UNIVERSITY OF WATERLOO | IQC Institute for Quantum Computing

Industry Canada Report

2012/13 Reporting Period
Institute for Quantum Computing
University of Waterloo
June 15, 2013

Note from the Executive Director

Harnessing the quantum world will lead to new technologies and applications that will change the world. The quantum properties of nature allow the accomplishment of tasks which seem intractable with today's technologies, offer new means of securing private information and foster the development of new sensors with precision yet unseen.

In a short 10 years, the Institute for Quantum Computing (IQC) at the University of Waterloo has become a world-renowned institute for research in the quantum world. With more than 160 researchers, we are well on our way to reaching our goal of 33 faculty, 60 post doctoral fellows and 165 students. The research has been world class and many results have received international attention. We have recruited some of the world's leading researchers and rising stars in the field.

2012 has been a landmark year. Not only did we celebrate our 10th anniversary, but we also expanded into our new headquarters in the Mike and Ophelia Lazaridis Quantum-Nano Centre in the heart of the University of Waterloo campus. This 285,000 square foot facility provides the perfect environment to continue our research, grow our faculty complement and attract the brightest students from around the globe.

In this report, you will see many examples of the wonderful achievements we've celebrated this year. IQC researcher Andrew Childs and his team proposed a new computational model that has the potential to become an architecture for a scalable quantum computer. Professors Thomas Jennewein and Kevin Resch generated three entangled photons, a powerful resource to fuel novel quantum technologies. Researchers Vadim Makarov and Thomas Jennewein successfully demonstrated quantum teleportation over 143 kilometres. These and other research discoveries at IQC are continuing to enhance the field of quantum science and elevate IQC to an internationally recognized leader in quantum research and experimentation.

IQC's recent accomplishments are notable, but only reveal half of the story. Over the coming years, IQC will expand to its full complement of researchers and students – rivaling the world's largest quantum information research institutes. Our research will expand from discovery and experimentation to discovery, experimentation and innovation. We will uncover new and exciting ways to utilize the quantum properties of nature to develop devices that will revolutionize fields such as geological exploration, health care, and information security. We will continue to reach into

the atomic world to understand, control and harness the laws of quantum mechanics for the betterment of society.

IQC has enjoyed a considerable lead in developing the infrastructure and resources required to remain a world leader in this important area of research. But the world has woken up to the quantum revolution. We are seeing significant investment in quantum science in China, Singapore, the United States and Europe. IQC is unique in the field as it grew out of strengths at the Univeristy of Waterloo in computer science and engineering. The ecosystem that surrounds IQC is filled with innovation – from the fundamental science of Perimeter Institute to the startup engine of Communitech and the new venture capital opportunities with Quantum Valley Investments. With all of the elements in place, IQC has the ideal environment to excel in quantum science and innovation.

And with this Canada has the opportunity to be a world leader in the quantum revolution. IQC has created an environment where research and innovation blossom, where theory meets experiments, where experimentation meets commercialization, where investments support results. The next decade promises to be an exciting time in our history - a time when new technologies will provide unprecedented precision and power...all to the benefit of our society. The quantum revolution is here and IQC is leading the charge for Canada.

I look forward to continuing this journey of innovation along with the Government of Canada. Thank you for your continued support.

Sincerely,

Raymond Laflamme, Executive Director

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NOTE: Cover photo courtesy of Savannah Lomack.

Executive Summary

Harnessing the quantum world

2012 was a hallmark year for the Institute for Quantum Computing at the Univeristy of Waterloo. Not only did we celebrate our 10th anniversary, but we also celebrated the opening of our new headquarters – the Mike and Ophelia Lazaridis Quantum-Nano Centre. These celebrations brought thousands of people through our doors and raised awareness of the incredible science that's happening here in Waterloo.

Over IQC's ten-year history, we have made incredible strides in the advancement of quantum science. Our research team has grown to over 160 resident researchers, 160 visiting researchers from institutions around the globe and a over 100 graduate students. These world-class researchers are exploring quantum information from various perspectives – theoretical foundations (quantum error correction, algorithms, complexity theory, quantum information theory) to experimental approaches (quantum processing via spin, optics, nanoelectronics and more). And increasingly, we see the innovations sparked by these endeavours lead to quantum technologies – sensors and actuators for example. The work at IQC now spans the full innovation spectrum.

As these quantum technologies expand beyond the lab into the marketplace, we'll see them become a driving force in the 21st century economy. From biomedical applications to geological exploration, we will soon see quantum technologies that provide precision and accuracy as yet unseen by today's technology. By harnessing the quantum world, quantum technologies will provide opportunities for technological development that will greatly impact society for the better.

Academic programs at IQC prepare the next generation for the quantum world. Our collaborative graduate program brings together six university departments from three faculties across campus. IQC summer schools introduce quantum science to high school and undergraduate students. Additionally, our outreach programs bring the science out of the labs and into realm of the general public. We strive to make the quantum world more easily understood and accessible.

The next ten years will see incredible advancements in quantum science. IQC will grow to its full complement of 33 faculty members, 60 postdocs, and 165 graduate students. We will continue to expand our research from theory and experimentation to theory, experimentation and innovation – bringing quantum technologies to life. IQC will continue to foster meaningful collaborations with international researchers to ensure Canada remains a leader in this important area of research.

Researchers at IQC share a common goal – to build a general purpose quantum computer. Although many believe this goal to be years, if not decades, away, IQC works to bring that goal closer to reality. We will continue to reach into the atomic world to understand, control and harness the laws of quantum mechanics for the betterment of society. Quantum information science is a relatively young field. Yet the work of quantum researchers has advanced the field at an incredible speed.

This success is in no small part due to the generous support of Industry Canada and our many other supporters. It has empowered IQC to build a world-class institution that can attract leaders in the quantum world, bring the best and brightest students to Waterloo and provide an environment that fosters collaboration and innovation at the highest level.

The Institute for Quantum Computing

The Institute for Quantum Computing is a scientific research institute at the University of Waterloo harnessing the quantum laws of nature to develop powerful new technologies that will transform information technology and drive the 21st century economy.

IQC was launched a decade ago thanks to the pioneering vision and incredibly generous personal investment of Mike Lazaridis. The BlackBerry creator understood that truly revolutionary technologies can only emerge when scientists are given the resources and intellectual freedom to pursue trailblazing research. Lazaridis had already demonstrated this passion and support for fundamental science by founding Waterloo's Perimeter Institute for Theoretical Physics, where scientists ponder the deepest questions of reality.

Lazaridis also saw the need to transform fundamental discoveries, through laboratory experiments, into practical technologies with widespread societal impact. He recognized quantum information science as a nascent area of research that was in the midst of moving from pure theory to lab experimentation and real applications. With this in mind, he teamed with David Johnson (then president of the University of Waterloo), to establish a new, cutting-edge research facility at the university. The duo recruited Raymond Laflamme, a top quantum information scientist then working at Los Alamos National Laboratory, to turn their idea into a reality.

Lazaridis, Laflamme and Johnston knew the University of Waterloo - with its established history of scientific excellence and entrepreneurial spirit - would provide fertile intellectual soil from which this new institute could grow. They worked closely with Prof. Michele Mosca, a University of Waterloo mathematics alumnus who had recently earned his doctorate at Oxford, to establish the core group of researchers and key areas of focus to plant the seeds. Through partnerships between the private sector, academia and the federal and provincial governments, IQC launched in 2002 with Laflamme as its executive director and Mosca as deputy director.

Today, IQC is home to over 160 researchers including faculty, post doctoral fellows and graduate students. Research at IQC is fundamentally interdisciplinary — spanning theory and experiment — to pursue many avenues of quantum information science. IQC's core areas of research include quantum information theory, quantum algorithms, quantum complexity, quantum cryptography, quantum error correction and fault tolerance, spin-based quantum information processing, nanoelectronics-based quantum information processing, and optical quantum information processing. Hundreds of advances and breakthroughs in quantum information science have happened through research conducted at IQC, with discoveries published in *Science, Nature, Physical Review Letters* and many other leading journals.

The multi-disciplinary approach involves interaction with the Faculties of Engineering, Mathematics and Science. IQC faculty members are appointed in the departments of Applied Mathematics, Chemistry, Combinatorics and Optimization, Computer Science, Electrical and Computer Engineering and Physics & Astronomy.

Why Quantum?

Quantum theory is not a new research endeavour. Scientists have been studying quantum effects for nearly a century. So, why do we embark on such research? The scientists at IQC have a common goal – to harness the quantum world and create a quantum computer – a computer that promises exponential increases in processing speed. The goal of building a quantum computer is no doubt the "holy grail" of quantum research and may be many years away. Yet, along the way to that goal, we are discovering many interesting, and potentially revolutionary, uses of quantum information.

Quantum devices - sensors and actuators - utilize the laws of quantum mechanics to reach the ultimate efficiencies and sensitivities allowed by nature. Nuclear Magnetic Resonance (NMR) technology has long been used in biomedical imaging (better known as MRI). NMR also serves as a natural test bed for quantum computing as the technology manipulates the quantum states of nuclear "spins" in molecules. Because the nuclei behave like tiny magnets, they can be controlled and manipulated using magnetic fields and radiofrequency pulses – and thus serve as qubits.

Spin-based systems can also be used as sensors that will achieve precision and robustness far beyond their classical counterparts. Research in spin-based systems has included the improvement of neutron interferometry (NI). The development of interferometers inspired by quantum error correction techniques has already resulted in greatly enhanced robustness and permitted the design of special purpose neutron interferometer for new applications to magnetic and soft matter. Quantum actuators currently under development include electron spin control of nuclear spins, electron spin control of transport, optical control of electron and nuclear spins, and electron spin control of superconducting circuits. Ultimately, this research aims to integrate quantum sensors and actuators into more complex systems and achieve higher levels of functionality. These complex systems could be used, for example, to detect single spins or even serve as building blocks for the development of practical quantum information processors.

In quantum optics, photons (particles of light) are used to carry quantum information. Each photon has a polarization - for instance, vertical or horizontal, which can be ascribed with the classic bit states of zero and one, respectively. But polarization can also be in a quantum superposition of these states - essentially zero and one at the same time. Since the means of manipulating the polarization of photons are well understood and easily achievable, optics makes an ideal test-bed for investigating quantum information processing.

Quantum Key Distribution (QKD) capitalizes on quantum optics to provide highly secure cryptography. The rules of quantum mechanics dictate that a quantum system cannot be observed without being disrupted. This means quantum "keys", delivered via entangled photons, will bear the indelible fingerprint of any attempted eavesdropping or hackers. Eavesdropped keys can then be abandoned, and only truly private keys are kept to be used in unbreakable encryption protocols. Today's encryption systems rely on mathematical problems too difficult for today's computers to crack. But future computers, in particular quantum computers, will be able to decrypt many such coded messages. Whereas, quantum encryption methods like QKD, have the potential to provide worldwide secure information channels.

IQC's endeavour to harness the quantum world has already led to discoveries that will benefit society. From quantum sensors to quantum information networks, the research

happening at IQC will produce a new generation of quantum technologies embracing the laws of nature for accuracy and precision unheard of today.

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 development 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 diagram outlines the Industry Canada funding spend by IQC over the term of the agreement to date.

	2010	2011	2012	2013	2014 Budget	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

Achievements & Results

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.

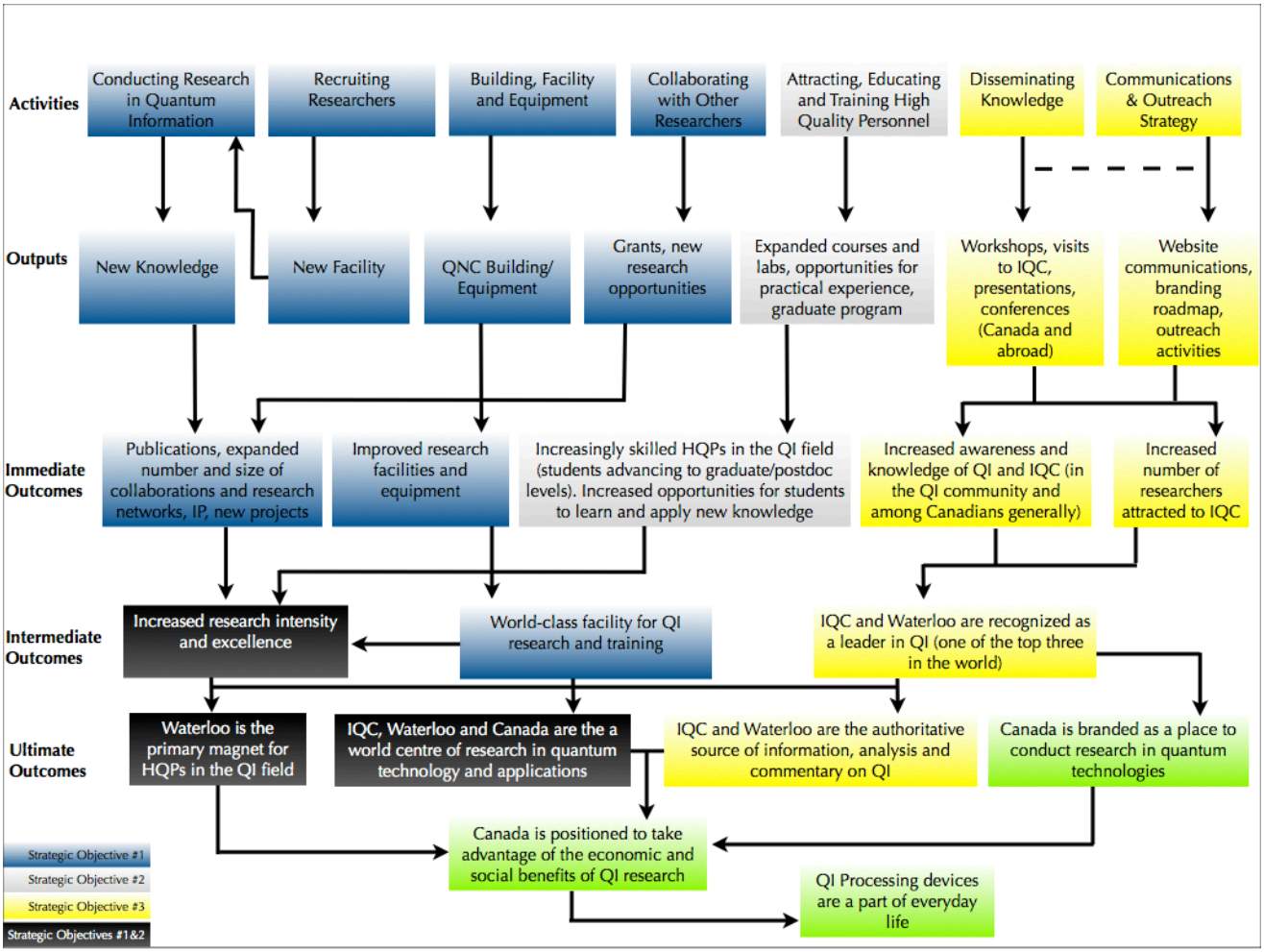


Figure 1: IQC Strategic Framework

This report will provide highlights of objectives and results under IQC's three strategic objectives while focusing on the activities, outputs and outcomes of the Strategic Framework above.

Establish Waterloo as a world-class centre for research in quantum technologies and their applications

Conducting Research in Quantum Information

Conducting research in quantum information at the highest international level is IQC's primary mandate. Our research produces new knowledge that leads to publications, presentations at conferences and commercialization opportunities.

OBJECTIVES FOR FISCAL 2012/13

- Continue leading-edge investigation of theoretical approaches to quantum information processing in order to better understand the impact of quantum mechanics for information processing, to develop technologies to control quantum systems and to investigate new applications.
- Continue developing approaches to quantum information using photonic, nuclear and electron spins, quantum dots, superconducting technologies; proceed with studying the requirements needed to design earth-to-satellite quantum cryptography systems; and develop quantum information processing prototypes.

HIGHLIGHTED RESULTS FROM FISCAL 2012/13

- The proposal of a new universal computational model that has the potential to become an architecture for a scalable quantum computer without the need to actively manipulate qubits during the computation. (A. Childs, D. Gossett, Z. Webb in *Science*)
- The demonstration of a new type of ultra-sensitive detector for oscillating magnetic fields. The experiment used a type of qubit called a persistent current qubit, or flux qubit, which behaves like an artificial atom. (A. Lupascu, M. Bal, F. Ong, C. Deng, JL. Orgiazzi in *Nature Communications*).
- The achievement of quantum teleportation over a record-breaking distance of 143 kilometres through free space. The breakthrough is a crucial step toward quantum communications via satellite. (T. Jennewein, V. Makarov, E. Anisimova in *Nature*)

CASE STUDIES

Quantum walk-based computing model

The IQC team of Andrew Childs (Associate Professor of Combinatorics and Optimization), David Gosset (Post-Doctoral Fellow) and Zak Webb (PhD student) have proposed a new universal computational model. This model has the potential to become an architecture for a scalable quantum computer without the need to actively manipulate qubits during the computation. The team's findings were published in the February 15, 2013 issue of *Science*.

In the paper titled "Universal computation by multi-particle quantum walk", the co-authors utilize quantum walks, the quantum mechanical analogue of classical random walks. Multi-particle quantum walks can be viewed as a collection of interacting particles that move in superposition on a graph, a structure in which pairs of vertices are connected by edges. Traditionally, quantum algorithms are implemented on a register of qubits by actively manipulating them according to a set of desired operations. In this new model, any

desired quantum algorithm can be implemented by letting the qubits “quantum walk” on an appropriately chosen graph, without having to control the qubits.

Whereas many previous quantum-walk experiments have not offered scalability, the new construction offers the potential for significant quantum speedup. The team believes the model could be naturally realized in a variety of systems, including traditional nonlinear optics, neutral atoms in optical lattices and photons in arrays of superconducting qubits.

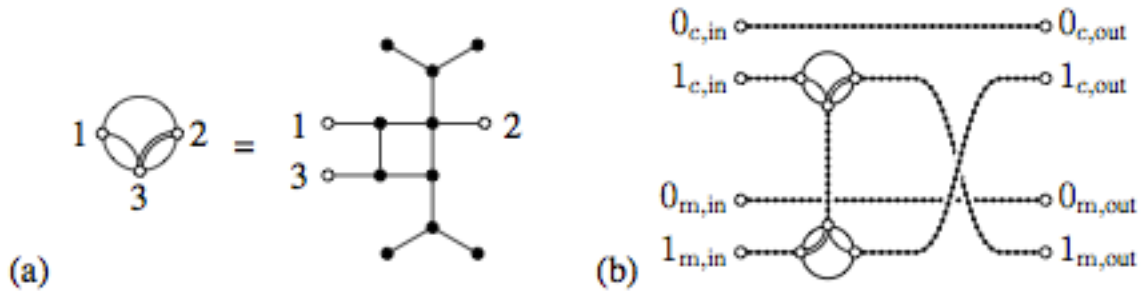


Figure 2: (A) Momentum switch. (B) C gate.

Article Abstract: A quantum walk is a time-homogeneous quantum-mechanical process on a graph defined by analogy to classical random walk. The quantum walker is a particle that moves from a given vertex to adjacent vertices in quantum superposition. Here we consider a generalization of quantum walk to systems with more than one walker. A continuous-time multi-particle quantum walk is generated by a time-independent Hamiltonian with a term corresponding to a single-particle quantum walk for each particle, along with an interaction term. Multi-particle quantum walk includes a broad class of interacting many-body systems such as the Bose-Hubbard model and systems of fermions or distinguishable particles with nearest-neighbor interactions. We show that multi-particle quantum walk is capable of universal quantum computation. Since it is also possible to efficiently simulate a multi-particle quantum walk of the type we consider using a universal quantum computer, this model exactly captures the power of quantum computation. In principle our construction could be used as an architecture for building a scalable quantum computer with no need for time-dependent control.

Ultra-sensitive magnetic field sensor

IQC researchers have demonstrated a new type of ultra-sensitive detector for oscillating magnetic fields. The research team including postdoctoral fellows Mustafa Bal and Florian Ong, PhD students Chunqing Deng and Jean-Luc Orgiazzi, led by Professor Adrian Lupascu, performed experiments using a type of quantum bit called a persistent current qubit, or a flux qubit, which behaves like an artificial atom. This type of qubit is a small ring, as wide as a strand of spider's silk, made of superconducting metal with several interrupting structures, called Josephson junctions, built into it.

This result, published in *Nature Communications*, represents an important development in the field of quantum sensing research, where quantum systems are used to create better measurement devices. The IQC researchers created a quantum detector that is more sensitive than other measurement methods for magnetic fields that oscillate between tens of thousands to tens of millions of times each second.

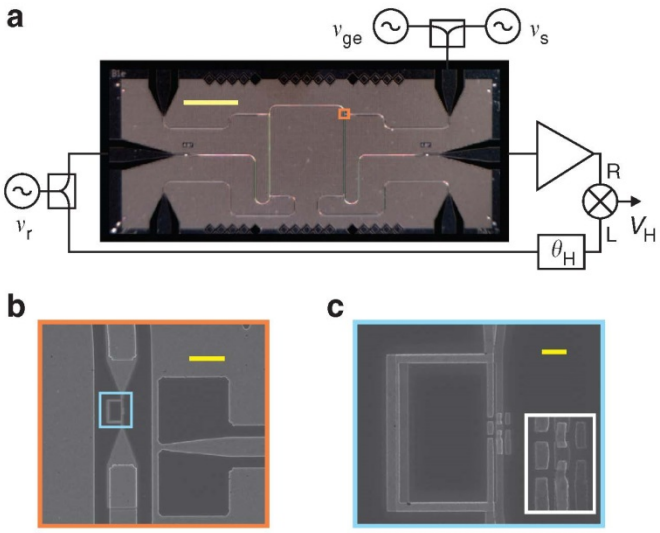


Figure 3:Qubit control/readout circuit and spectroscopy

The persistent current qubit can be used to explore the behaviour of quantum systems at very low temperatures, and it demonstrates the potential of artificial quantum systems for quantum sensing. Possible areas of application include the detection of electron spins and measurements of resonators. Magnetic field sensing is also important for a wide variety of applications including medical imaging, geological exploration, materials evaluation, and scanning probe microscopy.

Magnetometers have two main features – sensitivity and spatial resolution. Improvements to magnetometers have been limited in that improving one feature came at the expense of the other. Lupascu's quantum device is a step forward, achieving high sensitivity in a very small device. This team's persistent current qubit is able to detect magnetic fields as weak as a few picoTesla – less than 10 millions of the value of the Earth's magnetic field (50 microTesla).

Article Abstract: Efficient detection of magnetic fields is central to many areas of research and technology. High-sensitivity detectors are commonly built using direct-current superconducting quantum interference devices or atomic systems. Here we use a single artificial atom to implement an ultrasensitive magnetometer with micron range size. The artificial atom, a superconducting two-level system, is operated similarly to atom and diamond nitrogen-vacancy centre-based magnetometers. The high sensitivity results from quantum coherence combined with strong coupling to magnetic field. We obtain a sensitivity of 3.3 pT Hz−1/2 for a frequency at 10 MHz. We discuss feasible improvements to increase sensitivity by one order of magnitude. The intrinsic sensitivity of this detector at frequencies in the 100 kHz–10 MHz range compares favourably with direct-current superconducting quantum interference devices and atomic magnetometers of equivalent spatial resolution. This result illustrates the potential of artificial quantum systems for sensitive detection and related applications.

Three-photon energy–time entanglement

In 1935 Albert Einstein, Boris Podolsky, and Nathan Rosen, known jointly as EPR, published a thought experiment designed to show that quantum mechanics was not sufficient to describe reality. EPR tried to demonstrate, with two entangled particles, that there must be some hidden parameters not accounted for in quantum mechanics theory. John Bell would later follow EPR's arguments and determine that the hidden parameters that EPR argued for were incompatible with observations of nature, leaving the mystery of quantum mechanics intact. Today, the entanglement of two particles as first proposed by EPR, is a valuable resource in emerging quantum technologies like quantum computing, quantum cryptography, and quantum precision measurements.

Seventy-seven years after EPR's landmark work, researchers at IQC and at the University of Calgary have experimentally extended the original ideas of Einstein and his colleagues from two to three entangled particles. This new form of three-particle entanglement, based on the position and momentum properties of photons, may prove to be a part of future communications networks that operate on the rules of quantum mechanics and could lead to new fundamental tests of quantum theory that deepen our understanding of the world around us.

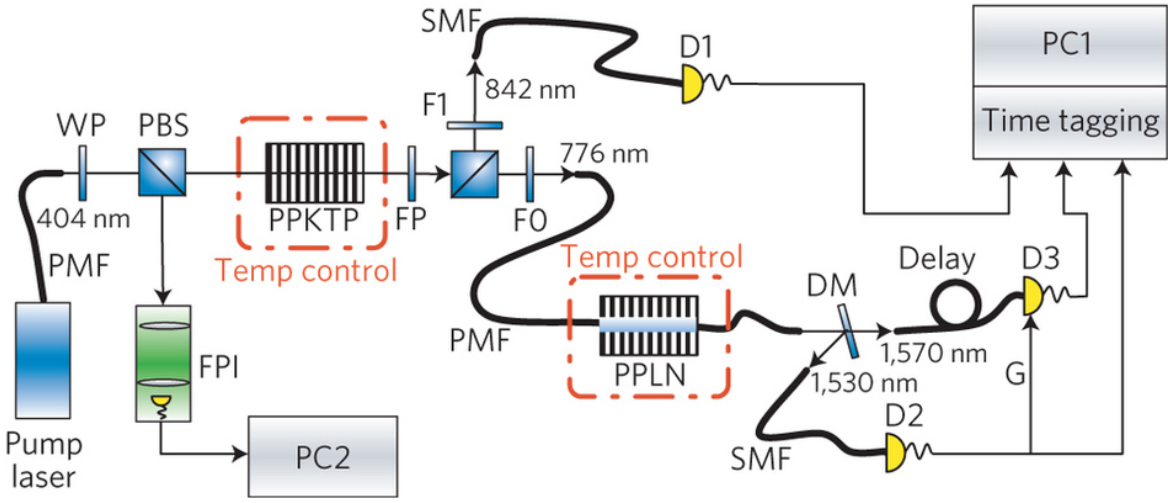


Figure 4: Three entangled photons are created using C-SPDC.

As described in their paper titled "Three-photon energy-time entanglement" in *Nature Physics*, the researchers created quantum correlations between three photons from a single input photon. "It is exciting, after all this time, to be able to create, control, and entangle quantum particles in this new way," says group leader Thomas Jennewein. "Using these states of light it may be possible to interact with and entangle distant quantum computer memories based on exotic atomic gases." Unlike classical particles, quantum particles work together as opposed to individually. The creation of three entangled particles could lead to new advances in quantum devices development.

Article Abstract: Entangled quantum particles have correlations stronger than those allowed by classical physics. These correlations are the focus of the deepest issues in quantum mechanics and are the basis of many quantum technologies. The entanglement of discrete particle properties has been studied extensively in the context of quantum

computing, cryptography, and quantum repeaters while entanglement between the continuous properties of particles may play a critical role in improving the sensitivity of gravitational wave detectors, atomic clocks, and other high precision instruments. The attributes of three or more entangled particles are fundamentally different from those of two entangled particles. While the discrete variables of up to 14 ions and the continuous variables between three intense optical beams have been entangled, it has remained an open challenge to entangle the continuous properties of more than two individual particles. Here we experimentally demonstrate genuine tripartite continuous-variable entanglement between three separated particles. In our setup the three particles are photons created directly from a single input photon; the creation process leads to quantum correlations between the colours, or energies, and emission times of the photons. The entanglement between our three photons is the three-party generalization of the Einstein-Podolsky-Rosen (EPR) correlations for continuous variables, and allows for new fundamental tests of quantum mechanics to be carried out. Our scheme can be extended to carry out multi-particle Franson interferometry, and opens the possibility of using additional degrees of freedom in our photons to simultaneously engineer discrete and continuous-variable hyper-entangled states that could serve as a valuable resource in a wide variety of quantum information tasks.

The classical-quantum boundary for correlations: Discord & related measures

IQC postdoctoral fellow Aharon Brodutch and a team of researchers have authored the first comprehensive history of research on quantum correlations. Published in the *Review of Modern Physics*, Brodutch's paper, titled "The classical-quantum boundary for correlations: Discord and related measures", summarizes the available research in the relationships between quantum systems, in particular the relationships that allow qubits to embody more information together than individually – quantum correlations.

This paper is an important step in the development of quantum correlations research. "Quantum correlations appear in every aspect of physics," says Brodutch, "from quantum information and quantum algorithms, to thermodynamics and many-body physics." Quantum correlations are used to measure the "quantumness" of a system. In classical systems, as opposed to quantum systems, the parts of the systems work individually. Whereas in a quantum system, with correlated behaviour, parts of the system work together to contain more information.

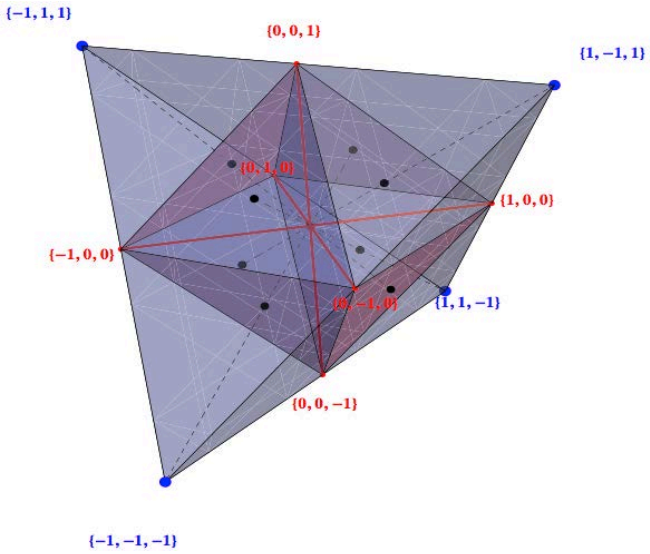


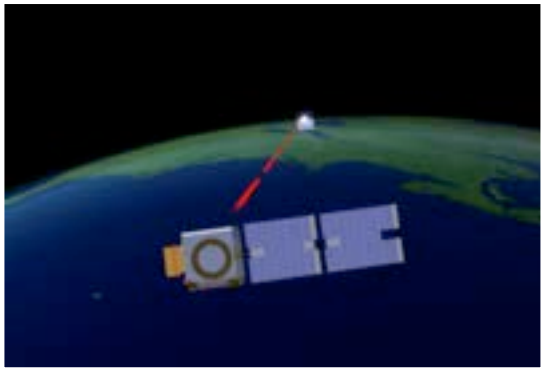
Figure 5: Quantum Discord

Until now, quantum information research typically focused on quantum entanglement, the most famous example of a quantum correlation. However, entanglement is notoriously fragile and difficult to use. Brodutch's

paper includes research on quantum discord and other types of correlations that could enable new discoveries in quantum tools that are more robust and easier to use.

Article Abstract: One of the best signatures of nonclassicality in a quantum system is the existence of correlations that have no classical counterpart. Different methods for quantifying the quantum and classical parts of correlations are among the more actively studied topics of quantum-information theory over the past decade. Entanglement is the most prominent of these correlations, but in many cases unentangled states exhibit nonclassical behavior too. Thus distinguishing quantum correlations other than entanglement provides a better division between the quantum and classical worlds, especially when considering mixed states. Here different notions of classical and quantum correlations quantified by quantum discord and other related measures are reviewed. In the first half, the mathematical properties of the measures of quantum correlations are reviewed, related to each other, and the classical-quantum division that is common among them is discussed. In the second half, it is shown that the measures identify and quantify the deviation from classicality in various quantum-information-processing tasks, quantum thermodynamics, open-system dynamics, and many-body physics. It is shown that in many cases quantum correlations indicate an advantage of quantum methods over classical ones.

Quantum Communications Network via Satellite



Schematic of QKD via Satellite

An exciting collaborative project spearheaded by IQC is the effort to establish a secure global quantum communication network. Such a network would allow for the testing of some fundamental concepts in physics, and open the possibility of a worldwide system for quantum key distribution. A research team led by Thomas Jennewein, Norbert Lütkenhaus and Raymond Laflamme is developing the theory and technology necessary to establish such a global network in collaboration with industry/government partners COM DEV (global designer and manufacturer of space hardware), the Institut National d'Optique and the Canadian Space Agency, along with academic partners Perimeter Institute, and the universities of Cambridge, Calgary, and Toronto.

Such work on quantum key distribution and other facets of quantum optics has resulted in IQC's first spin-off company: Universal Quantum Devices Incorporated (UQD).

PUBLICATIONS BY IQC RESEARCHERS

IQC researchers regularly publish in world-leading journals. Publications are one of several indicators of research output. In IQC's short 10-year history, we have established a strong publication record as indicated below.

In 2012-2013, there were 172 unique publications by IQC researchers. For a list of publications, see Publications on page 103.

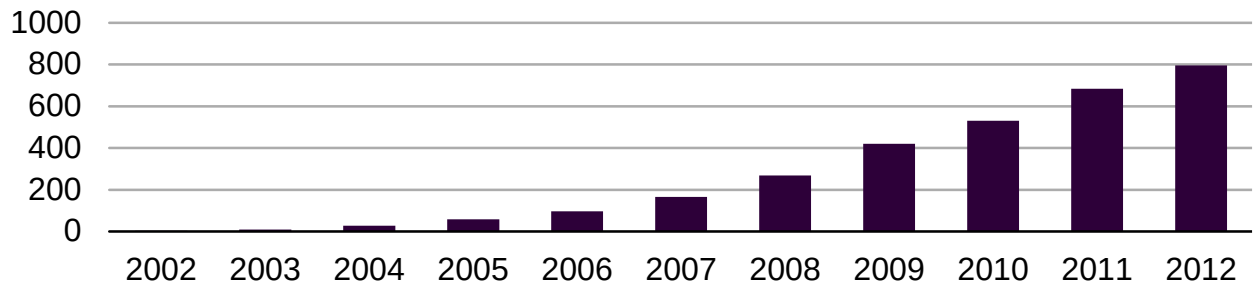
IQC Research Published in Prominent Journals Since 2007[1]

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

[1] The publication distribution listed above is collected from Thomson Reuter's ISI Web of Knowledge.

Below is a graph showing the number of cumulative publications by IQC researchers since 2002. This graph includes papers on arXiv.org and in other scientific publications. Each one of IQC's publications has been counted only once, regardless of how many IQC researchers collaborated on it.

Cumulative Publications by IQC Researchers



The table below shows the total number of published papers by IQC researchers per year dating back to 2002.

All Publications by IQC Researchers Per Year

Calendar Year	'02	'03	'04	'05	'06	'07	'08	'09	'10	'11	'12
# of Pubs	3	7	18	30	39	66	99	151	108	136	172

Note: The data shown above is from information collected from the curriculum vitae and annual faculty reports of each researcher at the institute annually.[23]

For a list of IQC publications in the 2012-2013 fiscal year, see Publications on page 103 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.

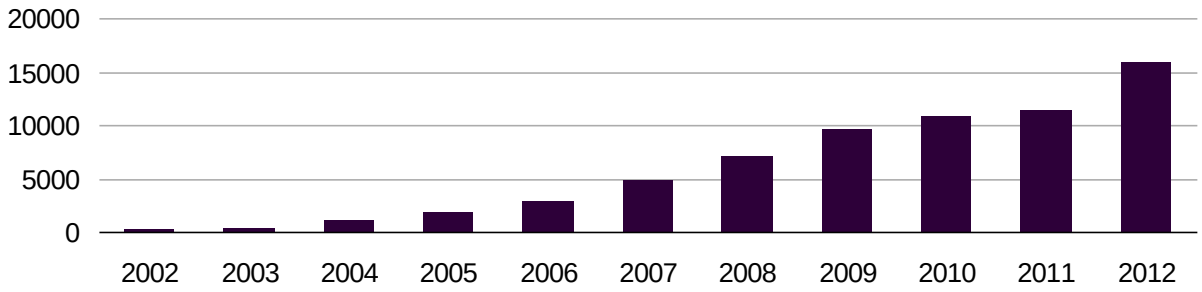
[2] IQC researchers include faculty, research assistant professors, IQC associate members, postdoctoral fellows, students and long-term visitors. A profile for each researcher was created in a repository and was populated with their respective IQC publications. The meta-data for each publication was imported from various research databases and electronic archives using the ISI Web of Science, Scopis, IEEE Xplore, arXiv, and Cryptography ePrint Archive.
[3] The number of publications listed for 2008-2011 differs from previously reported: preprints have now been published.

CITATIONS

Citations are another of the several indicators that IQC uses to demonstrate the authority of its research output.[4] These trends should be interpreted alongside other indicators that show IQC advancing research in quantum technology.

In 2012, there were 15,984 cumulative citations for all IQC publications since 2002. The graph below shows the cumulative number of citations of IQC publications as they were found on Google Scholar.[5] The chart below illustrates the number of citations, per year, of publications with the designation "Institute for Quantum Computing" dating back to 2002.

Cumulative Citations of IQC Publications: Google Scholar



The table below shows the citations in a given year of all papers published by IQC researchers.

Annual Distribution of Citations: Google Scholar

Calendar Year	2007	2008	2009	2010	2011	2012
Citations	2595	2635	2965	4130	4284	8876

RESEARCH GRANTS

IQC researchers garnered $10,676,418[6] in research funding in the term May 1, 2012 to April 30, 2013. These grants included $5,912,504 in government funding and $4,763,914 from industry partners.

Calendar Year	2010	2011	2012	2013
Research Grants	$7,379,979	$8,297,158	$5,130,070	$10,676,418

[4] The citation numbers were collected from Google Scholar in March 2013. They include self-citations and are approximations based on information available.
[5] A report for each year's list of publications was generated from IQC's publication repository. The repository is populated by importing metadata from ISI Web of Science, arXiv.org, SCOPUS, Spires, IEEE Xplore, etc.
[6] Data provided by University of Waterloo Office of Research

Additionally, IQC received $5.5 million from Industry Canada during this period.

For a detailed breakdown of grants received since 2012, see Summary of Other Grants and Gifts on page 98.

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. The following lists awards given to faculty members in the 2012 - 2013 fiscal year.

- Raymond Laflamme: Honorary Degree, University of Sherbrooke
- Matteo Mariantoni: 2013 Sloan Research Fellowship
- Michele Mosca: University Research Chair, University of Waterloo
- Kevin Resch: E.W.R. Steacie Fellowship, NSERC

IQC is also home to the following research chairs:

- 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)

Recruiting New Researchers

IQC continues to build a team of theoretical and experimental researchers who are leaders in their respective disciplines from computer science to engineering, from mathematicians to physicists.

OBJECTIVES AND RESULTS IN FISCAL 2013

- Recruit up to 5 new faculty members in fiscal 2012/13
- Recruit up to one new research assistant professor
- Recruit up to 15 new postdoctoral fellows

HIGHLIGHTED RESULTS FROM FISCAL 2013

The following section of this report highlights the new faculty and research assistant professors that have joined IQC since the beginning of the Industry Canada grant. It also includes a summary of the institute's membership, recruiting goals and the number of domestic and international researchers at the institute.

NEW FACULTY MEMBERS

Four new faculty members were added to IQC in 2012-2013 bringing our total to 19 faculty.

Robert Koenig

Professor Robert Koenig joined IQC in August 2012 following postdoctoral fellowships at the IBM Watson Research Center and the California Institute of Technology. He completed his PhD. at the University of Cambridge. His research focuses on important questions of quantum processing and error correction. Koenig is a member of the University of Waterloo's Department of Applied Mathematics, and his research focusses on the development of new quantum error-correcting codes, as well as new cryptographic schemes based on information processing limitations.

Chris Wilson

Christopher Wilson joined IQC in 2012 as an Associate Professor in Electrical & Computer Engineering. He received his PhD. in Physics from Yale University in 2002. His dissertation focused on the development of single-photon spectrometers using superconducting tunnel junctions. He then worked at Yale as a W.M. Keck postdoctoral fellow performing research on quantum computation and information processing using superconducting single-electronics. In 2004, he moved to Chalmers University of Technology in Sweden, later becoming an Assistant Professor in 2007 and an Associate Professor in 2011. His research at IQC will continue his work on quantum information, microwave quantum optics, and nonlinear dynamics.

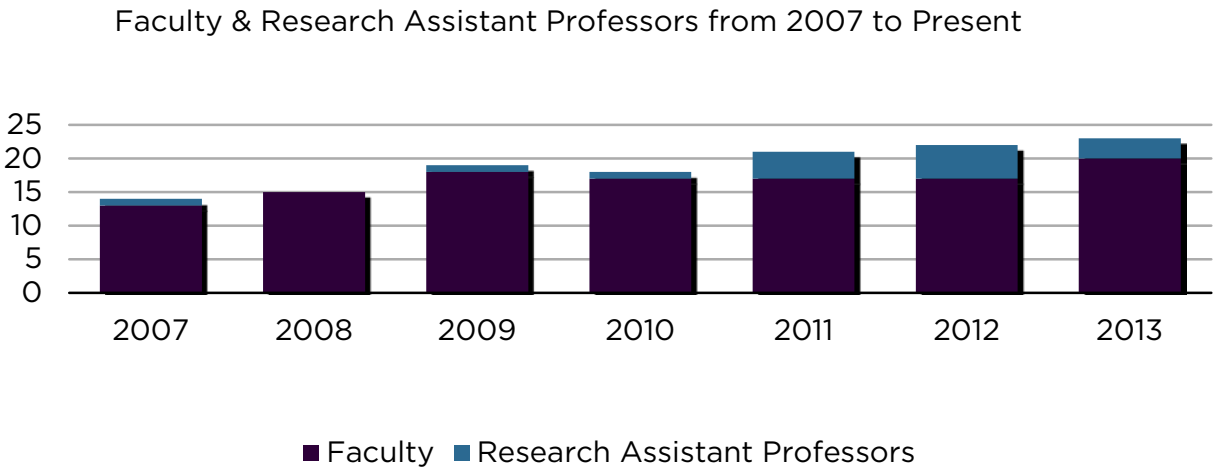
Guo-Xing Miao

Guo-Xing Miao joined IQC in September 2012 as a faculty member in Electrical and Computer Engineering. He received his B.Sc. from Shandong University, and M.Sc. and PhD from Brown University. He was a Research Scientist at MIT prior to joining IQC. Professor Miao's research interests lie in spintronics, using precise electron spin manipulation for information processing. His research effort has strong emphasis on newly emerging spin platforms, such as synthetic diamonds and topological insulators, where information can be processed coherently on the quantum level, rather than digitally on the classical level.

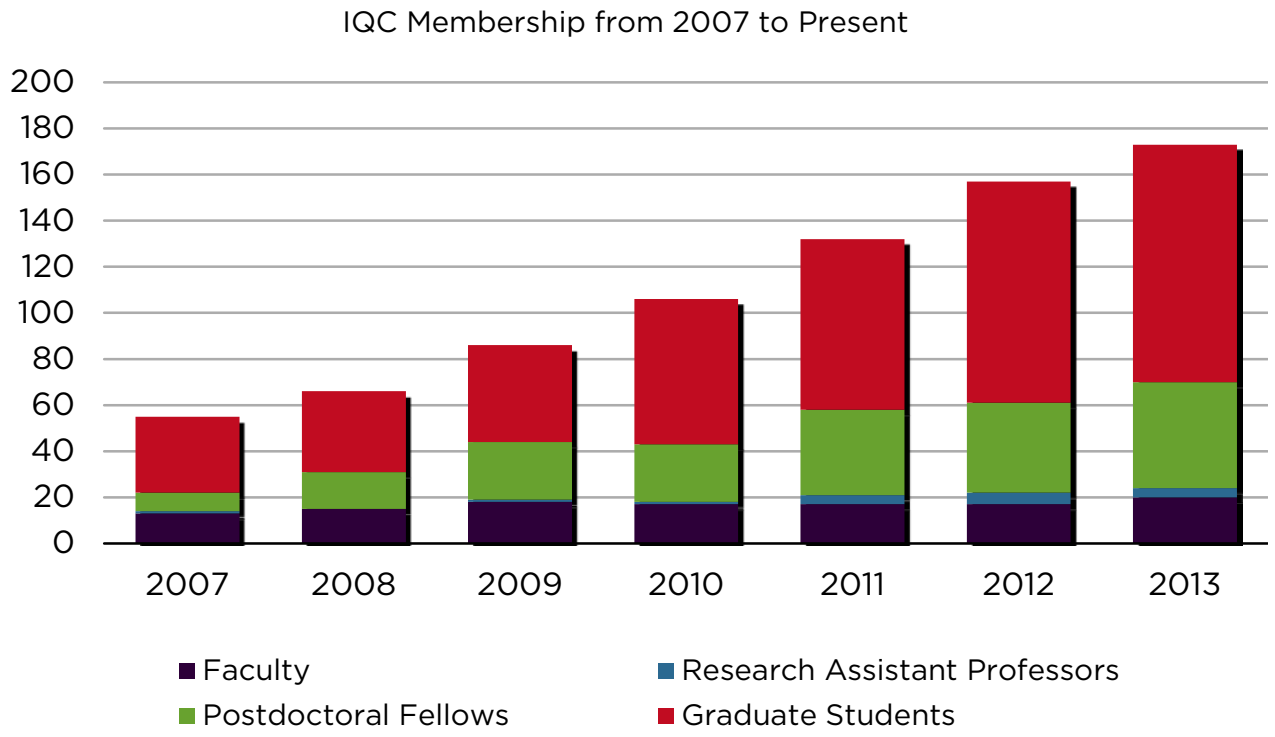
Matteo Mariantoni

Matteo Mariantoni is a PhD graduate of the Wather-Meissner-Institut and Technical University Munich in Germany. Matteo joins IQC after a post-doctoral fellowship at the University of California Santa Barbara with a strong background in cutting-edge research on superconducting qubits and circuit quantum electrodynamics. He brings experience and specialization in the experimental realization of low-level microwave detection schemes and pulsing techniques that allow for the measurement of ultra-low quantum signals generated by superconducting qubits coupled to on-chip resonators.

Below is a graph showing the increase of faculty and research assistant professors over time.



Recruiting and retaining the world's top researchers is a high priority for IQC. The graph below shows the growth of all IQC researchers from 2007 to fiscal 2012.



During the 2013 fiscal year IQC was home to 20 faculty members, 3 research assistant professors, 46 postdoctoral fellows, 103 graduate students, and 34 long-term visitors.

RECRUITMENT HISTORY AND GOALS

	Researchers Recruited in 2011	Researchers Recruited in 2012	Goal to Recruit in 2013	Researchers Recruited in 2013	Goal to Recruit in 2014
Faculty	1 - Canada Excellence Research Chair	2	up to 5	4	Up to 5
Research Assistant Professors	3	3	up to 1	0	Up to 2
Postdoctoral Fellows	18	10	up to 15	9	Up to 10
Graduate Students	20	31	up to 25	25	Up to 30

DOMESTIC V. INTERNATIONAL RESEARCHERS

IQC continues to attract high-quality personnel from around the world. The chart below shows the citizenship of IQC's faculty, research assistant professors, postdoctoral fellows and graduate students.

	Canadian	Dual Citizenship	International
Faculty	6	6	8
Research Assistant Professors	--	--	4
Postdoctoral Fellows	15	--	31
Graduate Students	65	--	38

Students attend from 13 different countries: Australia, Bangladesh, Cameroon, Canada, China, France, India, Iran, Italy, Norway, Singapore, the UK and the USA.

Post-doctoral fellows attend from 13 different countries: Australia, Austria, Canada, China, France, Ireland, Japan, Poland, Singapore, Spain, the Netherlands, the UK and the USA.

Collaborating with Other Researchers

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 2012/13

- 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 multi-disciplinary participants
- Continue, enhance and increase visits to IQC by international scientists and academics from around the world.

COLLABORATIVE RESEARCH PROJECTS

In 2012-2013, IQC collaborated with 221 researchers from 185 institutions in 134 locations in more than 20 countries. For a complete review of IQC's 2012 collaborations see Collaborations on page 113.

IQC researchers participated in collaborative research projects with institutes from more than 20 countries around the globe including:

- University of Erlangen-Nuremberg
- Massachusetts Institute of Technology
- National University of Singapore
- University of Queensland
- University of Bristol
- Austrian Academy of Science
- Griffith University
- University of Innsbruck
- Macquarie University
- University of Oxford
- Yale University
- University of Vienna
- Caltech
- Los Alamos National Laboratory

RESEARCH NETWORKS

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.

QuantumWorks

QuantumWorks, Canada's research network in quantum information processing, was based at IQC. The network was established as an NSERC Innovation Platform in 2006 and served as an umbrella organization, allowing for collaboration across diverse fields within quantum information in Canada. It also connected with stakeholders from the public and private sector, including the Communications Security Establishment Canada and the European Telecommunications Standards Institute (ETSI). The QuantumWorks program wrapped up in 2012 and lead to the establishment of two new research networks funded through the CREATE program: CryptoWorks21 and CREATE Program on Neutron Science and Engineering of Functional Materials.

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 with colleagues from University of Calgary, Université de Montréal and Intrique.

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.

CREATE Program on Neutron Science and Engineering of Functional Materials

Professor David Cory was granted a CREATE grant to launch a project called the Program on Neutron Science and Engineering of Functional Materials. The project will train graduate students, postdoctoral fellows and undergraduates in the use and development of quantum information processing and neutron methods. Neutron physics, in particular neutron interferometry, is a natural test-bed for quantum information processing. This program will help transform neutron interferometry into a practical tool for characterizing materials, including magnetic and biochemical samples. The program will also help train a cohort of young, uniquely skilled multidisciplinary researchers whose expertise will take neutron and quantum information science out of the lab and into society.

MEMORANDA OF UNDERSTANDING

IQC has a total of seven official agreements to date. Generally, these constitute an agreement between parties that can help to 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.

- National Science Council of Taiwan— Statement of Understanding (December, 2009)
- National University of Singapore— Memorandum of Understanding (March, 2010)
- Institut National de Recherche Scientifique (INRS) - Memorandum of Understanding
- INTRIQ (L'Institut Transdiciplinaire D'Information Quantique) - Memorandum of Understanding
- 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)

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

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 the Institute for Quantum Computing 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. INO is a technological design and development firm for optic and photons solutions, working with IQC on technology for the prospective QEYSSAT mission. The 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. IQC's participation in the program is led by Ashwin Nayak, Raymond Laflamme and Norbert Lütkenhaus.

National Institute for Science & Technology (NIST), USA

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 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.

SCIENTIFIC VISITORS

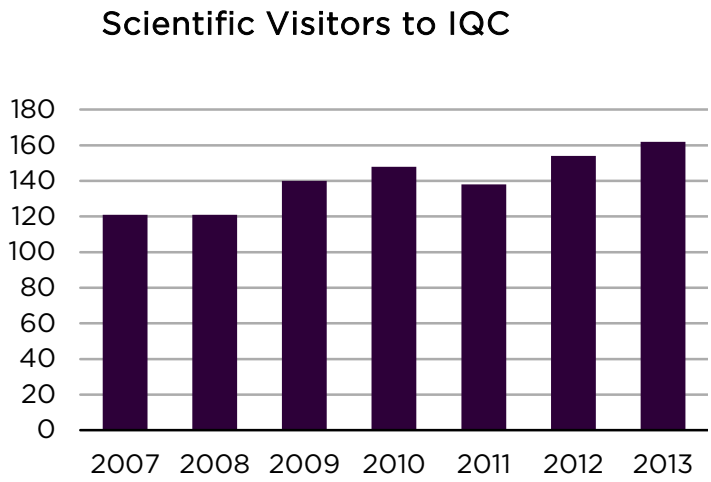
IQC welcomes visitors from around the world each year to further its collaborative relationships and strive for global excellence in quantum information processing. The institute has hosted the world's top scientists to conduct research, give talks, and meet with IQC's researchers and students.

For a full list of IQC's scientific visitors and their institutes, see Scientific Visitors on page 148. The following list shows the 108 different institutions visitors have come from:

- Amherst College, USA
- California Institute of Technology
- Canadian Space Agency, Canada
- Carnegie Mellon University, USA
- CEA-Saclay, France
- Chennai Mathematical Institute, India
- Comenius University in Bratislava Slovakia, Slovakia
- Cornell University, USA
- Cummins College of Engineering, India
- Czech Technical University Prague, The Czech Republic
- Dartmouth College, USA
- ETH Zürich, Switzerland
- Ewha Womans University, Korea
- Florida Atlantic University, USA
- Georgia Institute of Technology, USA
- Harvard University, USA
- Hokkaido University, Japan
- IBM TJ Watson Research Center, USA
- Imperial College London, United Kingdom
- India Institute of Technology, Delhi, India
- Indian Institute of Science Education and Research, India
- Indian Institute of Technology Hyderabad, India
- Indian Institute of Technology Kharagpur, India
- Indiana University Bloomington, USA
- Indiana University, USA
- Institute for Theoretical Physics ETH Zurich, Switzerland
- Instituto de Fisica Fundamental, Spain
- Instituto de FÍsica Universidade Federal Fluminense, Brazil
- Jagiellonian University, Poland
- Joseph Fourier University, France
- Khalifa University, Abu Dhabi
- Korea Institute of Science and Technology, Korea
- Lakehead University, Canada
- Louisiana State University, USA
- Massachusetts Institute of Technology, USA
- Max Planck Institute of Quantum Optics & Ludwig Maximilian University of Munich, Germany
- Max Planck Institute of Quantum Optics in Garching, Germany, USA
- McGill University, Canada
- Microsoft Research, USA
- Middle Tennessee State University, USA
- National Institute of Standards and Technology, USA

- National Research Council Canada, Canada
- National University of Ireland, Maynooth, Ireland
- Nicolaus Copernicus University, Poland
- Office of Naval Research, USA
- Penn State University, USA
- Pohang University of Science & Technology, Korea
- Portland State University, USA
- Purdue University, USA
- Queen's University, Canada
- Raytheon-BBN Technologies, USA
- Rheinisch-Westfaelische Technische Hochschule Aachen University, Germany
- Royal Holloway, University of London, UK
- Rutgers University, USA
- Saarland University, Germany
- Shandong University, China
- Slovak Academy of Sciences, Slovakia
- Stanford University, USA
- Stockholm University, Sweden
- Swiss Federal Institute of Technology Zurich, Switzerland
- Technische Universitat Dortmund, Germany
- The City University of New York, USA
- The University of Sydney, Australia
- Tsinghua University, China
- Tufts University, USA
- United States National Intelligence University, USA
- Universität Innsbruck, Austria
- Universität Siegen, Germany
- Universität Ulm, Germany
- Université de Montréal, Canada
- Université de Rennes, France
- University of British Columbia, USA
- University of Buffalo, USA
- University of Calgary, Canada
- University of California, Berkeley, USA
- University of California, Merced, USA
- University of California, Riverside, USA
- University of California, San Diego, USA
- University of California, Santa Barbara, USA
- University of Cambridge, UK
- University of Colorado at Boulder, USA
- University of Connecticut, USA
- University of Dhaka, Bangladesh
- University of Illinois at Urbana-Champaign, USA
- University of KwaZulu-Natal, South Africa
- University of Leeds, United Kingdom
- University of Maryland, USA
- University of Milan, Italy
- University of Oxford, UK
- University of Queensland, Australia
- University of Science and Technology, China
- University of Sherbrooke, Canada
- University of Southern California, USA
- University of Strathclyde, Scotland
- University of Sydney, Australia
- University of the Basque Country, Spain
- University of Tokyo, Japan
- University of Toronto, Canada
- University of Turku, Finland
- University of Vienna, Austria
- University of Warsaw, Poland
- University of Washington, USA
- University of Wisconsin, Milwaukee, USA
- Washington State University, Spokane, USA
- Yale University, USA

The chart below shows the trend in IQC's academic visitors over the past seven years.



Fiscal Year	# of Visitors
2013	162
2012	154
2011	138
2010	148
2009	140
2008	121
2007	121

SPIN-OFFS & PATENTS

The University of Waterloo has the most spin-off companies compared to any other university in the country, so it's natural that spin-offs would spawn out of IQC. In its short 10 years, IQC already has two spin-off companies.

Featured Spin-off: Universal Quantum Devices

Universal Quantum Devices (UQD) aims to provide 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, USA and Canada. UQD's next generation units will specifically accommodate the needs of satellite communications.

Patents

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

- Richard Cleve
- David Cory
- Thomas Jennewein
- Norbert Lütkenhaus
- Kevin Resch
- John Watrous
- Anne Broadbent
- Rolf Horn

Building, Facilities & Laboratory Support

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

FISCAL 2012/13 OBJECTIVES

- Migrate some of IQC's researchers, labs and staff into the Mike & Ophelia Lazaridis Quantum-Nano Centre before the September 2012 grand opening
- Host a ribbon cutting ceremony in September 2012 to mark the grand opening of the building
- Commence the QNC NanoFab fit-out in October 2012. Including: the installation of the multiple services required by the ensemble of lab equipment purchased to date as well as equipment which is on order. These services include the high purity water loop, acid waste neutralization system, high purity process gas lines, process chilled water lines, exhaust drops from the main ducts, compressed air & nitrogen lines, as well as power panels and equipment disconnects. Fit out is expected to take from three to five months to complete.

HIGHLIGHTED RESULTS FROM FISCAL 2012/13

In late 2012, IQC expanded into its new headquarters, the Mike and Ophelia Lazaridis Quantum-Nano Centre (QNC). This 285,000 architectural marvel provides purpose-built labs, fabrication facilities and collaboration space for members of the institute. Constructed to the most stringent scientific standards - including controls for vibration, temperature, humidity, electromagnetic radiation and more - the facility enables quantum information research at the highest international level.

The grand opening ceremony for the Lazaridis QNC was held on September 21, 2012. The event welcomed over 1500 people including officials from all levels of government. As of April 30, 2013, the Mike & Ophelia Lazaridis Quantum-Nano Centre was 99.8% per cent complete. As of January 31, 2013, the estimated value of outstanding work was $260k (provided by Aecon and being reviewed by KPMB). The project continues to track within budget although there are some change orders that have not been finalized. Industry Canada funding for building construction created 126 jobs in fiscal 2010, 123 jobs in fiscal 2011 and 120 jobs in fiscal 2012.

Currently, all staff and 80% of current researchers are moved into the Lazaridis QNC. Lab space is currently being configured to the specifications of researchers with one lab fully complete and two more labs scheduled for completion in the next two to three months. It is expected that by December 2013, all current researchers who have labs slated for the Lazaridis QNC will be fully operational in the space.

The Quantum-Nano Fabrication facility is located in the new Lazaridis QNC. This facility features a 6,700 sq. ft. class-100 cleanroom (less than 100 particles per cubic foot of air). The fit-out of the facility has begun with the installation of required services to the space. Over the next six-eight months the required laboratory equipment will be installed and certified.

Square Footage: IQC Lab Space by Year

Time Period	Buildings	Square Footage
2001 - 2004	Physics and Chemistry	2,625 sq. ft.
2004 - 2008	BFG, 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 QNC	51,832 sq. ft.

Square Footage: Lab Space by Building

Physics	777 sq. ft.
Chemistry	1,848 sq. ft.
BFG	4,069 sq. ft.
RACI	10,135 sq. ft.
RACII	13,149 sq. ft.
QNC	26,700 sq. ft. 6,700 sq. ft, cleanroom 20,000 sq. ft. lab space

IQC Buildings and space

THE MIKE AND OPHELIA LAZARIDIS QUANTUM NANO CENTRE

This year IQC marked a significant milestone with the opening of its new, state-of-the-art facility on the main University of Waterloo campus. The Mike & Ophelia Lazaridis Quantum-Nano Centre (QNC) opened its doors officially on September 21, 2012. IQC now occupies a total of 51,832 sq. ft. of lab space on campus.

The Quantum-Nano Centre houses a 6,700 sq. ft. fabrication and metrology facility, and is shared with the Waterloo Institute for Nanotechnology (WIN). The building fosters cross-disciplinary collaboration in its many common areas, lounges and meeting rooms. The Quantum-Nano Centre will allow IQC to continue its aggressive growth, as it expands to 33 faculty, 60 postdoctoral fellows and 165 graduate students.

Designers of the facility were guided by three principles:

- It must be functional, i.e. meet the highest scientific standards for temperature, vibration, humidity and electromagnetic radiation control
- It must encourage interaction and collaboration between researchers and students
- It should attract top scientists to Waterloo.

Building Highlights:

- 285,000 square feet, shared between the Institute for Quantum Computing and the Waterloo Institute for Nanotechnology
- Meets highest scientific standards for control of vibration, humidity, electromagnetic radiation and temperature
- Shared cleanroom/fabrication facility enables design of structures billionths of a metre in size
- Labs constructed underground to minimize electromagnetic interference and vibration
- Highly convertible “mind spaces” accommodate 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.

Labs

- Quantum Verification Lab (new in 2012)
  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.
- Quantum Photonics Laboratory (move to QNC 2013)
  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 transmitted through optical fibres and free space to satellites. They are also engineering novel and high-quality states of entangled photons and applying them to quantum communication protocols and fundamental quantum physics experiments.
- Quantum Optics & Quantum Information Laboratory (move to QNC 2013)
  Particles of light (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.

Fabrication & Metrology Facility

The Quantum-NanoFab facility in the Lazaridis QNC building 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 ft2 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 2008, IQC moved into the Research Advancement Centre I (RACI), a 10,000-square-foot building with a 1,650-square-foot cleanroom/fabrication facility.

In 2010, the Research Advancement Centre II (RACII) opened as the research base for then newly recruited Prof. David Cory (Canada Excellence Research Chair in Quantum Information Processing) and his team.

These adjacent three-storey buildings house IQC laboratories and researcher offices. Some of IQC's research will continue in these buildings on the north campus.

RAC I

RAC I houses eight 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.
- Integrated Quantum Optoelectronics Laboratory
  IQOL aims to develop a unique test-bed for the characterization of superconducting and photonic quantum devices and circuits. IQOL is equipped with a custom-designed optical/microwave cryogenic probe system.
- Superconducting Qubits Laboratory
  Harnessing quantum systems at the mesoscopic scale is possible by defining qubits using superconducting nano-devices embedded in electrical circuits (namely Josephson junctions, which offer a scalable way to perform quantum computation). Scientists in this lab explore the interaction between light and these qubits.

RAC I Cleanroom

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). Such conditions enable the use of e-beam lithography (for patterning designs with dimensions as small as 20 billionths of a metre), along with atomic layer deposition and optical lithography, which allow for the engineering of nanoscale devices.

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.

The RAC II laboratory is fully functioning and includes the following equipment:

- 7 nuclear magnetic spin resonance spectrometers made by Bruker BioSpin in the following strengths: 600 MHz, 400 MHz, 300 MHz, 142 MHz and 100MHz
- One optically detected nuclear magnetic resonance setup
- One electrically detected nuclear magnetic resonance setup
- One dilution refrigerator
- One helium3 system
- One probe station
- One continuos wave x-band electron spin resonance spectrometer
- One pulsed x-band with endor-electron spin resonance spectrometer
- One q-band pulsed electron spin resonance system
- One s-band pulsed electron spin resonance system
- One v-band electron spin resonance system
- One atomic force microscopy system
- One nuclear quadrupole resonance spectrometer
- One micro-CT scanner
- 2-axis superconducting magnet system
- One plasma-Enhanced Chemical Vapour Deposition System for Single Crystal Diamond Growth
- One powder X-Ray Diffraction system and Raman Microscope
- One dilution Refrigerator
- Gas cabinets
- Fume hoods
- One copper Electroplating system

Become a Magnet for Highly Qualified Personnel in the Field of Qauntum Information

The ability to attract the best and the brightest students is a key measure in any academic insitutions success. IQC has a stellar track record for recruiting talented students to its academic and research endeavours. 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 uWaterloo/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

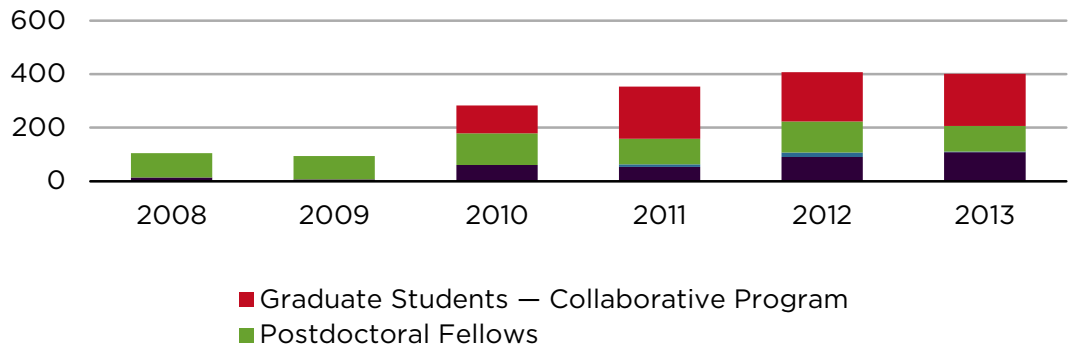
HIGHLIGHTED RESULTS

- IQC representatives attended six graduate fairs across the country
- IQC's collaborative graduate programs attracted 123 applications with 25 new students being accepted
- Expanded connections made with undergraduate programs at Ontario and Canadian universities
- IQC participated in 13 CAP lectures

RECRUITMENT

Applications for the graduate program include both students indicating an interest in quantum information (73) and those applying directly to the quantum information graduate program (123).

Applications to IQC Programs



	2008	2009	2010	2011	2012	2013
Faculty	14	7	60	53	90	108
Research Assistant Professors	N/A	N/A	N/A	10	17	3
Postdoctoral Fellows	91	87	119	96	116	95
Graduate Students — Collaborative Program	N/A	N/A	104	195	185	196

Postdoctoral Fellows

Recruitment

Postdoctoral fellowships bring young scientists with expertise and innovative approaches to the research at IQC. Postdocs contribute to every aspect of IQC's mission from research to publications, from teaching to outreach. Today at IQC, there are 46 postdoctoral fellows working alongside IQC's faculty and students.

Postdoctoral researchers were recruited to IQC from the following institutions:

- Academy of Sciences Technikerstr
- California Institute of Technology
- Chinese Academy of Sciences
- Concordia University
- Dartmouth College
- Griffith University
- Harvard University
- Joseph Fourier University
- Kinki University, Osaka
- Kyoto University
- Leiden Institute of Physics
- McMaster University
- McQuarrie University
- Massachusetts Institute of Technology
- National University of Ireland
- National University of Singapore
- Nicolas Copernicus University
- Pennsylvania State University
- Perimeter Institute
- Princeton University
- Rutgers, State University of New Jersey
- SPEC, CEA-Saclay
- Tsinghua University
- University of Alberta
- University of Calgary
- University of Guelph
- University of Montreal
- University of Pittsburgh
- University of Science and Technology of China
- University of Southern California
- University of Sydney
- University of Toronto

Post-doctoral fellows at IQC represent 13 different countries: Australia, Austria, Canada, China, France, Ireland, Japan, Poland, Singapore, Spain, the Netherlands, the UK and the USA.

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 2012/13:

- Anne Broadbent - Canadian Institute For Advanced Research, Junior Fellow
- Chris Erven - David Johnston Award for Scientific Outreach
- Silvano Garnerone - Google Research Award
- Oleg Gittsovich - Austrian Research Fund
- Nathaniel Johnston - NSERC Fellowship Award
- Eduardo Martin Martinez - NSERC Banting Fellowship

Profiles of Selected Postdoctoral Fellows

David Gosset: Postdoctoral fellow at IQC and the Department of Combinatorics and Optimization. He completed his PhD at MIT in 2011. His research interests include quantum algorithms, quantum walks, Hamiltonian complexity theory, and other areas of quantum computation and quantum information.

Eduardo Martin-Martinez: Completed his PhD in Theoretical Physics in 2011 at the UCM (Universidad Complutense de Madrid, Spain) with “summa cum laude” and received the "2010-2011 extraordinary PhD thesis award". During his PhD, he collaborated with top scientists in relativistic quantum information in Canada, United Kingdom, Austria, Japan and Poland. In 2012, he joined IQC for his first postdoctoral appointment. In October 2012, he was awarded a prestigious Banting Postdoctoral Fellowship. He is also an associate postdoctoral researcher at Perimeter institute.

Brendon Higgins: Completed his PhD at Griffith University in Brisbane, Australia. His research focus includes long-distance implementations of quantum key distribution (QKD), particularly the development of secure global communications networks connected by satellite. In 2011, Brendon was awarded a prestigious Banting Postdoctoral Fellowship.

Collaborative Graduate Program

A unique aspect to IQC's graduate programming is our approach to the 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, Univeristy of Toronto, Canadian Undergraduate Physics Conference, and Atlantic Undergraduate Physics and Astronomy Conference. In addition, the program was advertised to relevant QI researchers across the world. IQC also advertised 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 2012/13 fiscal year, 103 students were registered in graduate programs at IQC. Of those, 54 per cent had a grade point average of 90 per cent or more. Additionally, 85 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 8% from the last reporting year.

Highlights

In 2012-2013, IQC welcomed 25 new graduate students:

- 17 in the collaborative program
- 15 Master and 10 PhD students
- 9 Canadian and 16 international students
- 5 NSERC Award recipients
- 4 IQC Entrance Award recipients
- 2 Mike and Ophelia Lazaridis Fellowship recipients

Current Enrolment

- 103 students currently enrolled
- 52 Canadian students, 51 international students
- 51 Masters students, 52 PhD students
- Home departments: Applied Mathematics (6), Combinatorics & Optimization (10), Chemistry (1), Computer Science (13), Electrical and Computer Engineering (14), Physics (59)
- 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), USA (7)

- 40 students currently hold a total of 76 awards.
  17 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). 59 awards are external and include NSERC Postgraduate Scholarships, NSERC Alexander Graham Bell Canada Graduate Scholarship-Masters and QEII-Graduate Scholarship in Science and Technology.

Student Scholarships and Fellowships

The following students received awards in the 2012-2013 fiscal year. These awards include internal (*) and external awards

Student	Award(s)
Megan Agnew	IQC Entrance Award* NSERC Alexander Graham Bell Canada Graduate Scholarship-Masters President's Graduate Scholarship
Daniel Criger	Ontario Graduate Scholarship President's Graduate Scholarship
Chunqing Deng	Ontario Graduate Scholarship President's Graduate Scholarship
John Donohue	QEII-Graduate Scholarship in Science and Technology
Kent Fisher	NSERC Vanier Canada Graduate Scholarship
Deny Hamel	IQC Achievement Award*
Minyang Han	David R. Cheriton Graduate Scholarship NSERC Alexander Graham Bell Canada Graduate Scholarship-Masters President's Graduate Scholarship
Catherine Holloway	Ontario Graduate Scholarship President's Graduate Scholarship
Erika Janitz	NSERC Alexander Graham Bell Canada Graduate Scholarship-Masters President's Graduate Scholarship
Tomas Jochym-O'Connor	Ontario Graduate Scholarship President's Graduate Scholarship
Sarah Kaiser	Mike and Ophelia Lazaridis Fellowship*

Student	Award(s)
Shitikanth Kashyap	Mike and Ophelia Lazaridis Fellowship*
Alexandre Laplante	Ontario Graduate Scholarship President's Graduate Scholarship
Jonathan Lavoie	IQC Achievement Award* Ontario Graduate Scholarship
Michael Mazurek	NSERC Alexander Graham Bell Canada Graduate Scholarship-Masters President's Graduate Scholarship
Evan Meyer-Scott	IQC David Johnston Award for Scientific Outreach*
Maryam Mirkamali	IQC Entrance Award*
Farzad Qassemi	IQC David Johnston Award for Scientific Outreach*
Vincent Russo	IQC Entrance Award* David R. Cheriton Graduate Scholarship
William Stacey	NSERC Postgraduate Scholarship-Masters President's Graduate Scholarship
Denis-Alexandre Trottier	NSERC Alexander Graham Bell Canada Graduate Scholarship-Masters President's Graduate Scholarship
Kyle Willick	IQC Entrance Award* NSERC Alexander Graham Bell Canada Graduate Scholarship-Masters President's Graduate Scholarship

Graduate Supervisors

There are 38 approved quantum information supervisors: 4 of these are new in 2012-2013. Seventeen supervise or co-supervise at least 1 graduate student in the collaborative program. New supervisors include:

- Robert Koenig - Applied Mathematics
- Chris Wilson - Electrical and Computer Engineering
- Matteo Mariantoni – Physics
- Vadim Makarov - Physics.

For a full list of supervisors, see Supervisors on page 100.

Quantum Information Courses

The following courses are offered in fiscal 2012/13:

Term	Course	Description
Spring 2012	QIC 891 Sir Anthony Leggett Lecture Series 2012	This course discusses a number of different topics in many-body physics and quantum foundations/information. The topics have been requested by IQC members.
	QIC 890/890 Selected Advanced Topics in Quantum Information	This course consists of 10 2-week modules, presented by guest lecturers.
Fall 2012	QIC 710 Quantum Information Processing	Review of basics of quantum information and computational complexity.
	QIC 890 Magnetic Resonance and Spin-Based Quantum Information Processing	The course is intended to provide an in-depth introduction to quantum information processing (QIP) implementations based on nuclear and electron spin. It will describe how such implementations are advancing the state of the art for quantum devices, and are feeding back to improve metrology, spectroscopy, and enabling other potential real-world applications of use in Physics, Chemistry, Biology etc.
	QIC 890 Theory of Quantum Communication	This course will focus on the major results in the theory of quantum communication as well as how quantum information behaves and the powerful tools involved (many of these has been used in quantum communication complexity, fault-tolerance, and cryptography).
	QIC 890 Semi-Definite Programming in Quantum Information	This course covers basic aspects of semidefinite programming and a few simple connections to quantum information theory.
	QIC 890 Design in Quantum Systems	This course is addressed to students who are interested in learning to integrate quantuminformation processing into design of quantum devices. The course will teach design principles in the context of quantum devices.
Winter 2013	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 890 Implementations of Quantum Communication	Investigation of the experimental issues of realizing quantum communication schemes. The relevant experimental concepts and principles for quantum communication will be studied, leading to the “real world” possibilities and limitations of the most prominent quantum communication protocols.

Term	Course	Description
	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 electron, photon 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 845 Open Quantum Systems	Review of the axioms of quantum theory and derivation of generalized axioms by considering states, transformations, and measurements in an extended Hilbert space. Introduction to quantum control with applications in NMR, quantum optics, and quantum computing.
	QIC 823 Quantum Algorithms	This course investigates algorithms that allow quantum computers to solve problems dramatically faster than classical computers.

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
Queens 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 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.

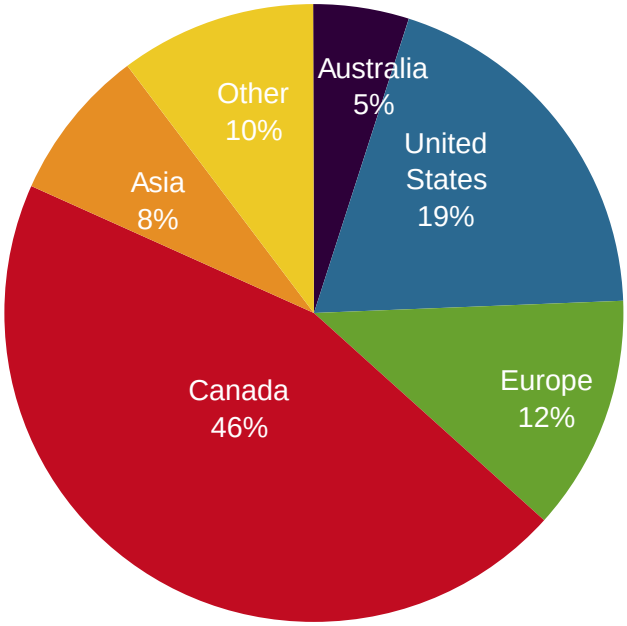
Students involved in the EU-Exchange program during the 2012-2013 fiscal year:

- Ansis Rosmanis from IQC visited the University of Latvia from May to August, 2012
- Robin Kothari from IQC visited the Université Paris Diderot from January 9 to February 10, 2013
- Alessandro Cosentino from IQC visited the Université Paris Diderot from February 7 to May 2, 2013
- Nathanael François from the Université Paris Diderot visited IQC in Waterloo for 2 weeks in June 2012

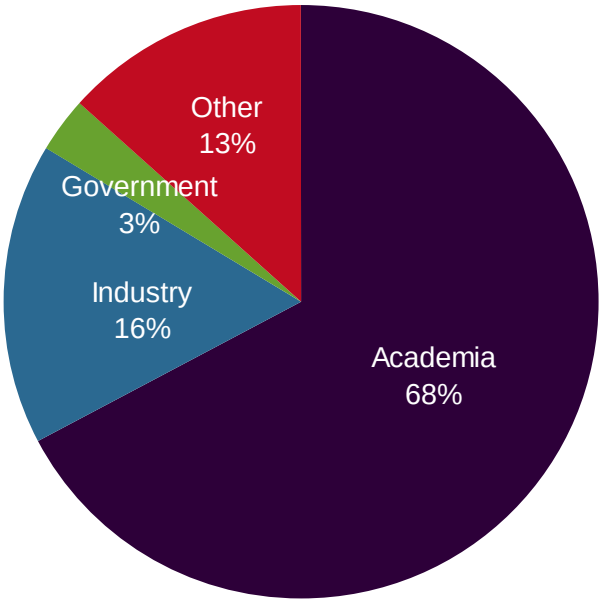
Alumni

IQC alumni are represented in various sectors around the world. The institute tracks where its former students go after IQC. The following graphs show the current locations of the IQC's 96 students and the sectors in which they are working[7].

Student Alumni: Where They Are Now



Student Alumni: Field of Employment



[7] IQC students since 2002.

Establishing IQC as the Authoritative Source of Insight, Analysis and Commentary on Quantum Information

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 2012/13

- Plan and manage the events related to the 10th anniversary and grand opening celebrations of the Mike & Ophelia Lazaridis Quantum-Nano Centre
- Increase interest in camps, workshops, conferences and programs through targeted marketing and increase the scale of the events with technology
- Reflect IQC's outreach priorities and programs on the web
- Host at least four conferences with three distinct target audiences
- Increase external media coverage, especially international media coverage

HIGHLIGHTED RESULTS FROM FISCAL 2012/13

- Hosted the Mike and Ophelia Lazaridis Quantum-Nano Centre grand opening event on September 21, 2012. Event attracted over 1200 guests including representatives from all levels of government.
- Hosted a series of grand opening events including an open house, quantum concert with the Qubits and a Quantum Symphony with the Kitchener-Waterloo Symphony Orchestra.
- Increased applications to IQC youth programs in 2012 by 47% over 2011.
- Hosted or sponsored 11 conferences at IQC and around the world.
- Significantly increased traffic to the IQC website and social media outlet.
- Extensive, worldwide media coverage for the Lazaridis Quantum-Nano Centre grand opening.

SCHOOLS, CONFERENCES & WORKSHOPS

Undergraduate School on Experimental Quantum Information Processing (USEQIP)
Date: May 28-June 8, 2012
Number of participants: 18
Number of applications in 2012: 144 (increased 47% over 2011)

USEQIP is a two-week program offered each year by IQC on the theory and experimental study of quantum information processing aimed primarily at students completing their junior year. The program is designed to introduce students to the field of quantum information processing. The lectures are geared to students in engineering, physics, chemistry and math.

12th Annual Canadian Summer School on Quantum Information

Date: June 11-16, 2012
Number of participants: 136

This annual Canadian event brings together students from around the world to learn about quantum information processing. The 2012 school was hosted at IQC and followed the tradition of educating young researchers in this rapidly-evolving field by gathering some of the world's top experts to offer lectures on various aspects of quantum information. The school is designed for graduate students and postdocs in computer science, mathematics and physics who are interested in learning about quantum information processing. It also provides an opportunity for students specializing in one sub-area to broaden their knowledge of the field as a whole.

9th Canadian Student Conference and 2nd AQuA Student Congress on Quantum Information

Date: June 18-22, 2012
Number of participants: 90

This student conference, hosted at IQC, combined two events — the 9th Canadian Student Conference on Quantum Information, and the 2nd AQuA Student Congress on Quantum Information and Computation. The event is a place for graduate students in the field of quantum information science from institutions around the world to come together and showcase their work to other graduate students in the field, at the same time making valuable contacts.

Quantum Cryptography School for Young Students (QCSYS)

August 13-17, 2012
Number of participants: 42
Number of applications in 2012: 133

QCSYS is a week-long program offered to students in Grades 11 and 12. Students were given a first-hand look into one of the most exciting topics in contemporary science — quantum cryptography. Not only were students exposed to cutting-edge topics like quantum physics and cryptography — they had the opportunity to meet some of the most renowned researchers the field has to offer. In addition, students also toured quantum computing and quantum cryptography labs.

Quantum Innovators

Date: September 6-9, 2012
Number of participants: 32

This invitation-only event connected the next generation of quantum researchers from around the world to Canada's research community. The Quantum Innovators workshop brought together the most promising researchers in quantum physics and engineering for a three-day conference aimed at exploring the frontier of our field.

SPONSORED CONFERENCES & EVENTS

- Workshop on Relativistic Quantum Information, June 25-28, 2012
  http://www.perimeterinstitute.ca/video-library/collection/relativistic-quantum-information-2012
- Matching, Matroids, and Extensions A Conference in Honour of Bill Cunningham's 65th Birthday, une 11-13, 2012
  http://www.fields.utoronto.ca/programs/scientific/11-12/bc65/
- Women in Physics Canada, August 2-4, 2013
  http://www.phas.ubc.ca/~wipc2012/
- QCRYPT 2012, September 10-14, 2012
  http://2012.qcrypt.net
- Canadian Undergraduate Physics Conference, October 25-29, 2012
  http://cupc.ca
- Post-Quantum Cryptography and Quantum Algorithms (Leiden Workshop), November 5-9, 2012
  http://lorentzcenter.nl/lc/web/2012/519/report.php3?wsid=519&venue=Oort
- 16th Workshop on Quantum Information Processing (QIP), January 21-15, 2013
  http://conference.iiis.tsinghua.edu.cn/QIP2013/index.html
- Conference in honor of John Preskill's 60th Birthday, March 14- 16, 2013
  http://www.caltech.edu/content/preskill-60th-birthday-conference

INVITED TALKS

IQC faculty and research assistant professors presented a total of 83 times during the 2012-2013 year. Of these, 24 were in Canada and 59 were at international events or organizations. For a full list of invited talks, see Invited Talks on page 152.

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 QNC, RAC I and RAC II at varying levels of technical complexity. In 2012, over 5,000 people visited the new Lazaridis QNC with 1200 attending the grand opening celebration and 2,650 visiting during the open house weekend. For a full list of tours, Tour Groups on page 182.

GOVERNMENT TOURS

Group	Date	# of Visitors
Chile delegation from CEDENNA (Centro para el Desarrollo de la Nanoscience y la Nanotecnologia)	May 7, 2012	1
Start-Up Canada delegation	May 17 2012	10
Maximo Hurtado, Trade commissioner (Information Technology and Communication), Embassy of Canada to Spain in Madrid and Robin MacNab (Canadian Trade Commissioner Service - Waterloo)	June 11, 2012	2
Dan Wayner	June 20, 2012	1
Taiwan delegation	July 9, 2012	20
Ted Hsu, Member of Parliament	October 29, 2012	1
Consul General of Greece	February 14, 2013	1
Industry Canada	March 6, 2013	1
Industry Canada	March 18, 2013	2
John Brackney and Norman Stucker, State of Colorado	April 3, 2013	2

BUSINESS/INDUSTRY TOURS

Group	Date	# of Visitors
Francine Dyksterhuis, Senior VP RBC	May 29, 2012	1
Maximo Hurtado, Trade commissioner (Information Technology and Communication), Embassy of Canada to Spain in Madrid and Robin MacNab (Canadian Trade Commissioner Service - Waterloo)	June 11, 2012	2
Chip Elliot, BBN-Ratheon	June 20, 2012	1
RIM Security Research Group	June 27 2012	15
Taiwan Delegation	July, 9 2012	20

Group	Date	# of Visitors
Huawei Technologies Canada	August 22, 2011	3
Sohrab Modi, Huawei Technologies Co.	October 23, 2012	1
International Wireless Industry Consortium	November 5, 2012	20
StrategyCorp	January 24, 2013	1
Organizers of TEDxMIT, TEDxAmsterdam, TEDxMaastrich & TEDxBaltimore	March 28, 2013	4

ACADEMIC TOURS

With the opening of the new Lazaridis Quantum-Nano 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 6,000 potential undergraduate students participate in campus tours that included the Lazaridis QNC. Additionally, IQC hosted 35 academic tours which included 123 delegates from the Electrostatic Society of America Conference, 45 members of Einstein Plus, and Keh-Yung Cheng and Yu Li Wang from the National Tsing Hua University, Taiwan. For a full list of academic tours, see Tour Groups on page 182.

Communications and Outreach

OBJECTIVES FOR FISCAL 2012/13

- Plan and manage the events related to the 10th anniversary and grand opening celebrations of the Mike & Ophelia Lazaridis Quantum-Nano Centre
- Hold an Open House in September 2012 in partnership with the University of Waterloo's main campus and the Waterloo Institute for Nanotechnology to mark IQC's expansion into the Mike & Ophelia Lazaridis Quantum-Nano Centre
- Continue and develop the research and creative work that will result in key messages per stakeholder group, consistent and compelling brand identity for IQC to help convey world-class science as broadly as possible
- Continue with website development to showcase IQC's scientific achievements and intensify the outreach activities
- Continue with government and stakeholder relations

HIGHLIGHTED RESULTS FROM FISCAL 2013

- Successfully hosted the grand opening celebrations of the Mike & Ophelia Lazaridis Quantum-Nano Centre on September 21, 2012 with over 1200 guests including special guest, Stephen Hawking.
- Successfully hosted a series of grand opening events including an open house, quantum concert with the Qubits and a Quantum Symphony with the Kitchener-Waterloo Symphony Orchestra.
- Signficantly increased traffic to IQC's website and social media outlets.

- Continued to build IQC's external relations team including expertise in branding, marketing, stakeholder and government relations.

GRAND OPENING CELEBRATIONS

On September 29, 2012, IQC hosted an open house as part of the grand opening celebrations for the new Mike & Ophelia Lazaridis Quantum-Nano Centre. During the day-long Community Open House, visitors toured the cutting-edge laboratories, met the scientists and learned about the quantum devices and nanotechnologies being pioneered in Waterloo. A series of public lectures by renowned guest speakers explored the joys and wonders of science, and an interactive Discovery Zone featured hands-on demos for explorers of all ages.

PUBLIC LECTURES

- Jay Ingram, one of the best-known and respected science journalists in Canada, delivered a retrospective talk about his fascinating career, from his early years hosting CBC Radio's Quirks and Quarks to his long tenure as host of Discovery Channel's Daily Planet.
- Chad Orzel, author of How to Teach Physics to Your Dog, explored everything you — and your canine best friend — needed to know about entanglement, superposition and other wonders of quantum science.
- Robert J. Sawyer, multi-award-winning author of 21 science fiction novels, explained how he weaves real, cutting-edge science — such as the quantum computing research happening in Waterloo — into compelling fictional tales.

PANEL DISCUSSION: BRIDGING WORLDS

A panel of world-leading experts explored how quantum science "bridges worlds" — the worlds of macro and micro, of our intuition and our experience, of present-day reality and future possibilities. Moderator Ivan Semeniuk, editor of Nature News, led a lively, wide-ranging discussion between Mike Lazaridis (Founder, Board Vice-Chair, Blackberry) Raymond Laflamme (Executive Director, Institute for Quantum Computing), Tom Brzustowski (expert on Canadian innovation), and Chad Orzel (author of How to Teach Physics to Your Dog).

SELF-GUIDED TOURS

Visitors had the opportunity to explore the most scientifically sophisticated building at the University of Waterloo. Visitors saw the cutting-edge laboratories of IQC and the Waterloo Institute for Nanotechnology, and met the scientists who are pioneering new technologies in the building. Video screens throughout the building explained the research that will unfold in the building, and how it will shape the 21st century. Visitors also had the opportunity to experience quantum science first-hand in the interactive Discovery Zone.

The Quantum Revue featuring Jay Ingram and the Qubits

In a truly one-of-a-kind experience, Canadian science guru Jay Ingram and his rock band, The Qubits, teamed up with researchers from IQC for an interactive mash-up of music and science. The concert featured classic rock songs with a quantum twist - and plenty of audience participation - in a fun and immersive evening for the whole family.

Publications

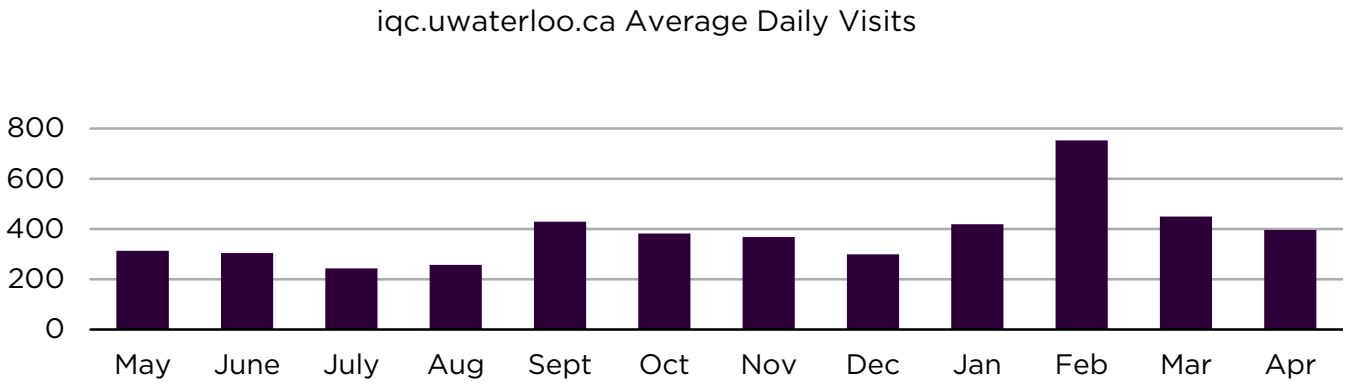
Publications are an important vehicle in IQC's external relations planning. The various publications produced, both in print and online, share research success and reach a varied audience.

Name	Publication Cycle
Annual Report	Yearly; 2011, 2012, 2013
"NewBit" Newsletter	Semesterly; January, May, September
IQC "one pager"	Yearly
Graduate Brochure/Poster	Yearly
USEQIP/QCSYS Brochure/Poster	Yearly
Industry Canada Annual Reports	Yearly; 2010, 2011, 2012, 2013

WEBSITE

IQC's website is one of the main vehicles for disseminating information to our varied stakeholders. Over the last year, traffic to our website has increased significantly, particularly around our grand opening celebrations. The IQC.ca home page averages close to 400 visitors daily.

The IQC website has received 140,000 visits in fiscal 2013 with over 50% of those visitors being new visitors.



The map below shows the global concentration of visitors to the IQC website. Seventy countries/territories are represented with Canadian visitors ranking #1 with 72,604 visits. Other large groups of visitors come from the United States, India, UK and Germany (in order).

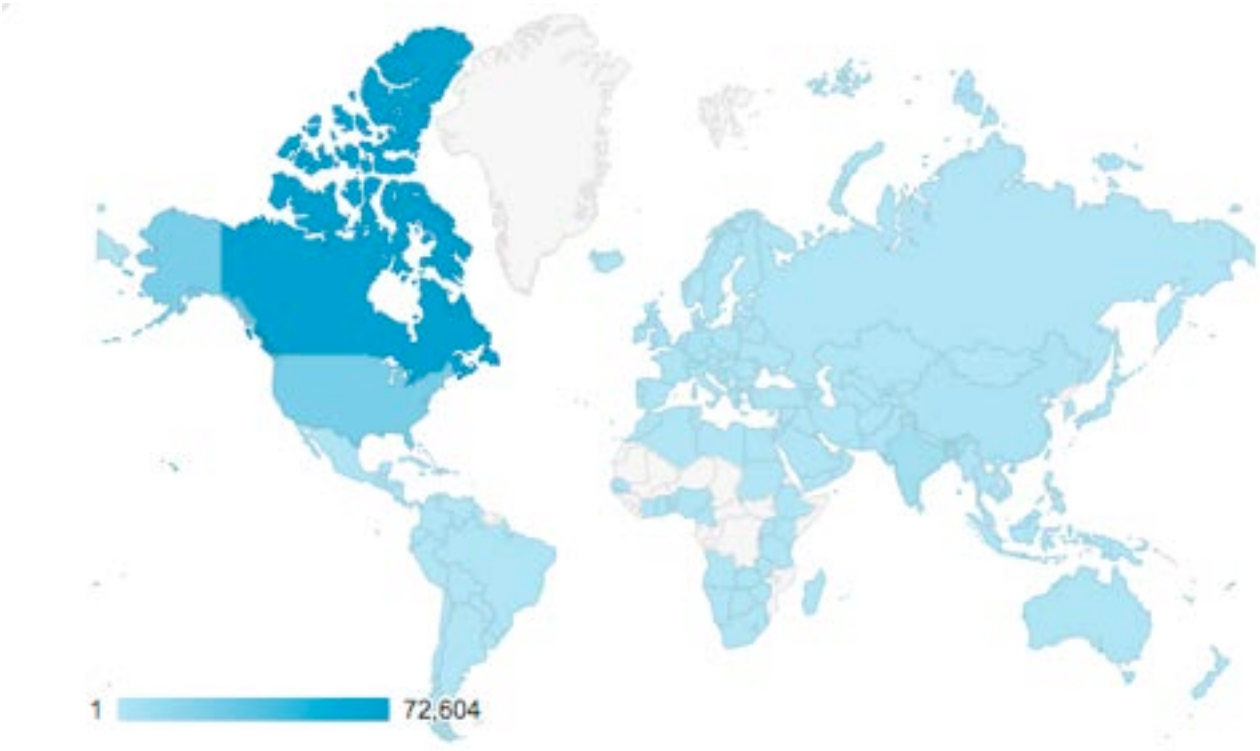


Figure 6: Visitors to iqc.ca

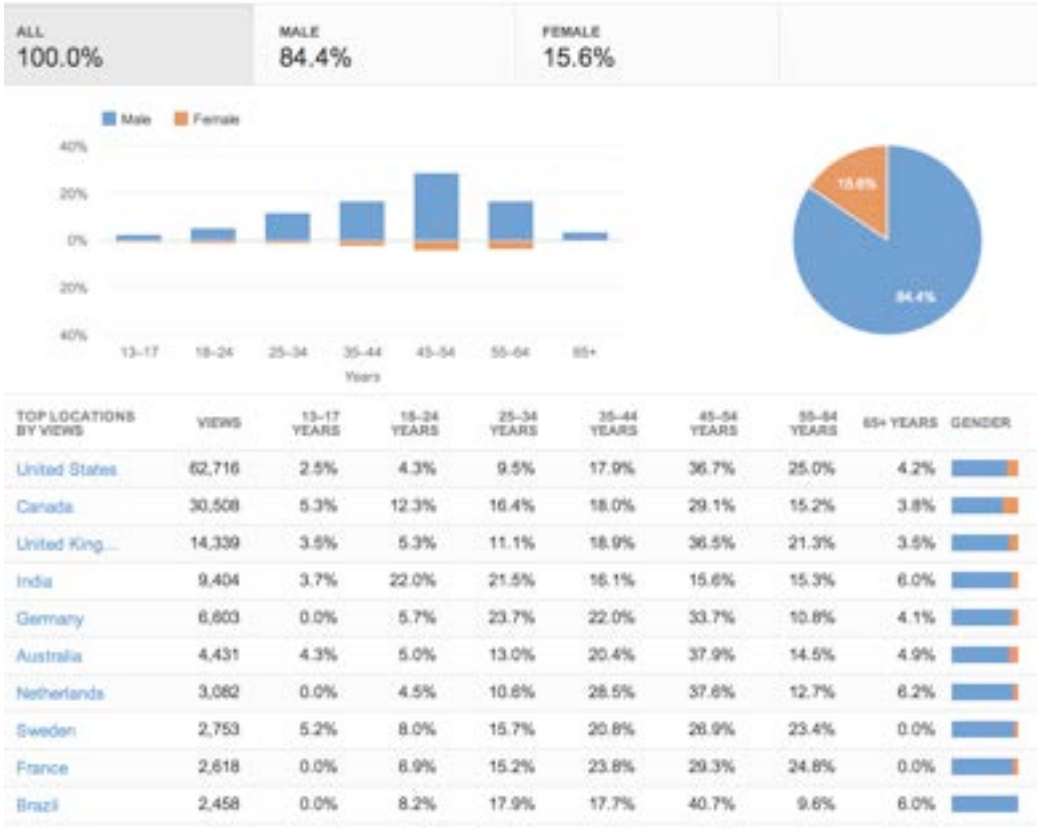
SOCIAL MEDIA

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 has created a large YouTube channel featuring over 100 videos. These videos share both academic and research success, as well as guest lectures and featured interviews. For a full list of IQC's videos, see YouTube Video Library on page 175.

- 1,760 subscribers (1,202 new in 2013)
- 293,475 views to date (188,909 in 2013)
- 943,645 minutes of video watched
- 648 likes
- 113 videos uploaded last year
- 84.4% of viewers are male
- High percentage of visitors 35+ years of age from European countries
- High number of viewers from the United States.



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	62,716	2.5%	4.3%	9.5%	17.9%	36.7%	25.0%	4.2%	
Canada	30,508	5.3%	12.3%	16.4%	18.0%	29.1%	15.2%	3.8%	
United King...	14,339	3.5%	5.3%	11.1%	18.9%	36.5%	21.3%	3.5%	
India	9,404	3.7%	22.0%	21.5%	16.1%	15.6%	15.3%	6.0%	
Germany	6,603	0.0%	5.7%	23.7%	22.0%	33.7%	10.8%	4.1%	
Australia	4,431	4.3%	5.0%	13.0%	20.4%	37.9%	14.5%	4.9%	
Netherlands	3,082	0.0%	4.5%	10.6%	28.5%	37.8%	12.7%	6.2%	
Sweden	2,753	5.2%	8.0%	15.7%	20.8%	26.9%	23.4%	0.0%	
France	2,618	0.0%	6.9%	15.2%	23.8%	29.3%	24.8%	0.0%	
Brazil	2,458	0.0%	8.2%	17.9%	17.7%	40.7%	9.6%	6.0%	

Figure 7: IQC YouTube channel demographics

Top 10 Videos, Views & Minutes Watched 2012-2013

Video	Views	Minutes Watched
The Quantum Mechanics of Time Travel	59,707	545,542
Stephen Hawking helps launch the Quantum-Nano Centre	14,103	38,533
Intro to Quantum Computing - Michele Mosca USEQIP 2011	8,194	48,839
Ion Trapping - Dr. David Wineland	5,152	6,761
Casimir Effects: Peter Milonni's lecture at the Institute for Quantum Computing	5,147	32,009
How Atomic Clocks Work - Dr. David Wineland	4,973	7,143
Seth Lloyd on the Universe as a Quantum Computer	3,243	3,414
Quantum Frontiers lecture: Dr. David Wineland on Atomic Clocks and Ion Trap Quantum Computing	2,369	17,824
John Preskill - Introduction to Quantum Information (Part 1). CSSQI 2012	2,369	17,824
Quantum Physics & Harry Potter	2,177	10,754

Facebook

IQC's Facebook page reached 1583 likes in 2012/13, a significant milestone 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.

Country	Likes
Canada	360
United States	299
India	271
Egypt	66

Country	Likes
Iran	63
United Kingdom	55
Pakistan	52

City	Likes
Waterloo	131
Toronto	57
Kitchener	48
Cairo, Egypt	32

Country	Likes
Calcutta, India	29
Tehran, Iran	21
Lahore, Pakistan	20

Twitter

In recent years, Twitter has become a trusted source of shared information. 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 over 2,400 followers and has tweeted over 800 times.

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

Figure 8: Twitter Statistics (tweets & retweets)

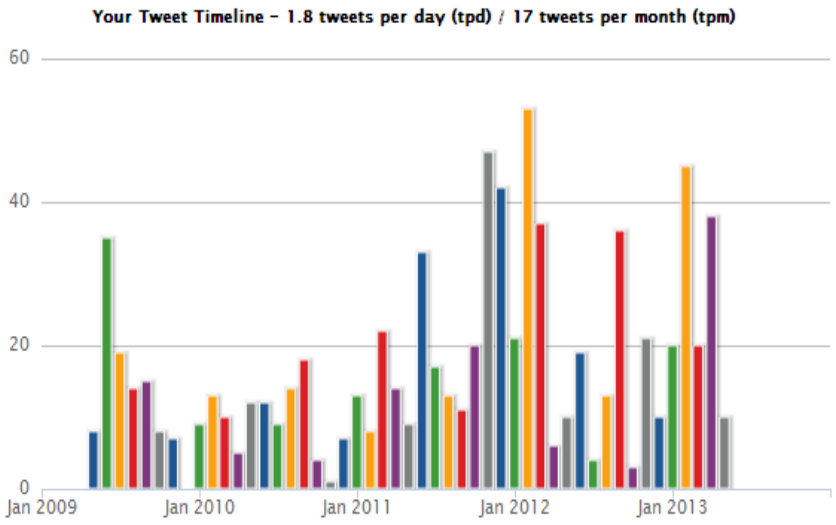


Figure 9: IQC Twitter Timeline (# of tweets)

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 2012/13, in no small part to the significance of the grand opening of the Mike and Ophelia Lazaridis Quantum-Nano Centre. The grand opening received over 60 media hits, below are a few of the highlights. For a full list of media coverage, see Media coverage on page 166.

Date	Media Outlet	Media Tier
Sept. 13	AZ oNano	International Science pub
Sept. 17	Toronto Star	Provincial
Sept. 18	CBC Radio	Provincial
Sept. 19	Bloomberg	International Business
Sept. 19	Business-Week	International Business
Sept. 20	Venture-Beat	International tech
Sept. 20	Digital Media Wire	International tech
Sept. 20	TechVibes	National tech
Sept. 20	Financial Post - Bloomberg	National
Sept. 21	CTV South-western Ontario	Regional
Sept. 21	Gov't website	National online
Sept. 21	The Waterloo Region Record	Regional
Sept. 21	BNN	Regional/national
Sept. 22	Chicago Daily Herald	U.S. Regional
Sept. 23	CTV SWO Province-wide	Provincial
Sept. 23	The Verge.com	International Tech
Sept. 24	TVO	Provincial
Oct. 10	University Affairs	National
Oct. 29	EON Business-wire	Provincial

Administrative Support

A full administrative team is necessitated by the ever-growing number of researchers and students at IQC. The institute plans to continue its growth to reach 30 faculty, 50 postdoctoral fellows and 125 graduate students within the next few years. The following section of this report reviews IQC's laboratory teams, the communications and outreach mandate, the information technology team and the administrative team functions.

Objectives:

Fiscal 2013 Objectives:

Execute the expansion into the Mike & Ophelia Lazaridis Quantum Nano Centre, including the commissioning of the labs, facilities and equipment

Participate in the fit-out of the new QNC facility including specifying the furniture; co-ordinating with central campus IT teams on the fit-out of networking and audio/visual infrastructure; migration of the IQC computing infrastructure to the new facility; plan (and execute) of the physical move of individual computing equipment of designated members; deliver a system solution to manage the scheduling of research meeting spaces for IQC in QNC

Highlighted Results from Fiscal 2013:

Highlighted Results from Fiscal 2012:

Designed and delivered the foundational elements of the information management repository including enhancements to the visitor tracking system, improved publication tracking, an enhanced members directory, a new grant management system and extended the "HUB" file sharing system

Provided ongoing support for the operation of the of qncfab.uwaterloo.ca website, implemented a solution for isolating the cleanroom tool equipment systems from software virus contamination, integrated existing booking data into a invoicing system for the cost recovery of the NanoFab operations

The mechanism for ongoing operating costs (utilities and maintenance) of the QNC prior to the winter semester did not occur because construction on the building was delayed

Expansion into the Mike & Ophelia Lazaridis Quantum Nano Centre was deferred due to construction delays

An effort to build, grow and rationalize stakeholder relations on all fronts is currently underway — see section 2.3.2.3 for more on IQC's stakeholder relations

Objectives for Fiscal 2013/14

Conducting Research in Quantum Information

Research at IQC continues to span the breadth of quantum information science. Our research is producing knowledge that leads to publications and presentations. As IQC research matures, we are gaining a better understanding of quantum information processors and our experiments are demonstrating control and development of new quantum technologies.

OBJECTIVES FOR 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 cryptography systems.
- Expand the development of commercialization opportunities in particular in quantum sensors which are showing incredible promise and significant societal impact.

Recruiting Researchers

Over the past 10 years, IQC has assembled a critical mass of theoretical and experimental researchers who explore a broad range of approaches to quantum information processing. IQC will continue its recruitment of top-tier faculty to further enhance the institute's fundamental objective of pursuing quantum information research at the highest international level.

OBJECTIVES FOR 2013/14

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

Collaborating with Other Researchers

By collaborating with key researchers across disciplines and around the world, IQC will enhance its international reputation, draw highly qualified personnel to IQC and increase the probability of experimental and theoretical breakthroughs. IQC will continue to build its reputation and foster positive research collaborations.

OBJECTIVES FOR 2013/14

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

- 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 multi-disciplinary participants
- Continue, enhance and increase visits to IQC by international scientists and academics from around the world.

Building, Facilities and Laboratory Support

With the completion of the Mike and Ophelia Lazaridis Quantum-Nano Centre, IQC's facilities are world-class. Over the coming year, the development and relocation of certain labs will take place, along with the fit-out of the Quantum-Nano Fab facility.

OBJECTIVES FOR 2013/14

- 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.

Attracting, Educating and Training Highly Qualified Personnel

IQC has a stellar track record for attracting talented students and researchers for its programs. These students training in quantum information research will lead the quantum revolution and drive future economic prosperity.

OBJECTIVES FOR 2013/14

- Attend at least four graduate fairs to connect with prospective students
- Field at least 200 applications to the uWaterloo/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

Disseminating Knowledge

For IQC to achieve its strategic objectives, it must share its research knowledge. This dissemination of knowledge will help to promote IQC, and Canada, as a world-class centre of research in quantum technologies and their applications.

OBJECTIVES FOR 2013:

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

Communications and Outreach Strategy

In 2012, IQC enjoyed increased communication and outreach activity through the events related to its 10th anniversary and the grand opening of the Lazaridis QNC building. Over the next 12 months, IQC will reinforce its brand messaging and look and feel to better reflect a mature institution and its world-class status. Our outreach activities will bring 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 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.

Administrative Support

Over the past eight months, IQC has undergone a seamless transition to the Lazaridis QNC and has begun the related commissioning of equipment. In the next year, that transition will continue with further researchers and labs moving into the new building. Additionally, IQC's growth strategy calls for an additional five faculty members to be recruited this year. Strong administrative systems and support will streamline new faculty transition to IQC and help establish their research agendas quickly and efficiently.

OBJECTIVES FOR 2013/14

- Continue to 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 QNC facility including the execution of the physical move of individual lab spaces of designated members and the fit out of the Quantum-Nano Fab 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 highly competitive, and IQC is still building brand awareness. However, researchers are the cornerstone on which institutional reputation is built	• 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

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	Med	Low	3	Delays may hinder IQC's recruitment efforts	• Ensure high-quality graduate program application

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 HQP 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/talent/skills • Develop and deliver a branding project plan • Foster close working relationships with appropriate units within the university
Construction costs may exceed budget	Low	Medium	2	The IC grant amount is fixed. University has committed to compensate for shortfall.	• N/A
Construction schedule may be delayed	Med	Low	3	Outcomes would be delayed, but not changed	• 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

Industry Canada Page Reference Guide

Section	Metric	Page #
Future Objectives	Conducting research in quantum information	63
	Recruiting new researchers	63
	Collaborating with other researchers	63
	Building, facility and laboratory support	64
	Attracting, educating and training highly qualified personnel	64
	Disseminating scientific knowledge	64
	Communications and outreach	65
	Administrative support	65
Past Objectives	Conducting research in quantum information	12
	Recruiting new researchers	22
	Collaborating with other researchers	27
	Building, facility and laboratory support	34
	Attracting, educating and training highly qualified personnel	41

Section	Metric	Page #
	Disseminating scientific knowledge	51
	Communications and outreach	55
Results		
Activity 1: Building facility and equipment	Per cent of construction that is complete	34
	Per cent of equipment is in place/labs finished	34
	Degree to which construction is on budget	34
	Degree to which construction is on schedule	34
	Number of jobs created (construction)	34
	Number of requests to visit the facility	53
Activity 2: Collaborating with Other Researchers	Number of new grants	91
	Number of collaborations (between two or more researchers)	27
	Type of collaborations	27
	Number of collaborators	27

Section	Metric	Page #
	Number of citations	20
	Number of peer reviewed publications	96
	Number of spinoffs, disclosures, patents, etc.	33
	MOUs with other universities or organizations	29
	Number of faculty awards	21
	$ investment by government and industry	91
Activity 3: Recruiting Researchers/Conducting Research in QI	Number of citations	20
	Number of peer reviewed publications	96
	Number of spinoffs, disclosures, patents, etc.	33
Activity 4: Attracting, Educating and Training HQPs	Number and type of new courses and labs	47
	Documented establishment of graduate program	41
	Type of practical opportunities for graduates	50

Section	Metric	Page #
	Number of scholarships/fellowships/awards received by IQC HQP	45
	Per cent of graduates working in the QI field in Canada	50
	Number of books/chapters authored by IQC researchers	19
	Per cent of IQC HQPs from top undergraduate/graduate schools (as ranked by the FT)	48
	Per cent of IQC HQPs with high GPAs	44
	Number of domestic/international HQPs at IQC/jobs created	13.5
Activity 5: Disseminating Knowledge	Number of workshops held	51
	Number of visitors to IQC	51
	Number of presentations at conferences made by IQC HQP	53
	Number of applications to IQC (faculty and postdocs)	41
	Number of visits to the IQC website	57
	Type of content on the IQC website	57

Section	Metric	Page #
	Number and type of outreach activities (including number of participants)	51
	Number of press releases by/articles written on IQC	62
	Number and type of researchers at IQC	24
Activity 6: Communications and Outreach Strategy	Documented communications/branding plan, roadmap	51
	Number and type of outreach activities (including number of participants)	51
Risks	Situational assessment	66
	Mitigation strategies	66
	Ongoing performance monitoring strategies	66

IQC MEMBERS FISCAL 2013

Faculty

1. Jonathan Baugh
2. Andrew Childs
3. Richard Cleve
4. David Cory
5. Joseph Emerson
6. Thomas Jennewein
7. Robert Keonig
8. Raymond Laflamme
9. Debbie Leung
10. Adrian Lupascu
11. Norbert Lutkenhaus
12. Hamed Majedi
13. Matteo Mariantoni
14. Guo-Xing Miao8
15. Michele Mosca
16. Ashwin Nayak
17. Kevin Resch
18. John Watrous
19. Frank Wilhelm
20. Christopher Wilson

Research Assistant Professors

1. Vadim Makarov
2. Marco Piani
3. Dmitry Pushin
4. Radu Ionicioiu[9]

Postdoctoral Fellows

1. Mohammad Ansari
2. Mustafa Bal
3. Olaf Benningshof
4. Troy Borneman
5. Anne Broadbent
6. Aharon Brodutch
7. Jianxin Chen
8. Lin Chen
9. Audrey Dot
10. Chris Erven
11. Silvano Garnerone
12. Oleg Gittsovich
13. David Gosset
23. Keith Lee
24. Ying Liu
25. Dawei Lu
26. Eduardo Martin Martinez
27. William Matthews
28. Rajat Mittal
29. Hamid Mohebbi
30. Osama Moussa
31. Mustafa Muhammad
32. Florian Ong
33. Zlatko Papic
34. Robabeh Rahimi Darabad
35. Aiden Roy

[8] Guo-Xing Miao becme a faculty member in August 2012. Previously, he was a Research Assistant Professor.
[9] Radu Ionicioiu was a Research Assistant Professor until September 2012. He is included here, but not counted in the year-end tally.

14. Patryk Gumann
15. Gus Gutoski
16. Chris Haapamaki
17. Brendon Higgins
18. Rolf Horn
19. Mark Howard
20. Zhengfeng Ji
21. Nathaniel Johnston
22. Piotr Kolenderski
36. Krister Shalm
37. Sarah Sheldon
38. Fang Song
39. Yipu Song
40. Jon Tyson
41. Glad Garnerone
42. Joel Wallman
43. Nathan Wiebe
44. Zizhong Yan
45. Huang Yang
46. Bei Zeng

Graduate Students

1. Megan Agnew
2. Matthew Amy
3. Elena Anisimova
4. Razeih Annabestani
5. Juan Miguel Arrazola
6. Srinivasan Arunachalam
7. Shima Bab Hadiashar
8. Jason Boisselle
9. Jean-Philippe Bourgoin
10. Steven Casagrande
11. Grant Cleary
12. Paulina Corona Ugalde
13. Alessandro Cosentino
14. Daniel Criger
15. Chunqing Deng
16. John Donohue
17. Amin Eftekharian
18. Agnes Ferenczi
19. Chris Ferrie
20. Kent Fisher
21. Joshua Geller
22. Naimeh Ghafarian
23. Kaveh Gharavi
24. Sevag Gharibian
25. Nickolay Gigov
53. Jeremy Kroeker
54. Stephane Labruyere
55. Alexandre Laplante
56. Jonathan Lavoie
57. Xian Ma
58. Easwar Magesan
59. Laura Mancinska
60. Iman Marvian
61. Michael Mazurek
62. Thomas McConkey
63. Corey Rae McRae
64. Evan Meyer-Scott
65. Maryam Mirkamali
66. Felix Motzoi
67. Hamidreza Nafissi
68. Takafumi Nakano
69. Mohamad Niknam
70. Joachim Nsofini
71. Jean-Luc Orgiazzi
72. Martin Otto
73. Yingkai Ouyang
74. Maris Ozols
75. Adam Paetznick
76. Kyungdeock Park
77. Om Patange

26. Luke Govia
27. Christopher Granade
28. Matthew Graydon
29. Peter Groszkowski
30. Nupur Gupta
31. Vibhu Gupta
32. Holger Haas
33. Deny Hamel
34. Minyang Han
35. Fatin Haque
36. Aimee Heinrichs
37. Ian Hincks
38. Catherine Holloway
39. Gregory Holloway
40. Amir Jafari Salim
41. Erika Janitz
42. Stacey Jeffery
43. Tomas Jochym-O'Connor
44. Sarah Kaiser
45. Shitikanth Kashyap
46. Milad Khoshnegar Shahrestani
47. Feyruz Kitapli
48. Vadym Kliuchnikov
49. Robin Kothari
50. Marcin Kotowski
51. Michal Kotowski
52.
78. Chris Pugh
79. Daniel Puzzuoli
80. Farzad Qassemi
81. Wenling Qiao
82. Sadegh Raeisi
83. Joseph Rebstock
84. Ansis Rosmanis
85. Vincent Russo
86. Shihan Sajeed
87. Yuval Sanders
88. Antonio Scotland
89. Ala Shayeghi
90. Feiruo Shen
91. Jamie Sikora
92. Jamie Smith
93. William Stacey
94. Gelo Noel Tabia
95. Yongchao Tang
96. Denis-Alexandre Trottier
97. Cozmin Ududec
98. Alexander Valtchev
99. Victor Veitch
100. Lydia Vermeyden
101. Zak Webb
102. Kyle Willick
103. Christopher Wood
104. Muhammet Yurtalan

Research Assistants

1. Abhijeet Alase
2. Madelaine Liddy
3. Maryam Mirkamali
4. Martin Otto
5. Alex Parent
6. Prasad Sarangapani
7. Daryoush Shiri

8. Chris Sutherland

Long-Term Visitors

1. Vikram Sharad Athalye, Cummins College of Engineering, India
2. Sam Bader, Massachusetts Institute of Technology, USA
3. Amin Baumeler,, ETH Zürich, Switzerland
4. Troy Borneman, Massachusetts Institute of Technology, USA
5. Tiago Debara, Instituto de Física Universidade Federal Fluminense, Brazil
6. Audrey Dot, Joseph Fourier University, France
7. Jonathan Friedman, Amherst College, USA
8. Daniel Gustaw, Nicolaus Copernicus University, Poland
9. Melanie Jensenworth, University of Washington, USA
10. Kelsey Johnsen, University of California, Berkeley, USA
11. Daniel Jost Brod, Instituto de FÍsica Universidade Federal Fluminense, Spain
12. Antti Karlsson, University of Turku, Finland
13. Maria Kieferova, Comenius University in Bratislava Slovakia, Slovakia
14. Kevin Krsulich, Massachusetts Institute of Technology, USA
15. Mehul Kumar, India Institute of Technology, Delhi, India
16. Srijita Kundu, Chennai Mathematical Institute, India
17. Qiang Li, Shandong University, China (2 visits)
18. Hang Li, Tsinghua University, China (2 visits)
19. Thomas Lutz, Universität Ulm, Germany
20. Mhlambululi Mafu, University of KwaZulu-Natal, South Africa
21. Ryan Marchildon, Queen's University, Canada
22. Mayank Mishra, Indian Institute of Science Education and Research, India
23. Keith Motes, Louisiana State University, USA
24. Taesik Nam, Pohang University of Science and Technology, Korea
25. Crystal Noel, Massachusetts Institute of Technology, USA
26. Michal Papaj, University of Warsaw, Poland
27. Laura Piispanen, None
28. Dominique Pouliot, University of Illinois at Urbana-Champaign, USA

29. Mouktik Raha, Indian Institute of Technology Kharagpur, India
30. Sarah Sheldon, Massachusetts Institute of Technology, USA
31. Hou Shiyao, Tsinghua University, China
32. Christophe Vulliot, Université de Rennes, France
33. Fei Wang, Tsinghua University, China
34. Amir Yacoby, Harvard University, USA

Short Term Visitors[10]

1. Scott Aaronson, Massachusetts Institute of Technology, USA
2. Markus Aspelmeyer, University of Vienna, Austria
3. Apoorva Athavale, Indian Institute of Technology Hyderabad, India
4. Nyeli Azucena Rodriguez-Briones, Max Planck Institute of Quantum Optics in Garching, Germany
5. Michal Bajcsy, Stanford University, USA
6. Konrad Banaszek, University of Warsaw, Poland
7. Julio Barreiro, Max Planck Institute of Quantum Optics & Ludwig Maximilian University of Munich, Germany
8. Jeremy Bejanin, McGill University, Canada
9. Steven Bennett, Harvard University, USA
10. Jacob Biamonte, University of Oxford, United Kingdom
11. Alexandre Blais, University of Sherbrooke, Canada
12. Thomas Blasi, Harvard University, USA
13. Sergey Bravyi, IBM TJ Watson Research Center, USA
14. Thomas Brougham, University of Strathclyde, Scotland
15. Ken Brown, Georgia Institute of Technology, USA
16. Todd Brun, University of Southern California, USA
17. Ian Burgess, Harvard University, USA
18. Nicolas C. Menicucci, University of Sydney, Australia
19. Robert Cameron, University of Strathclyde, Scotland
20. Yudong Cao, Purdue University, USA

[10] Denotes visits to a maximum of 2 weeks.

21. Stefano Chesi, McGill University, Canada
22. Matthias Christandl, Institute for Theoretical Physics ETH Zurich, Switzerland
23. Aashish Clerk, McGill University, Canada
24. Bill Coish, McGill University, Canada
25. Patrick Coles, Carnegie Mellon University, USA
26. Robin Cote, university of Connecticut, USA
27. Wei Cui, University of Toronto, Canada
28. Pawel Dabkowski, Czech Technical University Prague, The Czech Republic
29. Daniel David Bonior, Middle Tennessee State University, USA
30. Giuseppe Davide Paparo, University of Maryland, USA
31. Olivia N Di Matteo, Lakehead University, Ontario, Canada
32. Helen Fay Dowker, Imperial College London, United Kingdom
33. Jiangfeng Du, University of Science and Technology, China
34. Carolyn Earnest, Portland State University, USA
35. Chip Elliott, Raytheon-BBN Technologies, USA
36. Klaus Ensslin, Swiss Federal Institute of Technology Zurich, Switzerland
37. Pol Forn-Díaz, California Institute of Technology, USA
38. Sevag Gharibian, University of California, Berkeley, USA
39. Vlad Gheorghiu, University of Calgary, Canada
40. Cecile Grezes, CEA-Saclay, France
41. Simon Groeblacher, California Institute of Technology, USA
42. Otfried Guehne, Universität Siegen, Germany
43. Hartmut Haeffner, University of California, Berkeley, USA
44. Tae Hee Kim, Ewha Womans University, Korea
45. Mark Hillery, The City University of New Yor, USA
46. Mark Howard, National University of Ireland, Maynooth, ireland
47. Xuedong Hu, University of Buffalo, USA
48. Hannes Hübel, Stockholm University, Sweden
49. Dan Hussey, National Institute of Standards and Technology, USA
50. Annie Jihyn Park, University of British Columbia, Canada
51. Yoon-Ho Kim, Pohang University of Science & Technology, Korea

52. Alexey Kovaleve, University of California, Riverside, USA
53. Lindsey LeBlanc, National Institute of Standards and Technology, USA
54. Kuret Loutfi, Université de Montréal, Canada
55. Jean-Philippe MacLean, McGill University, Canada
56. Riccardo Manenti, University of Milan, Italy
57. Vladimir Manucharyan, Harvard University, USA
58. Matteo Mariantoni, University of California, Santa Barbara, USA
59. Wen Masters, Office of Naval Research, USA
60. William Matthews, University of Cambridge, UK
61. Nicolas Menicucci, The University of Sydney, Australia
62. David Meyer, University of California, San Diego, USA
63. Benjamin A. Milarch, United States National Intelligence University, USA
64. Kavan Modi, University of Oxford, United Kingdom
65. Ashley Montanaro, University of Cambridge, UK
66. Tobias Moroder, Universität Siegen, Germany
67. Holger Müller, University of California, Berkeley, USA
68. Daniel Nagaj, Slovak Academy of Sciences, Slovakia
69. Simon Nigg, Yale University, United States
70. George Noid, Indiana University, USA
71. Ryo Okamoto, Hokkaido University, Japan
72. Maris Ozols, IBM TJ Watson Research Center, USA
73. Gerardo Paz, University of Southern California, USA
74. Borja Peropadre, Instituto de Fisica Fundamental, Spain
75. Simon Phoenix, Khalifa University, Abu Dhabi
76. Jaques Pienaar, University of Queensland, Australia
77. Trey Porto, National Institute of Standards and Technology, USA
78. Katherine Quinn, McGill University, Canada
79. Chandrasekhar Ramanathan, Dartmouth College, USA
80. Sven Ramelov, University of Vienna, Austria
81. Mohsen Razavi, University of Leeds, United Kingdom
82. Ben Reichardt, University of Southern California, USA

83. John Rinehart, Washington State University, Spokane, USA
84. Andrey Rogachev, Cornell University, USA
85. David Rosenbaum, University of Washington, USA
86. Mary Beth Ruskai, Tufts University, USA
87. Martin Rust, Strategy Corp, Canada
88. Amir Safevi-Naeini, California Institute of Technology
89. Shihan Sajeed, University of Dhaka, Bangladesh
90. Louis Salvail, Université de Montréal, Canada
91. Lisa Samson, Strategy Corp, Canada
92. Barry Sanders, University of Calgary, Canada
93. Ruediger Schack, Royal Holloway, University of London, UK
94. Carey Schwartz, Office of Naval Research, USA
95. Guy Seguin, Canadian Space Agency, Canada
96. Feiruo Shen, Tsinghua University, China
97. Pragya Shukla, Indian Institute of Technology Kharagpur, India
98. Graeme Smith, IBM TJ Watson Research Center, USA
99. W. Michael Snow, Indiana University Bloomington, USA
100. Fang Song, Penn State University, USA
101. Kyung Soo Choi, Korea Institute of Science and Technology, Korea
102. Henriette Steiner, unknown
103. Rainer Steinwandt, Florida Atlantic University, USA
104. Markku Stenberg, Saarland University, Germany
105. Michal Studzinski, Nicolaus Copernicus University, The Czech Republic
106. Krysta Svore, Microsoft Research, USA
107. Mario Szegedy, Rutgers University, USA
108. Barbara Terhal, Rheinisch-Westfaelische Technische Hochschule Aachen University, Germany
109. Lin Tian, University of California, Merced, USA
110. Peter Turner, University of Tokyo, Japan
111. Umesh Vazirani, University of California, Berkeley, USA
112. Thomas Vidick, Massachusetts Institute of Technology, USA

113. Denis Vion, CEA-Saclay, France
114. Joel Wallman, The University of Sydney, Australia
115. Yingdan Wang, McGill University, Canada
116. Jie Wang, University of Science and Technology, China
117. Xiaoya Wang , McGill University, Canada
118. Dan Wayner, National Research Council Canada, Canada
119. Gregor Weihs, Universität Innsbruck, Austria
120. Sang Wook, Korea Institute of Science and Technology, Korea
121. Sung Wook Moon, Korea Institute of Science and Technology, Korea
122. Liu Ying, University of Wisconsin, Milwaukee, USA
123. Anton Zeilinger, University of Vienna, Austria
124. Zhenyu Zhang, University of Science and Technology, China
125. Jingfu Zhang, Technische Universitat Dortmund, Germany
126. Yanbao Zhang, University of Colorado at Boulder, USA
127. Zoltan Zimboras , University of the Basque Country, Spain
128. Karol Życzkowski , Jagiellonian University, Poland

Administrative Staff

1. Sean Collins
2. Matthew Cooper
3. Erin Cronin
4. Robert Crow
5. Andrew Dale
6. Lisa David*
7. Tobi Day-Hamilton
8. Monica Dey
9. Melissa Floyd
10. Matthew Fries
11. Jennifer Fung*
12. Brian Goddard
13. Jaymis Goertz
19. Lorna Kropf
20. Martin Laforest
21. Chin Lee
22. Vito Loguidice
23. Steve MacDonald*
24. Jessica Miranda
25. Nathan Nelson-Fitzpatrick
26. Mary Lyn Payerl
27. Wendy Reibel
28. Robert Romero
29. Rodello Saladanan
30. Matthew Schumacher
31. Kimberly Simmermaker

14. Ryan Goggin
15. Jasmine Graham*
16. Browyn Greavette
17. Katharine Harkins*
18. Colin Hunter*
32. Marta Szepietowski*
33. Jodi Szimanski
34. Carly Turnbull

Steve Weiss

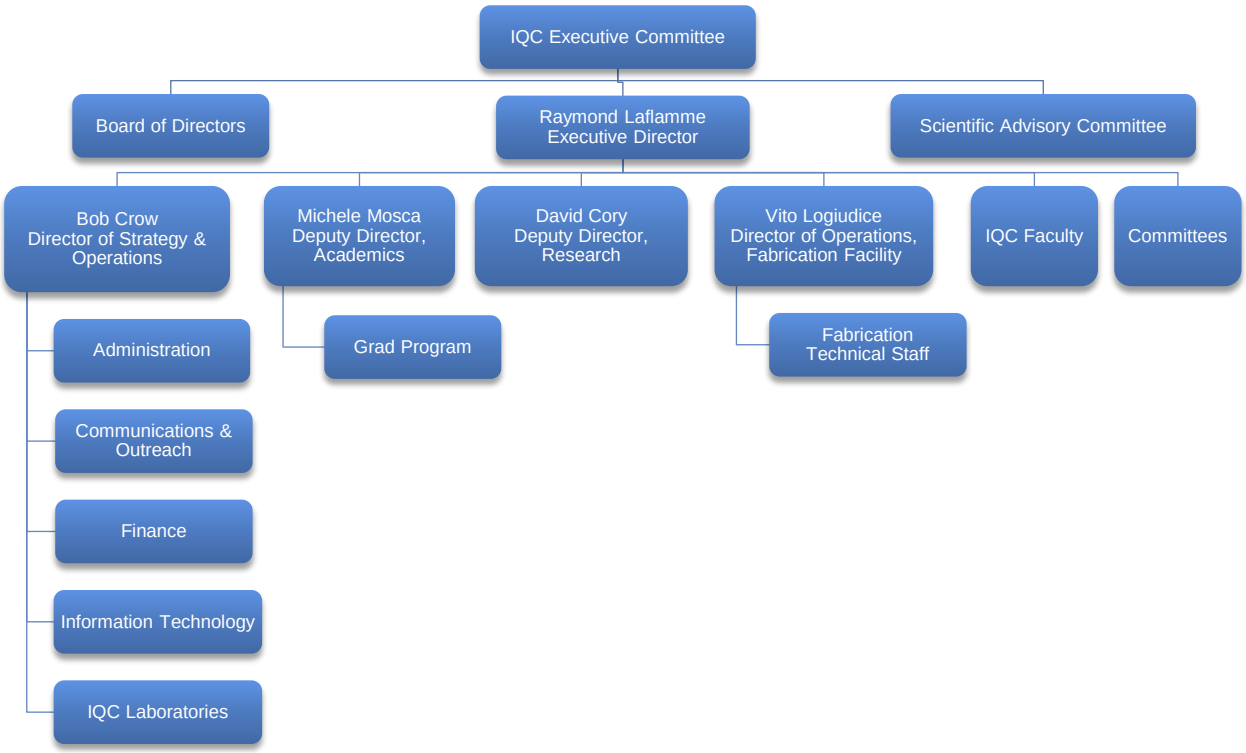
Technical Staff

1. Brian Goddard
2. Vito Logiudice
3. Nathan Nelson-Fitzpatrick
4. Roberto Romero
5. Rodello Salandanan
6. Ivar Taminiau

*These individuals were with IQC for a portion of fiscal 2012-2013.

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.[11] 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

[11] For biographies for the Executive Committee see IQC Board of Directors Biographies on page 83.

- 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

Board of Directors

IQC's Board of Directors is made up of internationally recognized leaders from academia, business and government.[12] 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
- Raymond Laflamme, Executive Director, Institute for Quantum Computing
- Mike Lazaridis, Co-Founder of Research In Motion
- Michele Mosca, Deputy Director Academic, Institute for Quantum Computing
- William R. Pulleyblank, Professor of Operations Research, United States Military Academy, West Point

Scientific Advisory Committee

IQC's Scientific Advisory Committee is made up of leading international scientists.[13] 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

[12] For biographies of the Board of Directors, see IQC Board of Directors Biographies on page 83.
[13] Biographies for the Scientific Advisory Committee Scientific Advisory Committee Biographies on page 86

- 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

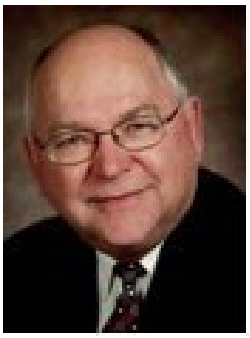
Faculty members at IQC hold appointments in departments at the University of Waterloo and as such, are governed by the University's policies on appointment, promotion and tenure. All faculty participate in annual evaluations conducted by their home departments. The Executive Director of IQC gives input 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.

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



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 Infinite Potential Group. 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 is currently 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

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

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.

SCIENTIFIC ADVISORY COMMITTEE BIOGRAPHIES

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.

Anthony J. Leggett

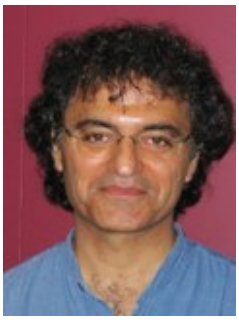
Anthony J. Leggett, the John D. and Catherine T. MacArthur Professor and Center for Advanced Study Professor of Physics, has been a faculty member at Illinois since 1983. He was a co-winner of the 2003 Nobel Prize in Physics for pioneering work on superfluidity. He is a member of the National Academy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

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 (M.Sc. 1974) and Austin, Texas (PhD 1979). He spent two years at Caltech as a Tolman Fellow, and began his appointment at LANL as a J. Oppenheimer Fellow. He was

the leader of the Theoretical Astrophysics Group at LANL from 1991 until he was made a Laboratory Fellow in the Theory Division in 1996. Zurek is currently a foreign associate of the Cosmology Program of the Canadian Institute for Advanced Research.

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 Research Chairs at IQC are: Raymond Laflamme, and Debbie Leung.

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 2012 - 2013 fiscal year.

Sponsor Type	Sponsor Name	Total Awarded
Canadian - Government and Public Sector - Federal - Other	CERC (Canada Excellence	1,400,000
	CFI - IOF (Infrastructure	437,375
	CFI - LEF (Leading Edge Fund)	250,000
	CRC - NSERC	300,000
	Industry Canada	1,750,000
	Sub-Total	**4,137,375**
Canadian - Government and Public Sector - Federal - Tri Agency	NSERC - Collaborative Research	300,000
	NSERC - Discovery Grants -	90,811
	NSERC - Discovery Grants -	695,257
	NSERC - Engage Grant	25,000
	NSERC - Research Tools and	449,110
	Sub-Total	**1,560,178**
Canadian - Government and Public Sector - Provincial - Ontario	MRI - ERA (Early Researcher	165,354
	MRI - ORF-RE (Ontario	49,597
	Sub-Total	**214,951**
Canadian - Not-for-Profit - Other	Canadian Institute for Advanced	347,750
	Communitech Inc.	578,000
	Sub-Total	**925,750**

Sponsor Type	Sponsor Name	Total Awarded
Canadian - Non Profit - Academic	McMaster University	60,000
	University of Waterloo	2,855,350
	University of Waterloo - VP	60,000
	Duke University	60,718
	University of California - Santa	-89,828
	Sub-Total	**2,946,240**
US Government and	US Army Research Office	369,126
	Sub-Total	**369,126**
US Private Sector -	Raytheon BBN Technologies	522,798
	Sub-Total	**522,798**
	Total	**10,676,418**

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
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
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
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

Supervisor	Supervisory Privileges	Quantum Information Research Interests
Robert Koenig*	Applied Mathematics	Quantum information theory Quantum Cryptography Quatum 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

Supervisor	Supervisory Privileges	Quantum Information Research Interests
Pierre-Nicholas Roy†	Chemistry	Quantum molecular dynamics simulations Quantum Monte Carlo Feynman path integrals Coherent molecular rotation in nano-superfluid clusters Semiclassical dynamics Biophysics
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*	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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Studying free-space transmission statistics and improving free-space quantum key distribution in the turbulent atmosphere.	B Heim	Max Planck Institute for the Science of Light and Erlangen Graduate School in Advanced Optical Technologies - University of Erlangen-Nuremberg	Erlangen, Germany
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An ultra low noise telecom wavelength free running single photon detector using negative feedback avalanche diode.	Xudong Jiang	Princeton Lightwave, Inc.	Cranbury, New Jersey, USA
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Three-photon energy-time entanglement	C. Simon	Institute for Quantum Information Science and Department of Physics and Astronomy, University of Calgary	Calgary, AlbertaCanada
Quantum erasure with causally disconnected choice	Xiao-Song Ma	Institute for Quantum Optics and Quantum Information, Austrian Academy of Sciences	Vienna, Austria
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A comprehensive design and performance analysis of low Earth orbit satellite quantum communication	B Kumar	COM DEV Canada	Cambridge, Ontario, Canada
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Optimal pair-generation rate for entanglement-based quantum key distribution	John A. Doucette	David R. Cheriton School of Computer Science, University of Waterloo	Waterloo, Ontario, Canada
Toward a downconversion source of positively spectrally correlated and decorrelated telecom photon pairs	Thomas Lutz	Institut für Quantenmaterie, Universität Ulm	Ulm, Germany
Generating polarization-entangled photon pairs using cross-spliced birefringent fibers	Vincent Roy	Institut National d'Optique	Quebec City, Quebec, Canada
Optimal Linear optical implementation of a single-qubit damping channe	Rainer Kaltenbaek	Vienna Center for Quantum Science and Technology, Faculty of Physics, University of Vienna	Vienna, Austria

Publication Title	External Collaborators	Collaborating Organization	Location
Three-photon energy-time entanglement	C. Simon	Institute for Quantum Information Science and Department of Physics and Astronomy, University of Calgary	Calgary, Alberta, Canada
Experimental violation of three families of Bell's inequalities	C. Noel	Massachusetts Institute of Technology	Cambridge, Massachusetts, USA
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Dispersion-cancelled biological imaging with quantum-inspired interferometry	R. Prevedel	Research Institute of Molecular Pathology (IMP) & Max F. Perutz Laboratories, University of Vienna	Vienna, Austria
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Spectral compression of single photons	A. Fedrizzi	Quantum Systems and Centre for Quantum Computer and Communication Technology, School of Mathematics and Physics, University of Queensland Centre for Engineered	Brisbane, Australia
Theory of Josephson photomultipliers: optimal working conditions and back action.	Emily J. Pritchett	Theoretical Physics, Universitat des Saarlandes	Saarbrucken, Germany
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High-fidelity quantum gates in the presence of dispersion	S. T. Merkel	Theoretical Physics, Saarland University	Saarbrucken, Germany
Insertable system for fast turnaround time microwave experiments in a dilution refrigerator	Arlette de Waard	Leiden Cryogenics b.v.	Delft, The Netherlands
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Selective darkening of degenerate transitions for implementing controlled-NOT quantum gates,	P C de Groot	Kavli Institute of Nanoscience, Delft University of Technology	Delft, The Netherlands
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Experimental analysis of the measurement strength dependence of superconducting qubit readout using a Josephson bifurcation readout method	K Kakuyanagi	NTT Basic Research Laboratories, NTT Corporation	Kanagawa, Japan
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Design of remnant magnetization FeCoV films as compact, heatless neutron spin rotators,	M.O. Abutaleb	Massachusetts Institute of Technology	Cambridge, Massachusetts, USA
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Spectroscopy of low-frequency noise and its temperature dependence in a superconducting qubit	Fei Yan	Massachusetts Institute of Technology	Cambridge, Massachusetts, USA
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Radical-free dynamic nuclear polarization using electronic defects in silicon	M.C. Cassidy	Harvard University	Cambridge, Massachusetts, USA
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Quantum correlations in a noisy neutron interferometer	Mohamed O. Abutaleb	Massachusetts Institute of Technology	Cambridge, Massachusetts, USA
	Micheal G. Huber	National Institute of Standards and Technology	Gaithersburg, Maryland, USA
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Negative Quasi-Probability as a Resource for Quantum Computation	David Gross	Institute for Physics, University of Freiburg	Freiburg, Germany
Aharon-Vaidman quantum game with a Young-type photonic qutrit.	Piotr Kolenderski	Nicolaus Copernicus University	Torun, Poland
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The robustness of magic state distillation against errors in Clifford gates	Yafei Yu	South China Normal University	Guangzhou, China
Studying Free-Space Transmission Statistics and Improving Free-Space QKD in the Turbulent Atmosphere	B. Heim	Max Planck Institute for the Science of Light	Erlangen, Germany
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Digital quantum simulation of the statistical mechanics of a frustrated magnet	Man-Hong Yung	Harvard University	Cambridge, Massachusetts, USA
	Alán Aspuru-Guzik	Harvard University	Cambridge, Massachusetts, USA
Experimental implementation of a codeword stabilized quantum code	Markus Grassl	National University of Singapore	Singapore, Singapore
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Experimental simulation of anyonic fractional statistics with an NMR quantum information processor	Guanru Feng	Tsinghua University	Beijing, China
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Fundamental quantum optics experiments conceivable with satellites - reaching relativistic distances and velocities	David Rideout	Perimeter Institute of Theoretical Physics	Waterloo, Ontario, Canada
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Experimental implementation of encoded logical qubit operations in a experimental implementation of encoded logical qubit operations in a perfect quantum error correcting code.	Dieter Suter	Dortmund University	Dortmund, Germany
A comprehensive design and performance analysis of low Earth orbit satellite quantum communication	B Kumar	COM DEV	Cambridge, ON, Canada
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Practical Experimental Certification of Computational Quantum Gates Using a Twirling Procedure	Marcus P. da Silva	University of Sherbrooke	Sherbrooke, Quebec, Canada
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Studying free-space transmission statistics and improving free-space quantum key distribution in the turbulent atmosphere	G. Weihs	University of Innsbruck	Innsbruck, Austria
Design of remnant magnetization FeCoV films as compact, heatless neutron spin rotators	M.O. Abutaleb	Massachusetts Institute of Technology	Cambridge, Massachusetts, USA
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	C.F. Majkrzak	National Institute of Standards and Technology	Gaithersburg, Maryland, USA
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A meet-in-the middle algorithm for fast synthesis of depth -optimal quantum circuits	Matthew Amy	University of Waterloo, Institute for Quantum Computing	
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Quantum Key Distribution in the Classical	Berkant Ustaoglu	Izmir Institute of Technology	Izmir, Turkey

Publication Title	External Collaborators	Collaborating Organization	Location
Authenticated Key Exchange Framework	Berkant Ustaoglu	Izmir Institute of Technology	Izmir, Turkey
Practical approximation of single-qubit unitaries by single-qubit quantum Clifford and T circuits	Dmitri Maslov	National Science Foundation	Arlington, VA, United States
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
Solving the shortest vector problem in lattices faster using quantum search	Thijs Laarhoven	Eindhoven University of Technology	Eindhoven Area, Netherlands
	Joop van de Pol	University of Bristol	Bristol, United Kingdom
Polynomial-time T-depth Optimization of Clifford+T circuits via Matroid Partitioning	Dmitri Maslov	National Science Foundation	Arlington, VA, United States
Plasmonic Superconducting Nanowire Single Photon Detector	H. Atikian	School of Engineering and Applied Sciences, Harvard University	Cambridge, Massachusetts, USA
Reduced Dark Counts in Optimized Geometries for Superconducting Nanowire Single Photon Detectors	H. Atikian	School of Engineering and Applied Sciences, Harvard University	Cambridge, Massachusetts, USA
	M. Loncar	School of Engineering and Applied Sciences, Harvard University	Cambridge, Massachusetts, USA
Negativity of quantumness and its interpretations	G. Adesso	University of Nottingham, School of Math Science	Nottingham, United Kingdom
Ancilla models for quantum operations: For what unitaries does the ancilla state have to be physical?	Z. Jiang	Center for Quantum Information and Control, University of New Mexico	Albuquerque, New Mexico, USA

Publication Title	External Collaborators	Collaborating Organization	Location
	C. M. Caves	Center for Quantum Information and Control, University of New Mexico	Albuquerque, New Mexico, USA
Quantum Discord Bounds the Amount of Distributed Entanglement	T. K. Chuan	Centre for Quantum Technologies, National University of Singapore	Singapore
	J. Maillard	Blackett Laboratory, Imperial College London	London, United Kingdom
	K. Modi	Department of Physics, University of Oxford, Clarendon Laboratory	Oxford, United Kingdom
	T. Paterek	Centre for Quantum Technologies, National University of Singapore	Singapore
	M. Paternostro	Centre for Theoretical Atomic, Molecular, and Optical Physics, School of Mathematics and Physics, Queen's University	Belfast, United Kingdom
Are general quantum correlations monogamous?	A. Streltsov	Heinrich-Heine-Universität Düsseldorf, Institut für Theoretische Physik III	Düsseldorf, Germany
	G. Adesso	School of Mathematical Sciences, University of Nottingham	Nottingham, United Kingdom
	D. Bruss	Heinrich-Heine-Universität Düsseldorf, Institut für Theoretische Physik III	Düsseldorf, Germany

Publication Title	External Collaborators	Collaborating Organization	Location
The quantumness of correlations revealed in local measurements exceeds entanglement	G. Adesso	School of Mathematical Sciences, University of Nottingham	Nottingham, United Kingdom
On quantum advantage in dense coding	M. Horodecki	Institute of Theoretical Physics and Astrophysics, University of Gdańsk	Gdańsk, Poland
Quantum benchmarking with realistic states of light	M. Hosseini	Centre for Quantum Computation and Communication Technology, Department of Quantum Science, The Australian National University,	Canberra, Australia
	B.C. Buchler	Centre for Quantum Computation and Communication Technology, Department of Quantum Science, The Australian National University,	Canberra, Australia
	P.K. Lam	Centre for Quantum Computation and Communication Technology, Department of Quantum Science, The Australian National University,	Canberra, Australia
Calibration-robust entanglement detection beyond Bell inequalities	T. Moroder	Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Technikerstraße	Innsbruck, Austria

Publication Title	External Collaborators	Collaborating Organization	Location
Encoding graphs into quantum states: an axiomatic approach	T.P. Spiller	Univ Leeds, Sch Phys & Astron, Leeds	West Yorkshire, England
Classical simulation of entanglement swapping with bounded communication	C. Branciard	University of Queensland, School Math & Physics	St Lucia, Australia
	N. Brunner	University of Bristol, HH Wills Physics Lab	Bristol, Avon, England
	H. Buhrman	University of Amsterdam	Amsterdam, Netherlands
	N. Gisin	University of Geneva, Applied Physics Group	Geneva, Switzerland
	S. Portmann	University of Geneva, Applied Physics Group	Geneva, Switzerland
	D. Rosset	University of Geneva, Applied Physics Group	Geneva, Switzerland
	M. Szegedy	Rutgers State University, Department of Computer Science	Piscataway, NJ, USA
Gate-efficient discrete simulations of continuous-time quantum query algorithms	D. Berry	University of Kentucky, Department of Psychology	Lexington, KY, USA
Reconstructing strings from substrings with quantum queries.	K. Iwama	Kyoto University	Kyoto, Japan
	F. Le Gall	University of Tokyo, Department of Computer Science	Bunkyo Ku, Tokyo, Japan
	H. Nishimura	Sendai Med Ctr, Virus Residence Centre	Sendai, Miyagi, Japan
	S. Tani	Osaka Prefecture University	Sakai, Osaka, Japan
	J. Teruyama	Kyoto University	Kyoto, Japan

Publication Title	External Collaborators	Collaborating Organization	Location
	S. Yamashita	University of Tokyo, Department of Electrical Engineering & Information Systems	Bunkyo Ku, Tokyo, Japan
Quantum entanglement and the communication complexity of the inner product function	W. van Dam	Department of Computer Science, University of California	Santa Barbara, CA, USA
	A. Tapp	Département IRO, Université de Montréal	Montréal, Québec, Canada
Quantum teleportation over 143 kilometres using active feed-forward	X.-S. Ma	Institute for Quantum Optics and Quantum Information (IQOQI), Austrian Academy of Sciences, Boltzmanngasse	Vienna, Austria
	T. Herbst	Faculty of Physics, University of Vienna, Boltzmanngasse	Vienna, Austria
	T. Scheidl	Institute for Quantum Optics and Quantum Information (IQOQI), Austrian Academy of Sciences, Boltzmanngasse	Vienna, Austria
	D. Wang	Institute for Quantum Optics and Quantum Information (IQOQI), Austrian Academy of Sciences, Boltzmanngasse	Vienna, Austria
	S. Kropatschek	Institute for Quantum Optics and Quantum Information (IQOQI), Austrian Academy of Sciences, Boltzmanngasse	Vienna, Austria

Publication Title	External Collaborators	Collaborating Organization	Location
	W. Naylor	Institute for Quantum Optics and Quantum Information (IQOQI), Austrian Academy of Sciences, Boltzmanngasse	Vienna, Austria
	B. Wittmann	Vienna Center for Quantum Science and Technology, Faculty of Physics,University of Vienna, Boltzmanngasse	Vienna, Austria
	A. Mech	Vienna Center for Quantum Science and Technology, Faculty of Physics,University of Vienna, Boltzmanngasse	Vienna, Austria
	J. Kofler	Max Planck Institute of Quantum Optics	Garching/Munich, Germany
	R. Ursin	Institute for Quantum Optics and Quantum Information (IQOQI), Austrian Academy of Sciences, Boltzmanngasse	Vienna, Austria
	A. Zeilinger	Institute for Quantum Optics and Quantum Information (IQOQI), Austrian Academy of Sciences, Boltzmanngasse	Vienna, Austria
The quantum query complexity of read-many formulas	Shelby Kimmel	Center for Theoretical Physics, Massachusetts Institute of Technology	Cambridge, MA
Electron transport in InAs-InAlAs core-shell nanowires	C. M. Haapamaki	McMaster University	Hamilton, ON Canada

Publication Title	External Collaborators	Collaborating Organization	Location
	R. R. LaPierre	McMaster University	Hamilton, ON Canada
Trapped charge dynamics in InAs nanowires	C. M. Haapamaki	McMaster University	Hamilton, ON Canada
	R. R. LaPierre	McMaster University	Hamilton, ON Canada
Critical shell thickness for InAs-AlInAs core-shell nanowires	C. M. Haapamaki	McMaster University	Hamilton, ON Canada
Digital quantum simulation of the statistical mechanics of a frustrated magnet	M.-H. Yung	Harvard University	Cambridge, Massachusettss, USA
	A. Aspuru-Guzik	Harvard University	Cambridge, Massachusettss, USA
Facilitating growth of InAs-InP core-shell nanowires through the introduction of Al	C. M. Haapamaki	McMaster University	Hamilton, ON Canada
	R. R. LaPierre	McMaster University	Hamilton, ON
Hedging bets with correlated quantum strategies	Abel Molina	University of Waterloo	Waterloo, ON N2L 3G1
Optimal counterfeiting attacks and generalizations for Wiesner's quantum money	Thomas Vidick	Massachusettss Institute of Technology	Cambridge, Massachusettss, USA
Quantum interactive proofs with weak error bounds	Hirotada Kobayashi	Principles of Informatics	Tokyo, Japan
Flux Noise Probed with Real Time Qubit Tomography in a Josephson Phase Qubit	Daniel Sank	University of California	Santa Barbara, California, USA
	R Barends	University of California	Santa Barbara, California, USA

Publication Title	External Collaborators	Collaborating Organization	Location
	Radoslaw C. Bialczak	University of California	Santa Barbara, California, USA
	Yu Chen	University of California	Santa Barbara, California, USA
	J. Kelly	University of California	Santa Barbara, California, USA
	M. Lenander	University of California	Santa Barbara, California, USA
	E. Lucero	University of California	Santa Barbara, California, USA
	A. Megrant	University of California	Santa Barbara, California, USA
	M. Neeley	University of California/LincolnLaboratory, Massachusetts Institute of Technology	Santa Barbara, California/ Lexington, Massachusetts USA
	P.J. O'Malley	University of California	Santa Barbara, California, USA
	A. Vainsencher	University of California	Santa Barbara, California, USA
	H. Wang	University of California/Zhejiang University	Santa Barbara, California/ Lexington, Massachusetts USA
	J. Wenner	University of California	Santa Barbara, California, USA
	T.C. White	University of California	Santa Barbara, California, USA
	T. Yamamoto	Green Innovation Research Laboratories, NEC Corporation	Tsukuba, Ibaraki, Japan

Publication Title	External Collaborators	Collaborating Organization	Location
	Yi Yin	University of California	Santa Barbara, California, USA
	A.N. Cleland	University of California/California NanoSystems Institute	Santa Barbara, California, USA
	John M. Martinis	University of California	Santa Barbara, California, USA
Computing Prime Factors with a Josephson Phase Qubit Quantum Processor	Erik Lucero	University of California	Santa Barbara, California, USA
	R. Barends	University of California	Santa Barbara, California, USA
	Y Chen	University of California	Santa Barbara, California, USA
	J. Kelly	University of California	Santa Barbara, California, USA
	A Megrant	University of California	Santa Barbara, California, USA
	P O'Malley	University of California	Santa Barbara, California, USA
	D Sank	University of California	Santa Barbara, California, USA
	A Vainsencher	University of California	Santa Barbara, California, USA
	J Wenner	University of California	Santa Barbara, California, USA
	T White	University of California	Santa Barbara, California, USA
	Y Yin	University of California	Santa Barbara, California, USA
	A N Cleland	University of California/California NanoSystems Institute	Santa Barbara, California, USA

Publication Title	External Collaborators	Collaborating Organization	Location
	John M. Martinis	University of California	Santa Barbara, California, USA
Surface Codes: Towards Practical Large-Scale Quantum Computation	A. G. Fowler	Centre for Quantum Computation and Communication Technology, School of Physics, The University of Melbourne	Victoria, Australia
	John M. Martinis	University of California	Santa Barbara, California, USA
	A N Cleland	University of California/California NanoSystems Institute	Santa Barbara, California, USA
Multiplexed Dispersive Readout of Superconducting Phase Qubits	Y Chen	University of California	Santa Barbara, California, USA
	D Sank	University of California	Santa Barbara, California, USA
	P O'Malley	University of California	Santa Barbara, California, USA
	T White	University of California	Santa Barbara, California, USA
	R. Barends	University of California	Santa Barbara, California, USA
	B. Chiaro	University of California	Santa Barbara, California, USA
	J. Kelly	University of California	Santa Barbara, California, USA
	E. Lucero	University of California	Santa Barbara, California, USA
	A Megrant	University of California	Santa Barbara, California, USA
	C.Neill	University of California	Santa Barbara, California, USA

Publication Title	External Collaborators	Collaborating Organization	Location
	A Vainsencher	University of California	Santa Barbara, California, USA
	J Wenner	University of California	Santa Barbara, California, USA
	Y Yin	University of California	Santa Barbara, California, USA
	A N Cleland	University of California/California NanoSystems Institute	Santa Barbara, California, USA
	John M. Martinis	University of California	Santa Barbara, California, USA
Catch and Release of Microwave Photon States	Yi Yin	University of California	Santa Barbara, California, USA
	Yu Chen	University of California	Santa Barbara, California, USA
	Daniel Sank	University of California	Santa Barbara, California, USA
	P.J. O'Malley	University of California	Santa Barbara, California, USA
	T.C. White	University of California	Santa Barbara, California, USA
	R. Barends	University of California	Santa Barbara, California, USA
	J. Kelly	University of California	Santa Barbara, California, USA
	Erik Lucero	University of California	Santa Barbara, California, USA
	A Megrant	University of California	Santa Barbara, California, USA
	C.Neill	University of California	Santa Barbara, California, USA

Publication Title	External Collaborators	Collaborating Organization	Location
	A Vainsencher	University of California	Santa Barbara, California, USA
	J. Wenner	University of California	Santa Barbara, California
	Alexander N. Korotkov	University of California	Riverside, California, USA
	A N Cleland	University of California/California NanoSystems Institute	Santa Barbara, California, USA
	John M. Martinis	University of California	Santa Barbara, California, USA
Excitation of Superconducting Qubits from Hot Non-Equilibrium Quasiparticles	J. Wenner	University of California	Santa Barbara, California, USA
	Y. Yin	University of California	Santa Barbara, California, USA
	E. Lucero	University of California	Santa Barbara, California, USA
	R. Barends	University of California	Santa Barbara, California, USA
	Y. Chen	University of California	Santa Barbara, California, USA
	B. Chiaro	University of California	Santa Barbara, California, USA
	J. Kelly	University of California	Santa Barbara, California, USA
	M. Lenander	University of California	Santa Barbara, California, USA
	M. Mariantoni	University of California	Santa Barbara, California, USA
	A. Megrant	University of California	Santa Barbara, California, USA

Publication Title	External Collaborators	Collaborating Organization	Location
	C. Neill	University of California	Santa Barbara, California, USA
	P.J.J. O''Malley	University of California	Santa Barbara, California, USA
	D. Sank	University of California	Santa Barbara, California, USA
	A. Vainsencher	University of California	Santa Barbara, California, USA
	H. Wang	University of California/Zhejiang University	Santa Barbara, California, USA/ Zhejiang University, Hangzhou, China
	T.C. White	University of California	Santa Barbara, California, USA
	A.N. Cleland	University of California/California NanoSystems Institute	Santa Barbara, California, USA
	J.M. Martinis	University of California	Santa Barbara, California, USA

Other Collaborating Organizations / Individuals	Location
Canadian Space Agency: Principal Investigator for the Canadian Space Agencies. Head of the Quantum Satellite Usergroup (QEYSSAT)	Montreal, QC
COMDEV Inc.	Cambridge, ON
National Institute of Optics (INO)	Québec City, QC
Excelitas (former Perkin Elmer)	Montreal, QC
Universal Quantum Devices (startup firm)	Waterloo, ON
Perimeter Institute for Theoretical Physics	Waterloo, ON
University of Innsbruck	Innsbruck, Austria

Other Collaborating Organizations / Individuals	Location
Christoph Simon - University of Calgary	Calgary, AB, Canada
Adan Cabello - University of Seville	Seville, Spain
Alberto Tosi - Politecnico di Milano	Milan, Italy
Anton Zeilinger - University of Vienna	Vienna, Austria
Rupert Ursin - University of Vienna	Vienna, Austria
Konrad Banaszek - University of Warsaw	Warsaw, Poland
Paolo Villoresi - University of Padova	Padova, Italy
Alipasha Vaziri - University of Vienna	Vienna, Austria
Morio Toyshima - National Instutute of Information and Communications	Tokyo, Japan
Valerio Pruneri - Institute of Photonic Sciences	Barcelona, Spain
David Rideout - University of California, San Diego	San Diego, USA
Daniel Terno - Macquarie University & Perimeter Institute for Theoretical Physics	Sydney, Australia
Tim Ralph - University of Queensland	Queensland, Australia
C2C Link Corp.	Hamilton, ON
Princeton Lightwave Inc.	Cranbury, NJ, USA
IBM	Piscataway, NJ, USA
Sahel Ashhab - RIKEN and University of Michigan	Ann Arbor, MI, USA
Jay Gambetta - IBM Watson Research Centre	Yorktown Heights, NY, USA
The superconduction qubit group at NTT	Tokyo, Japan
Steven Bartlett - University of Sydney	Sydney, Australia
Sarah Croke - Perimeter Institute for Theoretical Physics	Waterloo, ON
Alessandro Fedrizzi - University of Queensland	Queensland, Australia
David Kribs - University of Guelph	Guelph, ON, Canada
Terry Rudolph - Imperial College	London, UK
Gregor Weihs - University of Innsbruck	Innsbruck, Austria

Other Collaborating Organizations / Individuals	Location
Andrew White - University of Queensland	Queensland, Australia
Bei Zeng - University of Guelph	Guelph, ON, Canada
Intelligence Advanced Research Projects Activity / Multi-Qubit Coherent Operations Program, University of California	Riverside, California, USA
Michael R. Geller - University of Georgia	Athens, Georgia, USA
DARPA - QuEST	Arlington, Virginia, USA
Raytheon BBN Technologies	Cambridge, MA, USA
Raytheon BBN Technologies	Cambridge, MA, USA
Schlumberger Ltd.	Houston, TX, USA
Canadian Instititue for Advanced Research	Toronto, ON
Brockhouse Center, McMaster University	Hamilton, ON
Shanghai Center for Complex Physics -Shanghai Jiao Tong University	Shanghai, China
Department of Defence	Ottawa, ON, Canada
Communication Security Establishment	Ottawa, ON, Canada
Canadian Space Agency	Ottawa, ON, Canada
Australian Centre of Excellence for Quantum Computation & Communication Technology	Sydney, Australia
Quantum Valley Investment Funds	Waterloo, ON, Canada
Infinite Potential Inc.	Waterloo, ON, Canada
Massachusetts Institute of Technology	Cambridge, MA, USA
National Institute of Standards and Technology	Gaithersburg, MD, USA
Institut Laue Langevin	Grenoble, France
Petersburg Nuclear Physics Institute	Leningrad, Russia
Tools to Optimize Resources in Quantum Engineering (TORQUE) - Raytheon BBN Technologies Corp.	Cambridge, MA, USA
CryptoWorks 21: NSERC CREATE	Waterloo, ON, Canada

Other Collaborating Organizations / Individuals	Location
Norwegian University of Science and Technology	Trondheim, Norway
Institute for Quantum Optics and Quantum Information	Vienna, Austria
Heriot-Watt University	Edinburgh, UK
ID Quantique	Geneva, Switzerland
Max Planck Institute for the Science of Light	Erlangen, Germany
National University of Singapore - Centre for Quantum Technologies	Singapore
National Science Council of Taiwan	Taipei, Taiwan
Institut National de Recherche Scientifique (INRS)	Québec City, QC, Canada
INTRIQ (L'Institut Transdisciplinaire D'Information Quantique)	Sherbrooke, Québec, Canada
Raman Research Institute	Bangalore, Karnataka, India
Tsinghua University	Tsinghua, China
University of Science and Technology of China	Hefei, Anhui, China

SCIENTIFIC VISITORS

2012 - 2013 Long Term Visitors

Visitor	Institutions	Country
Vikram Sharad Athalye	Cummins College of Engineering	India
Sam Bader	Massachusetts Institute of Technology	USA
Amin Baumeler	ETH Zürich	Switzerland
Troy Borneman	Massachusetts Institute of Technology	USA
Tiago Debara	Instituto de Física Universidade Federal Fluminense	Brazil
Audrey Dot	Joseph Fourier University	France
Jonathan Friedman	Amherst College	USA
Daniel Gustaw	Nicolaus Copernicus University	Poland
Melanie Jensenworth	University of Washington	USA
Kelsey Johnsen	University of California, Berkeley	USA
Daniel Jost Brod	Instituto de FÍsica Universidade Federal Fluminense	Spain
Antti Karlsson	University of Turku	Finland
Maria Kieferova	Comenius University in Bratislava Slovakia	Slovakia
Kevin Krsulich	Massachusetts Institute of Technology	USA
Mehul Kumar	India Institute of Technology	Delhi, India
Srijita Kundu	Chennai Mathematical Institute	India
Qiang Li	Shandong University	China (2 visits)
Hang Li	Tsinghua University	China (2 visits)
Thomas Lutz	Universität Ulm	Germany
Mhlambululi Mafu	University of KwaZulu-Natal	South Africa
Ryan Marchildon	Queen's University	Canada
Mayank Mishra	Indian Institute of Science Education and Research	India
Keith Motes	Louisiana State University	USA
Taesik Nam	Pohang University of Science and Technology	Korea
Crystal Noel	Massachusetts Institute of Technology	USA
Michal Papaj	University of Warsaw	Poland
Laura Piispanen		None
Dominique Pouliot	University of Illinois at Urbana-Champaign	USA

Mouktik Raha	Indian Institute of Technology Kharagpur	India
Sarah Sheldon	Massachusetts Institute of Technology	USA
Hou Shiyao	Tsinghua University	China
Christophe Vulliot	Université de Rennes	France
Fei Wang	Tsinghua University	China
Amir Yacoby	Harvard University	USA

2012 - 2013 SEMINARS

Seminar	Date
Yanbao Zhang, University of Colorado : tbd	Apr 23, 2013
Simon Groeblacher, California Institute of Technology: Quantum experiments using the radiation pressure interaction between light and matter	Apr 16, 2013
Dan Hussey, National Institute of Standards and Technology: Seeing the world with neutron vision	Apr 03, 2013
Amir Safevi-Naeini, California Institute of Technology: Optomechanics in the quantum regime with Silicon Nanostructures	Mar 27, 2013
Ivette Fuentes, University of Nottingham: Q+ Hangout - Quantum information processing in spacetime	Mar 26, 2013
George Noid, Indiana University: A proposed experiment to characterize the Weak Interaction through mirror transitions	Mar 21, 2013
Michal Bajcsy, Stanford University: Nano-photonic structures for scalable applications of quantum optics	Mar 20, 2013
Vlad Gheorghiu, University of Calgary: Universal Uncertainty Relations	Mar 20, 2013
Adam Paetznick, IQC: Surface code braid compaction	Mar 19, 2013
David Gosset, IQC: Quantum 3-SAT is QMA1-complete	Mar 05, 2013
Julio Barreiro, Max Planck Institute of Quantum Optics & Ludwig Maximilian University of Munich, Germany: Harnessing additional degrees of freedom and the environment to experimentally enable quantum applications and simulations	Mar 04, 2013
Tobias Moroder, Universität Siegen: Device independent entanglement quantification	Mar 01, 2013
Vladimir Manucharyan, Harvard University Society of Fellows: Superconductivity with two electrons and its use for quantum information science	Feb 26, 2013
Dr. Graeme Smith, IBM TJ Watson Research Center: Quantum channels and their communication capacities	Feb 25, 2013
Andrey Rogachev, Cornell University: What Good Calculations Can Bring to Chemistry	Feb 20, 2013
Simon Nigg, Yale University: Stabilizer quantum error correction toolbox for superconducting qubits	Feb 13, 2013

Seminar	Date
Kyung Soo Choi, Korea Institute of Science and Technology: A quantum circus with acrobatic photons and floppy spins	Feb 12, 2013
Fang Song, Penn State University: Cryptography in a quantum world	Feb 06, 2013
Nathaniel Johnston, IQC: Uniqueness of Quantum States Compatible with Given Measurement Results	Jan 29, 2013
Roger Colbeck, ETH Zurich: Q+ Hangout - No extension of quantum theory can have improved predictive power	Jan 29, 2013
Thomas Vidick, Massachusetts Institute of Technology: The complexity of entangled games: hardness results and approximation algorithms	Jan 28, 2013
Lindsey LeBlanc, National Institute of Standards and Technology: Quantum simulation and artificial fields with ultracold neutral atoms	Jan 24, 2013
Trey Porto, National Institute of Standards and Technology: Coherent control of neutral atoms in optical lattices	Jan 23, 2013
Yoon-Ho Kim, Pohang University of Science & Technology: Protecting Entanglement from Decoherence via Weak Measurement and Quantum Measurement Reversal	Jan 08, 2013
Liu Ying, University of Wisconsin: Studying Dirac materials : graphene and topological insulator (Bi2Se3)	Dec 19, 2012
Kavan Modi, University of Oxford: Discord and its consumption as resource	Dec 06, 2012
Wei Cui, University of Toronto: Randomly distilling W-class states into general configurations of two-party entanglement	Dec 04, 2012
Joel Wallman, The University of Sydney: Quasiprobability representations of qubits	Nov 22, 2012
Steven Bennett, Harvard University: Using a single spin in diamond as a detector	Nov 20, 2012
Rob Spekkens, Perimeter Institute: Q+ Hangout - Quantum correlations from the perspective of causal discovery algorithms	Nov 20, 2012
Michal Studzinski, Nicolaus Copernicus University: Distillation of entanglement by projection on permutationally invariant subspaces	Nov 06, 2012
Borja Peropadre, Instituto de Fisica Fundamental: Switchable ultrastrong coupling in circuit-QED and relativistic simulations	Nov 01, 2012
Dr. Alexey Kovaleve, University of California, Riverside: Quantum low-density parity check codes and local codes (Hamiltonians) on graphs	Oct 30, 2012
Ken Brown, Georgia Technical Institute of Technology: Ion trap quantum computers for chemistry	Oct 23, 2012
Stacey Jefferey, IQC: Nested quantum walks	Oct 23, 2012
Tobias Moroder, University of Innsbruk: Detection of systematic errors in quantum experiments	Oct 04, 2012
Otfried Guehne, Universität Siegen: Characterizing multiparticle entanglement	Oct 02, 2012
Chris Sutherland, IQC: Mode Mismatch in a Mutually Unbiased Basis Measurement Scheme	Sep 06, 2012
Zhenyu Zhang, University of Science and Technology, China: IQC-WIN Special Seminar - Squeezing Electrons in Conventional Metal Films and Topological Insulator Heterostructures	Sep 05, 2012
Jlangfeng Du, University of Science and Technology, China: Spin-based quantum computing in solids	Sep 05, 2012

Seminar	Date
David Rosenbaum, University of Washington: Breaking the n^(log n) Barrier for Solvable-Group Isomorphism	Aug 28, 2012
Francesco Buscemi, Nagoya University: Q+ Hangout	Aug 28, 2012
Thomas Blasi, Harvard University: Coherent Control of Charge States in Coupled Quantum Dots	Aug 23, 2012
Konrad Banaszek, University of Warsaw: Experimental generation and characterisation of private quantum states	Aug 09, 2012
Ryo Okamoto, Osaka University: Special Seminar - Demonstration of Adaptive Quantum Estimation with Photons	Aug 09, 2012
Audrey Dot, Joseph Fourier University: Theoretical and experimental study of third-order nonlinear triple photons generation and quantum correlations	Jul 27, 2012
Barbara Terhal, RWTH Aachen University: From Majorana Fermions to Topological Order	Jul 26, 2012
Caslav Brukner, IQC: Q+ hangout - Quantum correlations with indefinite causal order	Jul 24, 2012
Melanie Jensenworth, University of Washington: Extending the welded tree speedup	Jul 17, 2012
Jonathan Friedman, Amherst College: Single-molecule Nanomagnets	Jul 12, 2012
Pragya Shukla, Indian Institute of Technology Kharagpur: Weak Measurements: typical weak and superweak values	Jul 10, 2012
Helen Fay Dowker, Imperial College London: The Path Integral Intepretation of Quantum Mechanics	Jul 05, 2012
Michael Snow, Indiana University: Physics with Slow Neutrons	Jun 28, 2012
Stefano Chesi, McGill University: Spin polarized transmission of holes in quantum point-contacts with strong spin-orbit coupling	Jun 21, 2012
Yingdan Wang, McGill University: Using interference for quantum state transfer in Opto-electro-mechanical systems	Jun 21, 2012
Scott Aaronson, MIT: Quantum Money from Hidden Subspaces	Jun 19, 2012
Patrick Coles, Carnegie Mellon University: Uncertainty relations, decoherence, and quantum correlations	Jun 14, 2012
Alexandre Blais, University of Sherbrooke: Qubit frequency modulations in circuit QED: from gates to noise probe	Jun 12, 2012
Zhenyu Zhang, University of Science and Technology of China & Harvard University: IQC-WIN Special Seminar - Squeezing Electrons in Conventional Metal Films and Topological Insulator Heterostructures	Jun 07, 2012
Markku Stenberg, Saarland University: Are “Pinholes” the Cause …	May 29, 2012
Maris Ozols, IQC: Three myths about quantum computing	May 22, 2012

INVITED TALKS

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

Name	Date	Invited Talk	Place	Location
Andrew Childs	25-Apr-13	Universal computation by multi-particle quantum walk, 3rd Heilbronn Quantum Algorithms Day, Bristol	University of Bristol	Bristol, England
Richard Cleve	30-Nov-12	Characterization of binary constraint system games	Massachusetts Institute of Technology	Cambridge, USA
David Cory	28-Oct-12	Spin-Based Quantum Processors	BIT's Annual World Congress of Nano-S&T	Qingdao, China
	30-Oct-12	Spin-Based Quantum Processors	Tsinghua University	Beijing, China
	01-Nov-12	Controlling Quantum Devices	University of Science and Technology of China	Hefei, China
	19-Dec-12	Progress Report on Implementing Electron/Nuclear Spin Quantum Information Processor	Perimeter Institute for Theoretical Physics	Waterloo, Ontario, Canada
	10-Jan-13	Implementing Electron/Nuclear Spin Quantum Information Processor	Shanghai Institute for Complex Physics	Shanghai, China
	15-Feb-13	Quantum Devices	American Association for the Advancement of Science (AAAS) 2013 Conference	Boston, USA

Name	Date	Invited Talk	Place	Location
Joseph Emerson	04-Oct-12	Equilibration of complex quantum systems in the thermodynamic and macroscopic limits	Center for Quantum Information and Control, University of New Mexico	Albuquerque, USA
	04-May-12	Equilibration of Measurement Statistics for Complex Quantum Dynamics	CIFAR Workshop	Toronto, Ontario, Canada
	16-Apr-13	Negative Quasi-Probability as a Resource	University of British Columbia	Vancouver, British Columbia, Canada
	25-Apr-13	Contextuality as a Resource for Quantum Computing	QM2013 workshop	Lilongwe, Malawi
Radu Ionicilіu	17-Apr-12	Is classical set theory compatible with quantum experiments?	Perimeter Institute	Waterloo, Ontario, Canada
Thomas Jennewin	19-Oct-12	Quantum Information: Fundamentals to a Future Technology (Invited Tutorial)	National Taiwan University	Taipei, Taiwan
	15-Oct-12	Quantum Entanglement Enabled Applications and Technologies (Invited Talk at the Horizons of Quantum Physics - Workshop)	Horizons of Quantum Physics - Workshop	Taipei, Taiwan
	26-Jun-12	Towards quantum science experiments with satellites (Invited Talk at the International Conference on Relativistic Quantum Information (ICRQI))	Perimeter Institute for Theoretical Physics	Waterloo, Ontario, Canada
	15-Jun-12	Quantum communication and fundamental physics experiments with satellites (Invited Talk at the annual conference of the Canadian Association of Physicists (CAP))	Canadian Association of Physicists - Talk was at University of Calgary	Calgary, Alberta, Canada

Name	Date	Invited Talk	Place	Location
	09-Jun-12	High transmission loss and classical-quantum multiplexing enabled with short-wavelength QKD (Invited Talk at the Photonics North Conference of SPIE)	The International Society for Optics and Photonics (SPIE)	Montreal, Quebec, Canada
	24-Apr-12	Quantum communication with satellites (Presentation at the Astro 2012 conference of the Canadian Aeronautics and Space Institute (CASI))	Canadian Aeronautics and Space Institute (CASI)	Montreal, Quebec, Canada
	22-Feb-12	QEYSSAT - Quantum Encryption and Science Satellite (Seminar Talk at TRIUMF: Canada's national laboratory for particle and nuclear physics)	TRIUMF: Canada's national laboratory for particle and nuclear physics	Vancouver, British Columbia, Canada
	19-Feb-12	Fundamental physics experiments with quantum communication satellites (Invited Presentation at the annual meeting of the American Association for the Advancement of Science (AAAS))	American Association for the Advancement of Science (AAAS)	Vancouver, British Columbia, Canada
	09-Jan-13	Entangled Photon Triplets (Invited Talk at International Conference on Quantum Information and Quantum Computing (ICQIQC))	The Centre for Quantum Information and Quantum Computing funded by the Department of Science and Technology, Government of India, at the Indiant Institute of Science, Bangalore	Bangalore, India

Name	Date	Invited Talk	Place	Location
Robert Koeing	22-Aug-12	Limits on classical communication over quantum channels and their cryptographic use	University of Waterloo	Waterloo, Ontario, Canada
	13-Aug-12	The quantum entropy power inequality and the classical capacity of thermal noise channels	University of Waterloo	Waterloo, Ontario, Canada
	01-May-12	Perimeter Institute PiQuDOS-Seminar	Perimeter Institute	Waterloo, Ontario, Canada
Raymond LaFlamme	03-Jun-12	Experimental Quantum Error Correction	Canadian Mathematical Society	Regina, Saskatchewan, Canada
	01-Nov-12	Quantum Error Correction: from theory to practice	University of Science and Technology of China	Hefei, China
	30-Oct-12	Quantum Error Correction: from theory to practice	Tsinghua University	Beijing, China
Debbie Leung	08-Jun-12	Nonlocality without entanglement revisited	9th Central European Quantum Information Processing Workshop	Smolenice, Slovakia
	05-May-12	Nonlocality without entanglement revisited	Canadian Institute For Advanced Research (CIFAR), quantum information processing program meeting	Toronto, Ontario, Canada

Name	Date	Invited Talk	Place	Location
	15-Jun-12	Nonlocality without entanglement revisited	The Centre for Quantum Information and Foundations Department of Applied Mathematics and Theoretical Physics, University of Cambridge	Cambridge, UK
	10-Jan-12	Finite amount of entanglement can be insufficient for a small size quantum game	Geometry of Quantum Entanglement (Workshop) hosted by: Centre International de Rencontres Mathematiques (CIRM)	Luminy, France
Adrian Lupascu	22-Mar-12	Quantum information and quantum optics with superconducting devices (at McGill Physics Colloquium)	McGill University	Montreal, Quebec, Canada
	01-Mar-12	(contributed) Simple ways to avoid leakage in qubit systems	Spring Meeting German Physical Society	Berlin, Germany
	01-Sep-12	Making optimal control work for superconducting qubits	First QUAINT Coordination-Meeting	Southampton, UK
	01-Oct-12	Circuit QED with engineered cavities	Workshop on Quantum Simulations 2012	Bilbao, Spain
	09-Mar-12	Quantum sensing with flux qubits	Massachusetts Institute of Technology	Boston, USA

Name	Date	Invited Talk	Place	Location
Norbert Lütkenhaus	20-Mar-11	Directions in Optical Implementations of Quantum Key Distribution	Quantum Information and Measurement (QIM)	Berlin, Germany
	23-May-12	Directions in Optical Implementations of Quantum Key Distribution	Tsinghua-Aarhus CTIC Workshop on Quantum Information Science, Tsinghua University	Beijing, China
	28-May-12	Accessible Nonlinear Witnesses	University of Pecs	Pecs, Hungary
	29-Aug-12	Security of Practical QKD Links and Networks	Quantum Communicatio n: Secure Information Transmission in the Maritime Environment Workshop	Los Angeles, USA
	06-Sep-12	Directions in optical implementations of Quantum Key Distribution	Quantum Africa 2	Drakensburg , South Africa
	25-Sep-12	Direction in optical implementations of quantum key distribution	Quantum-Physics-Based Information Security Conference	Edinburgh, UK
	14-Nov-12	Correlated Data & QKD	CIFAR Quantum Information Processing Meeting	Ottawa, Ontario, Canada
Hamed Majedi	03-Feb-12	Superconducting Nanowire Single Photon Detector: Quantum Tomographic Modeling & Gated-Mode Operation	EE Seminar Series, Harvard University	Cambridge, USA

Name	Date	Invited Talk	Place	Location
	26-Jan-12	Quantum Tomography of Superconducting Nanowire Single Photon Detecto	Electrical Engineering Department, MIT, Invited by Prof. T.P. Orlando	Cambridge, Massachusetts, USA
	03-Aug-12	Laser damage of photodiodes helps the eavesdropper	QCMC conference at Vienna University of Technology	Vienna, Austria
Vadim Makarov	08-Aug-12	Laser damage of photodiodes helps the eavesdropper	Heriot-Watt University	Edinburgh, UK
	28-Aug-12	Laser damage as a new tool for eavesdropping	Institute for Pure and Applied Mathematics, University of California, Los Angeles	Los Angeles, USA
	03-Oct-12	Quantum cryptography	RIM	Waterloo, Ontario, Canada
	25-Jan-13	Quantum hacking	Kavli Institute for Nanoscience, TU Delft	Delft, the Netherlands
	18-Mar-13	Quantum hacking	APS March meeting	Baltimore, USA
Guo-Xing Miao	27-Oct-12	Application of Spin-Filtering in Magnetoelectronics	[BIT 2nd Annual World Congress of Nano S&T – Nanoscience and Nanotechnology	Qingdao, China
Michele Mosca	14-May-12	Quantum Computing, Cryptography and Compilers	IEEE 42nd International Symposium on Multiple-Valued Logic (ISMVL-2012)	Victoria, British Columbia, Canada

Name	Date	Invited Talk	Place	Location
	27-May-12	Opening Doors-Opening Minds	Perimeter Institute-(OAPT) 34th Annual Conference	Waterloo, Ontario Canada
	04-Sep-12	Bridging Quantum Algorithms with Quantum Architectures	Quantum Africa 2	Northern Drakensberg, South Africa
	16-Jan-13	Quantum Key Distribution in the Classical Authenticated Key Exchange Framework	ICQIT2013	Tokyo, Japan
Ahswin Nayak	08-Jan-13	The Quantum Substate Theorem	International Conference on Quantum Information and Quantum Computing, IISc	Bengaluru, India
	09-Jan-13		Tata Institute for Fundamental Research	Mumbai, India
	January 3–5, 2013	Three lectures: “Quantum Algorithms”, “Quantum Information Theory”, “SDP in Quantum Information”	ICTS mini winter school on Quantum Information and Computation	Bengaluru, India
	26-Jan-12	Communication complexity and the Information Cost approach	Journées Nationales d’Informatique Mathématique, l’Université Paris Diderot	Paris, France
Marco Piani	July 1-6, 2012	Non-classical correlations in local broadcasting and entanglement distribution	Quantum Information Workshop	Seefeld, Tyrol, Austria
	May 31 - June 3, 2012	Think different (about the quantumness of correlations)	Quantum Twin Workshop	Favignana, Italy

Name	Date	Invited Talk	Place	Location
	May 18-19, 2012	Relating the general quantumness of correlations and entanglement	Symposium KCIK 2012, National Quantum Information Centre in Gdansk	Sopot, Poland
	January 9-13 , 2012	Tutorial on the role of discord in quantum information	Quantum Discord Workshop 2012, Centre for Quantum Technologies, National University of Singapore	Singapore
	01-Jun-12	Interplay between the general quantumness of correlations and entanglement	Max-Planck Institut fr Quantenoptik	Garching. Germany
	01-Nov-12	On the role of the general non-classicality of correlations in quantum information processing: three case studies	University College London	London, UK
	09-May-12	Relating the general quantumness of correlations and entanglement	University of Bristol,	Bristol, UK
	02-May-12	Relating the general quantumness of correlations and entanglement	University of Pavia	Pavia, Italy
	15-Jan-13	General non-classicality of correlations in quantum information processing: three case studies	Tsinghua University	Beijing, China
	24-Jan-13	Negativity of the quantumness of correlations	Academy of Mathematics and Systems Science	Beijing, China

Name	Date	Invited Talk	Place	Location
Dmitry Pushin	22-May-12	Decoherence-Free Subspace in Neutron interferometry	Atominstitut der Oesterreichischen Universitaeten, TU-Wien	Venna, Austria
	16-May-12	Neutron interferometry	Max-Planck-Institut für Physik	Munchen, Germany
Kevin Resch	15-Jun-12	Experimental detection and application of three-photon entanglement or What we can learn by converting one photon in to many (Invited Presentation at Cross-border Workshop in Laser Science)	McGill University & INRS (Institut national de la recherche scientifique)	Montreal, Quebec, Canada
Frank Wilhelm-Mauch	01-Jan-12	Optimal control: Time to apply it in the lab	SOLID Topical Workshop on Josephson Junction Circuits	Delft, the Netherlands
John Watrous	21-May-12	Quantum computing, interactive proofs, and QIP = PSPACE	Informatics Seminar, Kyoto University	Kyoto, Japan
	May 17 - 19, 2012	Quantum interactive proofs and semidefinite programming	Conference on Theory of Quantum Computation, Communication, and Cryptography	Tokyo, Japan
	May 17 - 19, 2012	Optimal counterfeiting attacks and generalizations for Wiesner's quantum money	Conference on Theory of Quantum Computation, Communication, and Cryptography,	Tokyo, Japan

Name	Date	Invited Talk	Place	Location
	June 11 - 16, 2012	Quantum computational complexity	12th Canadian Summer School on Quantum Information	Waterloo, Ontario, Canada
	May 28 - June 8, 2012	Quantum algorithms	2 hour lecture for USEQIP 2012	Waterloo, Ontario, Canada
Christopher Wilson	08-Oct-12	Nonadiabatic Electrodynamics and the Dynamical Casimir Effect," at Frontiers in Casimir Physics in Ushuaia, Patagonia, Argentina (October 8, 2012)	Frontiers in Casimir Physics Conference	Ushuaia, Patagonia, Argentina
	20-Nov-12	Hybrid Systems for Quantum Information" at Sherbrooke University (November 20, 2012).	Sherbrooke University	Sherbrooke, Quebec. Canada

COMMENTARY & ANALYSIS

Below is a list of papers, presentations and videos that give an overview or provide comments about advances and challenges in quantum information research.

Review Articles

Aaronson, S., Farhi, E., Gosset, D., Hassidim, A., Kelner, J., & Lutomirski, A. (2012). Quantum Money. Commun. ACM, 55(8), 84–92.

Criger, B., Passante, G., Park, D., & Laflamme, R. (2012). Recent advances in nuclear magnetic resonance quantum information processing. Philos. Trans. R. Soc. A-Math. Phys. Eng. Sci., 370(1976), 4620–4635.

Smith, J., & Mosca, M. (2012). Algorithms for Quantum Computers. Handbook of Natural Computing, Springer, , 1451– 1492.

Commentary Articles

Hwang, W. Y., & Gittsovich, O. (2012). Comment on "Security proof for cryptographic protocols based only on the monogamy of Bell's inequality violations". Phys. Rev. A, 85(4), 1 pp.

Piani, M. (2012). Problem with geometric discord. Phys. Rev. A, 86(3), 3 pp.

OUTREACH ACTIVITIES

Fiscal 2013 Events

May 3, 2012 **Enriching your future: Waterloo Region District School Board**
31 participants

Martin Laforest lead a series of interactive workshops entitled "Quantum Mechanics: How an insane theory has and continue to improve our lives".

May 15, 2012 **Waterloo Unlimited Workshops**
15 participants

Waterloo Unlimited is a unique enrichment opportunity for high school students. Each Waterloo Unlimited experience revolves around a different transdisciplinary theme—such as "change" or "design". These themes draw on all faculties across campus for a grand exploration of commonalities and differences leading to the integration of knowledge. Laforest led a series of interactive workshops entitled "Quantum Mechanics: How an insane theory has and continue to improve our lives".

May 23, 2012 **DevSum 2012**
200 participants

DevSum is an.NET developer conference that aims to share information and inspiration with developers. Martin Laforest presented a conference opening keynote talk in Stockholm, Sweden.

May 24, 2012 **Zoom Career Days/Canada 3.0**
100 participants

Martin Laforest and Marco Piani presented to a group of young students considering careers in Science, Engineering, Technology, Mathematics, etc.

June 21, 2012 **Screening of Alan Turing movie**
~200 participants

Two public showings of a documentary about Alan Turing, celebrating his 100th birthday, follow by a Q&A with scientists.

June 22, 2012 **Quantum Frontier Distinguished Lecture: Chip Elliot**
50 participanta

“Can we speak privately? Quantum cryptography in a broader context"

Chip Elliott is Project Director for GENI, a suite of experimental infrastructure being created by the National Science Foundation for research in network science and engineering. His talk introduces quantum cryptography and describes the speaker’s experience creating several types of quantum cryptography equipment, within the broader context of mainstream cryptography and secure communications.

July 9, 2012 **Shad Valley**
12 participants

Shad Valley is a four week summer enrichment program hosted on the UW campus. Laforest conducted an 8 hours workshop on quantum mechanics, cryptography and quantum information.

July 12, 2012 **Einstein Plus**
40 Participants

EinsteinPlus is a one-week intensive, Perimeter Institute workshop for Canadian and international high school teachers that focuses on modern physics, including quantum physics, special relativity, and cosmology. introduction to QIST to high school teachers.

July 18, 2012 **ISSYP**
40 participants

The International Summer School for Young Physicists (ISSYP) is an exciting and challenging two-week, Perimeter Institute program for Canadian and international high school students who have a keen interest in theoretical physics and intend to pursue physics studies at the university level. Provided an introduction to QIST to high school students

August 22, 2012 **Master For Math Teachers**
40 participants.

An introduction to Quantum Information Science and Technology (QIST) for high school students participating in the UW's Master for Math Teachers.

November 15, 2012 **Waterloo Unlimited Workshops**
15 Participants

Martin Laforest led a series of interactive workshops entitled "Quantum Mechanics: How an insane theory has and continue to improve our lives".

November 17, 2012 **TEDxUW**
240 participants

Hosted TEDxWaterloo in QNC and IQC manned a booth showcasing quantum computing and quantum cryptography.

February 14-18, 2013 **American Association for the Advancement of Science Symposium** (exhibition floor)
8000 + participants

IQC manned a booth with information about IQC as well as a quantum key distribution experiment.

February 14-18, 2013 **American Association for the Advancement of Science Symposium**
20 participants

Symposium presentation for AAAS. IQC-led panel discussion with Raymond Laflamme, David Cory, Amir Yacoby (Harvard) and Raffi Budakian (Urbana-Champain) on quantum sensors.

February 27, 2013 **Zoom Career Day**
25 participants

Marco Piani presents Quantum Information Science and Technology as part of the 2013 Zoom Career Day on Information and Communication Technology.

February - March 2013 **Canadian Association of Physicists (CAP) 2013 Lecture Tour**
12 full classes of undergraduate physics students

Martin Laforest conducted interactive workshops on cryptography for grade 10 students.

March 7, 2013 **Tech Leadership Conference**
600+ participants

Communitech's Tech Leadership Conference is the largest annual all-day gathering of tech community professionals in Waterloo Region. Laforest talked about quantum mechanics and its implementations to grade 8-9 students as part of the National Engineering Month.

March 13-14, 2013 Waterloo Unlimited
28 participants

Martin Laforest conducted interactive workshops on cryptography for grade 10 students.

March 25, 2013 **Shad Valley STEM Outreach Event**
300 participants

Martin Laforest talked about quantum mechanics and its implementations to grade 8-9 students as part of the National Engineering Month.

March 27, 2013 **TedxWaterloo**
1500 participants / each lecture

Raymond Laflamme did an on stage interview, giving an update on the status of quantum information science and technology research. It was a follow up to his 2010 TEDxWaterloo presentation

Martin Laforest was challenged to teach quantum mechanics to the audience, including an interactive experiment, in 5 minutes or less.

MEDIA COVERAGE

The following table outlines the media coverage IQC received related to the grand opening celebrations of the Mike and Ophelia Lazaridis Quantum-Nano Centre.

Date	Media Outlet	Media Tier	Subject	Link to Coverage
Sept. 13	AZ oNano	International Science pub	Preview of launch	http://www.azonano.com/news.aspx?newsID=25544
Sept. 13	Exchange Magazine	Regional	Preview of Quantum Symphony	http://www.exchangemagazine.com/morningpost/2012/week37/Thursday/12091303.htm
Sept. 13	Exchange Magazine	Regional	QNC opening announce-ment	http://www.exchangemagazine.com/morningpost/2012/week37/Thursday/12091304.htm
Sept. 13	Nanowerk	International science pub		http://www.nanowerk.com/news2/newsid=26702.php
Sept. 17	Toronto Star	Provincial	Profile of U Waterloo	http://www.thestar.com/specialsections/schoolsguide/article/1257949--university-profiles-university-of-waterloo
Sept. 18	CBC Radio	Provincial	Launch in human terms	ontariomorning_20120918_20229.mp3
Sept. 18	Electronic Products and Technology	National Tech	Preview using press release	http://www.ept.ca/news/quantum-nano-centre-at-u-of-waterloo-ready-to-open/1001694200/
Sept. 18	The Record	Regional	Speech re: innova-tion	http://www.therecord.com/news/business/article/801965--no-respite-in-need-to-innovate-uw-president-says

Date	Media Outlet	Media Tier	Subject	Link to Coverage
Sept. 19	Bloomberg	International Business	Quantum Valley	http://www.bloomberg.com/news/2012-09-19/blackberry-creator-lazaridis-puts-100-million-toward-nano-plan.html plus extensive repostings throughout North America + beyond
Sept. 19	Business-Week	International Business	Quantum Valley	http://www.businessweek.com/news/2012-09-19/blackberry-creator-lazaridis-puts-100-million-toward-nano-plan
Sept. 20	Venture-Beat	International tech		http://venturebeat.com/2012/09/20/lazaridis-quantum-computing-nanotech-center/
Sept. 20	Engadget	International tech	Preview of opening	http://www.engadget.com/2012/09/20/lazaridis-backed-quantum-nano-centre-opens-tomorrow-aims-to-be/
Sept. 20	N4BB	International tech	Preview of opening	http://n4bb.com/rim-founder-mike-lazaridis-puts-100m-nano-labs/
Sept. 20	Digital Media Wire	International tech	Preview of opening	http://www.dmwmedia.com/news/2012/09/20/rims-lazaridis-donates-100m-for-center-of-excellence
Sept. 20	Electronics Weekly	International tech	Donation described	http://www.electronicsweekly.com/Articles/20/09/2012/54612/blackberry-inventor-re-creates-bell-labs.htm
Sept. 20	TechVibes	National tech		http://www.techvibes.com/blog/rim-founder-invests-100-million-to-create-canadas-ultimate-hive-of-technological-innovation-2012-09-20

Date	Media Outlet	Media Tier	Subject	Link to Coverage
Sept. 20	Financial Post - Bloomberg	National	Quantum Valley	http://business.financialpost.com/2012/09/20/rims-blackberry-creator-mike-lazaridis-puts-100-million-into-nano-labs/
Sept. 20	TechVibes	National tech		http://www.techvibes.com/blog/rim-founder-invests-100-million-to-create-canadas-ultimate-hive-of-technological-innovation-2012-09-20
Sept. 21	The Record	Regional	Editorial	http://www.therecord.com/opinion/editorial/article/803808--a-quantum-leap-in-waterloo
Sept. 21	The Record	Regional	Preview story	http://www.therecord.com/sports/article/803526--hawking-to-help-open-new-quantum-nano-centre
Sept. 21	The Record	Regional	Symph-ony review	http://www.therecord.com/whatson/artsentertainment/article/803358--kw-symphony-shakes-up-the-tried-and-true
Sept. 21	CTV South-western Ontario	Regional	Impact of Official opening	http://kitchener.ctvnews.ca/world-famous-physicist-in-waterloo-for-opening-of-quantum-nano-centre-1.966063
Sept. 21	Exchange Magazine	Regional		http://www.exchangemagazine.com/morningpost/2012/week39/Monday/12092404.htm
Sept. 21	Canada Newswire	North American Wire		http://www.newswire.ca/en/story/1040393/stephen-hawking-mike-lazaridis-open-university-of-waterloo-quantum-nano-centre
Sept. 21	Gov't website	National online	Gov't view on QNC	http://news.gc.ca/web/article-eng.do?nid=696049

Date	Media Outlet	Media Tier	Subject	Link to Coverage
Sept. 21	4Traders	National online		http://www.4-traders.com/news/Department-of-Industry-Harper-Government-Celebrates-Opening-of-New-Quantum-Nano-Centre--15220377/
Sept. 21	The Waterloo Region Record	Regional		http://www.therecord.com/news/local/article/803526--hawking-to-help-open-new-quantum-nano-centre
Sept. 21	The Waterloo Region Record	Regional	Overview of the Official Opening	http://www.therecord.com/news/local/article/804539--the-new-heart-of-quantum-valley
Sept. 21	570 News Radio	Regional	Official Opening	http://www.570news.com/news/local/article/404156--a-quantum-leap-for-uw
Sept. 21	BNN	Regional/ national	Interview taped following opening	Coverage not available on-line; broadcast in Toronto area, possibly beyond
Sept. 21	The Waterloo Chronicle	Regional	Official Opening	http://www.waterloochronicle.ca/news/welcome-to-quantum-valley/
Sept. 22	Chicago Daily Herald	U.S. Regional	Quantum Valle	http://www.dailyherald.com/article/20120922/business/709229979/
Sept. 23	CTV SWO Province-wide	Provincial	Pre-opening tour QNC building	http://kitchener.ctvnews.ca/provincewide
Sept. 23	The Verge.com (NY tech-based tech pub)	International Tech	Extensive coverage : photos	http://www.theverge.com/2012/9/24/3382492/rim-waterloo-quantum-nano-centre
Sept. 24	TVO	Provincial		http://bit.ly/PDjrZY
Sept. 24	Exchange Magazine	Regional	Stephen Hawking with dignitaries	http://www.exchangemagazine.com/morningpost/2012/week39/Monday/12092404.htm#anchor

Date	Media Outlet	Media Tier	Subject	Link to Coverage
Sept. 24	Exchange Magazine	Regional		http://www.exchangemagazine.com/morningpost/2012/week39/Monday/12092405.htm
Sept. 25	Waterloo Chronicle	Regional		http://www.waterloochronicle.ca/whats-on/quantum-music/
Sept. 25	BlackBerry Rocks	Mobility tech		http://blackberryrocks.com/2012/09/25/blackberry-originator-lazaridis-invests-nano-labs/
Sept. 25	Nanowerk	International science pub	Focus on building/ Hawking	http://www.nanowerk.com/news2/newsid=26817.php
Sept. 26	Rogers TV	Regional	QNC Opening	Coverage not available on-line
Sept. 26	The Waterloo Chronicle	Regional		http://www.waterloochronicle.ca/opinion/the-new-normal/
Oct. 1,2,3	CTV South-western Ontario	Regional	3-part series on Waterloo as Tech Town	http://kitchener.ctvnews.ca/investigates/startup-tech-companies-flourishing-in-waterloo-region-1.980756
Oct. 2	AZ oNano	Science pub	Profile of opening	http://www.azonano.com/news.aspx?newsID=25602
Oct. 4	Electronic Products and Technology (EPT)	Vertical pub	Excellent overview of QNC and building opening	http://www.ept.ca/videos/play/?plid=1001743599
Oct. 10	University Affairs	National	Overview of QNC building parameters	http://www.universityaffairs.ca/new-environment-for-quantum-computing.aspx
Oct. 10	University Affairs	National	Overview colla-borative research spaces	http://www.universityaffairs.ca/brave-new-buildings.aspx

Date	Media Outlet	Media Tier	Subject	Link to Coverage
Oct. 15	YouTube	International	QNC Video posting	http://www.youtube.com/watch?v=Bi4q-ey5kms
Oct. 15	Daily Commer-cial News	National		http://www.dcnonl.com/article/id52315
Oct. 29	EON Business-wire	Provincial	Posting by the Ontario gov't	http://eon.businesswire.com/news/eon/20121029005178/en/Ontario/Canada/Ministry-of-Economic-Development-and-Innovation
Feb 2013	Fast Company	U.S. Trade + Bus Pub		http://www.fastcompany.com/3004344/rims-mike-lazaridis-takes-quantum-leap-faith-waterloo

The following lists the media coverage received by IQC from May 2012-April 2013:

http://www.tgdaily.com/general-sciences-features/68123-adding-to-einstein-s-quantum-world

http://science.compulenta.ru/728097/

http://www.rdmag.com/news/2012/12/researchers-demonstrate-new-kind-quantum-entanglement

http://www.dailygalaxy.com/my_weblog/2012/12/quantum-entanglement-leaps-beyond-einstein-new-states-of-light-.html

http://scienceblog.com/58502/extending-einstein-with-a-new-kind-of-quantum-entanglement/

http://www.sciencedaily.com/releases/2012/12/121214191522.htm

http://www.eurekalert.org/pub_releases/2012-12/uoc-ee121412.php

http://release.vfactory.jp/release/50935.html

http://www.presseschleuder.com/2012/10/einzigartiges-nanotechnologie-zentrum-in-ontario-eroffnet/

http://www.exchangemagazine.com/morningpost/2012/week44/Friday/12110202.htm

http://www.currentgame.de/einzigartiges-nanotechnologie-zentrum-in-ontario-eroffnet.html

http://www.businesswire.com/news/home/20121029005174/en/State-of-the-art-Mike-Ophelia-Lazaridis-Quantum-Nano-Centre-opens

http://eon.businesswire.com/news/eon/20121029005178/en/Ontario/Canada/Ministry-of-Economic-Development-and-Innovation

http://www.nanotech-now.com/news.cgi?story_id=46013

http://www.dailyherald.com/article/20120922/business/709229979/

http://www.itjungle.com/tfh/tfh102212-story04.html

http://www.4-traders.com/news/Department-of-Industry-Harper-Government-Celebrates-Opening-of-New-Quantum-Nano-Centre--15220377/

http://www.actualitte.com/international/un-cours-de-physique-quantique-aux-cotes-d-harry-potter-37395.htm

http://www.physicscentral.com/buzz/blog/index.cfm?postid=7851459490335999212

http://dcnonl.com/article/id52315/--university-of-waterloorsquos-quantum-nano-centre-a-showcase-for-innovation-worldwide

http://kunc.org/post/boulders-david-wineland-shares-2012-nobel-prize-physics-serge-haroche

http://metronews.ca/news/kitchener/361634/waterloo-researchers-key-to-teleportation-breakthrough/

http://www.dailygalaxy.com/my_weblog/2012/12/quantum-entanglement-leaps-beyond-einstein-new-states-of-light-.html

http://www.rdmag.com/news/2012/12/researchers-demonstrate-new-kind-quantum-entanglement

http://compulenta.computerra.ru/veshestvo/fizika/10003274/

http://www.tgdaily.com/general-sciences-features/68123-adding-to-einstein-s-quantum-world

http://www.spacedaily.com/reports/Extending_Einstein_999.html

http://www.therecord.com/news/local/article/865000--the-quest-for-computing-s-holy-grail

http://www.fastcompany.com/3004344/rims-mike-lazaridis-takes-quantum-leap-faith-waterloo

http://www.theglobeandmail.com/news/national/canadian-space-agency-head-leaving-to-focus-on-quantum-physics/article7384753/

http://www.itbusiness.ca/news/blackberry-creator-recruits-canadas-top-astronaut-for-quantum-physics-project/19645

http://www.marketwatch.com/story/university-of-waterloo-purchases-veeco-mbe-system-for-new-nano-research-center-2013-01-21

http://www.dailyfinance.com/2013/01/21/university-of-waterloo-purchases-veeco-mbe-system-/

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YOUTUBE VIDEO LIBRARY

1. Steven Girvin - Quantum Hall Effect
2. Helen Fay Dowker - Path Integral Interpretation
3. Helen Fay Dowker - Unifying Gravity and Quantum Mechanics
4. Steven Girvin - Quantum Computing
5. John Preskill - Introduction to Quantum Information (Part 1) - CSSQI 2012

6. Potential Uses for Quantum Computers - Charles Bennett
7. The Origins of Quantum Teleportation - Charles Bennett
8. Reconnecting Physics & Computer Science - Charles Bennett
9. The Evolution of Quantum Computing - Charles Bennett
10. The Mike & Ophelia Lazaridis Quantum-Nano Centre Ñ Interior Architecture
11. Stephen Hawking helps launch the Quantum-Nano Centre at the University of Waterloo
12. What are Superconductors? - Louis Taillefer
13. Quantum Mechanics and Industry - Chip Elliott
14. The Physics of Information - Dr. Wojciech Zurek
15. Future Quantum Technologies - Dr. Gerard Milburn
16. Quantum Memory - Dr. Christopher Monroe
17. How the Hippies Saved Physics Ñ David Kaiser
18. Quantum: Music at the Frontier of Science
19. Atomic Clock Applications - Dr. David Wineland
20. How Atomic Clocks Work - Dr. David Wineland
21. Ion Trapping - Dr. David Wineland
22. Ion Trapping for Quantum Computation - Dr. David Wineland
23. Quantum Frontiers lecture: Dr. David Wineland on Atomic Clocks and Ion Trap Quantum Computing
24. No Cloning Theorem - Andrew Childs - QCSYS 2011
25. Quantum Bomb Detector - Catherine Holloway - QCSYS 2011
26. Building for the Future: The Quantum-Nano Centre
27. The QCSYS Experience: Quantum Cryptography Summer School at IQC
28. The Many Worlds Theory - Anthony Leggett 2011
29. Quantum Physics & Harry Potter
30. Quantum Entanglement for Communication -- Gregoire Ribordy
31. Intro to Quantum Computing - Michele Mosca - USEQIP 2011
32. The USEQIP Experience
33. Quantum Mechanics: Two Rules and No Math
34. The Benefits of Quantum Research Ñ Tommaso Calarco
35. Understanding Quantum Computing: Tommaso Calarco
36. Quantum: Harnessing the Fundamental Forces of Nature
37. Quantum Gets Big: Andrew Cleland on the Breakthrough of the Year
38. Teleportation: Fact vs. Fiction
39. Quantum Cryptography Pioneer: Gilles Brassard
40. Quantum Computing Breakthrough: QIP=PSPACE
41. Casimir Effects: Peter Milonni's lecture at the Institute for Quantum Computing

42. The USEQIP Experience
43. The Quantum Mechanics of Time Travel
44. Seth Lloyd on the Universe as a Quantum Computer
45. Seth Lloyd on the Importance of Quantum Information Research
46. Seth Lloyd on "Quantum Weirdness"
47. Nuclear Magnetic Resonance @ IQC
48. Introduction to the Institute for Quantum Computing
49. Born to Rule - Dr. Urbasi Sinha explains the triple-slit experiment
50. Quantum Key Distribution Animation
51. The Future of Quantum Communication - Panel Discussion - AAAS 2012
52. The Future of Quantum Communication - Question and Answer - AAAS 2012
53. Steven Girvin - Circuit Quantum Electrodynamics
54. Helen Fay Dowker - Causal Set Theory
55. John Preskill - Introduction to Quantum Information (Part 2) - CSSQI 2012
56. Steve Simon - Topological Quantum Computing (Part 2) - CSSQI 2012
57. Steve Simon - Topological Quantum Computing (Part 1) - CSSQI 2012
58. Alexandre Blais - Quantum Computing with Superconducting Qubits (Part 1) - CSSQI 2012
59. Mark Wilde - Quantum Information Theory (Part 1) - CSSQI 2012
60. Superdense coding and entanglement-assisted communication - Charles H. Bennett
61. The Fathers of Quantum Cryptography - Charles Bennett
62. From molecular biology to quantum computing - Charles H. Bennett
63. Quantum: Music at the Frontier of Science - QNC Performance
64. Highlights of the Quantum-Nano Centre Launch
65. Can We Speak... Privately? Quantum Cryptography Lecture by Chip Elliott
66. Quantum Cryptography Networks - Chip Elliott
67. Quantum Darwinism - Dr. Wojciech Zurek
68. Nuclear Magnetic Resonance QIP, by Martin Laforest (USEQIP 2012)
69. Quantum Hacking - Vadim Makarov - USEQIP 2012
70. Quantum Algorithms - John Watrous - USEQIP 2012
71. The Academic Challenge for Quantum Computation - Dr. Christopher Monroe
72. Recent Progress in Quantum Algorithms Conference Ñ Waterloo, April 2012
73. Waterloo's Quantum Revolution -- Krister Shalm of IQC
74. Quantum Medical Research and Treatment - Jorg Wrachtrup
75. Developing a Quantum Processor - Jorg Wrachtrup
76. QCSYS One-Minute Promo
77. Atomic Clocks: Precision & Accuracy Ñ David Wineland
78. Quantum Frontiers Lecture: Louis Taillefer - The Puzzles of Superconductivity

79. Canada's Science Investment: CERC Launch at IQC
80. QKD - BB84 Protocol - Sarah Croke - QCSYS 2011
81. Quantum Optics - Krister Shalm - QCSYS 2011
82. Dr. Amir Yacoby: Quantum Information and Metrology Using Few Electron Spins
83. Intro to Quantum Mechanics - Andrew Childs - QCSYS 2011
84. Classical Cryptography - Stacey Jeffery - QCSYS 2011
85. Jacob Biamonte on Tensor Network States --- Interview and Series Trailer
86. Quantum Mechanics vs Macrorealism (Lecture 12) - Anthony Leggett 2011
87. Weak "Measurement": The General Idea and Postselection (Lecture 5) - Anthony Leggett 2011
88. Time Symmetry of Quantum Mechanics (Lecture 4) - Anthony Leggett 2011
89. Women in Physics Conference
90. Single Quantum Dots - Martin Laforest - USEQIP 2011
91. Quantum Error Correction - Raymond Laflamme - USEQIP 2011
92. Quantum Algorithms - Andrew Childs - USEQIP 2011
93. Linear Algebra Lecture #1 - Chris Ferrie - USEQIP 2011
94. Superconducting Qubits - Adrian Lupascu - USEQIP 2011
95. Quantum Frontiers Lecture: Don Eigler of IBM
96. Quantum Cryptography: The Future of Information Security
97. Harnessing Quantum Mechanics
98. Speaking the Language of Quantum Mechanics
99. Seth Lloyd on the Simple Beauty of Quantum Mechanics
100. Quantum Key Distribution
101. Canadian Summer School on Quantum Information (CSSQI)
102. Quantum Techniques for Stochastic Mechanics - Course Introduction
103. David Schuster - Hybrid Devices for Quantum Information Processing (Part 1) - CSSQI 2012
104. Tom Brzustowski - Quantum Entrepreneurship - Lecture 1 - Why be interested?
105. Tom Brzustowski - Innovation & Competition
106. Tom Brzustowski - Innovation & Commercialization
107. Tom Brzustowski - The Definition of Science
108. Lorenza Viola - Quantum Control Theory (Part 1) - CSSQI 2012
109. Bill Coish - Decoherence (Part 1) - CSSQI 2012
110. Daniel Gottesman - Quantum Error Correction and Fault Tolerance (Part 1) - CSSQI 2012
111. John Watrous - Quantum Complexity Theory (Part 1) - CSSQI 2012
112. Christopher Monroe - Ion Trapping (Part 1) - CSSQI 2012
113. Experiments on Macroscopic Quantum Coherence (Lecture 1) - Anthony Leggett 2012

114. Glass: The Cinderella Problem of Condensed-Matter Physics (Lecture 8) - Anthony Leggett 2012
115. Quantum Phase Slips in Superconducting Nanowires (Lecture 10) - Anthony Leggett 2012
116. Some Thoughts on Majorana Fermions in (p + ip) Fermi superfluids (Lecture 11) - Anthony Leggett 2012
117. Sir Anthony Leggett - 2012 Lecture Series Overview
118. Chad Orzel's Public Lecture at the QNC Open House
119. Robert Sawyer's Public Lecture at the QNC Open House
120. Opening Ceremonies for the QNC at uWaterloo
121. Practical Decoherence Modeling - Paola Cappellaro - USEQIP 2012
122. The Architecture of the Mike & Ophelia Lazaridis Quantum-Nano Centre
123. Sir Anthony Leggett on The University of Waterloo & IQC
124. The Continuum of Innovation - IQC & The Accelerator Centre
125. The computational complexity of multiple entangled provers - Thomas Vidick
126. Improving the Quantum Query Complexity of Boolean Matrix Multiplication Using Graph Collision
127. Quantum Rejection Sampling - Maris Ozols
128. Quantum Algorithms for the k-distinctness Problem - Aleksandrs Belovs
129. Quantum Technologies for Oil and Water Exploration - Jorg Wratchup
130. Quantum Error Correction - Jorg Wrachtrup
131. Developing Diamond-Nanostructures - Jorg Wrachtrup
132. Marko Lon?ar - Diamond Nanophotonics & Quantum Optics
133. Ten Quantum Years: The Institute for Quantum Computing
134. Atomic Clocks & Quantum Computation - Dr. David Wineland
135. Ion Trapping Schemes - Dr. David Wineland
136. Hybrid Ion traps: David Wineland
137. The Quantum Concert: IQC and the KW Symphony
138. Beni Yoshida, MIT - Studying Many-Body Physics Through Coding Theory
139. Authentication - Stacey Jeffery - QCSYS 2011
140. Validity Tests of Quantum Mechanics Part 1 (Lecture 10) - Anthony Leggett 2011
141. Implications of the Bell-EPR Experiment (Lecture 9) - Anthony Leggett 2011
142. Bell-EPR Experiments Part 1 (Lecture 7) - Anthony Leggett 2011
143. Jacob Biamonte on Tensor Network States --- Lecture 1
144. Jacob Biamonte on Tensor Network States --- Lecture 2 - Quantum Legos
145. The Human Double-Slit Experiment: Steel Rail Sessions 2011
146. Bringing Quantum Technology to the Marketplace - GrŽgoire Ribordy
147. Foundations of Quantum Mechanics - Joseph Emerson - USEQIP 2011
148. Double Quantum Dots - Martin Laforest - USEQIP 2011

149. Practical Decoherence Modeling - Frank Wilhelm-Mauch - USEQIP 2011
150. Seth Lloyd on Canada's Quantum Leadership
151. IQC Recipients of the Collaborative Research and Training Experience (CREATE) Program
152. Quantum Techniques for Stochastic Mechanics - Part 1 of 4
153. Quantum Techniques for Stochastic Mechanics - Part 3 of 4
154. Quantum Techniques for Stochastic Mechanics - Part 2 of 4
155. Quantum Techniques for Stochastic Mechanics - Part 4 of 4
156. Panel Discussion at the QNC Open House
157. Martin Roetteler - Quantum Algorithms (Part 1) - CSSQI 2012
158. Rolf Horn - Quantum Entrepreneurship - Lecture 1 - Starting a Company
159. David Miller - Quantum Entrepreneurship Lecture - Incorporation
160. Rolf Horn - Quantum Entrepreneurship Lecture 2 - Sustaining vs Disruptive Innovation
161. Lorenza Viola - Quantum Control Theory (Part 2) - CSSQI 2012
162. Bill Coish - Decoherence (Part 2) - CSSQI 2012
163. Daniel Gottesman - Quantum Error Correction and Fault Tolerance (Part 2) - CSSQI 2012
164. Alexandre Blais - Quantum Computing with Superconducting Qubits (Part 2) - CSSQI 2012
165. Peter Hċyer - Quantum Algorithms (Part 1) - CSSQI 2012
166. Mark Wilde - Quantum Information Theory (Part 2) - CSSQI 2012
167. Christopher Monroe - Ion Trapping (Part 2) - CSSQI 2012
168. Supersolidity in Solid 4He? - Part 1 (Lecture 2) - Anthony Leggett 2012
169. Supersolidity in Solid 4He? - Part 2 (Lecture 3) - Anthony Leggett 2012
170. Exotic Superconductors: What Do They Have in Common? - Part 1 (Lecture 4) - Anthony Leggett 2012
171. Exotic Superconductors: What Do They Have in Common? - Part 3 (Lecture 6) - Anthony Leggett 2012
172. Cold Atoms in Optical Lattices - Part 1 (Lecture 7) - Anthony Leggett
173. Cold Atoms in Optical Lattices - Part 2 (Lecture 9) - Anthony Leggett
174. Macrorealism and Weak Measurement (Lecture 12) - Anthony Leggett 2012
175. Jay Ingram's Public Lecture at the QNC Open House
176. Does Information Disappear? - Charles Bennett
177. Tom Brzustowski - Quantum Entrepreneurship - Lecture 4 - IP & Business Models
178. The Origins of the "KLM" Proposal - Dr. Gerard Milburn
179. A Parallel Approximation Algorithm for Positive Semidefinite Programming - Rahul Jain
180. Quantum query complexity: Adversaries, polynomials and direct product theorems - JŽrŽmie Roland

181. Quantum algorithm for deciding st-connectivity - Ben Reichardt
182. Quantum Computing with Magnetic Spins - Jorg Wrachtrup
183. Chip-Scale Atomic Clocks - Dr. David Wineland
184. Krister Shalm at TEDx: Poetry, Physics & Dance
185. Quantum Information Technologies: A New Era for Global Communication
186. QKD - Extraction of a Secure Key - Sarah Croke - QCSYS 2011
187. Entanglement-Based Protocols - Sarah Croke - QCSYS 2011
188. Introduction to QKD (Experiment) - Evan Meyer-Scott - QCSYS 2011
189. The Photoelectric Effect - Andrew Childs - QCSYS 2011
190. Double Slit Experiment - Andrew Childs - QCSYS 2011
191. Public Key Schemes - Stacey Jeffery - QCSYS 2011
192. Validity Tests of Quantum Mechanics Part 2 (Lecture 11) - Anthony Leggett 2011
193. Bell-EPR Experiments Part 2 (Lecture 8) - Anthony Leggett 2011
194. Jacob Biamonte on Tensor Network States --- Lecture 4
195. Jacob Biamonte on Tensor Network States --- Lecture 3
196. Weak "Measurement": Application to Continuous Measurement (Lecture 6) - Anthony Leggett 2011
197. Quantum Key Distribution - Norbert LŸtkenhaus - USEQIP 2011
198. Spin Polarized Transport - Guo Xing Miao - USEQIP 2011
199. Stephen Hawking at the Institute for Quantum Computing: The Boomerang of Time
200. Mike & Ophelia Lazaridis Quantum-Nano Centre -- Virtual Tour
201. David Schuster - Hybrid Devices for Quantum Information Processing (Part 2) - CSSQI 2012
202. Martin Roetteler - Quantum Algorithms (Part 2) - CSSQI 2012
203. Tom Brzustowski - Quantum Entrepreneurship - Lecture 2 - Innovation
204. Tom Brzustowski - Quantum Entrepreneurship - Lecture 3 - Competition
205. Tom Brzustowski - Canada's Prosperity Problem
206. John Watrous - Quantum Complexity Theory (Part 2) - CSSQI 2012
207. Exotic Superconductors: What Do They Have in Common? - Part 2 (Lecture 5) - Anthony Leggett 2012
208. Memory-efficient application of Kraus Maps - Ben Criger
209. IQC Food Drive (in Fast Forward)
210. QKD in Space - Evan Meyer-Scott - QCSYS 2011
211. Quantum Hacking - Evan Meyer-Scott - QCSYS 2011
212. MATLAB - Chris Ferrie - USEQIP 2011
213. Linear Algebra Lecture #2 - Chris Ferrie - USEQIP 2011
214. The Music of Quantum Science -- Tommaso Calarco

TOUR GROUPS

Academic Tour Groups: 35[14]

Chile delegation from CEDENNA (Centro para el Desarrollo de la Nanoscience y la Nanotecnologia)	May 7, 2012	2
Rockway Mennonite Collegiate	June 5, 2012	20
The Electrostatic Society of America Conference	June 12, 2012	120
Einstein Plus	June 12, 2012	45
Canadian Summer School in Quantum Information	June 15, 2012	123
Pearl Sullivan, incoming UW dean of Engineering	June 19, 2012	2
ShadValley	July 12, 2012	12
ISSYP	July 18, 2012	45
Exploring grad studies at UW	August 21, 2012	3
New IQC graduate students	September 14, 2012	25
High School Guidance Councillcors	October 25, 2012	10
Wellington Centre District High School	October 30, 2012	44
UW Liasion Team	November 2, 2012	10
Keh-Yung Cheng and Yu Li Wang, National Tsing Hua University, Taiwan	November 19, 2012	2
UW donors and VIP	November 22, 2012	10
Perimeter Institute IT team	November 27, 2012	15
Giovanni Fanchini, University of Western Ontario	November 29, 2012	1
Henry Street High School	November 30, 2012	45
Uxbridge Secondary School	November 30, 2012	70
Luke Santi Memorial Award recipient	December 5, 2012	2
Rockway Mennonite Collegiate	December 7, 2012	18

[14] The Chile delegation included academic and government personnel. It is included in both categories.

The Korean Institute for Technology	December 12, 2012	2
Isaac Kim, Caltech	December 12, 2012	1
Canadian Federation of Engineering Students Congress	January 3, 2013	180
Markus Aspelmeyer, University of Vienna	January 22, 2013	1
Trey Porto, Joint Quantum Institute/University of Maryland	January 23, 2013	1
UW IST team	February 1, 2013	50
UW alumni	February 11, 2013	3
University of Toronto Engineering Science Students	March 20, 2013	15
Dan Husssey, National Institute of Standards and Technology (NIST)	April 2, 2013	1
Bertrand Reulet, University of Sherbrooke	April 5, 2013	1
Michael Siu, VP Research, University of Windsor	April 8, 2013	1
Students of “Introduction to Quantum Computing” course (Mosca)	April 9, 2013	25