is provided by NIST. Cory, Pushin and colleagues have used principles of quantum error correction to achieve breakthroughs in sensing with neutron interferometry at NIST. Previously, neutron interferometry experiments needed to be shielded from "noise" inside a massive blockhouse, roughly the size of a garage. But Pushin and Cory, working alongside NIST researchers, developed a new type of neutron interferometer that is vastly more robust against noise and can be housed inside an apparatus roughly the size of a barbecue. The innovation is expected to greatly advance neutron interferometry as a technique for probing and characterizing materials.

Communications Establishment Security Canada

A number of IQC faculty members including Raymond Laflamme, Michele Mosca and Norbert Lütkenhaus have been supported by Communications Establishment Security Canada (CSEC) over the past five years to provide the organization with reports about advances in quantum computing and quantum cryptography. These faculty members serve as authoritative sources of information on the field for CSEC.

BlackBerry (formerly Research In Motion) & Certicom

A number of IQC researchers meet with representatives from Blackberry (and its wholly owned subsidiary Certicom Corp.) at least one day per term to discuss quantum cryptography, quantum computing and potential applications of these fields in information security and cryptography. Blackberry gains exposure to the latest advancements and highly qualified personnel in the area, and IQC gains insight into the interests and needs of industry in this important area of research.

Quantum Valley Investments

Quantum Valley Investments (QVI) is a private fund created by Mike Lazaridis and Doug Fregin. QVI invests and supports commercialization of breakthrough quantum information science technologies and applications. Two IQC faculty members and two IQC associate members sit on the QVI Scientific Advisory Committee. QVI provides commercialization advice and support to IQC researchers.

SCIENTIFIC VISITORS

IQC welcomes visitors from around the world each year to further its collaborative relationships and strive for global excellence in quantum information processing. The institute has hosted the world's top scientists to conduct research, give talks and meet with IQC's researchers and students. For a full list of IQC's scientific visitors and their institutes, see Visitors on page 77. The following list shows the 108 different visiting institutions:

- California Institute of Technology (CalTech), U.S.
- Chalmers University of Technology, Sweden
- Clemson University, U.S.
- Comenius University, Slovakia
- Delft University of Technology, The Netherlands
- Ewha Womans University, Korea
- Gdańsk University of Technology, Poland
- Haverford College, U.S.
- ID Quantique, Geneva, Switzerland
- Institute for Theoretical Physics ETH Zurich, Switzerland
- Instituto de Física Universidade Federal Fluminense, Brasil
- Istituto Nazionale di Fisica della Materia - Unit of Napoli, Italy
- Korea Institute of Science and Technology, Korea
- Ludwig Maximilian University Munich, Germany
- Macquarie University, Australia
- Max Planck Institute for the Science of Light, Germany
- Microsoft Research Station Q, Santa Barbara, U.S.
- National Institute of Standards and Technology, U.S.
- National University of Singapore, Singapore
- Principiæ, Belgium
- Queensland University, Australia
- Raytheon-BBN Technologies, U.S.
- Shandong University, China
- Stanford University, U.S.
- Stockholm University, Sweden
- Télécom ParisTech, France
- The City College of New York, U.S.
- The Hebrew University of Jerusalem, Israel
- The University of British Columbia, Canada
- The University of Edinburgh, Scotland
- The University of Sydney, Australia
- The University of Tokyo, Japan
- Thompson Rivers University, Canada
- Tufts University, U.S.
- Universidad del País Vasco, Bilbao, Spain
- Université de Sherbrooke, Canada
- University College London, UK
- University of Amsterdam, The Netherlands
- University of Calgary, Canada
- University of California, Davis, U.S.
- University of California, San Diego, U.S.
- University of Cambridge, UK
- University of Connecticut, U.S.
- University of Gdańsk/Polish Academy of Sciences, Poland
- University of Kwa-Zulu Natal - South Africa
- University of Maryland, U.S.
- University of Mumbai, India
- University of Ottawa, Canada
- University of Queensland, Australia
- University of South Carolina, U.S.
- University of Technology, Syndey, Australia
- University of Vienna, Austria
- Vienna Center for Quantum Science and Technology, Austria
- Yale University, U.S.
- Cape Town University, South Africa
- Chinese Academy of Sciences, China
- Columbia University, U.S.
- Dalhousie University, Canada
- École Normale Supérieure, France
- Florida Atlantic University, U.S.
- Harvard University, U.S.
- IBM TJ Watson Research Center, U.S.
- Indian Institute of Science Education and Research, India
- Instituto de Física Fundamental, Spain
- ISI Foundation – Institute for Scientific Interchange, Italy
- Karlsruhe Institute of Technology, Germany
- Los Alamos National Laboratory and Santa Fe Institute, U.S.
- M Squared Lasers Ltd, Scotland
- Massachusetts Institute of Technology, U.S.
- McGill University, Canada
- Mount Allison University, Canada
- National University of Defense Technology, China
- Peter Grünberg Institute, Germany
- Queen's University Belfast, Ireland
- Raman Research Institute, India
- Russian Academy of Sciences, Russia
- Simon Fraser University, Canada
- Stanford University, U.S.
- Technische Universität München, Germany
- The Chinese University of Hong Kong, China
- The College of William and Mary, U.S.
- The Templeton Foundation, U.S.
- The University of Calgary, Canada
- The University of Nottingham, UK
- The University of Sydney, Australia
- The University of Vermont, U.S.
- Tsinghua University, China
- Universidad de Zaragoza, Spain
- Universität Ulm, Germany
- Université Paris Diderot, France
- University of Amsterdam, Holland
- University of Basque Country, Spain
- University of California, Berkeley, U.S.
- University of California, Los Angeles. U.S.
- University of California, Santa Barbara, U.S.
- University of Cincinnati, U.S.
- University of Düsseldorf, Germany
- University of Illinois at Urbana-Champaign, U.S.
- University of Leeds, U.S.
- University of Michigan, U.S.
- University of New Mexico, U.S.
- University of Oxford, UK
- University of Science and Technology, China
- University of Strathclyde, Scotland
- University of Toronto, Canada
- University of Washington, U.S.
- Weizmann Institute of Science, Israel

PATENTS

Patents are one potential indicator of commercialization activity. The University of Waterloo's Intellectual Property (IP) policy – inventor owned IP – promotes patenting activity, but should be viewed as a broad tendency for a research group.

The time between initial filing and the granting of a patent is usually years, with a pending patent not being public knowledge for the first 18 months after application. Patents are also occasionally not pursued vigorously out of a concern to not delay a graduate student's opportunity to complete and defend a thesis. Some fields, such as computer science, produce intellectual property more suited to licensing than patenting.

Despite these factors, IQC researchers have a strong record of protecting their intellectual property by filing patents. Over their careers, IQC researchers have been granted 24 patents, including one jointly held by faculty members Richard Cleve and John Watrous. In the five years covered by this report, IQC researchers have been granted two patents with another four applications for patents pending. Note that the years quoted are for when the patent was granted, not necessarily when the filing took place. The information below is taken from the United States Patent and Trademark Office (USPTO) website.

The table below presents the patents granted to IQC researchers in the five years covered by this report.

IQC researcher	Year patent granted	Patent Number
Lütkenhaus	2011	8,068,741
Resch	2012	8,355,137

The table below presents the pending patent applications submitted by IQC researchers in the five years covered by this report.

IQC Researcher	Year patent applied for	Patent Application Number
Cory	2011	20110248715
Cory	2013	20130063142
Horn	2013	20130230270
Miao	2014	20140062350

The following IQC members are patent holders or have patents pending approval:

- Richard Cleve
- David Cory
- Thomas Jennewein
- Norbert Lütkenhaus
- Kevin Resch
- John Watrous
- Guoxing Miao
- Anne Broadbent (IQC alumna)
- Rolf Horn

SPINOFFS FROM IQC

Spinoff companies are emerging from research endeavours at IQC. Currently, two companies are underway with several more in the quiet phase of development.

Universal Quantum Devices

Universal Quantum Devices (UQD) provides instrumentation for use in sophisticated quantum optics laboratories around the world. The flagship instrument – the IQCLogic Unit – was designed and built in cooperation with DotFast Consulting. The unit combines a timing analyzer, a coincidence log unit and counters for 16 input channels on one device. UQD has sales in Asia, Australia, U.S. and Canada. UQD's next generation units will specifically accommodate the needs of satellite communications.

Entagled Photon Source

Together with the Waterloo Commercialization Office, a postdoctoral fellow at IQC has been developing a robust, cost-effective and maintenance-free entangled photon source. Occupying no more space than a regular pen, the device is targeted for the research and academic markets. It is presently in the last stages of development and a shelf-ready product is expected by the end of 2014.

Building, Facilities & Laboratory Support – 2013/14 Highlights

Quantum information research at IQC spans theory and experimentation requiring facilities that meet both office space and laboratory requirements.

FISCAL 2013/14 OBJECTIVES

- Continue to migrate IQC researchers and labs into the Mike & Ophelia Lazaridis Quantum-Nano Centre
- Continue the QNC NanoFab fit-out including the installation of laboratory equipment

HIGHLIGHTED RESULTS FROM FISCAL 2013/14

2013/14 saw continued moves into and installations in the Mike & Ophelia Lazaridis Quantum-Nano Centre. Opened in late 2012, the Lazaridis Centre is now home to faculty, students, postdoctoral fellows and staff of IQC.

The Mike & Ophelia Lazaridis Quantum-Nano Centre

Over the past five years, IQC has planned, built and occupied its new headquarters - the Mike & Ophelia Lazaridis Quantum-Nano Centre. This 285,000 square feet architectural marvel is shared between IQC and the Waterloo Institute for Nanotechnology. The building meets the highest scientific standards for control of vibration, humidity, electromagnetic radiation and temperature allowing for the highest level of research activities.

The building is now 100% per cent complete in terms of construction activities. As of January 31, 2013, the estimated value of outstanding work was $260K. Industry Canada funding for building construction created 114 jobs in fiscal 2010, 123 jobs in fiscal 2011 and 120 jobs in fiscal 2012.

2013/14 saw IQC faculty and staff continue to move into the Lazaridis Centre and new labs outfitted for existing and new faculty members.

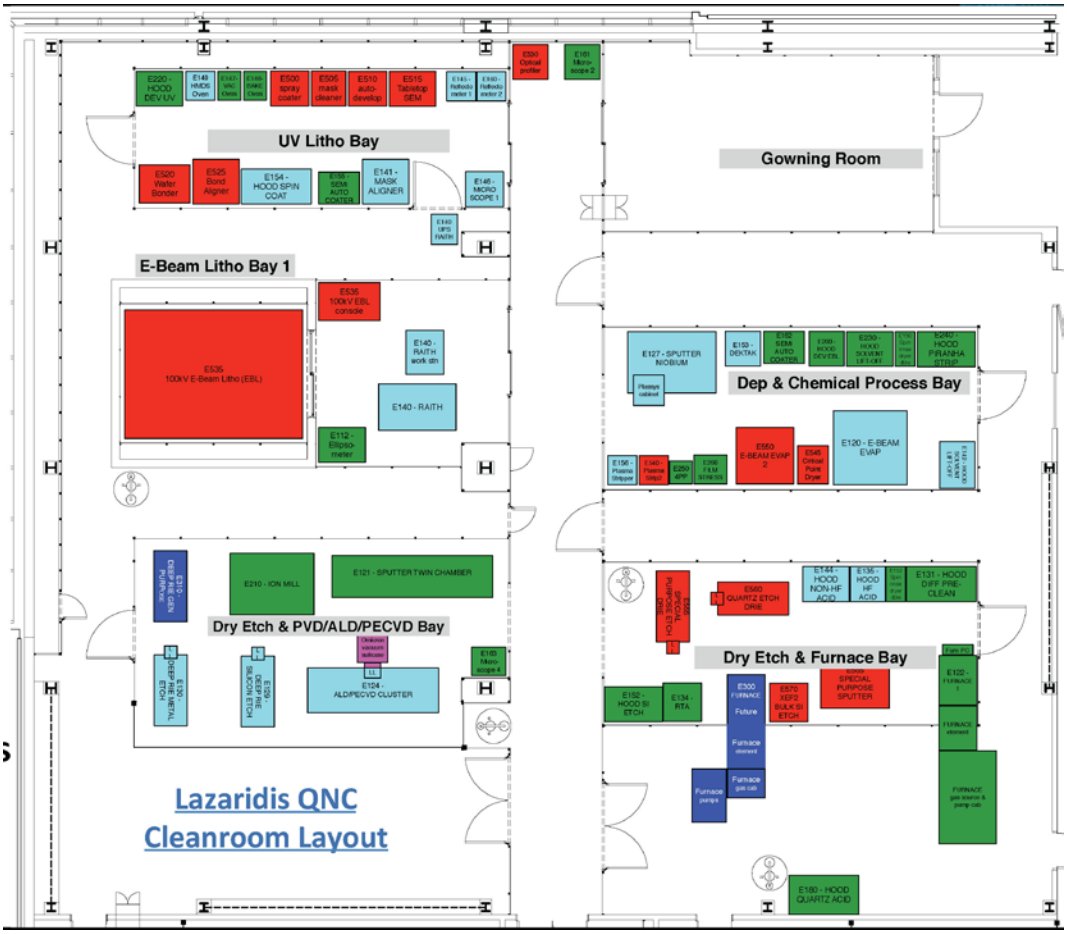
Laboratories

IQC now occupies a total of 53,943 sq. ft. of lab space on the University of Waterloo campus. Laboratories in the Lazaridis Centre include:

- Quantum Photonics Laboratory
- Satellite QKD Laboratory
- Integrated Quantum Optoelectronics Lab (QOC)
- Quantum Vertification Lab
- Laboratory for Digital Quantum Matter
- Quantum Optics and Quantum Information Group Laboratory
- Engineered Quantum Systems Laboratory.

Fabrication Facilities

The Quantum-NanoFab facility in the Lazaridis Centre is a world-class operation shared between IQC, WIN and the University of Waterloo.



The ultra-sterile cleanroom/fabrication facility is constructed upon a separate foundation from the rest of the building, ensuring that it will never vibrate more than a micron (a fraction of the width of a human hair). Other technical specifications include:

- Class-100 cleanroom (less than 100 particles per cubic foot of air)
- Stray magnetic fields of less than 0.1 uTesla
- Minimization of EMI interference with fibreglass rebar in 1-metre thick concrete floor
- Vibration isolation of all electrical and mechanical systems fastened to ceilings

- Floor vibration: displacement of less than 2um peak-to-peak
- AdvanceTEC Inter 6,700 ft^2 mediate ceiling grid installed
- Maintained temperature of 20C (+/- 1) and relative humidity of 35% (max 40)

Laboratories and Technical Specifications:

- Superconducting Qubits (solid-state and low temperature)
- Atomic & Ion-trapping Quantum Information Processing
- Quantum Optics
- NMR/Spin-Based Quantum Information Processing
- Quantum Communication/Cryptography

Deposition:

- Physical Vapour - Evaporator 1: IntlVac Nanochrome II e-beam and thermal deposition system dedicated to depositing various materials
- Physical Vapour - Sputter 1: The Plassys MP700S sputter system is designed for and dedicated to the deposition of Nb, NbN and NbTiN thin films on 4″ and smaller diameter samples
- PECVD/ALD: Oxford Instruments System 100 PECVD/FlexAl ALD (thermal + plasma) cluster system for depositing various materials via either PECVD or ALD or a combination of both

Dry Etch:

- Resist Stripper: YES-CV200RFS oxygen and nitrogen plasma etching system for photoresist strip/descum
- Silicon Etch: Oxford Instruments ICP380 plasma-based dry etching system for etching silicon ranging in size from small pieces to 4″ diameter wafers
- III-V & Metals: Oxford Instruments ICP380 plasma-based dry etching system for etching metal thin films as well as III-V substrates such as GaAs and InP ranging in size from small pieces to 4″ diameter wafers

Lithography:

- E-Beam Litho: Raith 150TWO direct write 30kV electron-beam lithography system
- Aligner: Suss-Microtec MA6 front and front-to-back optical mask aligner and exposure system with 350W broadband (250nm to 400nm) exposure lamp
- Coaters: Spin coater dedicated to photoresist coating of substrates ranging in size from pieces to 4″ diameter wafers

Wet Benches:

- Acids (non HF)
- Acids (HF): Only HF and HF-based etchants, including Buffered Oxide Etch solutions
- Develop & solvents only: Wet bench dedicated to solvent-based processes. This bench is typically used to develop photoresist after exposure

Characterization:

- Reflectometers: Systems available for measuring film thickness of optically transparent films: Filmetrics F40 (spot measurement) and F50-UV (wafer mapping)
- Profilermeter: Veeco Dektak 150 surface profilometer, a stylus-based scanning system for measuring surface topography and thin film step heights

- Microscopes: Olympus MX-61 semiconductor microscope for inspection and documenting

RESEARCH ADVANCEMENT CENTRES I & II (RAC I AND RAC II)

In addition to the Lazaridis Centre, IQC maintains laboratory and office space in two additional buildings – RAC I and RAC II.

RAC I

RAC I houses 4,370 square feet of experimental labs and a cleanroom/fabrication facility:

- Nuclear Magnetic Resonance (NMR) Laboratory
  The spin properties of nuclei are great candidates for qubits, and nuclear magnetic resonance (NMR) is a technique by which the spins are controlled and measured. NMR is one of the best test-beds for quantum computing research. A research collaboration between IQC and MIT resulted in a long-standing world record for the largest number of well-characterized qubits harnessed for computation (12).
- Electron Spin Resonance (ESR) Laboratory
  A natural extension of nuclear magnetic resonance is to use electron spins to control nuclear spins; this allows for faster operation while keeping the inherent robustness of the nuclear spins. These two systems demonstrate a high degree of control and make a good test-bed for quantum computer prototypes.
- Coherent Spintronics Laboratory
  Although nuclear magnetic resonance (NMR) and electron spin resonance (ESR) can achieve good quantum control, it is challenging to add more qubits to those systems. Thanks to advances in semiconductor fabrication technologies, researchers can build extremely small “quantum dots” that can hold a single electron. The qubits are the electron spins confined using charged electrodes on nanowires.
- The fabrication cleanroom in RAC I is certified Class-1000, meaning that one cubic foot contains less than 1,000 particles (as opposed to the 105 million in typical outdoor air).

RAC II

The RAC II laboratories are centered around spin-based approaches to quantum research, with emphasis on the development and engineering of sensitive and robust quantum sensors, actuators and transducers, with the long-term goal of engineering practical quantum devices. RAC II houses 15,260 square feet of laboratory space.

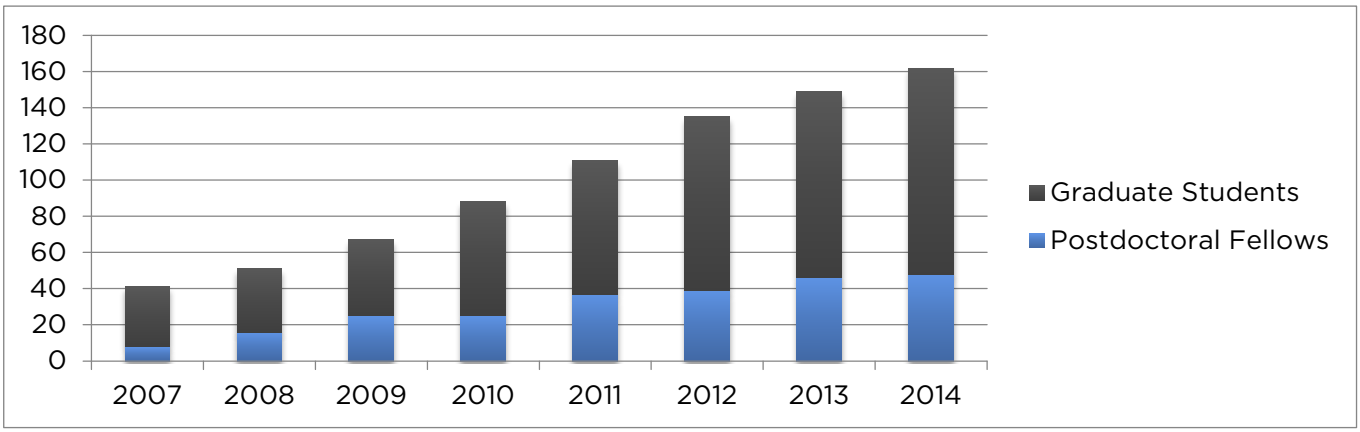
Laboratories

- Ultra-High Vacuum Depostion (UHV) system has three Molecular Beam Epitaxy (MBE) systems, two magnetron sputter systems, and one surface analysis module, all interconnected through a linear transfer line. This system is uniquely designed to combine the three major spin systems, magnetism, superconductivity, and quantum spin Hall state, completely in situ under ultra-high vacuum and maintain the cleanest interfaces possible. A sample preparation sub-chamber, located right next to the load-lock, allows for well controlled device surface treatment before, after, or in between film growths (annealing, ion milling, oxidation/nitridation, etc.). The system has detachable vacuum transfer shuttles for transporting delicate specimen, while maintaining under UHV, into other growth/characterization systems.
- Sputter/Evaporation Dual Chamber system designed for three-inch wafers. The system is equipped with 10 sputter guns, and RHEED growth monitoring. The evaporation chamber is equipped with one e-gun (5-pocket, 5kW) and four thermal sources, plus an atomic gas source for the reactive growth of oxides and nitrides. An additional wafer handler enables substrate tilting during evaporation.
- Diamond Chemical Vapour Deposition system is a microwave plasma reactor that incorporates 5 kW at 2.45 GHz microwave generator to produce plasmas at high power densities. This reactor is dedicated to synthesizing high quality single crystal and poly crystalline diamond. Light doping, e.g., with nitrogen, is facilitated with the natural presence of impurities in the processing gases, while heavy doping, e.g., with boron/phosphorus, is achieved by introducing additional gas channels.
- X-ray Diffraction system is capable of performing high-resolution X-ray diffraction, gracing incidence diffraction, reflectometry, and reciprocal space mapping. It consists of a centric Euclerian cradle with Chi/Phi rotations and X-Y-Z translations; high resolution optics with a Ge 2-bounce monochromator, a 3-bounce pathfinder, and fully automated slits; a Göbel mirror for Cu radiation. The system is equipped with a vacuum chuck holding up to five-inch wafers.

Become a Magnet for Highly Qualified Personnel in the Field of Quantum Information – 2013/14 Highlights

IQC has attracted international talent and has fostered a reputation for excellence in its research and teaching endeavours. Since 2008, IQC's student body has **grown by 170%** (from 42 students in 2009 to 114 in 2014).

IQC Students and Postdoctoral Fellows from 2007 to Present



IQC's stellar track record for recruiting talented students to its academic and research endeavours is a key measure in the institution's academic success. These students will form the next generation of practical quantum information specialists and will drive the quantum revolution in the 21st century.

FISCAL 2012/13 0BJECTIVES

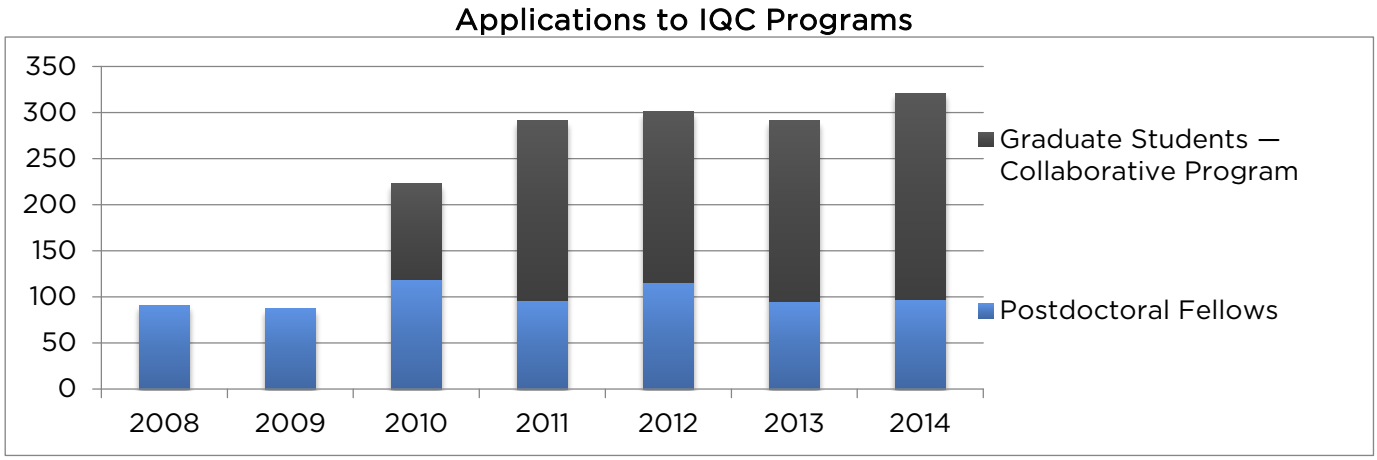
- Attend at least four graduate fairs to connect with prospective students
- Field at least 200 applications to the University of Waterloo/IQC graduate studies program
- Expand connections made with undergraduate programs at Ontario and Canadian universities
- Take part in at least two international outreach or recruitment events

HIGHLIGHTED RESULTS

- IQC representatives attended five graduate fairs across the country, and the Canadian Undergraduate Physics Conference (CAP)
- IQC's collaborative graduate programs attracted 134 applications with 30 new students being accepted
- Expanded connections made with undergraduate programs at Ontario and Canadian universities

RECRUITMENT

Applications for the graduate program include both students indicating an interest in quantum information (90) and those applying directly to the quantum information graduate program (134).



	2008	2009	2010	2011	2012	2013	2014
Postdoctoral Fellows	91	87	119	96	116	95	97
Graduate Students — Collaborative Program	N/A	N/A	104	195	185	196	224

Postdoctoral Fellows

Postdoctoral fellowships bring young scientists with expertise and innovative approaches to the research at IQC. Postdoctoral fellows contribute to every aspect of IQC's mission from research to publications, from teaching to outreach. Today at IQC, there are 48 postdoctoral fellows working alongside IQC's faculty and students.

Postdoctoral researchers were recruited to IQC from the following institutions:

California Institute of Technology
Concordia University
Kinki University, Osaka
Leiden Institute of Physics
Macquarie University
National University of Ireland
Perimeter Institute
Rutgers University
Universidad Complutense de Madrid
University of Calgary
University of Guelph
University of Pittsburgh
University of Southern California
University of Vermont
Columbia University
Griffith University
Joseph Fourier University
Kyoto University
McMaster University
Massachusetts Institute of Technology
Pennsylvania State University
Princeton University
Tsinghua University
University of Sherbrooke
University of California, Berkeley
University of Montreal
University of Sydney
University of Science & Technology of China
Hefei National Laboratory for Physical Sciences

Postdoctoral fellows at IQC represent 10 different countries: Australia, Canada, China, France, Ireland, Japan, Spain, the Netherlands, the UK and the U.S.

Awards

The Institute for Quantum Computing strives to recruit the world's best young minds — the generation who will turn the discoveries of today into the technologies of tomorrow. This is a chief motivation behind IQC's strong and ever-growing Postdoctoral Fellowships program. The high calibre of postdoctoral researchers at IQC is evidenced by the many awards and acknowledgements these early-career scientists have earned.

The following list summarizes academic awards and scholarships earned by IQC's postdoctoral fellows in 2013/14:

- David Gosset, NSERC
- Nathaniel Johnston, NSERC
- Eduardo Martin-Martinez, Banting Fellowship
- Brendon Higgins, Banting Fellowship

Profiles of Selected Postdoctoral Fellows

- Pol Forn-Diaz: After completing his PhD at the Delft Institute of Technology in the Netherlands, he was a visiting scholar at MIT to extend his work on superconducting qubits. Before moving to IQC in 2013 he was a postdoctoral scholar at Caltech. His current research studies the physics of superconducting qubits and superconducting resonators to develop quantum nodes in a quantum network.
- Gus Gutoski: Completed his PhD at IQC under the supervision of John Watrous. His PhD focus included quantum complexity theory and general quantum formalism. He completed three years of a postdoctoral researcher in 2013 to become a postdoctoral fellow at the Perimeter Institute for Theoretical Physics. During his postdoctoral research he continued to study complexity theory and also studied quantum cryptography.
- Troy Borneman: He completed his PhD in Nuclear Science and Engineering at MIT under Professor David Cory, now Canada Excellence Research Chair at IQC. His first postdoctoral appointment is at IQC where he's continuing to study control and decoherence suppression in noisy quantum systems. In particular, he's conducting experimental studies of quantum control using Nuclear Magnetic Resonance to test current control techniques and develop novel techniques in the presence of complex, non-idealized noise processes.

Collaborative Graduate Program

IQC's collaborative graduate program is offered jointly by the faculties of Mathematics, Science and Engineering with the departments of Applied Mathematics, Combinatorics and Optimization, Chemistry, Physics and Astronomy, Electrical and Computer Engineering, and the David R. Cheriton School of Computer Science. Students can pursue studies at the Masters and PhD levels leading to MMath, MSc, MASc or PhD degrees. The program exposes students to a wide range of advanced research projects and courses on the foundations, applications and implementations of quantum information processing.

To promote the collaborative graduate program, IQC attends several graduate fairs annually including those at the University of Waterloo, McMaster University, McGill University, University of Alberta, University of Toronto, Canadian Undergraduate Physics Conference, and Atlantic Undergraduate Physics and Astronomy Conference. In addition, the program was advertised to relevant quantum information researchers across the globe. IQC also advertised with the China Scholarship Council, including emailing relevant faculty in China. In addition, the University of Waterloo's Graduate Studies Office promotes the program at international graduate fairs.

In the 2013/14 fiscal year, 114 students were registered in graduate programs at IQC. Of those, 56 per cent had a grade point average of 90 per cent or more. Additionally, 83 per cent of students had a grade point average of 85 per cent or higher. Notably, the number of students with a GPA over 85 per cent increased two (2) per cent from the previous reporting year.

Highlights

In 2013-2014, IQC welcomed 31 new graduate students:

- 22 Masters and 9 PhD students
- 11 Canadian and 20 international students
- 5 NSERC Award recipients
- 7 IQC Entrance Award recipients
- 1 Mike and Ophelia Lazaridis Fellowship recipient

Current Enrolment

- 114 students currently enrolled
- 50 Canadian students, 64 international students
- 65 Masters students, 49 PhD students
- Home departments: Applied Mathematics (8), Combinatorics and Optimization (5), Chemistry (1), Computer Science (17), Electrical and Computer Engineering (16), Physics (67)
- Home countries: Australia (1), Bangladesh (1), Canada (65), China (3), France (2), India (4), Iran (11), Italy (1), Nigeria (1), Norway (1), Poland (2), Singapore (1), UK (2), Ukraine (1), U.S. (7)
- 45 students currently hold a total of 87 awards.
  21 of these are internal IQC scholarships (i.e., Mike and Ophelia Lazaridis Fellowship, IQC Entrance Award, IQC Achievement Award, IQC David Johnston Award for Scientific Outreach). 66 awards are external and include NSERC Postgraduate Scholarships, NSERC Alexander Graham Bell Canada Graduate Scholarship-Masters and Doctoral and QEII-Graduate Scholarship in Science and Technology.

Student Scholarships and Fellowships

The following students received awards in the 2013-2014 fiscal year. These awards include internal (*) and external awards.

Student	Award(s)
Chunqing Deng	Ontario Graduate Scholarship President's Graduate Scholarship IQC Achievement Award*
Gregory Holloway	Ontario Graduate Scholarship President's Graduate Scholarship
Laura Mancinska	IQC Achievement Award*
John Rinehart	IQC Entrance Award*
Arnaud Carignan-Dugas	IQC Entrance Award* NSERC Alexander Graham Bell Canada Graduate Scholarship - Masters President's Graduate Scholarship
Olivia Di Matteo	IQC Entrance Award* NSERC Alexander Graham Bell Canada Graduate Scholarship - Masters President's Graduate Scholarship
Mirmojtaba Gharibi	NSERC Alexander Graham Bell Canada Graduate Scholarship - Doctoral President's Graduate Scholarship
Deny Hamel	Ontario Graduate Scholarship
Catherine Holloway	IQC David Johnston Award for Scientific Outreach*
Darryl Hoving	IQC Entrance Award*
Li Li	Mike and Ophelia Lazaridis Fellowship* David R. Cheriton Graduate Scholarship
David Luong	Ontario Graduate Scholarship President's Graduate Scholarship
Jean-Philippe MacLean	IQC Entrance Award* NSERC Julie Payette Scholarship President's Graduate Scholarship NSERC 2013 André Hamer Postgraduate Prize
Michael Mazurek	President's Graduate Scholarship Ontario Graduate Scholarship
Tyler Nighswander	David R. Cheriton Graduate Scholarship IQC Entrance Award* Ontario Trillium Scholarship
Chris Pugh	IQC David Johnston Award for Scientific Outreach* NSERC Alexander Graham Bell Canada Graduate Scholarship-Doctoral
Ansis Rosmanis	IQC Achievement Award*
Jonn Schanck	IQC Entrance Award*
Sean Walker	NSERC Alexander Graham Bell Canada Graduate Scholarship - Masters President's Graduate Scholarship
Joshua Young	Ontario Graduate Scholarship President's Graduate Scholarship
Vadym Kliuchnikov	IQC Achievement Award*

Profiles of Selected Graduate Students

Jean-Luc Orgiazzi: A PhD student, Orgiazzi values the interdisciplinary and collaborative research experience at IQC and has been study with Adrian Lupascu for the past four years. His engineering background drew him towards the experimental side of quantum information science. Recently, Orgiazzi has proposed the fabrication, design and characterization of a two-qubit platform circuit quantum electrodynamics system with high coherence times – one requirement to achieve a scalable quantum computer.

Jean Philippe MacLean: MacLean received the prestigious André Hamer Postgraduate Prize from NSERC for 2013. He joined IQC in 2013 as a master's student. He's working with IQC researchers on quantum information processing, in particular creating entangled photon sources for quantum memory. He has participated in research at Institut Nationale de la Recherche Scientifique (INRS), Griffith University's Centre for Quantum Dynamics (Brisbane) and a student exchange with University of New South Wales (Sydney).

Sarah Kaiser: A 2012 recipient of the Mike and Ophelia Lazaridis Fellowship, Sarah is a PhD student at IQC focused on quantum cryptography. She studies new ways to guarantee information security in the future. Using lasers and other tools, she takes new "secure" systems and demonstrates how the security can be comprised.

Graduate Supervisors

There are 39 approved quantum information supervisors: two of these are new in 2013-2014. Seventeen supervise or co-supervise at least one graduate student in the collaborative program. New supervisors include:

- Kyung Soo Choi – Physics
- Michal Bajcsy - Electrical and Computer Engineering

For a full list of supervisors, see Supervisors on page 96.

Quantum Information Courses

The following courses are offered in 2013/14:

Term	Course	Description
Spring 2013	QIC 891 Sir Anthony Leggett Lecture Series	This course covers topological insulators and superconductors and topological quantum computing.
	QIC 890/891 Selected Advanced Topics in Quantum Information	This course consists of 10 two-week modules, presented by guest lecturers.
	QIC 891 Topics in Quantum Safe Cryptography	This course consists of six modules, presented by guest lecturers.
Fall 2013	QIC 710 Quantum Information Processing	Review of basics of quantum information and computational complexity.
	QIC 820 Theory of Quantum Information	This course presents a mathematical treatment of the theory of quantum information, with a focus on the development of concepts and methods that are fundamental to a broad range of studies in quantum algorithms and complexity, quantum cryptography, and quantum Shannon theory.
	QIC 880 Nanoelectronics for Quantum Information Processing	Topics include: Electrodynamics of superconductors, BCS theory and tunnel junctions, the Josephson effect, flux and fluxoid quantization, quantization of electric circuits, the basic types of superconducting qubits, decoherence in the solid state, circuit quantum electrodynamics, readout of nanoscale qubits, fabrication of qubit devices and measurement techniques.
	QIC 890 Recent Advances in Quantum Information	In this course, students get a taste of some of the exciting developments in quantum information and computation in the past few years. A couple of prominent themes among these are applications of semi-definite optimization and the use of ideas from quantum in classical computation.

Term	Course	Description
	QIC 891 Examples of Quantum Devices	Topics include: Linear optical quantum computing, quantum key distribution, teleportation, the modulation technique and the Rabi problem, spectroscopy and pulse tuning, Jaynes-Cummings Hamiltonian and the CZ-\Phi Gate.
Winter 2014	QIC 750 Implementations of Quantum Information Processing	Introduction of the fundamentals shared by all experimental studies of quantum devices, and particular approaches to building a quantum computer.
	QIC 885 Quantum Electronics and Photonics	This course is designed for engineers who are interested to learn applied quantum mechanics to study quantum behaviours of electrons, photons and their interaction. The course content invites a wide range of audiences who are working on areas such as engineering electromagnetics, solid state electronics, nanotechnology, applied quantum optics and quantum devices for classical and quantum information processing.
	QIC 890 Applied Quantum Cryptography	The goal of the course is to familiarize the students with the cryptographic context of Quantum Key Distribution (QKD), the basic ideas of QKD protocols, their optical implementation and their security analysis.
	QIC 890 Quantum Error Correction and Fault Tolerance	Topics that will be discussed include the stabilizer formalism for quantum error-correcting codes, efficient simulation of Clifford group circuits, the Gottesman-Knill theorem, fault-tolerant gadgets, Shor and Steane error correction, magic state distillation, noise models, the threshold theorem and topological codes.
	QIC 890 Building a Neutron Camera	Topics include: Neutron sources, basic properties of the neutron; Neutron as a matter wave (de Broglie wavelength for neutrons), neutron wavelength distributions; Neutron absorption and neutron shielding; The general expression for the cross section for neutron scattering; Neutron Detectors; Neutron experiments and application of the neutrons to study materials; Neutron Imaging and neutron cameras (invited speaker from NIST D. Jacobson); Different design of neutron cameras; Design parameters (such as beam size, spatial resolution, dark counts, and other errors.

Recruiting Students from Top Undergraduate Schools Internationally

The Times Higher Education World University Rankings judge educational institutions based on peer-review, academic polls, teacher-to-student ratios, internationalization rate and number of research citations. Over the past few years, IQC students have come from one or more of the following top ranked institutions:

California Institute of Technology
Dartmouth College
École Normale Supérieure
Indian Institute of Technology
Massachusetts Institute of Technology
McMaster University
McGill University
National University of Singapore
Nanjing University
Peking University
Queen's University
Tufts University
Tsinghua University
University of Alberta
University of Basel
University of Calgary
University of Cambridge
University of Massachusetts Boston
University of Oxford
University of Queensland
University of Toronto
University of Waterloo

For more information on the Times Higher Education World University Rankings visit: http://www.timeshighereducation.co.uk/world-university-rankings/.

Transatlantic Exchange Partnership

The Collaborative Student Training in Quantum Information Processing project is part of the European Union-Canada Programme for Cooperation in Higher Education, Training and Youth. The project is meant to give graduate students in Canada and the European Union exposure to study Quantum Information Processing (QIP) abroad.

Each year, the 36 students involved in the program participate in an internship with a faculty supervisor and course work in the relevant topics at the host institution. Students study QIP, its sub-disciplines and allied subjects including: algorithms and complexity, error correction, cryptography, communication, information theory, experimental implementations of QIP devices, communication and practical cryptography.

Students involved in the EU-Exchange program during the 2013-2014 fiscal year:

IQC Students participating

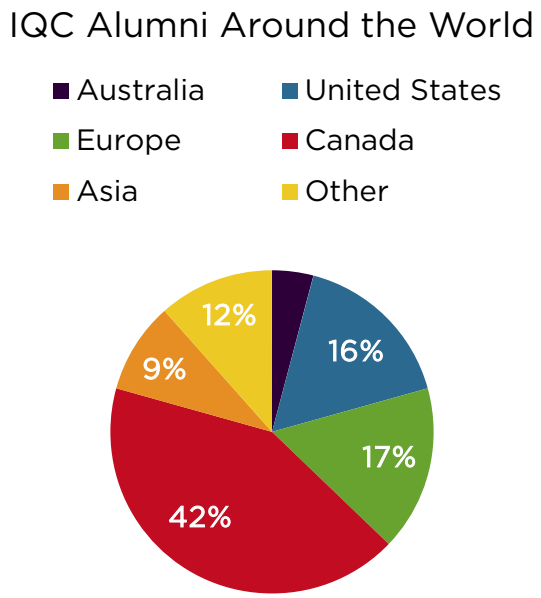
Student	Participating Institution	Term
Shima Bab Hadiashar	Centre for Quantum Technologies	January to April 2014
Ala Shayeghi	Centre for Quantum Technologies	January to April 2014
Sadegh Raeisi	Centre for Quantum Technologies	January to May 2014
Stacey Jeffery	Centre for Quantum Technologies	October to November 2013
Milad Khoshanegar	University of Innsbruck	May to August 2013

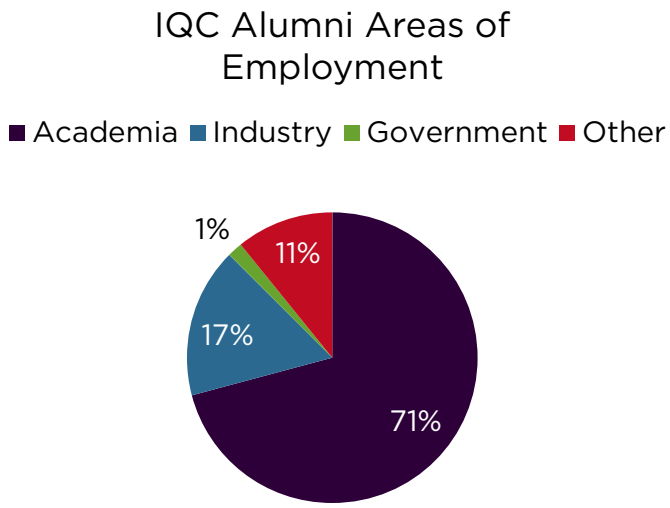
International Students to IQC

Student	Participating Institution	Term
Pavithran Iyer	Sherbrooke	January to May 2014
Zho Cao	Tsinghua	July to August 2013
Zhen Zhang	Tsinghua	July to August 2013
Fei Wang	Tsinghua	October 2013 to August 2014
Hang Li	Tsinghua	January to December 2013
Jun Li	USTC Hefei	January to September 2013

IQC Alumni – Where are they now

IQC's 121 student alumni are currently in various roles around the world from academia to industry.





Alumni Profiles

Douglas Stebila: After completing his PhD in 2009 with a focus on cryptographic key exchange protocols, Stebila ventured to Brisbane, Australia for a postdoctoral fellowship at the Queensland University of Technology (QUIT). Stebila is now a Senior Lecturer at QUIT investigating provable security of real-world cryptographic protocols – specifically looking at the security properties used in web browsers and other online communications. As quantum computing evolves and impacts classical cryptography, Stebila hopes to contribute to the development of new standards for cryptographic protocols.

Gina Passante: Since completing her PhD in 2012, Gina Passante has been working as a postdoctoral fellow at the University of Washington. Passante is part of the Physics Education Group where she is contributing to improving the education of future physicists. Passante explores how students learn quantum mechanics. She plans on continuing her research in this field and broadening her scope to include how a quantum mechanics curriculum might one day be incorporated into high school classrooms

Jay Gambetta: Gambetta completed his postdoctoral fellowship at IQC in 2011 with a research focus on quantum information processing with superconducting qubits. Since leaving IQC, he continues to investigate this area as a Research Staff Member at the Thomas J. Watson Research Center in Yorktown Heights, New York. Gambetta's work with superconducting qubits is promising for the future of quantum computation and the development of a quantum computer.

Establishing IQC as the Authoritative Source of Insight, Analysis and Commentary on Quantum Information – 2013/14 Highlights

The third strategic objective for IQC is to establish itself as the authoritative source of insight, analysis and commentary on quantum information. To achieve this objective means the research knowledge generated at IQC must reach a broad audience that includes research institutions around the globe, government, industry and the general public. The scientific reputation of IQC relies on the quality of its research and it is enhanced through effective communication to all its stakeholders.

Disseminating Scientific Knowledge

OBJECTIVES FOR FISCAL 2013/2014

- Establish a strong media relations plan that will increase media coverage for scientific discoveries, publications and presentations
- Increase promotion of IQC events, conference, workshops and programs through a strategic marketing plan that includes print materials, online presence and social media
- Reflect IQC's outreach priorities and programs on the web
- Host at least four conferences with three distinct target audiences

HIGHLIGHTED RESULTS FROM FISCAL 2013/2014

- Developed a strategic marketing plan that promoted scientific discoveries through both traditional and social media
- Hosted six scientific events with varied audiences including high school students to undergraduates to the founders of quantum information research
- Re-established the Quantum Frontiers lecture series to one a term

PUBLIC LECTURES

Quantum Frontiers Lecture Series

The Quantum Frontiers Lecture Series brings world-leading researchers to IQC to share research knowledge with students and faculty from IQC and the University of Waterloo. Lectures are also open to the general public.

Lecturer	Topic	Date	Attendance
John Preskill	Less weird than a quantum computer, and easier to understand	August 6, 2013	180
Paul Corkum	Attosecond science and high harmonic spectroscopy	December 5, 2013	40
John Kirtley	Scanning SQUID Microscopy of Topological Insulators	March 20, 2014	80

SCHOOLS, CONFERENCES & WORKSHOPS

Quantum Foundation and Quantum Information Conference - Decoherence And Friends

May 20 – 23, 2013
Participants: 48
Decoherence is a bridge between quantum and classical and an Achilles' heel of quantum computation. For the past 30 years Wojciech Zurek led the development of the theory of decoherence and studied its implications for the foundations of quantum physics and its consequences for quantum information science and technology. We invited his collaborators as well as prominent contributors to the field to celebrate Wojciech's 60th birthday and his 30 years of decoherence studies.

Undergraduate School on Quantum Information Processing

May 27 – June 7, 2013
Participants: 23
USEQIP is a two-week program on the theoretical and experimental study of quantum information aimed primarily at students completing their third undergraduate year. The lectures and experiments are geared toward students in engineering, physics, chemistry, mathematics and computer science.

Quantum Key Distribution Summer School

July 29 – August 2, 2013
Participants: 53
The International Quantum Key Distribution (QKD) Summer School is a five-day program focused on theoretical and experimental aspects of quantum communication with a focus on quantum cryptography.

QCrypt - 3rd International Conference on Quantum Cryptography

August 5 - 9, 2013
Participants: 176
Industrial participants (companies): 18
The annual conference on quantum cryptography (QCrypt) is a conference for students and researchers working on all aspects of quantum cryptography. This includes theoretical and experimental research on the possibilities and limitations of secure communication and computation with quantum mechanical devices or in the presence of quantum mechanical devices. (The conference includes, but is not limited to, research on quantum key distribution.) It is the goal of the conference to represent the previous year's best results on quantum cryptography and to support the building of a research community in quantum cryptography.

Quantum Cryptography School for Young Students (QCSYS)

August 12 – 16, 2013
Participants: 41
The Quantum Cryptography School for Young Students (QCSYS) is a unique, week-long enrichment program. The school offers an interesting blend of lectures, hands-on experiments and group work focused on quantum cryptography — a cutting-edge field that utilizes the fascinating laws of quantum mechanics to develop unbreakable encryption that protects communication.

Quantum Innovators

January 17 – 20, 2014
Participants: 23
The Quantum Innovators workshop brings together the most promising your researchers in quantum physics and engineering for a three-day conference aimed at exploring the frontier of our field. Each day of the event kicks off with a keynote talk from a world-leading researcher after which attendees, mostly postdoctoral fellows, speak about their current research in detail. In addition, attendees and are provided opportunities to connect with other Quantum Innovators participants and IQC researchers, to forge the relationships that will strengthen the quantum information research community in the future. There is also an informal mentorship lunch panel headed up by a handful of researchers whose careers are approximately five years ahead of the postdoctoral fellow attendees. These panelists share their experiences about the transition of their careers to industry, government or academic positions.

SPONSORED CONFERENCES & EVENTS

Conference/Event	Date	Location
Quantum Landscapes	May 13-17	Perimeter Institute
8th Conference on Theory of Quantum Computation, Communication and Cryptography (TQC)	May 21-13	University of Guelph
Theory Canada 8	May 23-26	Bishop's University
Quantum Information and Complex Networks	May 27-30	IQC
The Canadian Summer School on Quantum Information (CSSQI)	June 17-21	University of Calgary
The Canadian Quantum Information Student's Conference (CQISC)	June 24-28	University of Calgary
Women in Physics Canada	July 26-28	Simon Fraser University
Canadian-American-Mexican Graduate Student Physics Conference (CAM)	Aug 15-18	Perimeter Institute and IQC
Summer School on Quantum Information, Computing and Control (QuICC)	Aug 26-29	Imperial College London
Quantum-Safe-Crypto Workshop	Sept 26-27	ETSI
Quantum Simulation	Sept 29-Oct 4	Universidad del País Vasco UPV/EHU
Canadian Undergraduate Physics Conference (CUPC)	Oct 17-20	McMaster
The 7th International Conference on Information Theoretic Security (ICITS)	Nov 28-30	NTU Singapore
Jeux de la Physique	Jan 14-20	Sherbrooke
QIP	Feb 3-7	Barcelona

INVITED TALKS

IQC faculty and research assistant professors presented a total of **83 times** during the 2013-2014 year. Of these, 34 were in Canada and 49 were at international events or organizations. For a full list of invited talks, see Invited Talks on page 117.

TOURS OF IQC FACILITIES

A significant part of IQC's outreach program is opening its doors to visitors and providing tours of our facilities. Tours are offered at the new Lazardis Centre, RAC I and RAC II at varying levels of technical complexity. In 2013, over **1,200 visitors** participated in tours of the Lazaridis Centre during the annual Doors Open program. For a full list of tours, Tour Groups on page 137.

GOVERNMENT TOURS

Group	Date	# of Visitors
Minister Moridi, Minister of Research and Innovation, Ontario	July 3, 2013	3
Members of Government from Abu Dhabi	March 21, 2013	4
Brazilian Delegation	June 11, 2013	
India Deputy National Security Advisor, Nehchal Sandhu	June 24, 2013	3
Delegation from Oman	September 13, 2013	3
Charles Sousa, Minister of Finance, Ontario	September 13, 2013	4
General Walter Natychuk, Eric Lalibertie, Christian Choiulnard, Canadian Space Agency	October 29, 2013	3
U.S. Embassy in Ottawa	November 7, 2013	3
CSEC representative	November 12, 2013	3
Minister of State (Science and Technology), Greg Rickford	November 13, 2013	2
Delegation from the Government of India	November 14, 2013	6

BUSINESS/INDUSTRY TOURS

Group	Date	# of Visitors
CIBC	August 8, 2013	4
Fujistu	September 6, 2013	4
Waterloo alumni tour	September 13, 2013	2
Jim and Judy Mitchell	September 28, 2013	2
"Future Directions in Security, Cryptography, and Privacy" attendees	November 6, 2013	20
CIBC	April 21, 2014	4
VC Media Tour	May 1, 2013	
Laurel Society Tour	May 28, 2013	

ACADEMIC TOURS

With the opening of the new Lazaridis Centre, IQC has experienced a significant spike in requests for academic tours. This year's Fall Open House for the University of Waterloo saw close to **5,000 potential undergraduate students** participate in campus tours that included the Lazaridis Centre. For a full list of academic tours, see Tour Groups on page 137.

Communications and Outreach – 2013/14 Highlights

This year, IQC communications and outreach underwent an update in its communications. The communications team worked to reinforce IQC's brand messaging and look and feel to better reflect a mature, future-forward institution and its world-class status. IQC's outreach activities brought together a global community of scientific researchers, both student and faculty, to achieve IQC's strategic objectives.

OBJECTIVES FOR 2013/14

- Develop a comprehensive strategic marketing plan that reflects IQC's brand attributes and values
- Continue to develop the research and creative around the IQC brand identity to help convey world-class science as broadly as possible
- Undertake a redesign of the IQC website to better align with the brand identity of both IQC and the University of Waterloo
- Continue with government and stakeholder relations

HIGHLIGHTED RESULTS FROM FISCAL 2013/14

- Developed a strategic marketing plan that included a refresh of the IQC logo and communications materials
- Converted the IQC website to a new template to meet upcoming accessibility regulations and better reflect IQC's brand
- Significantly increased traffic to IQC's website and social media outlets
- Solidified IQC's external relations team now at near full complement

STRATEGIC COMMUNICATIONS

In order to successfully accomplish IQC's third strategic objective, IQC communications required a strategic vision. IQC's strategic communications plan, envisages IQC as the global leader in quantum information science and the relevant communications activities required to support that goal.

Long-term Goals

- Position IQC as a global leader in quantum information science and technology
- Brand Canada as a quantum nation
- Promote Waterloo Region as Quantum Valley

Communication Objectives

IQC's strategic communication objectives are to:

- Produce the highest level of communication activities that include face-to-face interactions to social media and everything in between
- Showcase scientific excellence
- Communicate societal impacts of quantum information science and technology

Target Audiences

From colleague researchers around the world to high school students, from potential students to alumni, IQC audiences are broad and varied. Communications activities must view target audiences both vertically and geographically to ensure activities reach international, national and local audiences.

Moving forward, this strategic communications plan will guide communications activities to ensure all activities are working to achieve IQC's strategic objectives.

Moving forward, this strategic communications plan will guide communications activities to ensure all activities are working to achieve IQC's strategic objectives.

COMMUNICATIONS MATERIALS

Communications materials are an important vehicle in IQC's external relations planning. The various publications produced, both in print and online, share research success and reach a varied audience.

Name	Publication Cycle
Annual Report	Yearly; 2011, 2012, 2013, 2014
"NewBit" Newsletter	Semesterly; January, May, September
IQC "one pager"	Yearly
IQC satellite project "one-pager"	Yearly
IQC core areas of research series "one pagers"	Yearly
IQC brochure	Every two years
Graduate Brochure/Poster	Yearly
USEQIP/QCSYS Brochure/Poster	Yearly
Industry Canada Annual Reports	Yearly; 2010, 2011, 2012, 2013, 2014

IQC WEBSITE

The IQC website was transitioned into a new content management system in 2013/14 in preparation for accessibility regulations. In 2013/14, 66.7% of visitors to the IQC website were new visitors to the site. The majority of visitors (61%) are between the ages of 18-34 and 54.2% were male. Over half of the visitors to the website are Canadian. Countries with the most new visitors are Iran, United States and Germany (all >60%).

1.	Canada	**35,787** (52.94%)
2.	United States	**11,195** (16.56%)
3.	India	**3,775** (5.58%)
4.	China	**1,695** (2.51%)
5.	United Kingdom	**1,626** (2.41%)
6.	Germany	**1,532** (2.27%)
7.	Iran	**865** (1.28%)
8.	South Korea	**667** (0.99%)
9.	Singapore	**650** (0.96%)
10.	France	**593** (0.88%)

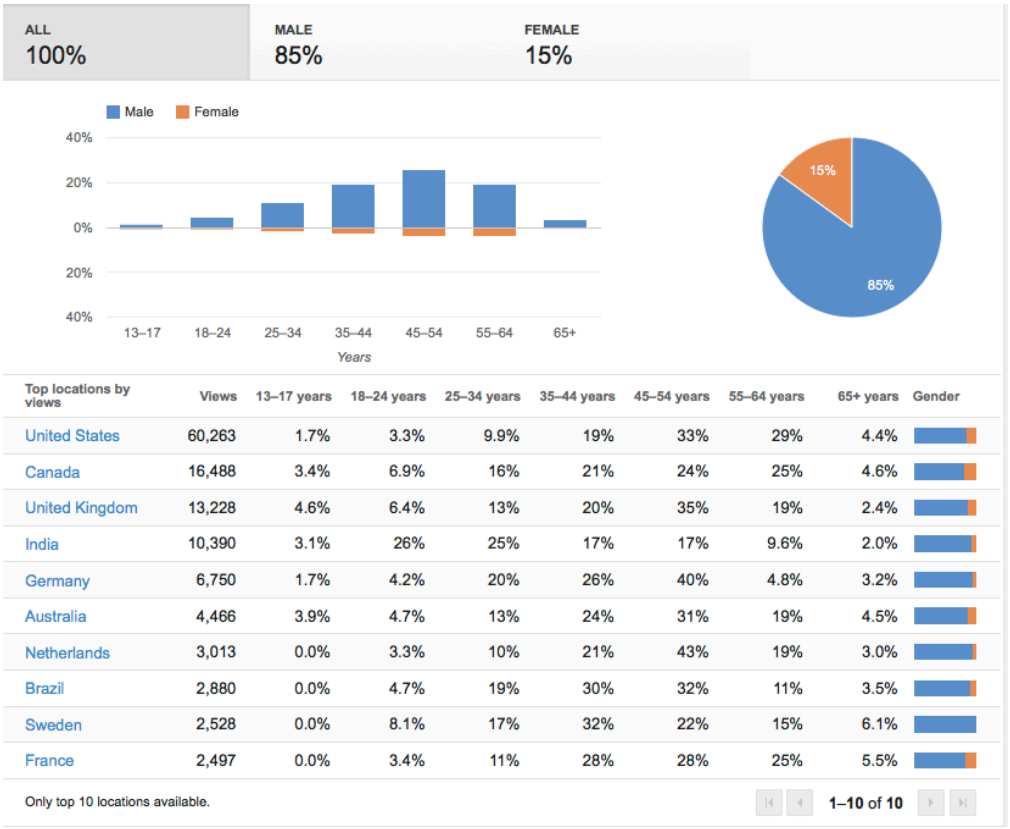
SOCIAL MEDIA

In today's highly connected world, social media is an important tool in any communications toolbox. IQC utilizes many social media outlets to share its research and successes including Facebook, Twitter, YouTube and Flickr.

YouTube Channel

IQC's YouTube channel, QuantumIQC, reached a major milestone in 2013/14 – the over 500 IQC videos now have **2,326,438 minutes watched**. These videos share both academic and research success, as well as guest lectures and featured interviews.

- 3,108 subscribers (1,613 new in 2014)
- 481,457 views to date (175,784 in 2014)
- 2,326,438 minutes of video watched
- 3,446 likes
- 108 videos uploaded last year
- High percentage of visitors 35+ years of age from European countries, largest percentage in the 45-54 age range
- High number of viewers from the United States (166,406 while next highest number is Canada with 69,109).



Top locations by views	Views	13–17 years	18–24 years	25–34 years	35–44 years	45–54 years	55–64 years	65+ years	Gender
United States	60,263	1.7%	3.3%	9.9%	19%	33%	29%	4.4%	
Canada	16,488	3.4%	6.9%	16%	21%	24%	25%	4.6%	
United Kingdom	13,228	4.6%	6.4%	13%	20%	35%	19%	2.4%	
India	10,390	3.1%	26%	25%	17%	17%	9.6%	2.0%	
Germany	6,750	1.7%	4.2%	20%	26%	40%	4.8%	3.2%	
Australia	4,466	3.9%	4.7%	13%	24%	31%	19%	4.5%	
Netherlands	3,013	0.0%	3.3%	10%	21%	43%	19%	3.0%	
Brazil	2,880	0.0%	4.7%	19%	30%	32%	11%	3.5%	
Sweden	2,528	0.0%	8.1%	17%	32%	22%	15%	6.1%	
France	2,497	0.0%	3.4%	11%	28%	28%	25%	5.5%	

Only top 10 locations available. 1–10 of 10

Top 10 Videos, Views & Minutes Watched 2013-2014

Video	Views	Minutes Watched
The Quantum Mechanics of Time Travel	30,490	399,192
Quantum Computing & the Entanglement...John Preskill	7,974	134,470
John Preskill – Introduction to Quantum Information (Part 1) – CSSQI 2012	5,456	61,681
Intro to Quantum Computing - Michele Mosca USEQIP 2011	4,235	51,205
Decoherence and consciousness...Max Tegmark	4,032	54,898
Universal Uncertainty Relations – Gilad Gour	3,550	87,833
Seth Lloyd on the Universe as a Quantum Computer	3,463	5.427
How Atomic Clocks Work - Dr. David Wineland	3,433	5,738
Casimir Effects: Peter Milonni's lecture at the Institute for Quantum Computing	3,019	33,008
Steven Girvin – Quantum Hall Effect	2,423	10,508

Facebook

IQC's Facebook page reached **2,563 likes** in 2013/4, with 820 new likes in the last year, which is significant for a research-intensive institute. IQC's Facebook group page can be found at facebook.com/QuantumIQC. The charts below display the top countries and cities of likes for IQC's Facebook group. The same cities are in the top seven listing, however India overtook the United States and Iran overtook Egypt for likes. For the cities, Chennai, India and Dhaka, Bangladesh have moved into the top seven this year.

Country	Likes
Canada	456
India	453
United States	409
Iran	87
Egypt	83
United Kingdom	73
Pakistan	66

City	Likes
Waterloo	161
Toronto	88
Kitchener	57
Dhaka, Bangladesh	43
Chennai, India	39
Calcutta, India	36
Tehran, Iran	36

As with YouTube, the majority of people visiting the Facebook page are male (80%). The largest percentage of visitors are in the 18-34 year age range.

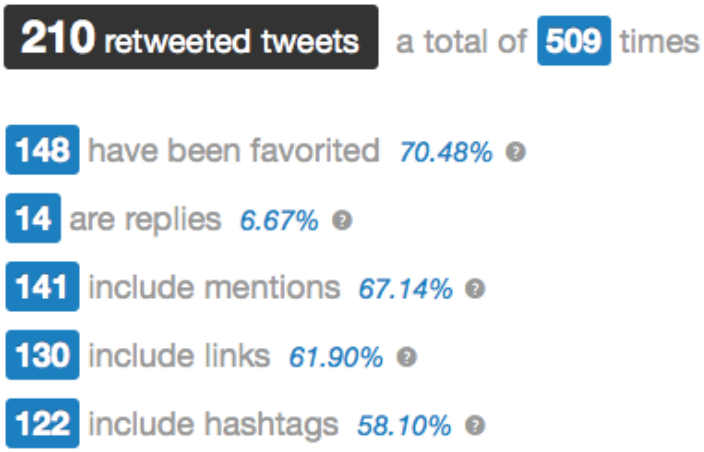
Top 10 reaching posts for 2013-2014

Post	Reach	Post clicks	Likes, comments and shares
Renewal of Government of Canada funding (Feb 12)	2.3K	629	124
Why we need quantum computers (July 30)	1.9K	115	46
Animated quantum computing (August 27)	1.7K	68	50
IQC featured in MIT (July 22)	1.6K	151	47
Physics style Bohemian Rhapsody (Sept 18	1.4K	79	35
Story in the Waterloo Region Record (April 26)	1.4K	99	53
Quest for Quantum Valley article (April 21)	1.4K	103	38
USEQIP announcement (May 28)	1.3K	507	68
Three-part series on IQC in Waterloo Region Record (May 6)	1.3K	90	37
David Wineland interview (October 22)	1.2K	43	29

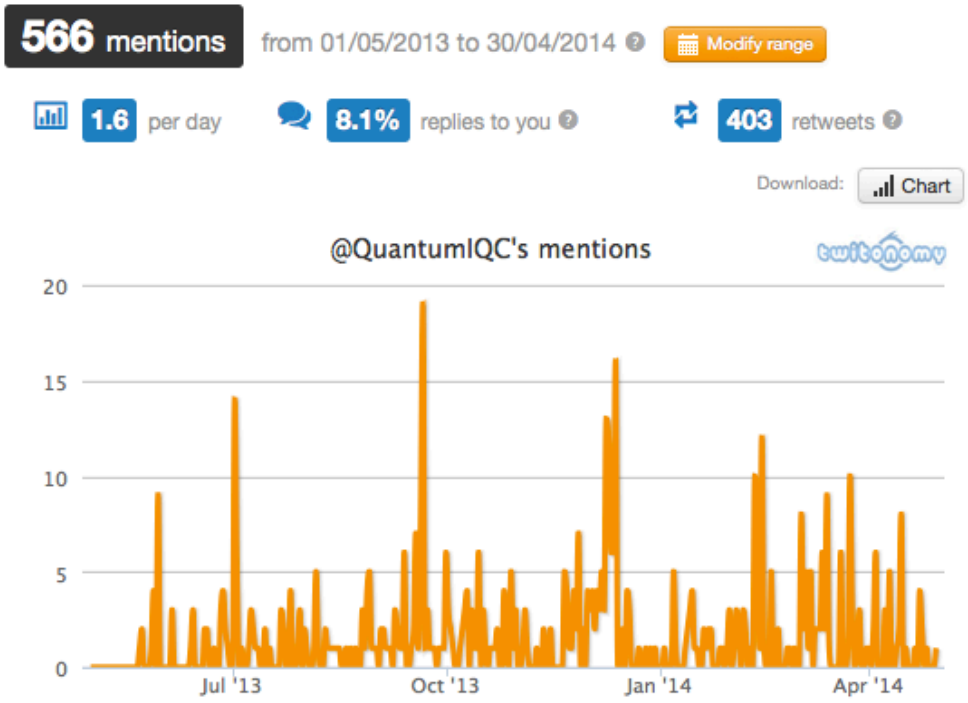
Twitter

IQC's twitter account (@QuantumIQC) has seen a dramatic increase in followers in the past year and has resulted in increased media coverage, attendance at events and other measurable successes. @QuantumIQC has 3,429 followers with a potential reach of 3,869,565, and has tweeted 1,229 times.

Year	Twitter Followers
2010	195
2011	649
2012	1,747
2013	2,492
2014	3,429



@QuantumIQC's mentions



IQC's Twitter account averages **2.42 retweets/day** and, as with Facebook, our largest following is in Waterloo, with London and Toronto close behind.

Top hashtags	Top keywords
#quantum	quantum
#quantumresearcher	science
#iqc	university
#12daysofquantum	student
#nobel	physics
#qcrypt	waterloo
#aaasmtg	about
#qcsys	research
#science	technology
#qnc	software

IQC's other social media avenues include LinkedIn (which connects IQC members with each other and the broader quantum science community), Picasa and FlickR (which increase the scope and visibility of IQC events, people and facilities through freely accessible photo galleries).

Media Coverage

IQC has garnered a significant amount of media coverage in 2013/14, in no small part to our Executive Director's profile, the opening of our UHV lab, the DATA.BASE project, the interest in quantum cryptography and a few high-profile published papers. Raymond Laflamme received over 40 media hits, below are a few of the highlights. For a full list of media coverage, see Media coverage on page 123.

Date	Media Outlet	Media Tier
May 4	The Waterloo Region Record	Regional
June	Phototonics Spectra	International science
June 25	The Waterloo Region Record	Regional
July 8	Bloomberg	International business
July 22	MIT Technology review	International tech
July 24	The Economist	International business
Aug. 22	The Waterloo Region Record	Regional
Aug. 31	The Waterloo Region Record	Regional
Sept. 11	The Waterloo Region Record	Regional
Sept. 26	Canadian Business	National business
Oct. 1	Metroland News Service	Provincial
Oct. 2	naturejobs.com	International science
Oct. 3	The Waterloo Region Record	Regional
Nov. 1	Bloomberg Business	International business
Nov. 11	Maclean's	National
Nov. 27	Maclean's	National
Dec. 7	National Post	National
Dec. 12	The Waterloo Region Record	Regional

Date	Media Outlet	Media Tier
Dec. 18	Bloomberg NOW	International business
Dec. 19	New Statesman	UK national
February	Physics World	International science
Feb. 11	Huff Post Canada	National
Feb. 24	The Waterloo Region Record	Regional
Mar. 14	Tech Generation Daily	International tech
Mar. 19	Jerusalem Post	Israel national
Mar. 19	IT World Canada	National tech
Mar. 20	Electronic Products and Technology	National tech
Apr. 8	Waterloo Chronicle	Regional
Spring 2014	Innovators Magazine	Regional

Administrative and Technical Support – 2013/14 Highlights

IQC's administrative and technical support teams provide support to the growing number of researchers, students, postdoctoral fellows and visitors. IQC's continued recruitement sees our researcher complement increase to 33 faculty, 50 postdoctoral fellows and 125 graduate students within the next few years.

Fiscal 2013/14 Objectives:

- Continue to execute the expansion into the Execute the expansion into the Mike & Ophelia Lazaridis Quantum-Nano Centre, including the commissioning of the labs, facilities and equipment
- Continue the fit-out of the new facility including execution of the physical move of individual lab spaces of designated members.
- Continue the fit-out of the Quantum NanoFab facility in the Mike & Ophelia Lazaridis Quantum-Nano Centre

Highlighted Results from Fiscal 2013/14:

- Completion of the expansion into the Mike & Ophelia Lazaridis Quantum-Nano Centre with 100% of current faculty and staff moved into the new facility.
- Four new lab spaces outfit and in operation in the Mike & Ophelia Lazaridis Quantum-Nano Centre
- Continued fit-out of the Quantum NanoFab fabrication facility

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

Risk Factor	Impact Score	Likelihood Score	Risk Rating	Explanation of Score	Mitigation Measures
Key staff may defect from IQC	High	Medium	8	IQC's research and recruitment efforts are largely the responsibility of a few key individuals. These individuals would be difficult to replace.	• Diversify the nature of staff members' work • Provide a challenging work environment • Ensure adequate technical and administrative support • Ensure world-class facilities and equipment • Provide a stimulating environment • Provide attractive benefits and employee/ spousal programs
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
Graduate program may not be approved or may suffer delays	N/A	N/A	N/A	N/A	• N/A

Risk Factor	Impact Score	Likelihood Score	Risk Rating	Explanation of Score	Mitigation Measures
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
Lack of financial information (regarding endowment) impedes long-term planning	High	Low	6	Sustainability/ source of funds (other than IC) is largely unknown	• Prepare a 10-year financial plan for ongoing operations
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
Construction costs may exceed budget	N/A	N/A	N/A	N/A	• N/A
Construction schedule may be delayed	N/A	N/A	N/A	N/A	• N/A

Appendix

Industry Canada Grant Agreement

This report focuses on two main evaluation issues (consistent with the new Treasury Board Policy on Evaluation effective April 1, 2009): relevance and performance. Within these two categories, the evaluation will consider:

- Appropriateness and effectiveness of the design and delivery of the research conducted by IQC
- Results achieved to date:
  - Outputs and immediate outcomes
  - Intermediate outcomes, such as the establishment of a world-class facility for QI (quantum information) research and training

According to the Grant Agreement, the University of Waterloo's Board of Governors must approve IQC's annual report to Industry Canada.

IQC's annual report will include:

1. A statement of the institute's objectives for that year and a statement on the extent to which the institute met those objectives
2. A list of activities undertaken with the grant
3. A statement of the institute's objectives for the next year and the foreseeable future
4. A description of the proposed activities for the next year to be undertaken within the context of this agreement, and a description of how the institute intends to implement them
5. A proposed schedule for the implementation of the activities for the next year
6. The anticipated results of those activities
7. Results achieved in the past year in accordance with a performance measurement strategy developed by Industry Canada
8. Risk assessment and mitigation strategies and ongoing performance monitoring strategies

The five-year grant from Industry Canada will enable the establishment of a new world-class research facility, which will support the government's science and technology strategy aimed at building a strong Canadian economy via knowledge and innovation. In the long-term, Industry Canada expects four key outcomes as a result of this grant:

1. Increased knowledge in quantum information
2. New opportunities for students to learn and apply new knowledge
3. Canada branded as a place to conduct research in quantum technologies
4. Canada positioned to take advantage of economic and social benefits of research

This chart illustrates the distribution of Industry Canada funds over five years:

Fiscal Year	Funding Amount ($ in millions)
2010	$16.5
2011	$17.0
2012	$5.0
2013	$5.5
2014	$6.0
Total	$50.0

With the aim of supporting IQC in its pursuit of these expected results, Industry Canada has allotted $25 million over two years to the construction of the new Mike & Ophelia Lazaridis Quantum-Nano Centre, $5 million over five years for the purchase of small equipment and $20 million over five years to the following four activities:

1. Recruiting and retaining highly qualified personnel
2. Transferring knowledge
3. Supporting administrative and technical staff members
4. Purchasing materials and supplies (other than small equipment

Industry Canada Funding Alottment

IQC MEMBERS FISCAL 2013/14

FACULTY

1. Michal Bajcsy
2. Jonathan Baugh
3. Andrew Childs
4. Richard Cleve
5. Kyung Soo Choi
6. David Cory
7. Joseph Emerson
8. Thomas Jennewein
9. Robert Koenig
10. Raymond Laflamme
11. Debbie Leung
12. Adrian Lupascu
13. Norbert Lutkenhaus
14. Hamed Majedi
15. Matteo Mariantoni
16. Guo-Xing Miao
17. Michele Mosca
18. Ashwin Nayak
19. Kevin Resch
20. John Watrous
21. Frank Wilhelm*
22. Christopher Wilson

RESEARCH ASSISTANT PROFESSORS

Vadim Makarov
Marco Piani
Dmitry Pushin

POSTDOCTORAL FELLOWS

Mohammad Ansari
Mustafa Bal
Olaf Benningshof
Troy Borneman
Anne Broadbent
Aharon Brodutch
Jianxin Chen
Lin Chen
Audrey Dot
Chris Erven
Francois Fillion-Gourdeau
Pol Forn-Diaz
Silvano Garnerone
Vlad Gheorghiu
Oleg Gittsovich
David Gosset
Patryk Gumann
Gus Gutoski
Christopher Haapamaki
Brendon Higgins
Rolf Horn
Mark Howard
Zhengfeng Ji
Nathaniel Johnston
Piotr Koenderski
Keith Lee
Catherine Lefebvre
Ying Liu
Dawei Lu
Eduardo Martin-Martinez
Rajat Mittal
Hamid Mohebbi
Osama Moussa
Mustafa Muhammad
Ryo Namiki
Florian Ong
Kazuto Otani
Zlatko Papic
Robabeh Rahimi
Sarah Sheldon
Daryoush Shiri
Fang Song
Jon Tyson
Joel Wallman
Nathan Wiebe
Huan Yang
Nengkun Yu
Yanbao Zhang
Hui Zhang

GRADUATE STUDENTS

Jean-Philippe Bourgoin
Chunqing Deng
Deny Hamel
Robin Kothari
Thomas McConkey
Adam Paetznick
Gelo Noel Tabia
Christopher Granade
Tomas Jochym-O'Connor
Kyungdeock Park
Christopher Wood
Victor Veitch
Vadym Kliuchnikov
Juan Miguel Arrazola
Gregory Holloway
Chris Pugh
Steven Casagrande
Matthew Graydon
Elena Anisimova
Megan Agnew
Sarah Kaiser
Maryam Mirkamali
William Stacey
Muhammet Yurtalan
Stephane Labruyere
Jason Boisselle
Feiruo Shen
Hamidreza Nafissi
Rahul Deshpande
Piers Lillystone
Jean-Philippe Maclean
Darryl Hoving
Li Liu
Poompong Chaiwongkhot
Nicolas Gonzalez
Anirudh Krishna
Kevin Liu
Alessandro Cosentino
Amin Eftekharian
Stacey Jeffery
Jonathan Lavoie
Evan Meyer-Scott
Ansis Rosmanis
Razeih Annabestani
Fatin Haque
Xian Ma
Om Patange
Michael Mazurek
Ian Hincks
Matthew Amy
John Donohue
Denis-Alexandre Trottier
Takafumi Nakano
Joachim Nsofini
Holger Haas
Daniel Puzzuoli
Vibhu Gupta
Shitikanth Kashyap
Vincent Russo
Yongchao Tang
Shima Bab Hadiashar
Paulina Corona Ugalde
Alexander Valtchev
Shihan Sajeed
Chung Wai Sandbo Chang
Zimeng Wang
Arnaud Carignan-Dugas
Jeremy Bejanin
Jonn Schanck
Jihyun Park
Olivia Di Matteo
Sumit Sijher
John Rinehart
Marie Barnhill
Daniel Criger
Peter Groszkowski
Milad Khoshnegar Shahrestani
Laura Mancinska
Jean-Luc Orgiazzi
Amir Jafari Salim
Kent Fisher
Catherine Holloway
Mohamad Niknam
Yuval Sanders
Grant Cleary
Alexandre Laplante
Feyruz Kitapli
Aimee Heinrichs
Zak Webb
Joshua Geller
Kaveh Gharavi
Sadegh Raeisi
Naimeh Ghafarian
Minyang Han
Lydia Vermeyden
Ala Shayeghi
Kyle Willick
Srinivasan Arunachalam
Corey Rae McRae
Erika Janitz
Martin Otto
Matthew Novenstern
Sean Walker
Tyler Nighswander
Carolyn Earnest
Mirmojtaba Gharibi
Nayeli Azucena Rodreiguez Briones
Joshua Young
David Luong
Chunhao Wang
Nigar Sultana

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Alvaro Martin-Alhambra
Angela Ruthven
Annamaria Dosseva
Asha Asvathaman
Thomas Alexander
Thomas Bohdanowicz
Weihao Gao
Wentao Ji
Carolyn Kimball
Carter Minshull
Chengyu Dai
Chris Sutherland
David Lu
Dmitry Serbin
Dusan Sarenac
Erika Janitz
Glendon Thompson
Ioana Craiciu
James Bateman
James Callahan
Jeremy Bejanin
John Dengis
Jordan Goulet
MacLean Kuraitis
Madelaine Liddy
Marc Burns
Maria Kieferova
Matthew Lavrisa
Mouktik Raha
Nigar Sultana
Pawel Jaworski
Philip Gores
Prasad Sarangapani
Saranyo Moitra
Shahab Akmal

VISITORS

The following list includes institutions whose faculty visited IQC since 2008:

Institution	Country
Macquarie University	Australia
Queensland University	Australia
The University of Sydney	Australia
University of Queensland	Australia
University of Technology Syndey	Australia
The University of Sydney	Australia
University of Vienna	Austria
Vienna Center for Quantum Science and Technology	Austria
Principiæ	Belgium
Instituto de Física Universidade Federal Fluminense	Brazil
The University of British Columbia	Canada
Thompson Rivers University	Canada
Université de Sherbrooke	Canada
University of Calgary	Canada
University of Ottawa	Canada
Dalhousie University	Canada
McGill University	Canada
Mount Allison University	Canada
Simon Fraser University	Canada
The University of Calgary	Canada
University of Toronto	Canada
Shandong University	China
Chinese Academy of Sciences	China
National University of Defense Technology	China
The Chinese University of Hong Kong	China
Tsinghua University	China
University of Science and Technology	China

Institution	Country
Télécom ParisTech	France
École Normale Supérieure	France
Université Paris Diderot	France
Ludwig Maximilian University of Munich	Germany
Max Planck Institute for the Science of Light	Germany
Karlsruhe Institute of Technology	Germany
Peter Grünberg Institute	Germany
Technische Universität München	Germany
Universität Ulm	Germany
University of Düsseldorf	Germany
University of Amsterdam	Holland
University of Mumbai	India
Indian Institute of Science Education and Research, Pune	India
Raman Research Institute	India
Queen's University Belfast	Ireland
Weizmann Institute of Science	Israel
The Hebrew University of Jerusalem	Israel
Istituto Nazionale di Fisica della Materia - Unit of Napoli	Italy
ISI Foundation – Institute for Scientific Interchange	Italy
The University of Tokyo	Japan
Ewha Womans University	Korea
Korea Institute of Science and Technology	Korea
Gdańsk University of Technology	Poland
University of Gdańsk/Polish Academy of Sciences Warsaw	Poland
Russian Academy of Sciences	Russia
The University of Edinburgh	Scotland
M Squared Lasers Ltd	Scotland
University of Strathclyde	Scotland
National University of Singapore	Singapore
Comenius University	Slovakia
University of Kwa-Zulu Natal	South Africa
Cape Town University	South Africa
Universidad del País Vasco Bilbao	Spain
Instituto de Física Fundamental	Spain
Universidad de Zaragoza	Spain
University of Basque Country	Spain
Chalmers University of Technology	Sweden
Stockholm University	Sweden
ID Quantique Geneva	Switzerland
Institute for Theoretical Physics ETH Zurich	Switzerland
Delft University of Technology	The Netherlands
University of Amsterdam	The Netherlands
University of Leeds	United Kingdom
University College London	United Kingdom
University of Cambridge	United Kingdom
The University of Nottingham	United Kingdom

Institution	Country
University of Oxford	United Kingdom
California Institute of Technology	U.S.
Clemson University	U.S.
Haverford College	U.S.
Microsoft Research Station Q	U.S.
National Institute of Standards and Technology	U.S.
Raytheon-BBN Technologies	U.S.
Stanford University	U.S.
The City College of New York	U.S.
Tufts University	U.S.
University of California, Davis	U.S.
University of California, San Diego	U.S.
University of Connecticut	U.S.
University of Maryland	U.S.
University of South Carolina	U.S.
Yale University	U.S.
Columbia University	U.S.
Florida Atlantic University	U.S.
Harvard University	U.S.
IBM TJ Watson Research Center	U.S.
Los Alamos National Laboratory and Santa Fe Institute	U.S.
Massachusetts Institute of Technology	U.S.
Stanford University	U.S.
The College of William and Mary	U.S.
The Templeton Foundation	U.S.
The University of Vermont	U.S.
University of California, Berkeley	U.S.
University of California, Los Angeles	U.S.
University of California, Santa Barbara	U.S.
University of Cincinnati	U.S.
University of Illinois at Urbana-Champaign	U.S.
University of Michigan	U.S.
University of New Mexico	U.S.
University of Washington	U.S.

SHORT-TERM VISITORS

Visitor	Home Institution
Fernando Pastawski	California Institute of Technology, U.S.
Joseph F. Traub	Columbia University, U.S.
Layla Hormozi	National University of Ireland, Ireland
Jingyun Fan	National Institute of Standards and Technology, U.S.
Takashi Imai	McMaster University, Canada
Michael Hilke	McGill University, Canada
Jie Wang	University of Science and Technology, China

Visitor	Home Institution
Raul Garcia-Patron	Ecole Polytechnique de Bruxelles, Belgium
Vinzenz Gangl	UCP Plasma Technologies, Liechtenstein
Christopher Portmann	Institute for Theoretical Physics ETH Zurich, Switzerland
Dr. Tae Hee Kim	Ewha Womans University, Korea
Harry Buhrman	University of Amsterdam, Holland
Paul Kwiat	University of Illinois at Urbana-Champaign, U.S.
Mathilde Soucarros	ID Quantique, Geneva, Switzerland
Sayed Ali Hamed Mosavian	University of Maryland, U.S.
Sylvia Bratzik	University of Duesseldorf, Germany
Kyung Soo Choi	Korea Institute of Science and Technology, Korea
Saikat Guha	Raytheon-BBN Technologies, U.S.
Thomas Lutz	The University of Calgary, Canada
Barry Sanders	University of Calgary, Canada
Tim Taminiau	Delft University of Technology, The Netherlands
Xinhua Peng	University of Science and Technology, China
Marilyne Thibault	McGill University, Canada
Jiangfeng Du	University of Science and Technology, China
Paul Corkum	University of Ottawa, Canada
Juan Jose Garcia Ripoll	Instituto de Física Fundamental, Spain
Chris Herdman	The University of Vermont, U.S.
Hemant Katiyar	Indian Institute of Science Education and Research, Pune, India
Paul Hess	Harvard University, U.S.
Haizhong Guo	Chinese Academy of Sciences, China
Jared B. Hertzberg	University of Maryland, U.S.
Zhang Jiang	University of New Mexico, U.S.
J. Michael Rowe	National Institute of Standards and Technology, U.S.
Joshua Combes	University of New Mexico, U.S.
Penghui Yao	National University of Singapore, Singapore
H. Jeff Kimble	California Institute of Technology, U.S.
Taehyun Yoon	Columbia University, U.S.
Xiaosong Ma	Yale University, U.S.
Gianluigi Catelani	Peter Grünberg Institute, Germany
Alexander Keesling	Massachusetts Institute of Technology, U.S.
Giacomo Torlai	Ludwig Maximilians University Munich, Germany
Hammam Elyas	University of Ottawa, Canada
Jeff Salvail	Simon Fraser University, Canada
Natascha Hedrich	Thompson Rivers University, Canada
Travis Russell	Dallahouise University, Canada
Jorma Louko	The University of Nottingham, UK
Nicolas Menicucci	The University of Sydney, Australia
Jintai Ding	University of Cincinnati, U.S.
Sascha Agne	University of Leeds, U.S.

Visitor	Home Institution
Fei Wang	Tsinghua University, China
Manuel Endres	Max Planck Institute of Quantum Optics in Garching, Germany
Mohammad H. Ansari	Delft University of Technology, The Netherlands
Peter Love	Haverford College, U.S.
Ni Ni	University of California, Los Angeles, U.S.
Paweł Horodecki	Gdańsk University of Technology, Poland
Alvaro Martin-Alhambra	University of Oxford, UK
Vladimir Buzek	The Templeton Foundation, U.S.
Claude Crépeau	McGill University, Canada
Xiongfeng Ma	Tsinghua University, China
Arturo Tagliacozzo	Istituto Nazionale di Fisica della Materia - Unit of Napoli, Italy
Roee Ozeri	Weizmann Institute of Science, Israel
Urbasi Sinha	Raman Research Institute, India
Zhu Cao	Tsinghua University, China
Ryan Sweke	University of Kwa-Zulu Natal - South Africa
Nitin Jain	Max Planck Institute for the Science of Light, Germany
Volkher Scholz	Institute for Theoretical Physics ETH Zurich, Switzerland
Ish Dhand	University of Calgary, Canada
Jamie Sikora	Université Paris Diderot, France
Yaoyun Shi	University of Michigan, U.S.
Toeno van der Sar	Delft University of Technology, The Netherlands
Luming Duan	University of Michigan, U.S., and Tsinghua University, China
Roman Lutchyn	Microsoft Research Station Q, Santa Barbara, U.S.
Shengyu Zhang	The Chinese University of Hong Kong, China
Nilanjana Datta	University of Cambridge, UK
Michael Fitzgerald	Massachusetts Institute of Technology, Technology Review, U.S.
Maris Ozols	IBM TJ Watson Research Center, U.S.
Rolando Somma	Los Alamos National Laboratory, U.S.
Diane Pelejo	The College of William and Mary, U.S.
Gerd Leuchs	Max Planck Institute for the Science of Light, Germany
Daniel Aitken	M Squared Lasers Ltd, Scotland
Enrique Solano	Universidad del País Vasco, Bilbao, Spain
Guillermo Esteban Romero Huenchuir	University of Basque Country, Spain
Wolfram Pernice	Karlsruhe Institute of Technology, Germany
David Low	University of California, Santa Barbara, U.S.
Dominic Berry	Macquarie University, Australia
Per Delsing	Chalmers University of Technology, Sweden
John Kirtley	Stanford University, U.S.
Brenden Roberts	Clemson University, U.S.
Aram Harrow	University of Washington, U.S.

Visitor	Home Institution
Francois Le Gall	The University of Tokyo, Japan
Harry Buhrman	University of Amsterdam, The Netherlands
Mao-Chuang Yeh	University of Illinois at Urbana-Champaign, U.S.
Tony Leggett	University of Illinois at Urbana-Champaign, U.S.
Anton Zeilinger	University of Vienna, Austria
Wojciech Zurek	Los Alamos National Laboratory and Santa Fe Institute, U.S.
Cory Dean	The City College of New York, U.S.
Jianming Cai	Universität Ulm, Germany
Michael Reimer	Delft University of Technology, The Netherlands
Matthias Christandl	Institute for Theoretical Physics ETH Zurich, Switzerland
Göran Johansson	Chalmers University of Technology, Sweden
Mark Zhandry	Stanford University, U.S.
David Reeb	Technische Universität München, Germany
Mary Beth Ruskai	Tufts University, U.S.
Raffi Budakian	University of Illinois at Urbana-Champaign, U.S.
Spyros Magliveras	Florida Atlantic University, U.S.
Christopher Roy Monroe	University of Maryland, U.S.
Umesh Vazirani	University of California, Berkeley, U.S.
Giulio Chiribella	Tsinghua University, China
Greg Kuperberg	University of California, Davis, U.S.
Simone Severini	University College London, UK
Matthieu Legré	ID Quantique, Geneva, Switzerland
David Rideout	University of California, San Diego, U.S.
Kerem Shah	University of Strathclyde, Glascow, Scotland
Stephen Fenner	University of South Carolina, U.S.
Anne Marin	Télécom ParisTech, France
David Zueco	Universidad de Zaragoza, Spain
Hui Zhang	University of Science and Technology, China
Robert Martin	Cape Town University, South Africa
Stefanie Barz	Vienna Center for Quantum Science and Technology, Austria
Rainer Kaltenbaek	University of Vienna, Austria
Alexandre Cooper-Roy	Massachusetts Institute of Technology, U.S.
Matthias Troyer	Institute for Theoretical Physics ETH Zurich, Switzerland
Dorit Aharonov	The Hebrew University of Jerusalem, Israel
Jacob Biamonte	ISI Foundation – Institute for Scientific Interchange, Italy
Ville Bergholm	ISI Foundation – Institute for Scientific Interchange, Italy
Dr. Graeme Smith	IBM TJ Watson Research Center, U.S.
Michaël Simoen	Chalmers University of Technology, Sweden
Shelby Kimmel	Massachusetts Institute of Technology, U.S.
Farzad Qassemi	Université de Sherbrooke, Canada
Douglas Stebila	Queensland University, Australia
Kristan Temme	Massachusetts Institute of Technology, U.S.

Visitor	Home Institution
Linmei Liang	National University of Defence Technology, China
Musheng Jiang	National University of Defense Technology, China
Xiangchun Ma	National University of Defense Technology, China
Casey Myers	University of Queensland, Australia
Michael Bremner	University of Technology, Syndey, Australia
Jean-Luc Doumont	Principiæ, Belgium
Magdalena Stobinska	University of Gdańsk/Polish Academy of Sciences, Warsaw, Poland
Zhizhong Yan	Macquarie University, Australia
Amr S. Helmy	University of Toronto, Canada
Josh Lockhart	Queen's University Belfast, Ireland

LONG-TERM VISITORS

Visitor	Home Institution
Adam Kulidjian	McGill University, Canada
Amir Yacoby	Harvard University, U.S.
Asha Devi Asvathaman	The University of British Columbia, Canada
Austin Fowler	University of California, Santa Barbara, U.S.
Barry Sanders	University of Calgary, Canada
Bo Wen	The City College of New York, U.S.
Chengyu Dai	Tsinghua University, China
Chi-Kwong Li	The College of William and Mary, U.S.
Daniel Jost Brod	Instituto de Física Universidade Federal Fluminense, Brasil
Dominic Berry	Macquarie University, Australia
Dominique Pouliot	University of Illinois at Urbana-Champaign, U.S.
Feihao Zhang	Tsinghua University, China
Giuseppe Davide Paparo	University of Maryland, U.S.
Glendon Thompson	The University of Edinburgh, Scotland
Guoming Wang	University of California, Berkeley, U.S.
Igor Radchenko	Russian Academy of Sciences, Russia
James Bateman	University of Toronto, Canada
James Michael Callahan II	Harvard University, U.S.
Jean-Philippe MacLean	McGill University, Canada
Jesse Bingjie Wang	University of Cambridge, U.S.
Junkai Zeng	University of Science and Technology, China
Maria Kieferova	Comenius University, Slovakia
Michael Simoen	Chalmers University of Technology, Sweden
Robin Cote	University of Connecticut, U.S.
Saranyo Moitra	University of Mumbai, India
Shuhao Wang	Tsinghua University, China
Simon Forest	École Normale Supérieure, France
Thomas Alexander	Mount Allison University, Canada
Tony Leggett	University of Illinois at Urbana-Champaign, U.S.

Visitor	Home Institution
Weihao Gao	Massachusetts Institute of Technology, U.S.
Wentao Ji	University of Science and Technology, China
Xuan Wang	Shandong University, China
Yi-Hang Yang	University of Science and Technology, China
Yiruo Lin	University of Illinois at Urbana-Champaign, U.S.
Zhen Zhang	Tsinghua University, China
Alf Pettersson	Stockholm University, Sweden
Nicolas C. Menicucci	University of Sydney, Australia
Xinhua Peng	University of Science and Technology, China

ADMINISTRATIVE STAFF

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Carly Payerl*
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Matthew Schumacher
Jodi Szimanski
Steve Weiss
Matthew Cooper
Andrew Dale
Kathryn Fedy*
Matthew Fries
Jaymis Goertz*
Lorna Kropf
Vito Loguidice
Brooke Mulder*
Mary Lyn Payerl
Robert Romero
Jessica Schumacher*
Dylan Totzke
Erin Cronin
Tobi Day-Hamilton
Mary Feldskov*
Jennifer Fung*
Ryan Goggin
Martin Laforest
Jessica Miranda
Nathan Nelson-Fitzpatrick
Sarah Reibel*
Rodello Saladanan
Kimberly Simmermaker
Carly Turnbull

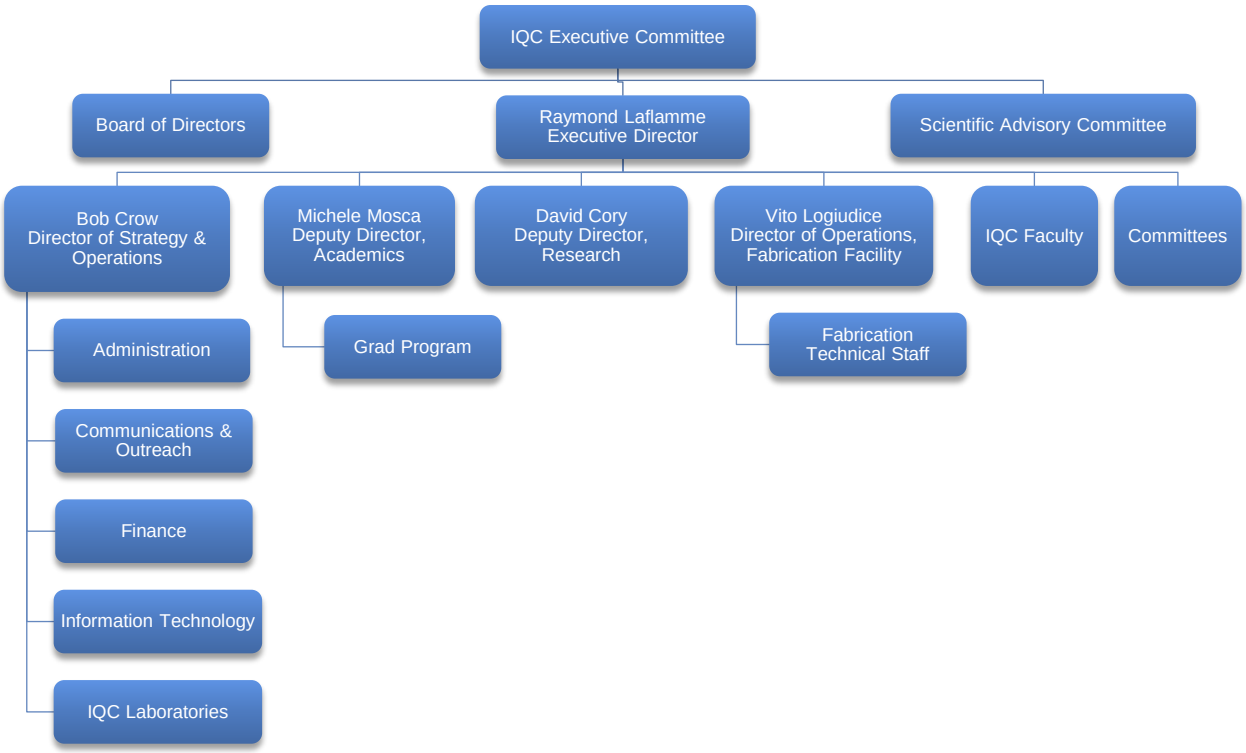
TECHNICAL STAFF

Brian Goddard
Roberto Romero
Mai-Britt Mogensen*
Vito Logiudice
Rodello Salandanan
Nathan Nelson-Fitzpatrick
Ivar Taminiau

*These individuals were with IQC for a portion of fiscal 2013-2014.

GOVERNANCE

This section outlines IQC's governance structure. The following chart depicts IQC's current organizational makeup.



IQC's collaborative and interdisciplinary research goes beyond the scope of one single department. Therefore, faculty members are appointed across six departments that span the University of Waterloo's faculties of Engineering, Math and Science. Departments include: Combinatorics and Optimization, Physics and Astronomy, The David R. Cheriton School of Computer Science, Electrical and Computer Engineering, Applied Mathematics, and Chemistry.

Executive Committee

IQC's Executive Committee is made up of senior administrators from the University of Waterloo who provide guidance to IQC's Executive Director and senior management team.[5] The committee meets twice per year.

- George Dixon, Vice-president, Chair, University Research, University of Waterloo (Chair)
- Ian Goulden, Dean, Faculty of Mathematics, University of Waterloo
- Raymond Laflamme, Executive Director, Institute for Quantum Computing
- Terry McMahon, Dean, Faculty of Science, University of Waterloo
- Michele Mosca, Deputy Director Academic, Institute for Quantum Computing
- Pearl Sullivan, Dean, Faculty of Engineering, University of Waterloo

5 For biographies for the Executive Committee see Governance on page 99.

Board of Directors

IQC's Board of Directors is made up of internationally recognized leaders from academia, business and government.[6] The Board provides advisory strategic advice on all aspects of management including finances, planning, commercialization and outreach. The Board of Directors includes:

- Douglas Barber, Distinguished Professor-in-Residence, McMaster University*
- Tom Brzustowski (Board Chair), RBC Professor, Telfer School of Management, University of Ottawa
- Paul Corkum, University of Ottawa and National Research Council
- George Dixon, Vice-president, University Research, University of Waterloo
- Cosimo Fiorenza, Vice-president and General Counsel, Infinite Potential Group
- David Fransen, Consul General, Canadian Consulate General in Los Angeles
- Peter Hackett, Executive Professor, School of Business at the University of Alberta & Fellow, National Institute for Nanotechnology
- Mike Lazaridis, Co-Founder of Research In Motion
- William R. Pulleyblank, Professor of Operations Research, United States Military Academy, West Point *

*Member was not on Board for full fiscal year

Scientific Advisory Committee

IQC's Scientific Advisory Committee is made up of leading international scientists.[7] The committee meets annually to assess IQC's progress toward fulfilling its mission and achieving its strategic goals. The committee advises the Executive Director on areas of strength and opportunity in the institute's scientific endeavours to ensure the success of IQC. Members of the Scientific Advisory Committee include:

- Prof. Harry Buhrman, Centrum voor Wiskunde en Informatica
- Prof. Anthony J. Leggett, University of Illinois at Urbana-Champaign
- Prof. Gerard Milburn, University of Queensland
- Prof. Christopher Monroe, University of Maryland
- Prof. Umesh Vazirani, University of California, Berkley
- Prof. Anton Zeilinger, University of Vienna
- Prof. Wojciech Hubert Zurek, Laboratory Fellow, Los Alamos National Laboratory and Santa Fe Institute

Internal Governance

Faculty members at IQC hold appointments in departments at the University of Waterloo and as such, are governed by the University's policies on appointment, promotion and tenure. All faculty participate in annual evaluations conducted by their home departments. The Executive Director of IQC gives input to the heads of departments about the contributions of each member. In addition, the institute tracks information on research, outreach and other contributions to IQC for its own membership renewal process. Members are elected to IQC for a period of five years.

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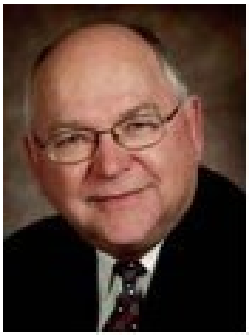
6 For biographies of the Board of Directors, see IQC Board of Directors Biographieson page 102.
7 Biographies for the Scientific Advisory Committee **Error! Reference source not found.** on page 96

IQC holds monthly faculty meetings to discuss issues arising related to faculty and postdoctoral fellow hiring, visiting scientists, the graduate program, upcoming colloquia and seminars, scholarships and others as they arise.

IQC BOARD OF DIRECTORS BIOGRAPHIES

Tom Brzustowski, Chair of the Board

Tom Brzustowski graduated with a BASc. 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.



H. Douglas Barber*

H. Douglas was an Athlone Fellow and NATO Scholar and received his PhD from Imperial College, University of London in 1965. In 1973 he was a founder of Linear Technology Inc., (now known as Gennum Corporation) which manufactures and markets microcircuits. He was President and CEO of Gennum when he retired in 2000 and he continues in his position as a director. He was a part-time Engineering Physics Professor at McMaster University from 1968 to 1994 and in 2001 he was appointed Distinguished Professor-in-Residence.

Dr. Barber's honours include the APEO Engineering Medal, the Professional Engineers of Ontario Gold Medal and Engineer of the Year Award of the Hamilton Engineering Institute. He has received an Honorary Doctorate of Engineering from the University of Waterloo, an Honorary Doctorate of Science from McMaster University, and in 1999 was named Ontario's Technology Entrepreneur of the Year and received the National Citation for Innovation & Technology. Most recently, Dr. Barber was named to the Order of Canada.

Paul Corkum

Paul Corkum earned his PhD in physics at Lehigh University in 1972. After a year at Lehigh as a postdoctoral researcher, he moved to the National Research Council in Ottawa. In 1990 he formed the Femtosecond Science Group within NRC's Steacie Institute for Molecular Sciences. In 2008 he was named a Canada Research Chair of Attosecond Photonics at the University of Ottawa and appointed Director of the Joint NRC/University of Ottawa Laboratory for Attosecond Science. He is a member of the Royal Societies of Canada (1995) and London (2005). He has been the recipient of the Gold Medal for Lifetime Achievement in Physics from the Canadian Association of Physicists (1996), the Einstein Award of the Society for Optical and Quantum Electronics (1999), the Golden Jubilee Medal of Her Majesty Queen Elizabeth II (2003), the Tory Medal of the Royal Society of Canada (2003), the Quantum Electronics Award of the Institute of Electrical and Electronics Engineers (IEEE, 2005), the Killam Prize for Physical Sciences (2006), and the Arthur Schawlow Prize for Quantum Electronics from the American Physical Society (2006) and the King Faisal Prize (2013).

George Dixon

D. 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.

Cosimo Fiorenza

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.

David Fransen

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 executive director of the Institute for Quantum Computing in 2006. He was most recently the Consul General, Canadian Consulate General in Los Angeles.

Peter Hackett

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).

Mike Lazaridis Managing Partner, Quantum Valley Investments

Mike Lazaridis, O.C., O.Ont., is Managing Partner and Co-Founder of Quantum Valley Investments (QVI), which he and Doug Fregin established in Waterloo with $100 million to provide financial and intellectual capital for the development and commercialization of quantum physics and quantum computing breakthroughs. QVI aims to help transform ideas and early-stage breakthroughs into commercially viable products, technologies, and services. It is Mr. Lazaridis' latest venture in more than a decade's work aimed at creating a "Quantum Valley" in Waterloo by bringing the world's best minds in physics, engineering, mathematics, computer science, and materials science together to collaborate on cutting-edge quantum research.

In 1984, Mr. Lazaridis co-founded BlackBerry (formerly Research In Motion) with Mr. Fregin. They invented the BlackBerry device, created the smartphone industry, and built Canada's largest global tech business. Mr. Lazaridis served in various positions including Co-Chairman and Co-CEO (1984-2012) and Board Vice Chair and Chair of the Innovation Committee (2012-13).

Mr. Lazaridis is the Founder and Board Chair of Perimeter Institute, where he helps generate important private and public sector funding for the Institute. He also founded the Institute for Quantum Computing at the University of Waterloo. He has donated more than $170 million to Perimeter, and more than $100 million to IQC.

William R. Pulleyblank*

William R. Pulleyblank is the IBM vice president responsible for the Center for Business Optimization. He was the director of exploratory server systems and director of the Deep Computing Institute. During this time, he was responsible for a number of IBM Research initiatives in ultra large-scale computing, including the creation of the Blue Gene/L supercomputer which, since November 2004, has been certified as the world's most powerful system. Dr. Pulleyblank has served on a range of boards and advisory panels, including the Advisory Committee of the Division of Mathematics & Physical Sciences of the National Science Foundation, the Board on Mathematical Sciences of the National Research Council, the iCORE Board of Directors, the Science Advisory Board of the National Institute of Aerospace, and the Scientific Advisory Panel of The Fields Institute for Research in Mathematical Sciences.

Harry Buhrman

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.

Sir Anthony J. Leggett

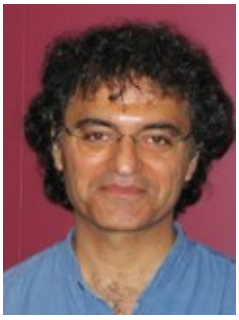
Anthony J. Leggett, the John D. and Catherine T. MacArthur Professor and Center for Advanced Study Professor of Physics, has been a faculty member at Illinois since 1983. He was a co-winner of the 2003 Nobel Prize in Physics for pioneering work on superfluidity. He is a member of the National Academy 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 (UK), the American Physical Society, and the American Institute of Physics. He is an Honorary Fellow of the Institute of Physics (UK). 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.

Gerard Milburn

Gerard Milburn obtained a PhD in theoretical Physics from the University of Waikato in 1982 for work on squeezed states of light and quantum nondemolition measurements. He was appointed to a postdoctoral research assistantship in the Department of Mathematics, Imperial College London in 1983. In 1994 he was appointed as Professor of Physics and in 1996 became Head of Department of Physics at The University of Queensland. In 2000 he became Deputy Director of the Australian Research Council Center of Excellence for Quantum Computer Technology. He is currently an Australian Research Council Federation Fellow at the University of Queensland.

Chris Monroe

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

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.

Anton Zeilinger

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.

Wojciech Hubert Zurek

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 (MSc 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.

FINANCIAL SUPPORTERS

IQC and its researchers are privileged recipients of donations, grants, gifts and awards. Over the next few pages you will find some highlights of these grants.

Industry Canada

In 2009, the Government of Canada through Industry Canada granted $50 million to IQC to be allocated over a five-year period. $25 million to fund the IQC share of the Mike and Ophelia Lazaridis Quantum-Nano Center and $25 million for operations. In the 2012//2013 year (2012 fiscal year), the funds were used in the following allotment: $1.6 million for equipment purchasing, $4.6 million toward highly qualified personnel and operations.

Mike and Ophelia Lazaridis

Mike and Ophelia Lazaridis have donated a total of $105 million to IQC since inception.

The Government of Ontario

The Government of Ontario has granted $50 million to the University of Waterloo to help strengthen Ontario's leading-edge research capacity. The Ontario Ministry of Research and Innovation granted IQC more than $18 million. (Includes the Ontario Innovation Trust and the Ontario Research Development Challenge Fund.)

The University of Waterloo

The University of Waterloo has committed to supporting the salaries of 33 IQC faculty.

Canadian Foundation for Innovation

CFI has contributed more than $14 million to IQC since inception.

Natural Sciences and Engineering Research Council of Canada

NSERC has committed nearly $12 million to developing quantum information science and technology since the inception of IQC in 2002.

Canada Research Chairs

The Canada Research Chairs Secretariat Program supports IQC through faculty positions at the University of Waterloo that are jointly appointed by IQC and one of the departments in the Faculties of Science, Engineering or Mathematics. Current Canada Research Chairs at IQC are: Raymond Laflamme, Debbie Leung and Kevin Resch.

Canada Excellence Research Chairs

The Canada Excellence Research Chairs program supports IQC with funding of $10 million over seven years to support faculty member David Cory.

SUMMARY OF OTHER GRANTS AND GIFTS

IQC and its researchers are privileged recipients of donations, grants, gifts and awards. Over the next few pages you will find some highlights of these grants from the 2013- 2014 fiscal year.

Sponsor Type	Sponsor Name	Total Awarded
Canadian - Government and Public Sector - Federal - Other	CERC (Canada Excellence Research Chairs)	1,400,000
	CFI - IOF (Infrastructure Operating Fund)	447,205
	CRC - NSERC	400,000
	Industry Canada PWGSC	623,334 600,000
Canadian - Government and Public Sector - Federal - Tri Agency	NSERC - Collaborative Research and Training Experience Program (CREATE)	600,000
	NSERC - Discovery Grants Accelerator Supplement (RGPAS)	80,000
	NSERC - Discovery Grants - Individual (RGPIN)	868,181
	NSERC - Engage Plus Grant	5,000
	NSERC - Prizes	160,000
Canadian - Government and Public Sector - Provincial - Ontario	MRI - ERA (Early Researcher Award)	147,434
	MRI - ORF-RE (Ontario Research Fund - Research Excellence)	49,599
Canadian - Government and Public Sector - Provincial - Ontario Centres of Excellence	OCE (Ontario Centres of Excellence)	30,000

Sponsor Type	Sponsor Name	Total Awarded
Canadian - Non Profit - Foundations/Charities	Alfred P Sloan Foundation	52,175
Canadian - Non Profit - Other	Mitacs Inc	32,500
Canadian - Non Profit - Universities	UW - Contribution	250,000
	UW - Vice President	50,000
	Wilfrid Laurier University	14,370
Canadian - Private Sector - Industry	C2C Link Corporation	5,000
	COM DEV International Limited	30,000
	Mitacs Partner Contribution	25,000
Canadian - Private Sector - Other	Canadian Institute for Advanced Research	235,000
US - Government and Public Sector -	Federal Office of Naval Research (ONR)	270,691
	Sandia National Laboratories	198,928
	US Army Research Office	525,891
US - Non Profit – Universities	Duke University	32,708
US - Private Sector - Other	Foundational Questions Institute	98,489
	Raytheon BBN Technologies Corp	97,339
	Total	7,328,844

SUPERVISORS

All supervisors are either regular members (*), associate members (‡) or affiliated (†) with the Institute for Quantum Computing, and have supervisory privileges in one or more units at the University of Waterloo.

Supervisor	Supervisory Privileges	Quantum Information Research Interests
Michal Bajcsy*	Electrical and Computer Engineering	Nanophotonics and quantum optics Atom cooling and trapping on chips Cavity quantum electrodynamics Quantum memory and dark-state polaritons
Jonathan Baugh*	Chemistry Physics and Astronomy	Experimental investigation of spin qubits in quantum dots Electron spin resonance Nuclear magnetic resonance
Andrew Childs*	Combinatorics and Optimization Computer Science Physics and Astronomy	Theory of quantum information Quantum algorithms Quantum complexity theory
Kyung Soo Choi*	Physics and Astronomy	Experimental & theoretical quantum optics Atomic, molecular, optical physics Cold atom physics Cavity quantum electrodynamics Nanophotonics
Richard Cleve*	Combinatorics and Optimization Computer Science	Quantum algorithms Quantum complexity theory Quantum cryptography Quantum communication Theory of quantum information
David Cory*	Applied Mathematics Chemistry Electrical and Computer Engineering Physics and Astronomy	Experimental application quantum information processing Magnetic resonance and its applications Quantum sensors and actuators Neutron interferometry
Joseph Emerson*	Applied Mathematics Physics and Astronomy	Theory of open quantum systems Randomized benchmarking algorithms Theory of quantum measurement Quantum state and process tomography
Christopher Fuchs† (Perimeter Institute)	Applied Mathematics Physics and Astronomy	Bayesian, epistemic, and quantum information approaches to quantum foundations Theory of quantum measurement Symmetric structures in Hilbert space Philosophical implications of quantum information theory
Shohini Ghose† (Wilfrid Laurier)	Physics and Astronomy	Theory of entanglement and nonlocality Quantum chaos Theory of open quantum systems Theory of quantum measurement Continuous variable quantum computing
Daniel Gottesman† (Perimeter Institute)	Combinatorics and Optimization Physics and Astronomy	Quantum cryptography Quantum complexity theory Fault-tolerant quantum error-correction

Supervisor	Supervisory Privileges	Quantum Information Research Interests
Thomas Jennewein*	Physics and Astronomy	Experimental quantum communication and cryptography Global satellite-based quantum communication Entangled photon sources
Achim Kempf‡	Applied Mathematics Physics and Astronomy	Quantum information applied to quantum gravity/cosmology/computing Data compression
Robert Koenig*	Applied Mathematics	Quantum information theory Quantum cryptography Quantum many-body physics Mathematical physics
David Kribs‡ (University of Guelph)	Physics and Astronomy	Theory of quantum error correction Quantum channels
Jan Kycia‡	Physics and Astronomy	Experimental superconducting qubits Noise in Josephson junctions
Raymond Laflamme*	Applied Mathematics Computer Science Physics and Astronomy	Theory of quantum error correction Quantum control Experimental implementations of QIP with nuclear and electron spins Quantum cryptography Quantum communication
Anthony Leggett‡ (UIUC, Illinois)	Physics and Astronomy	Theory of quantum measurement Condensed matter theory
Debbie Leung*	Combinatorics and Optimization	Theory of quantum information Quantum communication Quantum cryptography Theory of Quantum error correction Fault-tolerant quantum computing
Adrian Lupascu*	Physics and Astronomy Electrical and Computer Engineering	Experimental superconducting qubits and circuits Hybrid quantum systems for QIP Quantum measurement Superconducting detectors Atom chips
Norbert Lütkenhaus*	Physics and Astronomy	Quantum cryptography Quantum communication Quantum state discrimination, Theory of linear optics implementations of QIP
Hamed Majedi*	Electrical and Computer Engineering Physics and Astronomy	Superconducting and photonic devices for QIP Single photon detectors Novel quantum and electromagnetic phenomena and structures Quantum-Nano-electrodynamics Quantum photonics
Vadim Makarov*	Physics and Astronomy	Quantum hacking (practical security of quantum cryptography) Experimental quantum communication and cryptography Single photon detectors
Robert Mann‡	Physics and Astronomy	Quantum information applied to gravity

Supervisor	Supervisory Privileges	Quantum Information Research Interests
Matteo Mariantoni[*]	Physics and Astronomy	Experimental superconducting quantum circuits Experimental quantum emulations of many-body systems Fault-tolerant quantum error correction Qubits based on Josephson tunnel junctions Circuit quantum electrodynamics Quantum microwaves Microwave devices and measurement
James Martin[‡]	Physics and Astronomy	Experimental atomic implementations of QIP
Dmitri Maslov[‡]	Physics and Astronomy	Quantum circuits Quantum compilers
Roger Melko[†]	Physics and Astronomy	Theory of strongly-correlated many-body systems
Guoxing Miao[*]	Electrical and Computer Engineering	Quantum transport over topologically protected surface states Superconductivity manipulation with spin proximity Spin-based nanoelectronic logic/memory units
Michele Mosca*	Combinatorics and Optimization Computer Science Physics and Astronomy	Quantum algorithms Quantum complexity theory Quantum cryptography Quantum information security Quantum testing
Ashwin Nayak*	Combinatorics and Optimization Computer Science	Quantum complexity theory Quantum cryptography Quantum algorithms Theory of quantum information Quantum communication
Marco Piani[*]	Physics and Astronomy	Quantum information theory Quantum entanglement (theory and applications) Non-classicality Non-locality Open quantum systems
Bill Power[‡]	Chemistry Physics and Astronomy	Experimental NMR implementations of QIP
Ben Reichardt*	Computer Science	Fault tolerant quantum computing Quantum algorithms Quantum complexity theory
Kevin Resch*	Physics and Astronomy	Experimental optical implementation of QIP Photon entanglement Nonlinear optics Interferometry
Pierre-Nicholas Roy[†]	Chemistry	Quantum molecular dynamics simulations Quantum Monte Carlo Feynman path integrals Coherent molecular rotation in nano-superfluid clusters Semiclassical dynamics Biophysics

Supervisor	Supervisory Privileges	Quantum Information Research Interests
Rob Spekkens† (Perimeter Institute)	Physics and Astronomy	Quantum information pertaining to the foundations of quantum theory
John Watrous*	Computer Science	Theory of quantum information Quantum algorithms Quantum complexity theory Quantum cryptography Quantum interactive proof systems Quantum zero-knowledge Theory of entanglement
Frank Wilhelm* (no longer supervises as of June 2013)	Physics and Astronomy	Theory of solid state implementations of QIP Quantum decoherence Quantum error correction Optimal quantum control
Chris Wilson*	Electrical and Computer Engineering	Microwave Quantum Optics Superconducting Qubits Nonlinear Dynamics
Bei Zeng‡ (University of Guelph)	Physics and Astronomy	Quantum information theory Coding theory Quantum computation Theory of quantum entanglement Mathematical physics

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Temperature dependent electron mobility in InAs nanowires	Urbasi Sinha	Raman Research Institute	Bangalore, India
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Interpolatability distinguishes LOCC from separable von Neumann measurements	Maris Ozols	IBM TJ Watson Research Center	New York, USA
Time-Efficient Quantum Walks for 3-Distinctness	Aleksandrs Belovs	University of Latvia	Latvia
	Frederic Magniez	CNRS, LIAFA, Univ Paris Diderot	Sorbonne, Paris-Cite, France
A framework for bounding nonlocality of state discrimination	Maris Ozols	IBM TJ Watson Research Center	New York, USA
Quantum entanglement and the communication complexity of the inner product function	W. Van Dam	University of Montreal	Montreal QC
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Exponential improvement in precision for simulating sparse Hamiltonians	Somma, Rolando	Macquerie University	Sydney, Austratlia
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Tractable simulation of error correction with honest approximations to realistic fault models	Easwar Magesan	IBM TJ Watson Research Center	Yorktown Heights, New York, USA
The resource theory of stabilizer quantum computation	Seyed Ali Hamed Mousavian	Perimeter Institute for Theoretical Physics	Waterloo, ON, Canada
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Demonstration of active routing of entanglement in a multi-user network.	I. Herbauts	Department of Physics, Stockholm University	\Stockholm, Sweden
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The entropy power inequality for quantum systems	G. Smith	IBM TJ Watson Research Center	Yorktown Heights, New York, USA
An optimal dissipative encoder for the toric code	Fernando Pastawski	CIT, Inst for Quantum Informatio and Matter	Pasadena, CA, USA
Classification of topologically protected gates for local stabilizer codes	S Bravyi	IBM TJ Watson Research Center	Yorktown Heights, New York, USA

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The classical capacity of quantum thermal noise channels to within 1.45 bits	G. Smith	IBM TJ Watson Research Center	Yorktown Heights, New York, USA
Limits on classical communication from quantum entropy power inequalities	G. Smith	IBM TJ Watson Research Center	Yorktown Heights, New York, USA
The robustness of magic state distillation against errors in clifford gates	Yafei yu	Laboratory of nanophotonic functional materials and devices, sipse & lqit, south china normal university	Guangzhou, china
Private Quantum Subsystems	Kribs, David W.	University of Guelph	Guelph, Ontario
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Experimental simulation of anyonic fractional statistics with an NMR quantum-information processor	Feng, Guanru	Tsinghua University	Guelph, Ontario
	Long, Guilu	Tsinghua University	Guelph, Ontario
Experimental realization of post-selected weak measurements on an NMR quantum processo	Jun Li	University of Science and Technology of China	China
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Experimental Three-Particle Quantum Nonlocality under Strict Locality Conditions	C. Erven	University of Bristol	Bristol, UK
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Interpolatability distinguishes LOCC from separable von Neumann measurements	Maris Ozols	IBM TJ Watson Research Center	Yorktown Heights, New York, USA
A framework for bounding nonlocality of state discrimination	Maris Ozols	IBM TJ Watson Research Center	Yorktown Heights, New York, USA
The locking-decoding frontier for generic dynamics	Frédéric Dupuis	Institute for Theoretical Physics, ETH Zurich	ETH Zurich, Switzerland
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Quantum Ground State Effect on Fluctuation Rates in Nano-patterned Superconducting Sturctures	H. Atikian	Harvard University	Massachusetts, USA
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Plasmonic Superconducting Nanowire Single Photon Detector	H. Atikian	Harvard University	Massachusetts, USA
Observation of tunnel magnetoresistance in a superconducting junction with Zeeman-split energy bands	Bin Li	Massachusetts Institute of Technology	Cambridge, Massachusetts, USA
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Direct evidence of spin filtering across MnFe2O4 tunnel barrier by Meservey-Tedrow experiment	S. Matzen	CEA-Saclay	Gif-Sur-Yvette, France
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Observing tunnel magnetoresistance in junctions comprising of superconductors with Zeeman-split energy bands	Bin Li	Massachusetts Institute of Technology	Cambridge, Massachusetts, USA
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A meet-in-the middle algorithm for fast synthesis of depth -optimal quantum circuits	Dmitri Maslov	National Science Foundation	Arlington, VA, United States
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Asymptotically optimal approximation of single qubit unitaries by Clifford and T circuits using a constant number of ancillary qubits	Dmitri Maslov	National Science Foundation	Arlington, VA, United States
Fast and efficient exact synthesis of single qubit unitaries generated by Clifford and T gates	Dmitri Maslov	National Science Foundation	Arlington, VA, United States
Solving the shortest vector problem in lattices faster using quantum search"	Thijs Laarhoven	Eindhoven University of Technology	Eindhoven, Netherlands
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Quantum Key Distribution in the Classical Authenticated Key Exchange Framework",	Douglas Stebila	Queensland University of Technology	Brisbane, Australia
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Quantum computing on encrypted data	A. Broadbent	University of Ottawa	Ottawa ON Canada
	L.K. Shalm	National Institute of Standards and Technology	Boulder Colorado, USA
	Z. Yan	Centre for Ultrahigh Bandwidth Devices for Optical Systems (CUDOS), Macquerie University	New South Wales, Australia
	R. Prevedel	Research Institute of Molecular Pathology, Max F. Perutz Laboratories GmbH	Vienna, Austria

Publication Title	External Collaborators	Collaborating Organization	Location
Coherent state exchange in multi-prover quantum interactive proof systems	B. Toner	University of Melbourne	Melbourne, Australia
The pumpistor: a linearized model of a flux-pumped dc-SQUID for use as a negativeresistance parametric amplifier	K.M Sundqvist	Chalmers University of Technology	Goteborg, Sweden
	S. Kintas	Chalmers University of Technology	Goteborg, Sweden
	M. Simoen	Chalmers University of Technology	Goteborg, Sweden
	P. Krantz	National Institute of Standards and Technology	Boulder, Colorado, USA
	P. Delsing	Chalmers University of Technology	Goteborg, Sweden
Proposal for a coherent quantum memory for propagating microwave photons	M Afzelius	University of Geneva	Geneva, Switzerland
	N. Sangouard	University of Geneva	Geneva, Switzerland
	G. Johansson	Chalmers University of Technology	Goteborg, Sweden
	M.U. Staudt	Chalmers University of Technology	Goteborg, Sweden
Fractional and integer quantum Hall effects in the zeroth Landau level in graphene	Dmitry A.	Harvard University	USA
	Benjamin E. Feldman	Harvard University	USA
	Amir Yacoby	Harvard University	USA
	Bertrand I. Halperin	Harvard University	USA
The effect of environmental coupling on tunneling of quasiparticles in Josephson junctions	Wilhelm, F. K.,	Saarland University Germany	Germany
	Sinha, U	Raman Research Institute	India
	Sinha, A	Centre for High Energy Physics, Indian Institute of Science, Bangalore, India	India
A comprehensive design and performance analysis of low Earth orbit satellite quantum communication	B Kumar2	COM DEV Canada	Cambridge, ON, Canada
	D Hudson2	COM DEV Canada	Cambridge, ON, Canada
	D'Souza2	COM DEV Canada	Cambridge, ON, Canada
	R Girard3,	Canadian Space Agency	Canada
Universality and thermalization in the Unruh effect	Brown, E. G.,	University of Waterloo	Cambridge,
	Brenna, W. G.,	University of Waterloo	
Vanishing quantum discord is not necessary for completely positive maps	Rodriguez-Rosario, C. A.	Harvard University, Cambridge, Massachusetts	
	Rivas, A.,	Universidad Complutense	Madrid, Spain
	Modi, K.,	Centre for Quantum Technologies, National University of Singapore, Singapore	
	Datta, A	Clarendon Laboratory, University of Oxforf	United Kingdom
Purified discord and multipartite entanglement	Brown, E. G.,	University of Waterloo	Ontario, Canada
	Webster, E. J.,	University of Waterloo	Ontario, Canada
	Kempf, A	Centre for Quantum Computing Technology, Department of Physics, University of Queensland,	Australia
Coherent manipulation of cold Rydberg atoms near the surface of an atom chip	Martin, J. D. D.	University of Waterloo	Waterloo, Ontario Canada
	Carter, J. D	University of Waterloo	Waterloo, Ontario Canada
Uniqueness of quantum states compatible with given measurement results	Kribs, D	University of Guelph	Guelph, Ontario, Canada
	Dawkins, H	University of Guelph	Guelph, Ontario, Canada
	Shultz, F	Wellesley College	Massachusetts, USA
Four-qubit pure states as fermionic states	Grassl, Markus	Centre for Quantum Technologies, National University of Singapore, Singapore	
Spontaneous emission and collection efficiency enhancement of single emitters in diamond via plasmonic cavities and gratings	Choy, Jennifer T	Harvard University	Cambridge, Massachusetts, USA
	Bulu, Irfan	Harvard University	Cambridge, Massachusetts, USA

Publication Title	External Collaborators	Collaborating Organization	Location
	Hausmann, Birgit J,	Harvard University	Cambridge, Massachusetts, USA
	Huang, I-Chun	Harvard University	Cambridge, Massachusetts, USA
	Loncar, Marko	Harvard University	Cambridge, Massachusetts, USA
Localized detection of quantum entanglement through the event horizon	Dragan, Andrzej	University of Nottingham,	Nottingham UK
		University of Warsaw	Warsaw Poland
	Doukas, Jason	Nationa; Institute for Informatics,	Tokyo, Japan
Berry phase quantum thermometer	Andrzej Dragan	University of Nottingham,	Nottingham UK
	Ivette Fuentes	University of Nottingham,	Nottingham UK
Universal Uncertainty Relations	Gour, G	Institute for Quantum Science and Technology, University of Calgary	Calgary, Canada
	Friedland, S	University of Illinois at Chicago,	Chicago, IL Usa
Generalized quantum microcanonical ensemble from random matrix product states	de Oliveira, T. R	Instituto de Fisica, Universidade Federal Fluminense,	Brazil
Phase transition of light on complex quantum networks. Optimal pair-generation rate for entanglement-based quantum key distribution. Electron transport in InAs-InAlAs core-shell nanowires Ancilla models for quantum operations: for what unitaries does the ancilla state have to be physical? Nonclassical microwave radiation from the dynamical Casimir effect Optimal working points for continuous-variable quantum channels	Halu, Arda	Northeastern University	Massachusetts, USA
	Vezzani, Alessandro	Dipartimento di Fisica, Universitá degli Studi di Parma	Italy
	Bianconi, Ginestra	Queen Mary University of London	UK
	Doucette, John	University of Waterloo (CS)	Waterloo, Ontario Canada
	LaPierre, Ray R.,	McMaster University	Hamilton, Canada
	Caves, C. M.	Centre for Quantum Inforation and Control, University of New Mexico,	Albuqurque, NM USA
		University of Queenland	Australia
	Jiang, Z.,	Centre for Quantum Inforation and Control, University of New Mexico,	Albuqurque, NM USA
	Johansson, J. R	Advanced Science Institute, RIKEN,	Japan
	Johansson, G	Microtechnology and Nanoscience, MC2, Chalmers University of Technology	Sweden
	Delsing, P	Microtechnology and Nanoscience, MC2, Chalmers University of Technology	Sweden
	Nori, Franco	Advanced Science Institute, RIKEN,	Japan
		University of Michigan	Ann Arbor, Michigan USA
	Marquardt, Chris	Max Planck Institute for the Science of Light, University of Erlangen-Nuernber	Germany
	Leuchs, Gerd	Max Planck Institute for the Science of Light, University of Erlangen-Nuernber	Germany
	Jain, Nitin	Max Planck Institute for the Science of Light, University of Erlangen-Nuernber	Germany
	Khan, Imran	Max Planck Institute for the Science of Light, University of Erlangen-Nuernber	Germany
	Wittmann, Christoffer	Max Planck Institute for the Science of Light, University of Erlangen-Nuernber	Germany
Spectral compression of single photons	Fedrizzi, A	Centre for Engineered Quantum Systems and Centre for Quantum Computer and Communication Technology, University of Queensland	Brisbane, Australia

Publication Title	External Collaborators	Collaborating Organization	Location
Higher-dimensional orbital-angular-momentum-based quantum key distribution with mutually unbiased bases	Mhlambululi Mafu	University of KwaZulu-Natal,	South Africa
	Angela Dudley	CSIR National Laser Centre,	South Africa
	Sandeep Goyal,	University of KwaZulu-Natal,	South Africa
	Daniel Giovannini,	SUPA, University of Glasgow,	Glasgow, United Kingdom
	Melanie McLaren,	CSIR National Laser Centre,	South Africa
	Miles J. Padgett,	SUPA, University of Glasgow,	United Kingdom
	Thomas Konrad,	School of Chemistry and Physics, University of KwaZulu-Natal, South Africa	
		National Institute for Theoretical Physics (NITheP), University of KwaZulu-Natal, South Africa	
	Francesco Petruccione,	School of Chemistry and Physics, University of KwaZulu-Natal, South Africa	
	Andrew Forbes	CSIR National Laser Centre, South Africa	
New Separations in Zero-Error Channel Capacity Through Projective Kochen-Specker Sets and Quantum Coloring	Scarpa, Giannicola	CWI, Organization for Scientific Research	Netherlands
	Severini, Simone	University College London	
Axis-matching excitation pulses for CPMG-like sequences in inhomogeneous fields	Mandal, S	Schlumberger-Doll Research	Cambridge, Massachusetts, USA
	Koroleva, V. D. M.,		
	Song, Y. Q.,		
	Hurlimann, M. D.		
Processing Quantum Information with Relativistic Motion of Atoms	Aasen, D.,	University of Waterloo (AM)	Waterloo, Canada
Wavepacket detection with the Unruh-DeWitt model	Miguel Montero,	nstituto de Fisica Fundamental, CSIC, Serrano 113-B, 28006 Madrid, Spain	
	Marco del Rey	nstituto de Fisica Fundamental, CSIC, Serrano 113-B, 28006 Madrid, Spain	
Sustainable entanglement production from a quantum field	Eric G Brown	University of Waterloo (AM)	Waterloo, Ontario Canada
	William Donnelly,	University of Waterloo (AM)	Waterloo, Ontario Canada
Dispersion-cancelled biological imaging with quantum-inspired interferometry	Prevedel, Robert.,	Research Institute of Molecular Pathology (IMP) & Max F. Perutz Laboratories, University of Vienna, Dr. Bohr Gasse 7-9, 1030 Vienna, Austria	
	Kaltenbaek, Rainer	Vienna Center for Quantum Science and Technology, Faculty of Physics, University of Vienna, Vienna, Austria	
Generating polarization-entangled photon pairs using cross-spliced birefringent fibers	Roy, Vincent	Institut National d'Optique, 2740 Rue Einstein, Quebec City, Quebec, Canada	
Improving frequency selection of driven pulses using derivative-based transition suppression	Motzoi, F	University of California, Berkeley, California	California, USA
Negativity of quantumness and its interpretations.	Adesso, G	University of Nottingham,	UK
Quantum Heating of a Nonlinear Resonator Probed by a Superconducting Qubit	Boissonneault, M.,	University of Sherbrooke	Quebec, Canada
		University Laval	Quebec, Canada
	Mallet, F	University Pierre, et Marie Curie	Paris, France
	Doherty, A. C.,	Centre for Engineered Quantum Systems, School of Physics, The University of Sydney,	
	Blais, A.,	University of Sherbooke	Quebec, Canada
	Vion, D	Quantronics group, Service de Physique de l'Etat Condense	France
Mode invisibility and single-photon detection	Onuma-Kalu, M.,	University of Waterloo	Waterloo, Ontario Canada
Truncated quantum channel representations for coupled harmonic oscillators	Ng, Wee Hao	Cornell University	Ithaca, NY USA
Universal Fault-Tolerant Quantum Computation with Only Transversal Gates and Error Correction	Reichardt, Ben	University of Southern California, USA	California, USA
Absence of Pauling's residual entropy in thermally equilibrated Dy2Ti2O7.	Ross, K. A	McMaster University	Hamilton ON Canada
	Noad, H. M. L	McMaster University	Hamilton ON Canada

Publication Title	External Collaborators	Collaborating Organization	Location
	Dabkowska, H. A	McMaster University	Hamilton ON Canada
	B. D. Gaulin	McMaster University	Hamilton ON Canada
Juxtaposition of spin freezing and long range order in a series of geometrically frustrated antiferromagnetic gadolinium garnets	Craig, H. A.,	University of California-Davis,	California, USA
	M. J. P. Gingras1	Guelph-Waterloo Physics Institute	Guelph, Ontario, Canada
	Corruccini, L. R	University of California-Davis,	California, USA
	Balakrishnan, G.,	University of Warwick	Coventry, United Kingdom
	Petrenko, O. A.,	University of Warwick	Coventry, United Kingdom
	Gomez, A.	Guelph-Waterloo Physics Institut, University of Guelph	Guelph, Ontario, Canada
	S. W. Kycia	Guelph-Waterloo Physics Institute, University of Guelph	Guelph, Ontario, Canada
Evidence of impurity and boundary effects on magnetic monopole dynamics in spin ice.	B. D. Gaulin	McMaster University	Hamilton, ON Canada
	Ross, K. A.,	McMaster University	Hamilton, ON Canada
	Noad, H. M. L	McMaster University	Hamilton, ON Canada
	Dabkowska, H. A.	McMaster University	Hamilton, ON Canada
New Dirac points and multiple Landau level crossings in biased trilayer graphene.	Serbyn, Maksym	Massachusetts Institute of Technology	Massachusetts, USA
Local Conservation Laws and the Structure of the Many-Body Localized States.	Serbyn, Maksym	Massachusetts Institute of Technology	Massachusetts, USA
	Papic, Z.,	Princeton University	Princeton NJ USA
Universal Slow Growth of Entanglement in Interacting Strongly Disordered Systems.	Papic, Z	Princeton University	Princeton NJ USA
	Serbyn, Maksym	Massachusetts Institute of Technology	Massachusetts, USA
Three-photon energy-time entanglement.	., Simon, C.,	Institute for Quantum Information Science and Department of Physics and Astronomy, University of Calgary,	Calgary Alberta, Canada
Exploring the geometry of qutrit state space using symmetric informationally complete probabilities	Appleby, D. M	Perimeter Institute for Theoretical Physics	Waterloo, Ontario Canada
		Stellenbosch Institute for Advanced Study, Stellenbosch University, Stellenbosch, South Africa	
Experimental violation of three families of Bell's inequalities	Noel, C.,	Massachusetts Institute of Technology	Massachusetts, USA
	Wolfe, E.	University of Connecticut	Connecticut, USA
Precision requirements for observing macroscopic quantum effects	Wang, Tian	Institute for Quantum Science and Technology, University of Calgary	Calgary, Alberta, Canada
	Ghobadi, Roohollah	Institute for Quantum Science and Technology, University of Calgary	Calgary, Alberta, Canada
	Simon, Christoph	Institute for Quantum Science and Technology, University of Calgary	Calgary, Alberta, Canada

2013 - 2014 SEMINARS AND COLLOQUIA

Seminar	Given By	Time
Ultimate Communication Capacity Of Quantum Optical Channels	Raul Garcia-Patron, Max-Planck-Institut für Quantenoptik, Germany	April 28, 2014
NMR As A Low Energy Probe Of Condensed Matter	Takashi Imai, McMaster University, Canada	April 21, 2014
Exponential Improvement In Precision For Simulating Sparse Hamiltonians	Robin Kothari, IQC	April 17, 2014
Operationally-Motivated Uncertainty Relations For Joint Measurability And The Error-Disturbance Tradeoff	Volkher Scholz, Institute for Theoretical Physics ETH Zurich, Switzerland	April 9, 2014
Algorithms and Complexity For Quantum Computing	Joseph F. Traub, Columbia University, U.S.	April 9, 2014
Quantum Receivers Beyond The Stand Quantum Limit Of Coherent Optical Communications	Jingyun Fan, National Institute of Standards and Technology, U.S.	April 8, 2014
Using Dissipation For Quantum Information Processing.	Fernando Pastawski, California Institute of Technology, U.S.	April 7, 2014
Topological Quantum Compiling With Fractional Quantum Hall States	Layla Hormozi, National University of Ireland, UK	April 7, 2014
Nano-Scale Quantum Sensing With Color Centers In Diamond	Jianming Cai, Universität Ulm, Germany	March 31, 2014
Semiconductor Quantum Light Sources	Michael Reimer, Delft University Of Technology, The Netherlands	March 31, 2014
Quantum Behaviour In Layered-2D Materials	Cory Dean, The City College Of New York, U.S.	March 31, 2014
Quantum Complexity Of Matrix Multiplication	Francois Le Gall, The University Of Tokyo, Japan	March 24, 2014
Interaction Between Propagating Phonons And A Superconducting Qubit	Per Delsing, Chalmers University Of Technology, Sweden	March 17, 2014
New Trends In Circuit Quantum Electrodynamics	Guillermo Esteban Romero Huenchuir, University Of Basque Country, Spain	March 13, 2014
Light Force Devices And Non-Classical Optics On A Chip	Wolfram Pernice, Karlsruhe Institute Of Technology, Germany	March 11, 2014
Quantum Simulations As Our Quantum Theatre	Enrique Solano, Universidad Del País Vasco, Bilbao, Spain	March 10, 2014
Inverse Spontaneous Emission Of An Atom In Free Space – An Example Of Time Reversal Symmetry In Optics	Gerd Leuchs, Max Planck Institute For The Science Of Light, Germany	March 5, 2014
Quasiparticle Effects In Superconducting Qubits	Gianluigi Catelani, Peter Grünberg Institute, Germany	Feb. 27, 2014
An Atom Trap Trace Analysis (ATTA) System To Measure Trace Contamination By Kr Of XENON Dark Matter Detector	Taehyun Yoon, Columbia University, U.S.	Feb. 25, 2014
Harnessing Single Photons In Quantum Information Processing: From 143 Km Quantum Teleportation To On-Chip Interaction-Free Measurement	Xiaosong Ma, Yale University, U.S.	Feb. 24, 2014
Atom-Light Interactions In Photonic Crystals	H. Jeff Kimble, California Institute of Technology, U.S.	Feb. 24, 2014
How To Demonstrate Contextuality In A Realistic Experiment	Matthew Pusey, Rob Spekkens, Perimeter Institute, Canada	Feb. 21, 2014
Applications Of Information Theory In Direct Sum And Direct Product Problems	Penghui Yao, National University Of Singapore, Singapore	Feb. 13, 2014
Non-Equilibrium Phonons In Nanostructures: From Mhz To Thz.	Jared B. Hertzberg, University of Maryland, U.S.	Feb. 3, 2014
Tuning The Ground State Of Fe Pnictide Superconductors	Ni Ni, University of California, Los Angeles. U.S.	Jan. 27, 2014

Seminar	Given By	Time
Probing Quantum Many-Body Systems At The Single-Particle Level	Manuel Endres, Max Planck Institute Of Quantum Optics In Garching, Germany	Jan. 21, 2014
New Directions In Quantum Simulation Of Quantum Chemistry	Peter Love, Haverford College, U.S.	Jan. 20, 2014
Gigantic Quantum Computers Made Out Of Laser Light	Nicolas Menicucci, University of Sydney, Australia	Jan. 8, 2014
Probing Particle Physics On The Tabletop: ACME's Improved Limit On The Electron's Electric Dipole Moment	Paul Hess, Harvard University, U.S.	Dec. 17, 2013
Entanglement In Quantum Fluids Via Quantum Monte Carlo	Chris Herdman, University of Vermont, U.S.	Dec. 17, 2013
Entanglement Farming: Harnessing The Properties Of Fixed Points In Quantum Evolution	Eduardo Martin-Martinez, IQC	Dec. 16, 2013
Relativistic Quantum Cryptography	Igor Radchenko, Russian Academy of Sciences, Russia	Dec. 10, 2013
Quantum Circuits: From Qubits To Condensed Matter Physics	Juan Jose Garcia Ripoll, Instituto De Física Fundamental, Spain	Dec. 9, 2013
Strong Converse Theorems In Quantum Information Theory	Mark Wilde, Louisiana State University, U.S.	Nov. 26, 2013
The Security Loophole In Real Quantum Cryptography System	Linmei Liang, National University Of Defence Technology, China	Nov. 26, 2013
Quantum Mixing Time Bounds From Poincare And Logarithmic Sobolev Inequalities	Kristan Temme, Massachusetts Institute of Technology, U.S.	Nov. 25, 2013
Perfect Squeezing By Damping Modulation In Circuit QED	Farzad Qassemi, Université De Sherbrooke, Canada	Nov. 21, 2013
Classical Signatures Of Quantum Annealing	Dr. Graeme Smith, IBM TJ Watson Research Centre, U.S.	Nov. 19, 2013
High Fidelity Spin Entanglement Using Optimal Control	Ville Bergholm, ISI Foundation – Institute for Scientific Interchange, Italy	Nov. 12, 2013
The Quantum PCP Conjecture	Dorit Aharonov, The Hebrew University of Jerusalem, Israel	Nov. 11, 2013
Quantum Annealing	Matthias Troyer, Institute for Theoretical Physics Eth Zurich, Switzerland	Nov. 4, 2013
Many-Body Entanglement And Tensor Network States	Guifre Vidal, IQC	Oct. 28, 2013
Structuring Your Research Paper	Jean-Luc Doumont, Principiæ, Belgium	Oct. 22, 2013
Coherent Electronic States In Semiconductor Nanowires: Flux Quantization, And Proximity-Effect Superconductivity	Jonathan Baugh, IQC	Oct. 21, 2013
Vibrationally Enhanced Quantum Transport	Casey Myers, University of Queensland, Australia	Oct. 10, 2013
Towards A Proof Of The Classical Intractability Of Quantum Simulation	Michael Bremner, University of Technology, Syndey	Oct. 7, 2013
An Inequality Between Entanglement Entropy And A Number Of Encoded Qubits	Dr. Isaac Kim, Perimeter Institute, Waterloo	Sept. 23, 2013
Monolithic Nonlinear And Quantum Photonics	Amr S. Helmy, University of Toronto, Canada	Sept. 19, 2013
Quantum Interactive Proofs And The Complexity Of Entanglement Detection	Gus Gutoski, IQC	Sept. 16, 2013
Quantum Networks With Spins In Diamond	Tim Taminiau, Delft University of Technology, The Netherlands	Aug. 19, 2013
On Attaining The Quantum Limit Of Classical Optical Communication	Saikat Guha, Raytheon-BBN Technologies, U.S.	Aug. 15, 2013

Seminar	Given By	Time
Quantum Repeaters And Secret Key Rates: The Role Of Distillation And Classical Communication	Sylvia Bratzik, University of Duesseldorf, Germany	Aug. 12, 2013
Abstract Cryptography	Christopher Portmann, Institute For Theoretical Physics Eth Zurich, Switzerland	Aug. 2, 2013
G+ Hangout: Thermalization, Error-Correction, And Memory Lifetime For Ising Anyon Systems	Steven Flammia, University of Washington, U.S.	July 30, 2013
Entropy On Quantum System With Infinitely Many Degrees Of Freedom And Their Applications	Volkher Scholz, Institute for Theoretical Physics ETH Zurich, Switzerland	July 29, 2013
Butterflies In Moire Patterned Graphene	Cory Dean, The City College of New York, U.S.	July 24, 2013
Active Decoherence-Prevention Methods For Metrology	Roee Ozeri, Weizmann Institute of Science, Israel	July 22, 2013
Computational And Cryptanalytic Consequences Of Time Travel	Debbie Leung, IQC	July 19, 2013
Parallel Approximation Of Min-Max Problems	Gus Gutoski, IQC	July 12, 2013
Quantum Contextuality Can Be Operationally Quantified	Paweł Horodecki, Gdańsk University of Technology, Poland	July 8, 2013
Security Of Quantum Communication Networks: Beyond QKD	Rolando Somma, Los Alamos National Laboratory, U.S.	June 24, 2013
Recent Progress In Studies Of Communication Complexity Of XOR Functions	Shengyu Zhang, Chinese University Of Hong Kong, China	June 18, 2013
Lossy Quantum Data Compression	Nilanjana Datta, University of Cambridge, UK	June 17, 2013
The Search For Majorana Modes In Solid-State Systems.	Roman Lutchyn, Microsoft Research Station Q, Santa Barbara, U.S.	June 10, 2013
	Luming Duan, University of Michigan, U.S. and Tsinghua University, China	June 10, 2013
Recent Progress In Quantum Computation And Simulation With Trapped Ions	Luming Duan, University of Michigan, U.S. and Tsinghua University, China	June 10, 2013
Finite-Precision Computation Of Ordered Operator-Exponential Decomposition	Ish Dhand, University of Calgary, Canada	June 6, 2013
Quantum Simpsons Paradox And High Order Bell-Tsirelson Inequalities	Yaoyun Shi, University of Michigan, U.S.	June 3, 2013
Time-Resolved Magnetic Sensing With Electronic Spins In Diamond	Alexandre Cooper-Roy, Massachusetts Institute of Technology, U.S.	May 30, 2013
MAQRO - Testing The Foundations Of Quantum Physics In Space	Rainer Kaltenbaek, University of Vienna, Austria	May 29, 2013
Electronic Excitations And Charge Inhomogeneity In Indium Atomic Chains	Hui Zhang, University of Science And Technology, China	May 29, 2013
Collective Dynamics In Circuit QED: Criticality, Entanglement Chirality And Quantum Chaos.	David Zueco, Universidad De Zaragoza, Spain	May 28, 2013
Polylog Quantum Simulation + The Stochastic Heisenberg Limit	Dominic Berry, Macquarie University, Australia	May 28, 2013
Quantum Replication At The Heisenberg Limit	Giulio Chiribella, Tsinghua University, China	May 27, 2013
Tradeoffs Between Thermal And Quantum Fluctuations In 2D Quantum Memories	David Poulin, Université De Sherbrooke	May 27, 2013
Connections Between Quantum Computing And Quantum Algebra	Greg Kuperberg, University f California, Davis, U.S.	May 24, 2013
Quantum Computation And Phenomenological Hermeneutics	Michele Mosca, IQC	May 24, 2013

Seminar	Given By	Time
The Direct Detection Of Classically Undetectable Dark Matter Through Quantum Decoherence	Jess Riedel, IBM, U.S.	May 21, 2013
Quantum Hamiltonian Complexity: Through The Computational Lens	Umesh Vazirani, University of California, Berkeley, U.S.	May 17, 2013
Proving Laundauer's Principle	David Reeb, Technische Universität München, Germany	May 13, 2013
Group-Theoretic Cryptography	Spyros Magliveras, Florida Atlantic University, U.S.	May 13, 2013
The Rank Method And Applications To Post-Quantum Cryptography	Mark Zhandry, Stanford University, U.S.	May 6, 2013
QND Microwave Photon Detection And Relativistic Physics In Superconducting Circuits	Göran Johansson, Chalmers University of Technology, Sweden	May 6, 2013
Entangled?	Matthias Christandl, Institute for Theoretical Physics ETH Zurich, Switzerland	May 1, 2013

INVITED TALKS

Note: Talks in the list below which fall outside the May 1, 2013 - April 30, 2014 time period are included if they were not captured in the 2011 - 2012 report.

Faculty Member	Date	Title	Where	Location
Jonathan Baugh	1-Mar-14	Quantum transport in nanowires: developing platforms for semiconductor-based QIP	Technion Quantum Information Workshop	Haifa, Israel
	1-Dec-13	Phase-coherent transport in nanowires: normal and superconducting regimes", Quantum Materials to Quantum Devices Workshop, Dec. 2013 (Waterloo)	University of Waterloo	Waterloo, Ontario
	1-Nov-13	Spin dynamics under continuous fields: noise spectroscopy	NMR QIP Conference	Rio de Janeiro, Brazil
	21-Oct-13	Coherent electronic states in semiconductor nanowires: flux quantization, and proximity effect superconductivity	IQC Colloquium	Waterloo, Ontario
	1-Jun-13	Electronic coherence in nanoscale semiconductor devices	International Workshop on Frontiers in Quantum Information Science	Shanghai, China
Michal Bajcsy	18-Mar-14	"Light-matter interactions in photonic-crystal nanocavities: applications and potential for scalability," QUBIT Workshop	Technion, Israel Institute of Technology	Haifa, Israel
	17-Jan-14	"Nano-photonic structures for scalable applications of quantum optics," Quantum Innovators Workshop	IQC, University of Waterloo	Waterloo, Ontario
	7-Jan-14	Cavity enhanced light-matter interactions and their use for non-classical light generation	44th Winter Colloquium on the Physics of Quantum Electronics	Snowbird, Utah
	7-Feb-14	Ultra-low power all-optical switching with a single quantum dot in a photonic-crystal cavity	Advances in Photonics of Quantum Computing, Memory, and Communication IV, SPIE Photonics West	San Francisco, California

Faculty Member	Date	Title	Where	Location
Andrew Childs	31-Mar-14	Exponential improvement in precision for simulating sparse Hamiltonians	NIST-UMD Workshop on Quantum Information and Computer Science	East Hyattsville, Maryland
	11-Apr-14	The computational power of quantum walk	Perimeter Institute for Theoretical Physics	Waterloo, Ontario
	10-Feb-14	The computational power of quantum walk	University of Maryland	College Park, Maryland
	9-Dec-13	Simulating Hamiltonian dynamics on a small quantum computer,	IBM TJ Watson Research Center	Yorktown Heights, New York
	16-Nov-13	The computational power of multi-particle quantum walk	CIFARWorkshop on Quantum Information Processing	Sherbrooke, Quebec
	1-May-13	Universal computation by multi-particle quantum walk	Georgia Institute of Technology	Atlanta, Georgia
	24-May-13	Workshop on Quantum Com-putation and Complex Networks	University of Waterloo	Waterloo, Ontario
Richard Cleve	6-Dec-13	Simulating quantum behavior with quantum computers	National University of Singapore	Singapore, SIngapore
David Cory	20-Jun-13	Realizing Quantum Information Processors	13th Canadian Workshop on Information Theory	Toronto, Ontario
	29-Jul-13	Coupling Electron Spins to Superconductors	Rocky Mountain Conference on Magnetic Resonance	Copper Mountain, Colorado
	28-Sep-13	Cavity Cooling Spin Qubits	BIT Nano Science and Technology	Xi'an, China
	25-Sep-13	Quantum Computing with Spins	University of Science and Technology China	Hefei, China
	16-Feb-14	Quantum Sensor	AAAS 2014 Annual Meeting	Chicago, Illinois
Joseph Emerson	2-Jul-13	Negative quasi-probability and contextuality are equivalent resources for quantum computation	University of British Columbia	Vancouver, British Columbia
	16-Aug-13	Negative quasi-probability, contextuality and magic are equivalent resources for quantum computation	Fields Institute	Toronto, Ontario
	18-Jun-13	Negativity, Contextuality and Quantum Speed-up	Last Frontiers in Quantum Information Science	Denali Park, Alaska
	5-Nov-13	Contextuality supplies the magic for quantum computing	FQXi Workshop on Quantum Contextuality and Sequential Measurements	Madrid, Spain
	3-Mar-14	The resource theory of stabilizer computation	American Physical Society March Meeting	Denver, Colorado
Thomas Jennewein	24 - 28 Jun-13	The Quantum Space Race, and how it can help Exploring new Physics	invited talk at the conference Relativistic Quantum Information North	University of Nottingham, UK
	26-Feb-14		University of Ottawa - (Part of Quantum Photonics Series)	Ottawa, Ontario
	05-Feb-14	QEYSSAT: a mission proposal for a quantum receiver in space	SPIE (Photonics West, OPTP - Advances in Photonics of Quantum Computing, Memory, and Communication VII)	San Francisco, California
Robert Koenig	21-Jan-13	16th Workshop on Quantum Information Processing (QIP) ,Classification of topologically protected gates for local stabilizer codes	Institute for Interdisciplinary Information Sciences (IIIS), Tsinghua University	Beijing, China

Faculty Member	Date	Title	Where	Location
	9-Jan-13	Beyond iid in quantum information theory. The entropy power inequality and the classical capacity of thermal noise channels	Statistical Laboratory, University of Cambridge	Cambridge, UK
	17-Dec-13	Quantum information seminar, RWTH	Institute for Quantum Information, RWTH Aachen	Aachen, Germany
	28-Aug-13	Mathematical Challenges in Quantum Information, Newton Institute,	Newton Institute	Cambridge, UK
	17-Jul-13	Institute for Quantum Information and Matter group meeting, Caltech,	Institute for Quantum Information and Matter, Caltech	Pasadena, California
	9-Jul-13	IEEE Summer Topicals	IEEE Photonics Society	Waikoloa, Hawaii
	12-Jun-13	CIFAR Quantum Information Processing Meeting	Canadian Institute for Advanced Research	Alberta,
	23-May-13	Symposium KCIK 2013,	National Quantum Information Centre, Gdansk	Sopot, Poland
	3-May-13	Viterbi School of Engineering seminar, University of Southern California	Ming Hsieh Department of Electrical Engineering, University of Southern California	Los Angeles, California
	1-May-13	Institute for Quantum Information and Matter group meeting, Caltech	Institute for Quantum Information and Matter, Caltech	Pasadena, California
Raymond Laflamme	1-Jun-13	Keynote talk	OSA Student conference in Ottawa	Ottawa, Ontario
	24-Jun-13	Experimental Quantum Error Correction	Qsart conference at Inst for Advanced studies, Hebrew University	Jerusalem, Israel
	Oct-13	Brain STEM	Perimeter Institute	Waterloo, Ontario
	22-Oct-13	Quantum Information Processing	WWRF conference	Vancouver, British Columbia
	27-Nov-13	Experimental Quantum Error Correction	NMR-QIP conference	Rio de Janeiro, Brazil
	10-Dec-13	Accelerating a Fin Tech Ecosystem	Bloomberg Tech conference	London, UK
	7-Jan-14	Measuring And Manipulating Information	FQXi conference	Vieques Island, Puerto Rico
	4-Feb-14		QEC course guest lecture, IQC	Waterloo, Ontario
	16-Feb-14	Moderator on a panel	AAAS 2014 Symposium	Chicago, Illinois
	26-Feb-14		Research Matters	Queen's Park, Toronto, Ontario
Debbie Leung	2 - 6 Sep, 2013	"The little we know about LOCC"	New Mathematical Directions for Quantum Information, Isaac Newton Institute, University of Cambridge	Cambridge, UK
	14 - 16 Mar, 2013	Computational and Cryptanalytic Consequences of Time Travel	From Monopoles to Fault-Tolerant Quantum Computation - Conference in honor of John Preskill's 60th birthday, Caltech	Pasadena, California

Faculty Member	Date	Title	Where	Location
Adrian Lupascu	19 - 21 Oct-13	Superconducting flux quantum bits: magnetometry and quantum control	6th International Workshop on Solid State Quantum Computing	Beijing, China
	27 - 31 May-13	Artificial atoms based on superconducting tunnel junctions: fundamentals and applications	CAP Annual Congress	Montreal, Quebec
	5 Apr, 2013	Using an artificial atom to measure magnetic signals and noise	Seminar in the Department of Physics, Syracuse University	Syracuse University, Syracuse, New York
Matteo Mariantoni	15-Jun-13	Building a Superconducting Quantum Computer with Surface Codes	Canadian Institute for Advanced Research (CIFAR), Quantum Information Processing Meeting, Matrix Hotel	Edmonton, Alberta
Vadim Makarov	10-Nov-13	Hot topics in physical informatics	Hunan University	Hunan, China
	23-Sep-13	SPIE Security+Defence	SPIE - the international society for optics and photonics	Dresden, Germany
	15-May-13	Quantum telecommunications workshop	Instituto de Telecomunicações	Lisbon, Spain
Guo-Xing Miao	27-Sep-13	Methods of Realizing Superconducting Spin Valves	BIT 3rd Annual World Congress of Nano S&T	Xi'an, China
	24-Sep-13	Spin Filtering and Magnetic Proximity with Rare-Earth Magnetic Insulator	University of Science and Technology of China	Hefei, China
Michele Mosca	24-May-13	Quantum Computation and Phenomenological Hermeneutics	St. Jerome's University	Waterloo, Ontario
	27-May-13	Introduction to Quantum Information	Undergraduate School on Experimental Quantum Information Processing (USEQIP 2013)	Waterloo, Ontario
	11-Jun-13	Quantum-safe Cryptography and Information Security	CIBC	Toronto, Ontario
	5-Jul-13	Quantum Computing and the Synthesis and Optimization of Quantum	5th conference on Reversible Computation (RC2013)	Victoria, British Columbia
	17-Jul-13	Computer and Internet Security	University of Calgary	Calgary, Alberta
	14-Nov-13	Towards Quantum-Safe Cryptography	Université de Montréal	Montreal, Quebec
	2-Dec-13	Preparing for the Future World of Quantum Computing	Taft lectures, Taft Research Center	Cincinnati, Ohios
	31-Jan-14	Towards Quantum-Safe Cryptography	Manulife	Waterloo, Ontario
	5-Mar-14	Towards Quantum-Safe Cryptography	CIBC	Toronto, Ontario
	14-Mar-14	Quantum computing and cryptography	BITS Pilani, India	Pilani, India
	11-Apr-14	Quantum computing and cryptography	CIFAR Lunch and Learn workshop	Toronto, Ontario
Kevin Resch	8 - 9 Jul, 2013	Dispersion-cancelled imaging using chirped laser pulses	International Workshop on New Science and Technologies using Entangled Photons (NSTEP), Osaka University	Osaka, Japan
	9 - 14 Jun, 2013	Dispersion-cancelled imaging and quantum nonlinear optics with shaped light pulses	Conference on Lasers and Electro-Optics (CLEO) 2013, San Jose, U.S.	San Jose, California

Faculty Member	Date	Title	Where	Location
Chris Wilson	1-Nov-13	Observation of the Dynamical Casimir Effect in a Superconducting Circuit	Colgate University	Hamilton, New York
	1-May-13	Hybrid Systems for Quantum Information	University of Waterloo	Waterloo, Ontario

OUTREACH ACTIVITIES

Fiscal 2013 Events

Name	When	# Attendees	Description
Canadian Undergraduate Technology Conference	May 4, 2013	200	M. Laforest giving presentations about the application of QIP to undergraduate engineering students from accross Canada
Norwell District Secondary School	May 21, 2013	22	Presentation and tour for high school students
Public Talk: Serge Haroche	May 23, 2013	120	Public lecture by Nobel laureate
Municipal Information Systems Association annual conference	June 5, 2013	250	Presentation about the future of information technology to IT professional
Discovery Square - City of Kitchener	July 2, 2013	100	Provided physics based demos for an outdoor science exhibits. Open to all ages.
Catalyst Summer Leadership Program	July 9-23, 2013	30	Provided 3x90min workshop on quantum cryptography and information security
ISSYP 2013	July 15, 2013	45	Presentation and tour for the International Summer School for Young Physicists
Science Media Centre of Canada Webinar	July 24, 2013		Webinar featuring Raymond Laflamme and Michele Mosca and the future of quantum information technology
Quantum Frontier Distinguished Lecture:: John Preskill	August 6, 2013	200	"Quantum computing and the entanglement frontier"
CEMC Summer Conference for Computer Studies Educator	August 15, 2013	50	Presentation about basic quantum computing and how it can be taught to high school students
Avonova technology leaders, Stratford	September 3, 2013	25	Presentation about quantum information technology to the technology leaders in Stratford
StarSpot podcast	September 8, 2013		Podcast featuring M. Laforest about quantum information and the quantum sattelite proposal
Doors Open	September 21, 2013	1154	IQC was part of the Doors Open - Waterloo region. Visitors followed a self-guided tour throughout the Mike and Ophelia Lazaridis Quantum-Nano Centre and had access to a "Ask a scientist" section
Q-Kids Science Show	September 21, 2013	220	In parallel to Doors Open, M. Laforest presented a 45min science show for kids age 2-12
Public Lecture: David Cory	September 21, 2013	180	In parallel to Doors Open: "Not you typical ghost story: telling stories in a quantum world"

Name	When	# Attendees	Description
Perimeter Institute's BrainSTEM	September 30-October 6 2013	25000	IQC prepared and presented an interactive booth on quantum cryptography that was part of the "Physica Fanstastica" portion of the "BrainSTEM: Your future is now" festival organized and help at the Perimeter Institute
St-John's Kilmarnock high school	October 8-9	30	Presentation and tour for grade 9 students
Conestoga College IEEE Chapter	October 29, 2013	30	Presentation about QIP
Waterloo Unlimitted	November 13, 2013	12	E. Meyer-Scott conducted a workshop entitled "Using quantum mechanics to explore new frontiers in cryptography" to grade 12 Waterloo Unlimited participants
University of Guelph undergraduate students	November 15, 2013	30	Presentation and tour for undergrads taking a quantum information course by Bei Zeng
Sunshine Montessori School	November 18, 2013	13	Hands-on workshop on quantum mechanics and tour for grade 7-8 students
Laurentian University Science Communication Program	November 22, 2013	15	M. Laforest and J. Szimanski explain the reality and challenges of science communication within a scientific institute and presented the science of IQC
Quantum Frontier Distinguished Lecture: Paul Corkum	December 5, 2013	45	"Attosecond Science and High Harmonic Spectrosocpy"
Ecole Secondaire Sainte-Famille	December 4, 2013	15	Hands-on workshop on quantum mechanics and tour for grade 11-12 students
ManuLife Data Privacy Month Exhibit	January 29, 2014	~100	IQC presented an interactive exhibit during lunch time at ManuLife focused on quantum cryptogrphy and the future of information security. This was part of a month-long awarness campaign.
ManuLife Data Privacy Month: Toward Quantum Safe Cryptograph	January 31, 2014	60	Michele Mosca gave a presentation to ManuLife staff in Waterloo and was broadcast to other ManuLife offices across Canada
AAAS symposium: Quantum Information Technology	February 16, 2014	~100	Raymond Laflamme and David Cory participated in a symposium at AAAS 2014. They were joined by Michel Devoret from Yale and Gregoire Ribordy from ID Quantique.
ZOOM Career day, Business Education Partnership, Waterloo Region	February 27, 2014	40	Marco Piani gave an interactive workshop about quantum mechanics and quantum cryptography to ICT oriented high school students
Collegiate Peaks Forum Series	March 6, 2014	200	M. Laforest delivered a public lecture in Buena Vista, CO, about Quantum Information Science and Technology
Science International Women's Day	March 8, 2014	60	Catherine Holloway organized a session for girls 8-13 years old
Waterloo Unlimited	March 10, 2014	20	Intereactive workshop entitled "Design of Classical and Quantum Cryptography Systems" to grade 11 participants in the Waterloo Unlimited "Design" program.
PI day: "The history of Pi and prime numbers"	March 14, 2014	40	The IQC Graduate Students Association co-organized, with MathSoc, a talk featuring Jason Bell from the department of Pure Mathematics in celebration of PI day
Quantum Frontier Distinguished Lecture: John Kirtley	March 20, 2014	80	"Scanning SQUID Microscopy of Topological Insulators"

Name	When	# Attendees	Description
Shad Valley - Design your Future	March 24, 2014	285	M. Laforest delivered an inspiring quick lecture about the importance of curiosity driven scientific research in the technological landscape to grade 8-9 students. This was part of a day long activity organized by Shad Valley during the national Engineering Month.
Screening of "Gravity", with astronaut and IQC Associate Faculty Steve Maclean	April 2, 2014	150	IQC Graduate Students Association organized a screening of "Gravity" followed with a Q&A with Canadian astronaut and IQC associate faculty Steve Maclean
Woodland high school	April 2, 2014	38	Presentation, interactive demos on quantum cryptography and superconductivity and tours
Rockway high school	April 7, 2014	20	Presentation and tour for high school students
Uxbridge Secondary High school	April 11, 2014	42	Presentation, interactive demos on quantum cryptography and superconductivity and tours
Centre Wellington District High School	April 23, 2014	25	Presentation and tour for high school students

MEDIA COVERAGE

The following table outlines the media coverage IQC received mentioning our Executive Director Raymond Laflamme.

Date	Media Outlet	Media Tier	Subject	Link to Coverage
May 4	The Waterloo Region Record	Regional	IQC and its work in quantum	http://www.therecord.com/news/local/article/928949--imagining-a-quantum-future
June	Phototonics Spectra	International science	Quantum computers	http://www.photonics.com/Article.aspx?AID=54048
June 25	The Waterloo Region Record	Regional	Institute for Quantum Computing	http://www.therecord.com/community-story/3855521-institute-for-quantum-computing/
July 8	Bloomberg	International business	Canada's technology advancement and quantum computers	http://www.bloomberg.com/news/2013-07-08/ex-goldman-executive-taps-google-in-quantum-bet.html
July 22	MIT Technology review	International tech	Development of quantum computing	http://www.technologyreview.com/news/516536/the-bell-labs-of-quantum-computing/
July 22	Top News	International	Development of quantum computing	http://topnews.net.nz/content/228610-facts-about-quantum-computing
July 24	The Economist	International business	IQC, quantum computing and quantum devices	http://www.economist.com/blogs/babbage/2013/07/babbage-july-24th-2013
Aug. 22	The Waterloo Region Record	Regional	Perimeter Institute event	http://www.therecord.com/news-story/4042413-perimete-presents-technology-and-science-future-festival/

Date	Media Outlet	Media Tier	Subject	Link to Coverage
Aug. 31	The Waterloo Region Record	Regional	IQC and its part in boosting uWaterloo's goal of global recognition	http://www.therecord.com/news-story/4058329-uw-to-boost-co-op-education-and-focus-research-as-it-strives-for-global-recognition/
Sept. 11	The Waterloo Region Record	Regional	Perimeter Institute event	http://www.therecord.com/news-story/4073301-perimeter-institute-reaches-out-to-young-students-with-brainstem/
Sept. 14	livescience	International science	Teleportation experiments	http://www.livescience.com/39655-qubits-teleported-across-computer-chip.html
Sept. 17	GMA News online	Filipino national	Teleportation experiments	http://www.gmanetwork.com/news/story/326840/scitech/technology/teleportation-technology-paves-the-way-for-quantum-computers
Sept. 26	Canadian Business	National business	Quantum computers	http://us7.campaign-archive1.com/?u=e42c58640b8594c67503814f3&id=fdeed191bf&e=276aed7537
Oct. 1	The Waterloo Region Record	Regional	Perimeter Institute event	http://www.therecord.com/news-story/4133313-code-crackers-helped-turn-war-s-tide
Oct. 1	Metroland News Service	Provincial	Perimeter Institute event	http://metronews.ca/news/kitchener/811504/code-crackers-helped-turn-wars-tide/
Oct. 2	naturejobs.com	International science	History of quantum mechananics in Waterloo	http://www.nature.com/naturejobs/science/articles/10.1038/nj7469-129a
Oct. 3	The Waterloo Region Record	Regional	Lucy Hawking's book	http://www.therecord.com/news-story/4136636-lucy-hawking-answers-questions-big-and-small/?&article_id=15534372783
Nov, 1	Bloomberg Business	International business	University of Waterloo as a feeder school to Silicon Valley	http://www.businessweek.com/articles/2013-10-31/university-of-waterloo-silicon-valleys-canadian-feeder-school
Nov. 21	Maclean's	National	Mike Lazaridis on Power List	http://www2.macleans.ca/2013/11/21/no-10-on-our-power-list-mike-lazaridis/
Nov, 24	Quantum Bayesian Networks	Quantum blog	Mike Lazaridis on Power List	http://qbnets.wordpress.com/2013/11/24/quantum-computers-and-canadian-wimpiness/
Nov. 27	Maclean's	National	Mike Lazaridis on Power List	http://www2.macleans.ca/2013/11/27/in-conversation-with-mike-lazaridis/
Dec. 7	National Post	National	Mike Lazaridis' investment in quantum	http://news.nationalpost.com/2013/12/07/the-quantum-computing-revolution-blackberry-billionaire-mike-lazaridis-is-betting-on-tech-that-hasnt-been-invented-yet/

Date	Media Outlet	Media Tier	Subject	Link to Coverage
Dec. 12	The Waterloo Region Record	Regional	Hawking documentary	http://www.therecord.com/news-story/4264391-hawking-documentary-comes-to-waterloo/
Dec. 18	Bloomberg NOW	International business	Bloomberg Enterprise Technology Summit	http://www.bloomberg.com/now/2013-12-18/bloomberg-enterprise-technology-summmit/
Dec. 19	New Statesman	UK national	Bloomberg Enterprise Technology Summit	http://www.newstatesman.com/2013/12/quantum-leap-profit?&article_id=16251870664
Jan. 31	Science Codex	International science	NSA researching quantum technologies	http://www.sciencecodex.com/nsa_pursues_quantum_technology-127101
February	Physics World	International science	NSA researching quantum technologies	N/A
Feb. 10	Waterloo stories	University of Waterloo	AAAS annual meeting	https://uwaterloo.ca/stories/meeting-global-challenges
Feb. 11	Huff Post Canada	National	Finding talent in Waterloo Region	http://www.huffingtonpost.ca/pat-d-lynch/post_6726_b_4703534.html?1392135247
Feb. 17	Waterloo stories	University of Waterloo	Commercialzation of quantum technologies	https://uwaterloo.ca/stories/leading-quantum-revolution
Feb. 18	Daily Bulletin	University of Waterloo	Address at the Canadian Club	http://www.bulletin.uwaterloo.ca//2014/feb/18tu.html
Feb. 21	uw Imprint	University of Waterloo	Allocation of federal budget to IQC	http://www.uwimprint.ca/article/4081-federal-government-allocates-15-million-towards
Feb. 24	The Waterloo Region Record	Regional	Music partnership with Edwin Outwater	N/A
Mar. 14	Tech Generation Daily	International tech	Oblivious transfer paper published	http://www.tgdaily.com/general-sciences-features/89941-quantum-physics-secures-new-cryptography-scheme
Mar. 18	Waterloo News	University of Waterloo	Partnership with Technion University	https://uwaterloo.ca/news/news/waterloo-technion-partner-advance-research-commercialization
Mar. 18	Waterloo stories	University of Waterloo	Partnership with Technion University	https://uwaterloo.ca/stories/waterloo-technion-partner-advance-research-commercialization
Mar. 18	Lab Product News	National tech	Partnership with Technion University	http://www.labcanada.com/news/new-partnership-to-advance-research-commercialization/1002967199/?&er=NA
Mar. 19	Jersulem Post	Israel national	Partnership with Technion University	http://www.jpost.com/National-News/Technion-inks-cooperation-deal-with-Canadas-University-of-Waterloo-345791
Mar. 19	Daily Bulletin	University of Waterloo	Partnership with Technion University	http://www.bulletin.uwaterloo.ca/2014/mar/19we.bak

Date	Media Outlet	Media Tier	Subject	Link to Coverage
Mar. 19	Space Daily	International science	Oblivious transfer paper published	http://www.spacedaily.com/reports/Quantum_physics_secures_new_cryptography_scheme_999.html?&article_id=17136141480
Mar. 19	IT World Canada	National tech	Partnership with Technion University	http://www.itworldcanada.com/article/uwaterloo-israels-technion-partner/90469
Mar. 20	Electronic Products and Technology	National tech	Partnership with Technion University	http://www.ept.ca/news/waterloo-technion-partner-to-advance-research-nanotechnology/1002970666/?&er=NA
Mar. 27	Asian Scientist	Asian science	Oblivious transfer paper published	http://www.asianscientist.com/in-the-lab/1-2-random-oblivious-transfer-cybersecurity-2014/
Apr. 8	Waterloo Chronicle	Regional	Oblivious transfer paper published	http://www.waterloochronicle.ca/news/iqc-displays-quantum-cryptography/
Spring 2014	Innovators Magazine	Regional	Institute for Quantum Computing	Print publication

Both quantum cryptography and the satellite project by Associate Professor Thomas Jennewein have attracted a large amount of media coverage. The following table lists the coverage with regards to quantum cryptography.

Date	Media Outlet	Media Tier	Subject	Link to Coverage
May 1	Venture Beat	International tech	Quantum cryptography and the quantum hacking lab	http://venturebeat.com/2013/05/01/this-white-hat-hacker-cracks-quantum-encryption-for-fun-and-profit/
July 9	New Scientist	International science	Quantum key distribution	http://www.newscientist.com/article/dn23837-quantum-version-of-nazi-enigma-machine-is-uncrackable.html#.Ud2Sn1NgPuQ
Aug. 2	Phys Org	International science	QCrypt conference	http://phys.org/wire-news/136892516/waterloo-hosts-international-conference-on-future-of-quantum-cry.html
Aug. 2	Waterloo Stories	University of Waterloo	QCrypt conference	https://uwaterloo.ca/stories/will-quantum-cryptography-hold-key-data-security
Aug. 6	Exchange	Regional	QCrypt conference	http://www.exchangemagazine.com/morningpost/2013/week32/Tuesday/13080606.htm
Aug. 6	Canada's Tech Triangle	Regional	QCrypt conference	http://www.scoop.it/t/canada-s-technology-

Date	Media Outlet	Media Tier	Subject	Link to Coverage
				triangle
Aug. 8	CBC	National	QCrypt conference	http://www.cbc.ca/kitchener-waterloo/ (may not be posted online)
Aug. 9	Waterloo Stories	University of Waterloo	QCSYS	https://uwaterloo.ca/stories/not-your-typical-week-camp
Aug. 13	Daily Bulletin	University of Waterloo	QCSYS	http://www.bulletin.uwaterloo.ca//2013/aug/13mo.html
Sept. 11	Optics.org	Interntional science	ID Quantique Winter School on Practical Quantum Communications	http://optics.org/press/2114
Oct. 16	The American Conservative	US National	Encryption of digital communications	http://www.theamericanconservative.com/can-quantum-encryption-protect-your-data/?utm_source=rss&utm_medium=rss&utm_campaign=can-quantum-encryption-protect-your-data&article_id=1565056 0988
Fall 2013	@alumni	University of Waterloo	Student profile of a quantum hacker	https://uwaterloo.ca/alumni/sites/ca.alumni/files/uploads/files/accessible_pdf.pdf
Jan. 1	Popular Science	International science	Spyproof Code	N/A
Mar. 7	Business Insider	International business	Encryption	http://www.businessinsider.com/what-is-quantum-encryption-2014-3?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+typepad%2Falleyinsider%2Fsilicon_alley_insider+%28Silicon+Alley+Insider%29
Mar. 8	Business Insider Australia	Australia National business	Encryption	http://www.businessinsider.com.au/what-is-quantum-encryption-2014-3
Mar. 10	Business Insider	National business	'100-year problem' in data security	http://www.businessinsider.com/quantum-encryption-2014-3?utm_source=partner&utm_medium=newstex&utm_term=original&utm_campaign=partner
Mar. 10	Seattle Post Intelligence	US local	'100-year problem' in data security	http://www.seattlepi.com/technology/businessinsider/article/Quantum-Encryption-Is-On-The-Verge-Of-Solving-The-4920613.php
Mar. 12	IT World Canada	National tech	Oblivious transfer paper published	http://www.itworldcanada.com/article/waterloo-researchers-team-

Date	Media Outlet	Media Tier	Subject	Link to Coverage
				on-quantum-based-security/90283
Mar. 12	Scientific Computing	International science	Oblivious transfer paper published	http://www.scientificcomputing.com/news/2014/03/quantum-physics-secures-new-cryptography-scheme
Mar. 14	New Electronics	UK national tech	Oblivious transfer paper published	http://www.newelectronics.co.uk/electronics-news/quantum-based-random-oblivious-transfer-could-enable-trusted-communication/60119/
Mar. 14	Tech Generation Daily	International tech	Oblivious transfer paper published	http://www.tgdaily.com/general-sciences-features/89941-quantum-physics-secures-new-cryptography-scheme
Mar. 17	Wired	International tech	Oblivious transfer paper published	http://www.wired.com/wiredenterprise/2014/03/quantum-crypto-google/
Mar. 19	Space Daily	International science	Oblivious transfer paper published	http://www.spacedaily.com/reports/Quantum_physics_secures_new_cryptography_scheme_999.html?&article_id=17136141480
Mar. 27	Asian Scientist	Asian science	Oblivious transfer paper published	http://www.asianscientist.com/in-the-lab/1-2-random-oblivious-transfer-cybersecurity-2014/
Mar. 27	Overclockersclub.com	Tech blog/forum	Experiment Opens the Door to Multi-Party Quantum Communication	http://www.overclockersclub.com/news/35895/
Mar. 27	TVTechnology	US National tech	Experiment Opens the Door to Multi-Party Quantum Communication	http://www.tvtechnology.com/distribution/0099/experiment-raises-possibility-of-multiparty-quantum-communication/269605#sthash.PETH9D7X.dpuf

The satellite project led by Thomas Jennewein has amounted in a large amount of media coverage due to the partnerships with industry partners and its tie to the DATA.BASE project. The table below lists the media coverage.

Date	Media Outlet	Media Tier	Subject	Link to Coverage
May 4	The Record	Regional	Imagining a quantum future	http://www.therecord.com/news/local/article/928949--imagining-a-quantum-future
May 6	IEEE Spectrum	International science	Commercial Quantum Cryptography Satellites Coming	http://spectrum.ieee.org/aerospace/satellites/commercial-quantum-cryptography-satellites-coming

May 20	The Commercial Space Blog	Blog	The New World of Space Based Quantum Cryptography	http://acuriousguy.blogspot.ca/2013/05/the-new-world-of-space-based-quantum.html
May 25	The Economist	International business	The solace of quantum	http://www.economist.com/news/science-and-technology/21578358-eavesdropping-secret-communications-about-get-harder-solace?fsrc=rss%7Csct
May 27	Communitech blog	Regional blog	Communitech and the Institute for Quantum Computing: Detaangling the Code	https://www.communitech.ca/communitech-and-the-institute-for-quantum-computing-detangling-the-code/
Jun. 25	Space News	International science	Com Dev Aims To Place Quantum Cryptography System on Microsatellite	http://www.spacenews.com/article/military-space/35970com-dev-aims-to-place-quantum-cryptography-system-on-microsatellite#.UcuDCBZgPFJ
Jun. 25	The Record	Regional	Institute for Quantum Computing	http://www.therecord.com/community-story/3855521-institute-for-quantum-computing/
Jul. 8	Bloomberg	International business	Canada Pins Fresh Tech Hopes on Quantum Computing	http://www.bloomberg.com/news/2013-07-08/ex-goldman-executive-taps-google-in-quantum-bet.html
Jul. 11	RE$EARCH MONEY	International business	Communitech to build cluster around new satellite business with $6.4M FedDev grant	Teamer:\\op.d\com-team\News Coverage\2013 News coverage\Communitech_in_ResMoney.pdf
Jul. 11	Next Big Future	National tech	Quantum Canada	http://nextbigfuture.com/2013/07/quantum-canada.html
Jul. 22	MIT Technology Review	International tech	The Bell Labs of Quantum Computing	http://www.technologyreview.com/news/516536/the-bell-labs-of-quantum-computing/
Aug. 13	CNW	National	Building the world's first structured big data ecosystem	http://www.newswire.ca/en/story/1209691/building-the-world-s-first-structured-big-data-ecosystem
Aug. 13	Digital Journal	International tech	Building the world's first structured big data ecosystem	http://www.digitaljournal.com/pr/1410803
Aug. 13	TechVibes	National tech	Communitech Launches Data.Base, the World's First Structured Big Data Ecosystem	http://www.techvibes.com/blog/communitech-launches-database-the-worlds-first-structured-big-data-ecosystem-2013-08-13
Aug. 13	itbusiness.ca	National business	Communitech's Database program to launch satellites, harvest 'big data'	http://newsle.com/article/0/88630423/
Aug. 14	The Record	Regional	Communitech project aims to create businesses from big data	http://www.therecord.com/news-story/4030205-communitech-project-aims-to-create-businesses-from-big-data/
Oct. 23	Bloomberg TV	International business	Life Beyond BlackBerry	http://www.bloomberg.com/video/the-town-blackberry-built-is-anything-left-YetV~cw7Q82O77RDV2lkhw.html

Nov. 1	CASI Toronto Flyer	Provincial science	IQC Researcher Awarded Canadian Space Agency Contract	http://www.casi.ca/assets/casi%20flyer%20nov13.pdf (page 7)
Nov. 15	Hispanic Business News	International business	Findings from University of Waterloo Provides New Data on Science	http://www.hispanicbusiness.com/2013/11/7/findings_from_university_of_waterloo_provides.htm
Dec. 7	National Post	National	The quantum computing revolution: BlackBerry billionaire Mike Lazaridis is betting on tech that hasn't been invented … yet	http://news.nationalpost.com/2013/12/07/the-quantum-computing-revolution-blackberry-billionaire-mike-lazaridis-is-betting-on-tech-that-hasnt-been-invented-yet/
Dec. 9	Canadian Space Society News Highlights	National science	Big CSA contract to u of Waterloo researchers for quantum encryption	
Dec. 11	Popular Science	International science	2014: The Year In Science - Lasers Unleash A Flood Of Space Data	http://www.popsci.com/article/science/year-science-2014
Jan. 1	Popular Science	International science	2014: The Year in Science	http://www.popsci.com/article/science/year-science-2014
Feb. 14	Photonics Spectra	International science	Quantum Communications Finds any Paths to Comercialization	http://www.photonics.com/Article.aspx?AID=55841
Mar. 23	Digital Journal	Internatinal tech	Experiment Opens the Door to Multi-Party Quantum Communication	http://www.digitaljournal.com/pr/1806028
Mar. 23	Photonics Online	International science	Experiment Opens The Door To Multi-Party Quantum Communication	http://www.photonicsonline.com/doc/experiment-opens-the-door-to-multi-party-quantum-communication-0001
Mar. 24	The Register	UK national	EXPOSED: bizarre quantum sibling LOVE TRIANGLE	http://www.theregister.co.uk/2014/03/24/exposed_bizarre_quantum_sibling_love_triangle/?&article_id=17180699155
Mar. 24	International Science Times	International science	Scientists Demonstrate Three-Way Quantum Communication: What's Faster Than The Speed Of Light?	http://www.isciencetimes.com/articles/6986/20140324/scientists-demonstrate-three-way-quantum-communication-light-speed.htm?&article_id=17186813431
Mar. 25	Science World Report	International science	Experiment Opens the Door to Multi-Party Quantum Communication	http://www.scienceworldreport.com/articles/13666/20140325/experiment-opens-the-door-to-multi-party-quantum-communication.htm
Mar. 25	Liberty Voice	U.S. national	Multi-Party Quantum Communication Possible	http://guardianlv.com/2014/03/multi-party-quantum-communication-possible/
Mar. 28	PlanetSave	Science blog	Experiment Opens the Door to Multi-Party Quantum Communication	http://planetsave.com/2014/03/28/quantum-entanglement-experiment-proves-non-locality-for-first-time-will-permit-multi-party-quantum-communication/

Apr. 5	Frankfurter Allgemeine Wissen	German regional	Experiment Opens the Door to Multi-Party Quantum Communication	http://www.faz.net/aktuell/wissen/physik-chemie/einsteins-fernwirkung-drei-photonen-treiben-seltsamen-spuk-12873620.html
Apr. 10	@uwaterloo alumni newsletter	University publication	Experiment Opens the Door to Multi-Party Quantum Communication	http://alumni.uwaterloo.ca/alumni/e-newsletter/2014/apr/
April	CIFAR Knowledge circle	National scientific membership	Experiment Opens the Door to Multi-Party Quantum Communication	http://knowledgecircle.cifar.ca/towards-secure-three-party-quantum-communications/

The opening of David Cory's UHV lab in December also attracted a fair amount of media coverage.

Date	Media Outlet	Media Tier	Link to Coverage
Dec. 9	Digital Journal	International tech	http://www.digitaljournal.com/pr/1630922
Dec. 10	RTBlog		http://www.mediapost.com/publications/article/215239/a-picture-worth-a-thousand-quants.html
Dec. 10	Exchange Morning	Regional	http://www.exchangemagazine.com/morningpost/2013/week50/Tuesday/13121004.htm#anchor
Dec 12	Cambridge Times	Regional	http://www.cambridgetimes.ca/news-story/4270137-scientists-hail-milestone-in-quantum-quest/
Dec. 12	The Waterloo Region Record	Regional	http://www.therecord.com/news-story/4270137-scientists-hail-milestone-in-quantum-quest/
Dec. 18	Waterloo Chronicle	Regional	http://www.waterloochronicle.ca/news/a-quantum-leap-foward/
Jan/Feb	Chemical Institute of Canada	National science	http://www.cheminst.ca/magazine/news/new-quantum-laboratory-opens-university-waterloo?&article_id=16313758518
Jan	@uwaterloo alumni	University of Waterloo	http://alumni.uwaterloo.ca/alumni/e-newsletter/2014/jan/
Jan. 3	betakit	Blog	http://www.betakit.com/new-5-million-quantum-computing-tool-will-revolutionize-u-of-waterloos-iqc-program/
Jan. 10	UW Imprint	University of Waterloo	http://www.uwimprint.ca/article/3899-new-funding-will-provide-further-opportunities
Jan. 22	AZtoM	International science	http://www.azom.com/news.aspx?newsID=39796

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http://spectrum.ieee.org/aerospace/satellites/commercial-quantum-cryptography-satellites-coming

http://venturebeat.com/2013/05/08/how-ontario-plans-to-become-the-worlds-top-technology-hub/

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http://venturebeat.com/2013/05/15/an-inside-look-at-the-worlds-newest-quantum-computing-and-nanotechnology-center/

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TOUR GROUPS

Group	Date	# of Participants
Perimeter Institute Particle Physics group	May 9,2013	8
School of Accounting Tour	May 10, 2013	8
Alojzy Nowak, Andrzej Twardowski, University of Warsaw	May 15, 2013	2
Kelly McManus Tour	May 30, 2013	5
Laura Ferrarese	June 10, 2013	1
University of Ghana MBA students	July 2, 2013	28
James Grimm (Numberfile youtube channel)	October 4, 2013	1
Karl Gebhardt	October 11, 2013	1
Guidance councillors	October 24, 2013	15
Muhibur Rahman (University Grant Commission, Bangladesh)	October 31, 2013	1
Dayal Pyari Srivastava (ECE postdoc candidate)	AprilApril 16, 2014	3
Jeff Crelinstem (Impact group)	June 18, 2013	1
Alumni Council Tour	June 25, 2013	
PhD Students from University of Ghana	July 5, 2013	27
Laurier Center for Women in Science	July 11, 2013	10
ISSYP: PI Summer school tour	July 15, 2013	45
Bill Frezza and Mike Lazaridis	July 18, 2013	2
Catalyst Group	July 23, 2013	10
QKD summer school participant	August 2, 2013	50
WGSI	September 29, 2013	30
University of Guelph	November 15, 2013	30
Greg Mumford	November 21, 2013	1
Laurentian University	November 22, 2013	15
National University of Defense Technology:	November 26, 2013	3

Group	Date	# of Participants
Linmei Liang, Xiangchun Ma, Mucsheng Jiang		
President of Monash University, Mr. Byrne	MarchMarch 27, 2014	3
Introduction to Quantum Information Processing students	AprilApril 1, 2014	40
Woodland high school	AprilApril 4, 2014	38
Rockway high school	AprilApril 7, 2014	20
Uxbridge Secondary High school	AprilApril 11, 2014	42
Centre Wellington District High School	AprilApril 23, 2014	25
KPMB Architech Tour + Guests from Lethbridge University	AprilApril 2, 2014	8
KW NerdNite	July 3, 2013	15
Minister Moridi, Minister of Research and Innovation, Provinicial	July 3, 2013	3
Members of Government from Abu Dhabi	MarchMarch 21, 2014	4
Rick Filsinger (Peter Braid's office)	April 16, 2014	1
Brazilian Delegation Tour	June 11 2013	
Deputy NSA Nehchal Sandhu Tour	June 24 2013	3
City of Waterloo Mayor: Brenda Hollaran	July 2 2013	3
Assistant Deputy Shereen Benzvy Miller Industry Canada	August 9, 2013	1
Mr. Andrew Bevan, Premier Wynne's Principle Secretary	August 22, 2013	2
Kelly Gillis, Industry Canada	August 29, 2013	2
Delegation from Oman	September 13, 2013	3
Charles Sousa, Minister of Industry	September 13, 2013	4
Harold Albrecht- MP	October 3, 2013	2
Peter Braid- MP	October 3, 2013	2
US Embassy in Ottawa	November 7, 2013	3
CSEC representative	November 12, 2013	3
Minister Greg Rickford (Science and Technology)	November13th, 2013	2
Joshua Bowie, industry Canada	December 5, 2013	1
Julie Sunday and Debbie Kemp, the Directors and Deputy Director of Department Foreign Affairs Trade Development, Science, Technology and Innovation branch	JanuaryJanuary 15, 2014	2
Tracey Weiler, Ontario PC Candidate	JanuaryJanuary 30, 2014	
Stephen Del Duco	FebruaryFebruary 13, 2014	2
Tracey Weiler, Ontario PC Candidate	JanuaryJanuary 11, 2014	2
Ministry of Economic Development, Trade Employment	JanuaryJanuary 14, 2014	2
Blackberry: Delegation from the Government of India	November 14, 2013	6
CIBC: Ken Giuliani, Max Cizauskas, Siman Baker, Atefeh Masatan	August 8, 2013	4
Fujistu	September 6, 2013	4
Dr. John Bergsma (retired, Former President & CEO, Union Gas) BASc Mechanical Engineering 1969 MASc Civil Engineering 1971 Honourary Doctor of Laws 1997 Nathan Brown (Vice President and Advisor, Brown Financial Security) BASc Civil Engineering 1996	September 13, 2013	2
Jim and Judy Mitchell	September 28, 2013	
General Walter Natychuk, Eric Lalibertie, Christian Choiulnard	October 29, 2013	3
"Future Directions in Security, Cryptography, and Privacy" attendees	November 6, 2013	20
CIBC	April 21, 2014	4

Group	Date	# of Participants
VC Media Tour	May 1, 2013	
Laurel Society Tour	May 28, 2013	
Donor Tour	June 6, 2013	
Bonnie Oberl Math Alumni QNC Tour	June 7, 2013	
Canadian Tire Headquarters-Craig Hanley	September 25, 2013	3
BMO- Dawn Lutchman	October 28, 2013	2
Canada's Technology Tour	December 5, 2013	19
RBC: Francine Dyksterhuis - Regional President SWO for RBC, Jonathan Shepherd, who is a Director in RBC Corporate Development and possibly Larry Smith (former Prof. at Waterloo)	FebruaryFebruary 6, 2014	3
Ian D'Souza, ComDev President Rob Spurrett	MarchMarch 7, 2014	2
Mr. Gerry Schwartz, Chairman of the Board, President and Chief Executive Officer of Onex	MarchMarch 11, 2014	2
Avvey Peters from Communitech	August 8, 2013	2