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Institute for Quantum Computing

INSTITUTE FOR QUANTUM COMPUTING
ANNUAL REPORT
APRIL 1, 2014 – MARCH 31, 2015

SUBMITTED TO INDUSTRY CANADA
JULY 27, 2015

FROM THE EXECUTIVE DIRECTOR

The Institute for Quantum Computing sits among the top-five quantum information research institutes worldwide. This is in no small part to the continued investments from our partners – the Government of Canada, the Province of Ontario, the University of Waterloo and Mike and Ophelia Lazaridis. Since 2002, these investments have enabled IQC to embrace a bold vision, recruit top talent and build unique infrastructure. Our researchers are continuing to lead the quantum revolution right here in Canada.

Over the past year, we've seen continued growth in our research activities with over 152 papers published by our faculty members. We welcomed three new researchers – faculty members Raffi Budakian and Michael Reimer, and research assistant professor Eduardo Martin-Martinez. Additionally, our graduate program grew to over 160 students from around the world. In our three locations (our headquarters, the Mike and Ophelia Lazaridis Quantum-Nano Centre, and the two Research Advancement Centre buildings), labs are continuing to be outfit as new faculty and students join our growing team. The Quantum NanoFab facility is in full operation and is now an integral part of the research activities of our faculty and students.

Going forward, we will continue our aggressive research agenda and continue to grow. We'll welcome new faculty, students and postdoctoral fellows. We'll continue to see spin offs from our research and more quantum technologies hit the market. It's an exciting time for quantum information research and I'm delighted that our work is leading the field in many significant ways. The quantum revolution is here and I'm proud to have our country playing a major role.

Sincerely,

Raymond Laflamme
Executive Director
Institute for Quantum Computing
University of Waterloo

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EXECUTIVE SUMMARY

Quantum information research will lead to the engineering of systems with capabilities far beyond those available today. Quantum technologies are truly game changing; they present an opportunity to harness and deploy the ultimate capabilities of nature for remarkable and many yet-to-be-imagined technologies.

Canada's quantum opportunity. The Institute for Quantum Computing (IQC) at the University of Waterloo holds Canada's leadership position in quantum information science and technology. Since its founding in 2002, IQC has become an engine driving the creation of knowledge and technology in quantum science, and is sparking commercialization initiatives that will benefit Canadians in the very near future and for decades to come.

IQC has been awarded $15M over three years through the generous support of the Government of Canada. This funding will serve to support five key objectives and IQC has already made great strides in achieving each of them. Highlights from the past year in these five areas include:

- **Increase knowledge in the various fields and sub-fields of quantum information, thereby positioning Canadians at the leading edge of quantum information research and technology.**
  IQC is advancing quantum information science and technology research is happening at the highest international levels. IQC researchers collectively published 152 papers over the last year and IQC papers reached a cumulative total of 15,435 citations *(Source: Web of Science, April 2, 2015).* Additionally, IQC's world-leading researchers have been awarded over $7 million in research grants.
  In 2014-15, IQC's faculty complement grew to 22 faculty members and three research assistant professors as the best and brightest senior and young researchers join the team. IQC most recently welcomed:
  - Raffi Budakian, Nanotechnology (WIN) Endowed Chair in Superconductivity in Waterloo's Physics and Astronomy department from the University of Illinois at Urbana-Champaign;
  - Michael Reimer, Assistant Professor, Electrical & Computer Engineering from Technical University of Delft;
  - Eduardo Martin-Martinez, Research Assistant Professor and received the 2014 John Charles Polanyi Prize for Physics.
- **Create new opportunities for students to learn and apply new knowledge to the benefit of Canada, spurring innovation and investment in R&D activities through highly qualified personnel development.**
  IQC's graduate programs have seen a **103% increase** from 62 students in 2007 to 126 in the 2014-2015 academic year. These students have garnered national and international

awards, scholarships and fellowships including NSERC awards, Banting Fellowships, Vanier Fellowships and many others.

- **Brand Canada as the destination of choice for conducting research in quantum technologies and attract the best in the world to Canada, creating partnerships with the international quantum information community and promoting a world-class excellence in quantum information science and technology.**
  IQC researchers collectively participated in 84 conferences this year, disseminating knowledge and building collaborations across the globe. Additionally, the visitor program welcomed 154 visitors from 111 leading institutions to exchange ideas and research in quantum information.
- **Enhance and expand the Institute's public education and outreach activities to effectively promote science and quantum information science and demonstrate how the research from quantum information science can be applied for the purpose of sustaining and attracting world-class talent.**
  This year, IQC has promoted quantum information science across the country to school groups and the general public, participating in 46 outreach activities and reaching more than 2,500 people through tours, workshops, public lectures and educational sessions. IQC's premier summer school programs brought 21 undergraduate students for the Undergraduate School on Experimental Quantum Information Processing (USEQIP) and 42 high school students for the Quantum Cryptography School for Young Students (QCSYS) to Waterloo to experience the world-class environment of IQC.
- **Position Canada to take advantage of economic and social benefits of research through seizing opportunities to commercialize breakthrough research.**
  As quantum research leads to more and more emerging technologies, IQC is uniquely positioned to promote the commercialization and realization of quantum technologies. IQC's researchers are forging forward with commercial ready technologies and have now spun off four companies. Additionally, IQC hosted a commercialization and entrepreneurship workshop in partnership with CryptoWorks21 to educate and support researchers through the commercialization process.

With its industry partners, IQC is building Canada's quantum information industry – the Quantum Valley – here in Waterloo. IQC will leverage its world-leading infrastructure and outstanding scientific capability to create the world's first market-facing environment for designing, building and testing quantum information services and devices.

As IQC continues its rapid growth and advances the understanding of the quantum world, Waterloo Region's – and Canada's – reputation as the Quantum Valley will continue to be solidified.

ABOUT THE INSTITUTE FOR QUANTUM COMPUTING

The Institute for Quantum Computing (IQC) was established in 2002 to seize the potential of quantum information science for Canada. IQC's vision was bold: position Canada as a leader in quantum information research and provide the necessary infrastructure for Canada to emerge as a quantum research powerhouse. Today, IQC stands among the top quantum information research institutes in the world. Leaders in all fields of quantum information science come to IQC to conduct research, share knowledge and encourage the next generation of scientists. IQC is leading the next great Canadian technological revolution – the quantum revolution. Quantum technologies and applications developed in IQC labs are creating the foundation for the next generation of technologies – quantum technologies.

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

Vision & Mission

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

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

Strategic Objectives

IQC is guided by three strategic objectives developed in partnership with Industry Canada in 2008:

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

FUNDING OBJECTIVES 2014-2017

IQC has been awarded $15M over three years through the generous support of the Government of Canada. This funding will serve to support the following five objectives:

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

Through the activities planned and undertaken with the contribution of Industry Canada in the past year (2014-2015), IQC is well on the way in positioning Canada to take full advantage of the benefits of quantum research.

Objective A

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

Expected Outcomes for 2014-2015

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

Highlighted Results for 2014-2015

- Continued research agenda and made advancements in quantum computing, quantum communications, quantum sensors and quantum materials:
    - Kevin Resch and his team built a photonic circuit, allowing the causal structure realized by the experiment to vary, to confirm quantum effects of entanglement and coherence provide an advantage for causal inference (*Nature Physics,* 2015)
    - Eduardo Martin-Martinez and collaborators discovered a possible communication channel that does not require energy transmission from the sender to the receiver (*Physical Review Letters,* 2015)
    - Marco Piani and John Watrous showed that the quantum steering effect is the key to providing a specific advantage in the discrimination of physical processes (*Physical Review Letters*, 2015)
    - Guo-Xing Miao and colleagues from the Korea Institute of Science and Technology (KIST) detected the interface and spin current of a magnetic insulator, a practical finding for actively regulating spin flows in electronic devices (known as spintronics) and for energy harvesting (*Nature Communications*, 2014)

- Raymond Laflamme, Aharon Brodutch, and Dawei Lu developed and demonstrated the first experiment of a weak measurement with post-selection on an NMR quantum processor (*New Journal of Physics*, 2014)

- IQC researchers collectively published 152 papers in this reporting period and reached a cumulative total of 15,435 published citations *(Source: Web of Science, April 2, 2015)*
- Successfully recruited two new faculty members and one new research assistant professor
- IQC researchers were awarded a total of $7,397,541 in research grants

Progress Achieved for 2014-2015

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

IQC conducts research in quantum information at the highest, international level and its research produces new knowledge that leads to publications, presentations at conferences and commercialization opportunities. Below are summaries of select research highlights from the 2014-2015 year.

Quantum correlation can imply causation

Nature Physics: http://www.nature.com/nphys/journal/vaop/ncurrent/full/nphys3266.html

Contrary to the statistician's slogan, in the quantum world, certain kinds of correlations *do* imply causation. Research from the Institute for Quantum Computing (IQC) at the University of Waterloo and the Perimeter Institute for Theoretical Physics shows that in quantum mechanics, certain kinds of observations will let you distinguish whether there is a common cause or a cause-effect relation between two variables. The same is not true in classical physics.

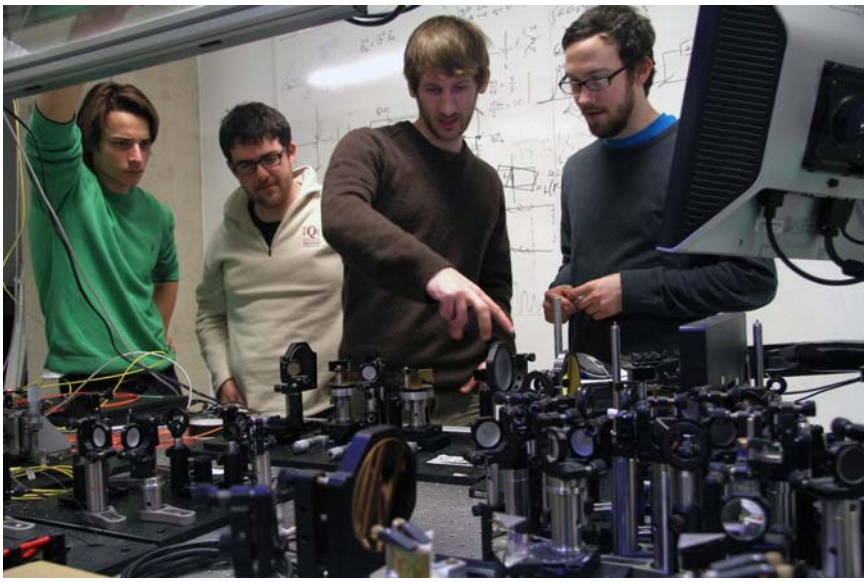
Explaining the observed correlations among a number of variables in terms of underlying causal mechanisms, known as the problem of 'causal inference', is challenging but experts in the field of machine learning have made significant progress in recent years. Physicists are now exploring how this problem appears in a quantum context.

Causal inference hinges on the distinction between correlation and causation. If A and B are correlated, then when you learn about A, you update your knowledge of B – this is inference. If A causes B, then by manipulating A, you can control B – this is influence. In quantum foundations, this distinction is key.

Knowing if a correlation arises from a cause-effect relation or a common cause relation is a fundamental problem in science. A prime example: drug trials. When physicians observe a correlation between treatment and recovery, they cannot presume that the treatment is the cause of the recovery. If men are more likely to choose the treatment and also more likely to

recover spontaneously, regardless of treatment, then the correlation would be explained by a common cause.

That is why, when testing treatments, pharmaceutical companies intervene and randomly assign either the drug or a placebo to participants. This ensures that the treatment variable is statistically independent of any potential common causes. This is a general feature of classical statistics: one needs to intervene in order to determine whether the correlations are due to a cause-effect relation, a common cause relation, or a mix of both.



The paper, published in Nature Physics, demonstrates that quantum effects can eliminate the need for intervention. This research provides a new way to think about quantum mechanics. It is also a useful framework for thinking about foundational problems.

Spekkens, along with PhD student Katja Ried and fellow theorist Dominik Janzing, considered the situation of an observer who is probing two variables and finds them to be correlated. The observer doesn't know whether this is because they are the input and output of a quantum process, that is, cause-effect related, or because they are the two halves of an entangled quantum state, and therefore correlated by a common cause. They realized that certain patterns of correlations are distinctive to each scenario.

Resch, together with his students Megan Agnew and Lydia Vermeyden, had the tools to put this idea to the test. They built a photonic circuit that could switch between the two scenarios proposed by the theorists, allowing them to vary the causal structure realized by the experiment.

Their results confirmed that the quantum effects of entanglement and coherence provide an advantage for causal inference. This parallels the way in which quantum effects can help to solve computational problems and make cryptography more secure. Thinking about which practical tasks are easier in a quantum world has traditionally led to many insights into its foundations.

Information Transmission Without Energy Exchange

Physical Review Letters: http://journals.aps.org/prl/abstract/10.1103/PhysRevLett.114.110505

IQC Research Assistant Professor Eduardo Martin-Martinez, in collaboration with PhD student Robert Jonsson and Professor Achim Kempf, both of the Department of Applied Mathematics at the University of Waterloo, have found a possible communication channel that does not require energy transmission from the sender to the receiver, but instead requires only the receiver to spend energy to run its detector, similar to a collect call.

They found that any interaction of matter with a massless quantum field produces a perturbation – like an echo – that could travel more slowly than the speed of light. This is unlike typical communication, which is done via the emission and absorption of light. This echo can be used to transmit information, an effect that is made possible with quantum fields of certain dimension or in the presence of space time curvature. Since it is the receiver who spends the energy to read the information carried in the echo, this kind of communication without energy exchange may be called "Quantum Collect Calling." This new type of communication channel makes it possible for the sender to transmit information without energy exchange, without the receiver being present and without spending extra energy to broadcast to many receivers. The paper, *Information Transmission Without Energy Exchange*, was published in *Physical Review Letters* March 20.

Correlations of quantum particles help in distinguishing physical processes

Physical Review Letters: http://journals.aps.org/prl/abstract/10.1103/PhysRevLett.114.060404

Communication security and metrology could be enhanced through a study of the role of quantum correlations in the distinguishability of physical processes, by researchers at Universities of Waterloo and Strathclyde.

The study involved analysing the impact of quantum steering, that is, the way through which a measurement performed on a particle can affect another distant particle. The researchers devised a method for both precisely quantifying steering's impact and relating it to the task of distinguishing physical processes.

The research could have significant implications for quantum information processing. The study was carried out by faculty members John Watrous of Waterloo's Institute for Quantum Computing (IQC) and David R. Cheriton School of Computer Science, and Marco Piani of Strathclyde's Department of Physics. Piani was also at IQC at the time of the study.

Quantum particles can be in a particular state known as `entangled'. Albert Einstein, with Boris Podolsky and Nathan Rosen, scrutinised quantum mechanics and specifically the entanglement of quantum particles. Faced with the perspective of the steering effect, they argued that quantum mechanics was still an incomplete theory, since it predicted what Einstein considered a `spooky action at a distance' – indeed, two particles can be at opposite ends of a galaxy and still be entangled.

Steering has since been determined as a crucial and real quantum effect; however, knowledge about what steering is actually useful for has remained limited. In this study, Watrous and Piani related steering to the discrimination of physical processes, which seeks to answer questions about what happens in time to physical systems of interest, like microscopic particles. They showed that the steering effect is the key to providing a specific advantage in this type of task.

The results, including the tools introduced to quantify steering, could be applied to fields such as quantum cryptography, where secret keys are created between two parties so they can submit and encrypt messages to communicate privately – as it happens, for example, in online banking. The results could also be useful in quantum metrology and in other areas of quantum information processing.

Steering is an interesting phenomenon in quantum physics. The work ties this concept in a new way to a specific information-theoretic task in which it functions as an essential resource. It is a hypothetical task that you won't find on your to-do list, but it is both natural and intuitive, and the connection offers a new insight into the nature of steering.

The paper *Necessary and Sufficient Quantum Information Characterization of Einstein-Podolsky-Rosen Steering* was published in Physical Review Letters February 12. Piani presented the paper at the 18th Conference on Quantum Information Processing in Sydney, Australia in January. It was one of 40 accepted from more than 200 submissions.

Spintronics and Energy Harvesting

Nature Communications:
http://www.nature.com/ncomms/2014/140423/ncomms4682/full/ncomms4682.html

The electrons making up electrical current have a quantum magnetic property known as "spin", which unlike a regular bar magnet, can only point along or against a magnetic field. In traditional electronics, this property is ignored because of the difficulty to create spin-polarized current. Magnetic insulators have two very interesting properties. The first is they can selectively allow the passage of electrical current containing electrons with only one type of spin through them – known as the spin-filtering effect. The second interesting property occurs when they are interfaced with a low-dimensional electronic system, they can generate a very large effective magnetic field at the interface. The magnetic field could be as large as tens of Tesla, which is equivalent to the largest man-made magnets.

IQC faculty member Guo-Xing Miao and colleagues from the Korea Institute of Science and Technology (KIST), Northeastern University and the Massachusetts Institute of Technology (MIT) recently detected this interface field and spin current. The team reported these measurements in the paper *Spin regulation in composite spin-filter barrier devices*.

Their findings could be practical for actively regulating spin flows in electronic devices, known as spintronics, and for energy harvesting. The paper was published in April in Nature Communications.

Post-selection and weak measurements

New Journal of Physics: http://iopscience.iop.org/1367-2630/16/5/053015/

Post-selection – the technique of conditioning measurement statistics by considering experiments meet a certain outcome criteria — is a powerful theoretical and experimental tool in quantum information. Previously, weak measurements with post-selection were mostly limited to optics experiments and the method used is outside the scope of implementation schemes using nuclear magnetic resonance, electron spins and rare-earth crystals.

However, postdoctoral fellows Dawei Lu and Aharon Brodutch, along with IQC Executive Director Raymond Laflamme and visitors from the University of Science and Technology of China and Tsinghua University, developed and demonstrated the first experiment of a weak measurement with post-selection on an NMR quantum processor. This experiment can help those studying and exploiting post-selection and weak measurements in systems where projective measurements are difficult to accomplish experimentally. The paper *Experimental realization of post-selected weak measurements on an NMR quantum processor* was published in *New Journal of Physics* in May.

Recruiting New Researchers:
Recruit up to two new faculty members and one research assistant professor

IQC continues to recruit world-leading theoretical and experimental researchers in a range of disciplines. In the 2014-2015 year, IQC reviewed 100 applications from prospective faculty members and is proud to welcome new faculty members Raffi Budakian, Michael Reimer and Research Assistant Professor Eduardo Martin-Martinez.

Raffi Budakian joined IQC in July 2014 as the Nanotechnology (WIN) Endowed Chair in Superconductivity in Waterloo's Physics and Astronomy department. After earning his Bachelor's, Master's and PhD degrees in physics and completing a postdoctoral fellowship at the University of California, Los Angeles, Budakian was a visiting scientist at the IBM Almaden Research Centre. The World Technology Network awarded him the World Technology Award in 2005 for his work in the detection and manipulation of electron spins. That same year Budakian joined the University of Illinois at Urbana-Champaign. His work in the past decade has focused on developing the experimental tools for ultra sensitive detection of electron and nuclear spins. At IQC, he will continue his research in the use of spins, one of the most promising approaches being applied to quantum information processing.

Michael Reimer joined IQC in February 2015 as an Assistant Professor in Electrical & Computer Engineering department at the University of Waterloo. From 2009 to 2014, Michael was a postdoctoral researcher at the Technical University of Delft in the quantum optics lab of Professor Val Zwiller where he developed solid-state quantum devices. During that time, Reimer made an impact in the development of single photon and entangled photon sources based on shaped nanowire heterostructures, as well as nanowire-based single electron devices and efficient nanowire avalanche photodiodes. In 2013, Michael was also an integral part of a recent start-up company, Single Quantum, developing highly efficient single-photon detectors based on superconducting nanowires. His research at IQC will focus on the development of quantum photonic devices and optical approaches needed to advance quantum information science and technologies, as well as to test fundamental questions in quantum photonics.

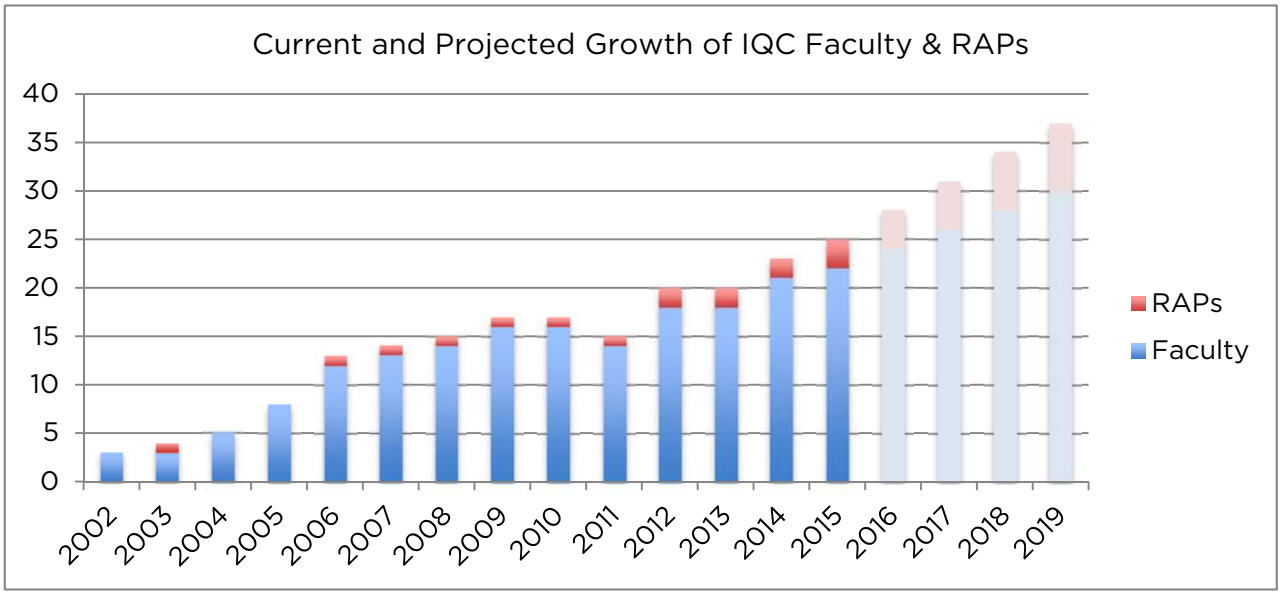
Eduardo Martin-Martinez joined IQC in 2014 as a Research Assistant Professor. Martin-Martinez completed his PhD in Theoretical Physics in 2011 at the Universidad Complutense de Madrid, Spain summa cum laude and received the 2010-2011 extraordinary PhD thesis award. During his PhD, he collaborated with top scientists in relativistic quantum information in Canada, United Kingdom, Austria, Japan and Poland. His first postdoctoral appointment was with the Institute for Quantum Computing at the University of Waterloo in 2012, the same year he was awarded the prestigious Banting Postdoctoral Fellowship. He was also an associate postdoctoral researcher at Perimeter institute. In 2014, Eduardo was named a Research Assistant Professor at the Institute for Quantum Computing, cross-appointed to the Perimeter Institute. In November 2014, Martin-Martinez was awarded the John Charles Polanyi Prize in Physics, recognizing Nobel areas of research. His research combines the fields of quantum information science, quantum field theory and general relativity; studying quantum effects induced by gravity from the perspective of quantum information to gain information about the spacetime structure. This approach has a wide range of potential outcomes and applications from quantum computing technology to the basic physics of the question of how the spacetime curvature and quantum theory impact the flow and the processing of information.

As IQC is on the path to its full complement of 33 faculty members, recruitment of the world's leading researchers remains a priority. The charts below illustrate the growth of IQC

members to its current level of 22 faculty and three research assistant professors and shows IQC's success in meeting its goals in researcher recruitment.

The full list of current IQC faculty members and research assistant professors as of March 31, 2015 is in Appendix C.

Recruitment Goals			
	Researchers Recruited in 2013-2014	Goal to Recruit in 2014-2015	Researchers Recruited in 2014-2015
Faculty	2	2	2
Research Assistant Professors		1	1
Postdoctoral Fellows	14	5	19



Researchers are recruited to IQC from universities and institutes around the world. The following table illustrates the global makeup of the current complement.

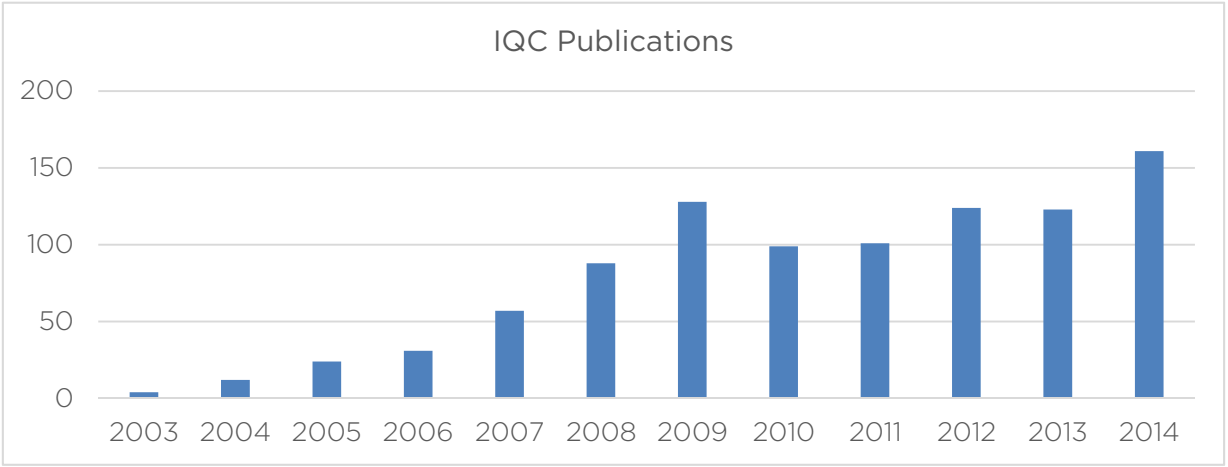
	Canadian	Dual Citizenship	International
Faculty	6	-	16
Research Assistant Professors	-	-	3
Postdoctoral Fellows	18	-	28
Graduate Students	52	-	74

Continue to publish research results in world-leading journals.

Studies generated by IQC researchers are published worldwide in prominent journals, one indicator of research output.

Papers Published

IQC is proud to report 981 publications by IQC researchers since 2002, 152 of which were published between April 1, 2014 and March 31, 2015. The chart below illustrates IQC's publications growth per year since 2003.



Note: *Source for Publications and Citations: Thomson Reuters' Web of Science on April 2, 2015. Data compiled using an address search for Institute for Quantum Computing (inst* quant* comp*). Citations are cumulative for all IQC publications for all years.*

IQC researchers have been successful in attracting attention from and being published in notable journals each year, as the chart below illustrates.

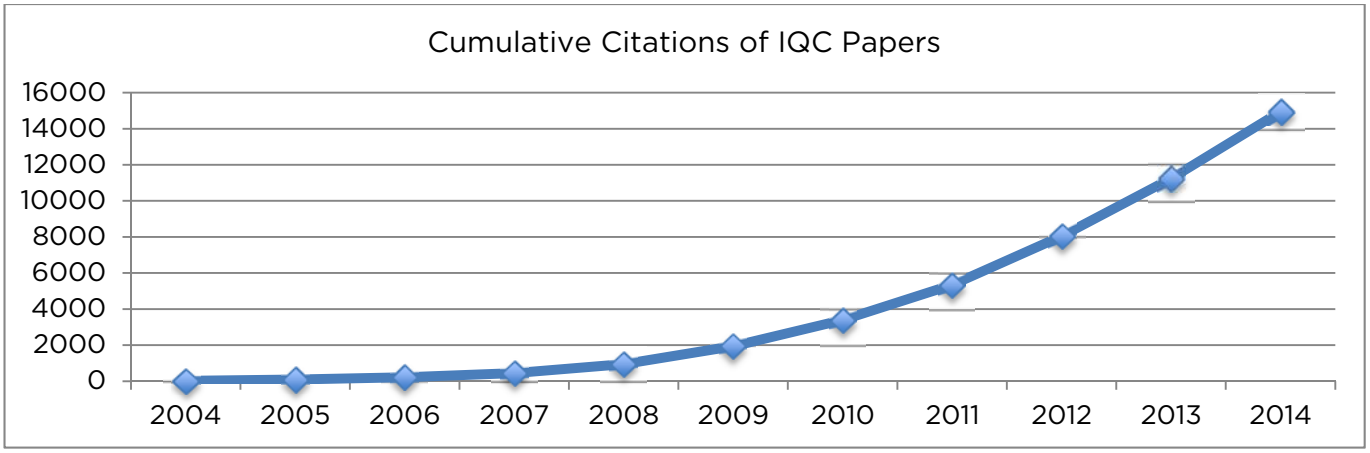
IQC Research Published in Prominent Journals Since 2007

Publication	2007	2008	2009	2010	2011	2012	2013	2014
Nature	3	2	1	1	1	1		2
Nature Photonics			1	1	1		3	2
Nature Physics	1	1	5	5	3	2	3	
Nature Communications					1	1	1	5
Physical Review Letters	10	7	16	14	17	14	14	16
Science	2	1	1	1	2	1	1	3
STOC	1	2	1	2				
FOCS			3		1	1		
Journal of Mathematical Physics		1	2	2	4	6	4	4

For a full list of papers published in 2014-2015, see Appendix E.

Citations

In addition to publications, citations are another indication of research output. At the time of this report, there have been **15,435 cumulative citations** for all publications by IQC researchers, while at IQC. The chart below illustrates the cumulative growth of citations year over year.



Research Grants

IQC researchers have collectively been awarded $7,397,541 in research funding during the period March 1, 2014 to April 30, 2015 from both government and industry partners and

programs. The chart below demonstrates the total research grant amounts year over year since 2008.

IQC Fiscal	09-10	10-11	11-12	12-13	13-14	14-15
Grant	$11,905,391	$12,551,733	$8,350,363	$10,862,426	$7,325,082	$7,397,541

Note: Information on research grants is reported for the University of Waterloo fiscal year from May 1, 2014 to April 30, 2015.

Faculty Awards

The calibre of quantum information research by IQC faculty members continues to make a global impact. The quality and ability of these members is evidenced not only by their research, but also by the many awards and acknowledgements they receive.

IQC faculty received the following awards in 2014-2015:

- Eduardo Martin-Martinez: John Charles Polanyi Prize
- Ashwin Nayak: Queen Elizabeth II Diamond Jubilee Scholarship
- John Watrous: NSERC Discovery Accelerator Supplement

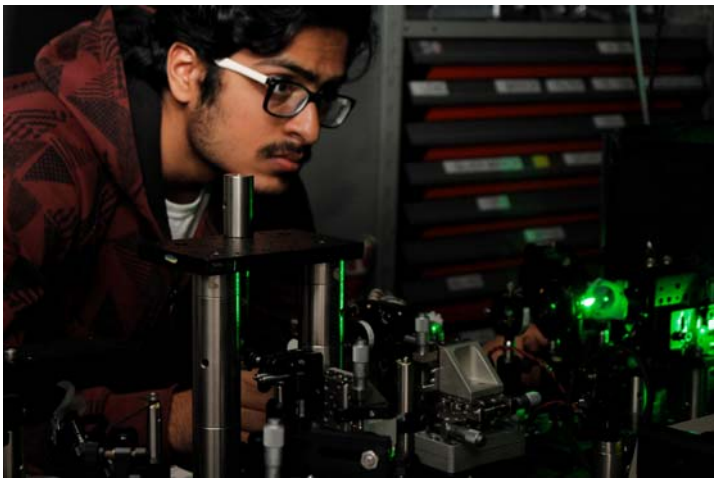
IQC is also home to the following Research Chairs:

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

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

IQC prioritizes the continued updating and outfitting of labs in the Mike & Ophelia Lazaridis Quantum-Nano Centre to ensure researchers have access to the necessary resources to accommodate their respective research. In 2013-2014, IQC welcomed new faculty members, Kyung Soo Choi and Michal Bajcsy, and throughout the past year, both members have worked to create operational lab spaces. Additionally, Raffi Budakian procured a new silicon nano-wire growth system for his lab space, Vadim Makarov has expanded his security verification lab and Adrian Lupascu has been preparing to move his superconducting quantum devices lab from RAC to the Lazaridis Centre and expand with another dilution fridge.

Kyung Soo Choi: Ultracold Quantum Matter & Light Laboratory



Choi's research investigates exotic bottom-up quantum systems built by individual atoms and photons for simulating exotic quantum phases and for building on-chip quantum networks. Since October, Kyung Soo Choi and his research team have been designing and building custom lasers for ultimate precision and control – currently not available commercially – required for his work with Rydberg atoms and photonic crystals. Other equipment advances include the development of a complex ultra-high-vacuum (UHV) system for the preparation of quantum gases and the expected arrival of an ultra low expansion cavity later this year.

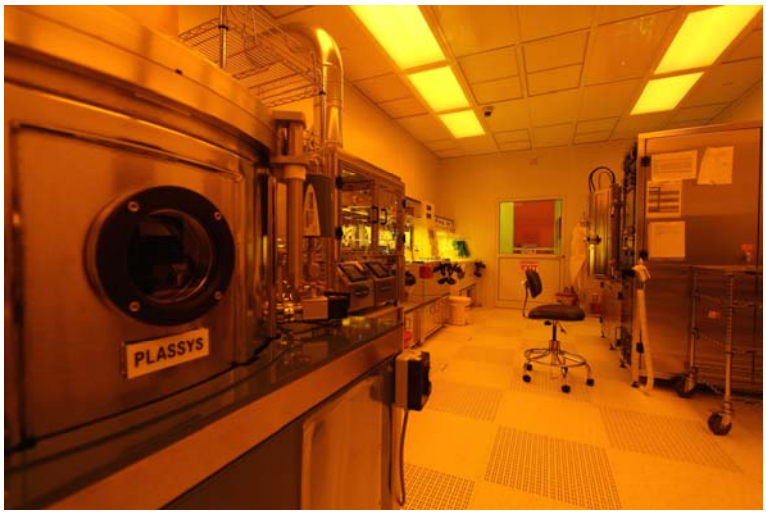
Michal Bajcsy: Nano-Photonics and Quantum Optics Laboratory

Michal Bajcsy's Nano-Photonics and Quantum Optics Lab focuses on the development of scalable photonic devices and quantum optics experimental platforms based on quantum emitters, such as laser cooled atoms, quantum dots, and colour centers, coupled to nanophotonic structures. Arrivals over the past year include a laser system for atom cooling and probing, which consists of four individually controllable laser heads that can be stabilized to an atomic reference and phase-locked together with arbitrary frequency offsets, and components for a compact, custom-designed ultra-high-vacuum system for atom cooling and trapping with an optical-contact assembled antireflection-coated glass cell serving as the science chamber.

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

September 2, 2014 marked the official opening of the Quantum NanoFab cleanroom in its new home in the Mike and Ophelia Lazaridis Quantum-Nano Centre. Since the opening, 85 graduate and post-graduate lab users have been registered and trained to use the facility. These 85 users fall under 26 different faculty members from five different departments spanning the Faculties of Science and Engineering. Interest in accessing the facility continues to grow and a new facility access protocol was established and published to facilitate access for both internal and external users.

In the past year IQC has seen the installation of several new pieces of equipment, including:



- Ion Mill for etching of thin films;
- Twin Chamber Sputter system for the physical vapour deposition of multiple thin films;
- Rapid Thermal Processor for high-temperature processing of 4″ and 6″ wafers;
- 4-tube furnace with several deposition and growth capabilities including LTO, PolySi and SiC, Silicon nitride and thermal oxidation;
- Several characterization systems including an ellipsometer, film stress measurement system and a 4-point probe;
- Full complement of Packaging Lab equipment including wire bonders, a dicing saw, a die bonder and a hydrogen plasma cleaner;
- High performance, state-of-the-art 100kV electron–beam lithography system was ordered in March 2015.

To ensure a continued high standard of care for the cleanroom, the operations team has been augmented to better align with its published Management and Operational Plan. April 2014 saw the hiring of Cleanroom Certification prime, Mai-Britt Mogensen, and more recently (December 2014), the addition of a new Equipment Technologist, Matthew Scott, who is serving to augment technical coverage of facility operations.

Update and maintain lab space in Research Advancement Centres I & II (RAC I & RAC II) buildings.

In addition to the Mike & Ophelia Lazaridis Quantum-Nano Centre, IQC maintains laboratory and office space in two additional buildings located in the David Johnston Research & Technology Park, north of the University of Waterloo campus.

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

- Nuclear Magnetic Resonance (NMR) Laboratory
- Electron Spin Resonance (ESR) Laboratory
- Coherent Spintronics Laboratory

RAC II houses 15,260 square feet of lab space. The labs 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. Operational labs include:

- Ultra-High Vacuum Deposition (UHV) System
- Sputter/Evaporation Dual Chamber System
- Diamond Chemical Vapour Deposition System
- X-ray Diffraction System

Currently in RAC II, a silicon chemical vapor deposition (CVD) system is in the process of being installed. This instrument will be used for growing silicon nanowire for the force-detected magnetic resonance project. The next installation, shipping in April 2015, is a custom 350-mK low temperature refrigerator that is also for the force-detected magnetic resonance project. This system will be installed in the quiet labs under construction in the back of the RAC II building.

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

IQC is always exploring and pursuing opportunities to form meaningful and relevant relationships with partners. Below are summaries of three notable partnerships established in 2014-2015.

Technion – Israel Institute of Technology

A delegation from the Technion-Israel Institute of Technology toured IQC on September 18, 2014, the first visit by Technion to Waterloo since signing a cooperation agreement in Israel in March 2014. Ideas were exchanged and collaborations began during Technion's visit to IQC. Feridun Hamdullahpur, President of the University of Waterloo, and Raymond Laflamme, IQC Executive Director, attended the Qubit Symposium at Technion in March where the cooperation agreement was signed, bringing great minds and students together at both universities. Currently the agreement extends to the fields of quantum information systems, nanotechnology and water. The partnership will facilitate technology transfer, connect faculty and students with industrial partners and increase international opportunities for undergraduate, graduate and postdoctoral student research exchanges.

Korea Institute of Science and Technology (KIST)

IQC hosted Ambassador Cho, Republic of Korea, on November 21 during a follow-up visit to Waterloo after signing an agreement with the Korea Institute of Science and Technology (KIST). The IQC/KIST Memorandum of Understanding will expand research partnerships in the field of quantum information science and accelerate the development of quantum technologies for the benefit of both countries.

Canadian Queen Elizabeth II Diamond Jubilee Scholarship

IQC faculty member and Quantum Information Graduate Program Director, Ashwin Nayak, received $260,000 in Canadian Queen Elizabeth II Diamond Jubilee Scholarship funding announced March 25. The funding will be used to financially assist 24 Canadian undergraduate and graduate students from IQC to visit the National University of Singapore's Centre for Quantum Technologies (CQT), and support 16 CQT students (Singaporean or from other Commonwealth countries) to come to IQC for a period of four months.

In addition to collaborating on quantum research with leading experts across the world, visiting students will have the opportunity to connect with the local community through scientific outreach activities. Leveraging an existing Memorandum of Understanding (MOU)

between IQC and CQT, the program facilitates graduate student mobility among the centres and will create a strong network of young qunatum information science and technology (QIST) researchers in the Commonwealth. The first students from CQT participating in the program arrived at IQC for the 2015 Spring term.

Objective B

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

Expected Outcomes for 2014-2015

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

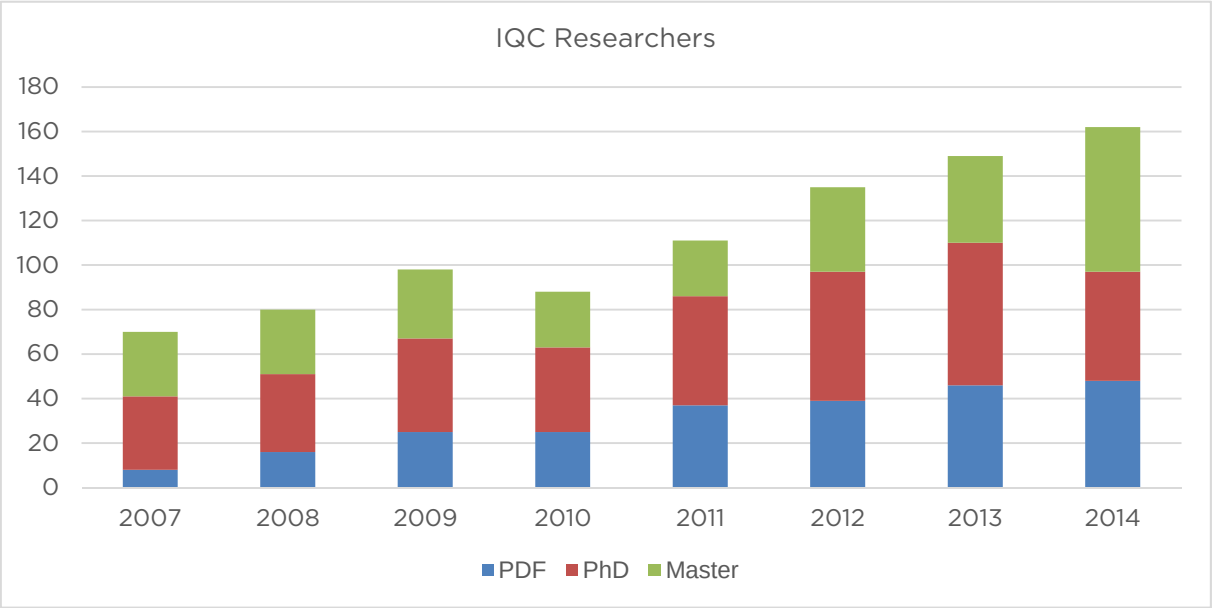
Highlighted Results for 2014-2015

- IQC is currently home to 126 graduate students and 46 postdoctoral fellows
- Recruited 29 new graduate students and 19 new postdoctoral fellows
- Fielded 246 applications to IQC programs
- Hosted four major conferences and sponsored an additional 15

Progress Achieved for 2014-2015

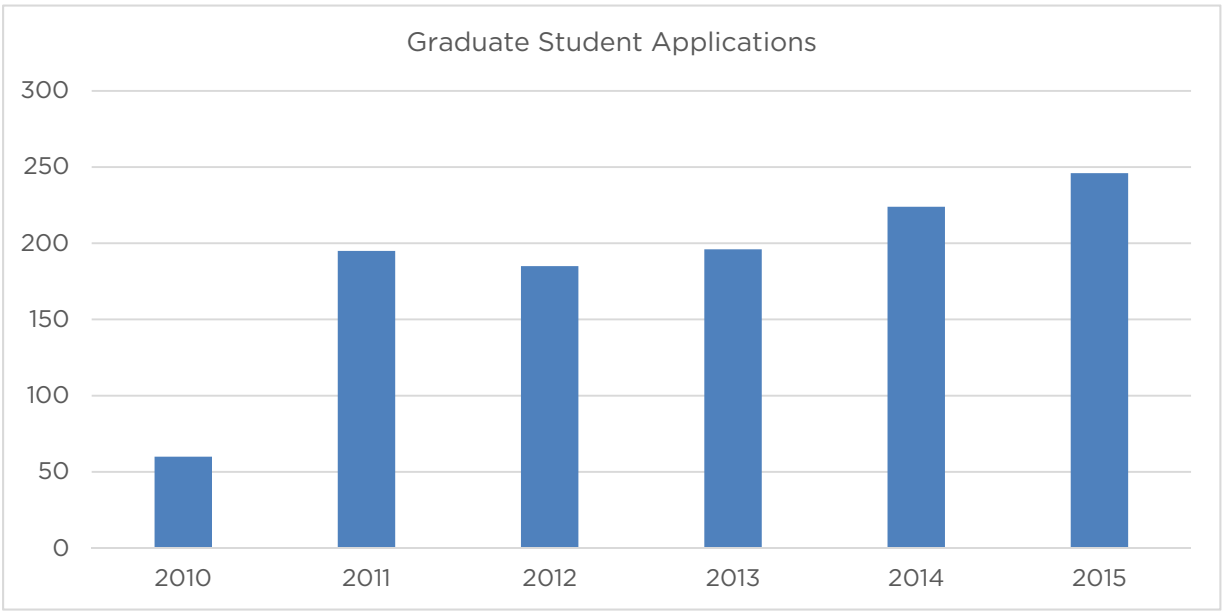
Continue to grow and attract the best talent to IQC's graduate program

IQC has attracted international talent and fostered a reputation for excellence in its research and teaching endeavours. Since 2007, IQC's graduate student body has grown by 103% from 62 students to 126 in the 2014-2015 academic year.



Recruitment

IQC surpassed its goal to field at least 200 applications from Master's and PhD students with 246 applications this academic year, as of March 31, 2015. Applications for the graduate programs include both students indicating an interest in quantum information (102) and those applying directly to the quantum information graduate program (144). The chart below illustrates the overall growth in applications year over year since 2010.



Postdoctoral fellowships bring young scientists with expertise and innovative research approaches and contribute to every aspect of IQC's mission. IQC has attracted a total of 19 new postdoctoral fellows in the 2014-2015 year, bringing the total current number to 46. These postdoctoral fellows represent institutions in the United States, China, Canada, Singapore and South Korea. Postdoctoral researchers have been recruited from the following institutions this year.

Canada	USA	International
University of Waterloo	Harvard University	Tsinghua University, China
University of Calgary	University of California, Berkeley	University of Stuttgart, Germany
University of Ottawa	Columbia University	National University of Singapore, Singapore
	University of New Mexico	Hong Kong University of Science & Technology, Hong Kong
	University of Vermont	University of Strathclyde, UK
		Seoul National University, South Korea
		University of London, UK

Postdoctoral Fellow Profile

Postdoctoral fellow, Aharon Brodutch, joined IQC in August 2012 after completing his Bachelor's and Master's degrees in Physics and Astronomy at Tel Aviv University in Israel. Brodutch's graduate research in weak measurements was performed under the supervision of Professor Lev Vaidman. He then moved to Macquarie University in Australia for his PhD, where his research with Associate Professor Daniel Terno focused on relativistic quantum information and the role of quantum in various

scenarios such as quantum information and thermodynamics. As a postdoctoral fellow at IQC, Brodutch continues his work on the weak measurement project, relativistic quantum information and quantum correlations, and is involved in NMR quantum computing research as part of the Technion partnership.

For a full list of postdoctoral fellows, see Appendix F.

Graduate and Undergraduate Fairs and Connections

Continuing to attract talented students from around the world remains a priority for IQC. This year, IQC attended graduate fairs at McGill University, the University of British Columbia and the Canadian Physics Conference Graduate Fair.

Through IQC's connections to universities across the country, including attendance at the above noted graduate fairs, additional connections are consistently made to increase awareness of IQC's programs and research activities. In February 2015, two IQC PhD students attended the Atlantic Universities Physics and Astronomy Conference which featured a graduate fair and represented IQC. IQC also supported the Canadian Conference for Undergraduate Women in Physics in January by sending two IQC students to represent the Institute. Finally, IQC sponsored the 2015 "Jeux de la Physique" in Montreal, which features a large undergraduate component, in January. There was an IQC experimental challenge and for the first time at the conference, the event featured a section dedicated to quantum information as part of the theoretical challenge.

International Recruitment

Several IQC faculty members frequently travel abroad and include recruitment activities in their travel. Professor Michele Mosca frequently travels to Singapore, Professors David Cory and Guo-Xing Miao travelled to China and IQC Executive Director Raymond Laflamme has twice travelled to Israel. IQC researchers also frequently travel to give invited talks, attend and participate in conferences, as well as host national and international colleagues.

IQC Collaborative Graduate Program

The collaborative graduate program at IQC 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 Master's and PhD levels leading to MMath, 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.

For a full list of graduate students from the 2014-2015 year, see Appendix G.

Graduate Students - Awards

The best and brightest minds are studying and researching at IQC, earning awards and scholarships in recognition of their work. The chart below summarizes the awards, scholarships and fellowships earned by IQC students (Masters and PhD) in 2014-2015.

Student	Award
Vadiraj Ananthapadmanabha Rao	IQC Achievement Award
Alessandro Cosentino	IQC Entrance Award
Juan Miguel Arrazola	David R. Cheriton Graduate Fellowship
Hillary Dawkins	IQC Entrance Award NSERC Alexander Graham Bell Canada Graduate Scholarship - Masters President's Graduate Scholarship
John Donohue	IQC Achievement Award IQC David Johnston Award for Scientific Outreach NSERC Alexander Graham Bell Canada Graduate Scholarship – Doctoral President's Graduate Scholarship
Honghao Fu	IQC Entrance Award
Matthew Graydon	Ontario Graduate Scholarship President's Graduate Scholarship
Aimee Gunther	IQC David Johnston Award for Scientific Outreach Ontario Graduate Scholarship President's Graduate Scholarship
Gregory Holloway	NSERC Postgraduate Scholarship - Doctoral President's Graduate Scholarship
Vinay Iyer	IQC Entrance Award NSERC Alexander Graham Bell Canada Graduate Scholarship - Masters President's Graduate Scholarship
Tomas Jochym-O'Connor	IQC Achievement Award NSERC Vanier Canada Graduate Scholarship
Sumeet Khatri	IQC Entrance Award
Maria Kieferova	Mike and Ophelia Lazaridis Fellowship
Robin Kothari	IQC Achievement Award
David Layden	NSERC Alexander Graham Bell Canada Graduate Scholarship - Masters President's Graduate Scholarship
Xingliang (David) Lou	Ontario Graduate Scholarship President's Graduate Scholarship
Corey Rae McRae	IQC David Johnston Award for Scientific Outreach
Jihyun Park	QEII-Graduate Scholarship in Science and Technology
Daniel Puzzuoli	IQC Entrance Award
Hammam Qassim	Mike and Ophelia Lazaridis Fellowship

Student	Award
Jeff Salvail	IQC Entrance Award NSERC Alexander Graham Bell Canada Graduate Scholarship - Doctoral President's Graduate Scholarship
Sean Walker	Ontario Graduate Scholarship President's Graduate Scholarship
Chunhao Wang	Ontario Graduate Scholarship President's Graduate Scholarship
Kyle Willick	IQC Entrance Award NSERC Alexander Graham Bell Canada Graduate Scholarship - Doctoral President's Graduate Scholarship

Graduate Student Profile

Carolyn Earnest was first introduced to nanofabrication techniques during her undergraduate studies at the University of Massachusetts, where she was making a single electron out of a combination of superconducting and non-superconducting metals. Now, as a PhD student at IQC, Earnest uses those skills in the Quantum NanoFab facility making junctions and working with other fabricators to find a parametrized recipe for qubits for use in Matteo Mariantoni's superconducting lab. The group is working on a form of error correction called surface code. This method arranges qubits in a chain-link fence-like lattice. Through interaction with the lattice and lattice topological properties, researchers can detect any kind of error that might happen if the lattice is big enough.

IQC Alumni

As of March 31, 2015, IQC proudly reports 131 student alumni currently in various roles around the world including both academic and industry careers.

Profiles of Selected Alumni

During her postdoctoral research at IQC, **Urbasi Sinha** worked on the very first fundamental triple-slit experiment that served as a precision test for the Born Rule for probabilities in quantum mechanics.

In March 2012, Sinha accepted a position at the Raman Research Institute (RRI) in Bangalore, India as Associate Professor. She continues her research in quantum optics and solid state quantum computing. Her laboratory at RRI, the Quantum Information and Computing lab (QuIC), is part of the Light and Matter Physics group.

Since graduating from IQC in 2013, **Nathan Wiebe** has been an associate researcher in the Quantum Architectures and Computation (QuArC) group at Microsoft Research. In this role, his research is focused on developing practical algorithms for quantum computation. In particular, he works on quantum simulation, Hamiltonian inference and quantum algorithms for linear algebra.

On October 14, Wiebe returned to IQC to share his experience of pursuing a career in industry with current IQC graduate students and postdoctoral fellows as part of the IQC Graduate Student Association Quantum Industry lecture series.

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

Through conferences, workshops, seminars and courses, IQC members have been collaborating and sharing new ideas with colleagues from around the world.

Major Conferences - Highlights

6th International Summer School and Conference on Post-Quantum Cryptography
Summer School: September 29-30, 2014 | Conference: October 1-3, 2014 | Participants: 85

The Post-Quantum Cryptography Summer School aims to provide an overview and introduction to the main approaches to providing cryptographic tools that may be safe against quantum algorithmic attacks. Students studying across all areas of quantum information science and technology came together to discuss the convergence of their fields and to learn about the major areas of cryptographic research for quantum-resistant cryptography.
The PQCrypto conference on post-quantum cryptography created discussion about the need for standardizing quantum-resistant cryptography with researchers spanning all areas of quantum information science from different institutions.

Quantum Innovators
October 6-8, 2014 | Participants: 15

Promising young researchers from quantum physics and engineering gathered for a three-day conference to learn about the most recent advances in quantum information research.

Workshops and Seminars - Highlights

IQC Weekly Seminars and Colloquia

To maintain a rich and vibrant research culture internally, IQC hosts weekly seminars and colloquia for all members and students. Almost 80 separate events took place in the 2014-2015 year – the full list of seminars and colloquia is in Appendix H.

ETSI 2nd Quantum-Safe Crypto Workshop
October 6-7, 2014 | Partner: European Telecommunications Standards Institute (ETSI)
Participants: 92

IQC partnered with ETSI to present the 2nd annual ETSI Quantum-Safe Crypto workshop in Ottawa from October 6-7. The diverse communities of industry, government and academia met to discuss the standardization and deployment of the next-generation cryptographic infrastructure – specifically, one that will be secure against emerging quantum computing technologies. This IQC-led effort involving over 20 researchers and industry and government leaders worldwide describes the impact that quantum computation will have socially, technically and economically on information security. Corinne Charette, Chief Information Officer of the Government of Canada, was among the invited speakers. IQC board member and CEO of Approach Infinity Inc., Mark Pecen, presented the ETSI Quantum-Safe whitepaper.

Dr. Carla Fehr - FemPhys Talk
November 26, 2014

FemPhys presented a talk by Carla Fehr: *Strategies for Improving the Representation of Women in STEM* at IQC in November. Fehr is the Wolfe Chair in Scientific and Technological Literacy in the Philosophy Department at the University of Waterloo. Her research focuses on ways that diversity promotes innovation and excellence in science and technology. The talk weighed the pros and cons of various strategies to make the academic culture more inclusive.

Sponsored Workshops and Conferences

IQC continues to promote and support collaboration and idea sharing by sponsoring workshops and conferences for quantum information researchers together with national and international partner organizations. Listed below are highlights of the sponsored conferences and workshops from the 2014-2015 year, followed by a complete list of 15 sponsorships.

Highlights

Algebraic Combinatorics: Spectral Graph Theory, Erdös-Ko-Rado Theorems and Quantum Information Theory | June 23-27, 2014 | Participants: 168

Partners: The Fields Institute, Waterloo Department of Combinatorics & Optimization, Perimeter Institute for Theoretical Physics, Worcester Polytechnic Institute, NSF
More than 120 mathematicians from around the world met at the University of Waterloo to present new results in a variety of areas with themes all relating to the work of Dr. Chris Godsil, whose work centered in algebraic combinatorics, ranging from group actions to spectral graph theory to quantum information theory, has been largely influential. Participants included current undergraduate students to recent PhDs to established, internationally acclaimed senior mathematicians, and researchers from industry.

Conference & Workshop Sponsorships 2014-2015

Conference title	Date	Location
Theory Canada 9	June 12-15, 2014	Wilfrid Laurier University, Waterloo ON
Canadian Association of Physicists (CAP) Congress	June 16-20, 2014	Laurentian University, Sudbury, ON
The Canadian Summer School on Quantum Information (CSSQI)	June 16-20, 2014	University of Guelph, Guelph ON
The Canadian Quantum Information Student's Conference (CQISC)	June 23-27, 2014	University of Guelph, Guelph ON
Algebraic Combinatorics: Spectral Graph Theory, Erdös-Ko-Rado Theorems and Quantum Information Theory (Godsil65)	June 23-27, 2014	IQC, University of Waterloo, Waterloo ON
Quantum LDPC Codes	July 14-16, 2014	Perimeter Institute for Theoretical Physics, Waterloo ON
5th IUPAP International Conference on Women in Physics (ICWIP)	Aug 5-8, 2014	Wilfrid Laurier University, Waterloo ON
QCrypt	Sept 1-5, 2014	Paris, France
ETSI 2nd Quantum-Safe Crypto Workshop	Oct 6-7, 2014	Ottawa, ON
Quantum Optimization Workshop	Oct 27-29, 2014	Fields Institute, Toronto ON
Canadian Undergraduate Physics Conference	Oct 23-26, 2014	Queen's University, Kingston ON

Canadian Conference for Undergraduate Women in Physics (CCUWiP)	Jan 9-11, 2015	Laval University, Quebec, QC
Conference on Quantum Information Processing (QIP)	Jan 12-16, 2015	Sydney, Australia
Science Expo	Feb 20, 2015	Ontario Science Centre, Toronto ON
Quantum Simulation	Feb 22-27, 2015	Benasque, Spain

Objective C

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

Expected Outcomes for 2014/2015

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

Highlighted Results for 2014/2015

- Successfully continued collaborations through scientific networks including CIFAR and NSERC
- IQC researchers collectively participated in or attended 87 conferences
- Welcomed 154 scientific visitors from 111 institutions across the globe

Progress Achieved for 2014/2015

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

IQC is dedicated to providing an atmosphere that encourages and celebrates collaborations at every level. Below are descriptions of two major collaborative projects made possible this year: CIFAR and NSERC. Appendix I provides a full list of all collaborative efforts this year (NB: this list does not include co-authored publications. A list of collaborative published papers can be found in Appendix L.)

Quantum Information Science Program Meeting November 23-26, 2014

IQC partnered with CIFAR to promote scientific exchange with international delegates from the National Laboratory of Beijing Computational Science Research Centre (CSRC), the Interdisciplinary Information Sciences (IIIS) at Tsinghua University (also based in Beijing) and the University of Science and Technology of China (USTC) located in Hefei, Anhui. The four-day Quantum Information Science Program Meeting, hosted at IQC, showcased Canada as a destination for quantum information science research. The meeting brought together IQC, CIFAR and six Chinese researchers to discuss the fundamental aspects of quantum information, applications and devices, and cryptography.

NSERC - CREATE Grants

Two years ago, two IQC faculty members, David Cory and Michele Mosca, were awarded CREATE Grants through NSERC. CREATE Grants are enhanced training grants that, in both cases, are to provide and allow for unique learning opportunities for students to gain skills not normally developed in the course of regular study. In each case, faculty are continuing to work with their respective established program. David Cory is working to connect the quantum information community at IQC with the neutron science community at McMaster University. Michele Mosca is continuing to develop a similar strong network through his work in establishing CryptoWorks21, which is a supplementary program for graduate students and postdoctoral fellows who would like to develop next-generation cryptographic tools.

Promote collaborations through participation in national and international conferences

IQC is dedicated to finding opportunities to participate in national and international conferences. Below are some highlights of conferences attended this year. A complete list of invited talks and conference participation of IQC faculty is listed in Appendix J.

- Ontario Centres of Excellence (OCE) Discovery Conference, Toronto, Ontario May 12-13, 2014
- International Space University (ISU) – Space Study Program, Montreal, Quebec July 17-18, 2014
- QCrypt 2014, Paris, France September 1-4, 2014
- Canadian Network for Advancement of Research, Industry and Education (CANARIE) National Summit, Toronto, Ontario September 18, 2014
- Bringing the Nanoworld Together Workshop, Beijing, China September 24-25, 2014
- 50th Annual Canadian Undergraduates in Physics Conference, Kingston, Ontario October 23-26, 2014

- Quantum Optimization Workshop, Toronto, Ontario October 27-29, 2014
- National Research Council (NRC) uOttawa Schawlow-Townes Symposium – Ottawa, Ontario October 30, 2014
- International Conferences of Asian Union of Magnetics (IcAUMS) 2014, Haikou, China October 28-November 2, 2014
- Quantum Communication, Measurement and Computing (QCMC) Conference, Anhui, China November 2-6, 2014
- American Association for the Advancement of Science (AAAS), San Jose, US February 11-16, 2015

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

Researchers at IQC regularly collaborate with other researchers and scientists around the world in an effort to create scientific networks that produce the highest standard of research. A full list of papers published in collaboration with researchers from other universities and institutions is in Appendix K.

Organize at least four conferences that involve multidisciplinary participants

Bringing together researchers from various backgrounds, IQC hosted several conferences to encourage young researchers, emphasize collaboration, promote idea exchange and demonstrate IQC and Canada as a leader in quantum information science research.

Undergraduate School on Quantum Information Processing (USEQIP) | May 26-June 2, 2014 | Participants: 21

Undergraduate students from nine countries came to IQC to explore both the theoretical and experimental aspects of quantum information.

Quantum Cryptography School for Young Students (QCSYS) | August 11-15, 2014 | Participants: 42

Senior high school students investigated topics such as quantum mechanics, advanced mathematics, information security and quantum cryptography, experiencing both lectures and in-lab demonstrations.

Algebraic Combinatorics: Spectral Graph Theory, Erdös-Ko-Rado Theorems and Quantum Information Theory | June 23-27, 2014 |Participants: 127

Mathematicians from around the world met at the University of Waterloo to present new results in a variety of areas with themes all relating to the work of Dr. Chris Godsil.

PQCrypto Conference | October 1-3, 2014 | Participants: 85

PQCrypto created discussion about the need for standardizing quantum-resistant cryptography with researchers spanning all areas of quantum information science from different institutions.

Quantum Innovators | October 6-8, 2014 | Participants: 15

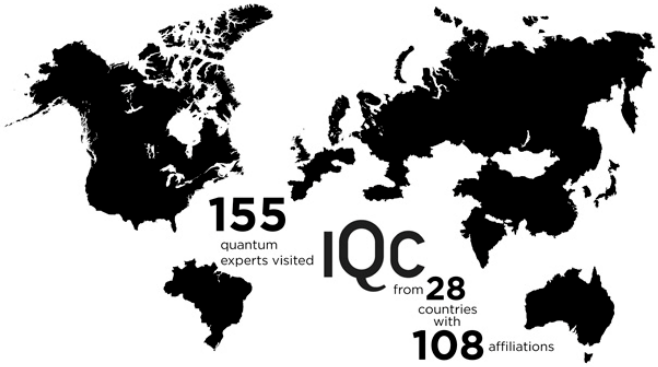
Promising young researchers from quantum physics and engineering gathered for a three-day conference to learn about the most recent advances in quantum information research.

Quantum Information Science Program Meeting | November 23-26, 2014 | Participants: 52

IQC partnered with CIFAR to host international delegates from the National Laboratory of Beijing Computational Science Research Centre (CSRC), the Interdisciplinary Information Sciences (IIIS) at Tsinghua University (also based in Beijing), and the University of Science and Technology of China (USTC) located in Hefei, Anhui.

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

IQC welcomes visitors from around the world every year to further collaborative relationships and strive for global excellence in quantum information processing. IQC has hosted the world's top scientists to conduct research, give talks and meet with IQC researchers and students. From April 1, 2014 to March 31, 2015, IQC hosted 155 visitors from 108 different institutions. A full list of scientific visitors is available in Appendix L.



Visitor Profiles

Paola Cappellaro is an Assistant Professor in the Nuclear Science & Engineering Department at the Massachusetts Institute of Technology (MIT). Cappellaro worked with Professor David Cory during her PhD at MIT, focusing on Quantum Information Processing (QIP). Her current research topics include methods of physical systems that can deliver QIP devices (including quantum computers, simulators, measuring and communication devices) which exceed the capacities of the corresponding classical devices.

Following a postdoctoral fellowship at IQC from 2003-2004, **Martin Roetteler** began a career in industry with NEC Laboratories America. Currently, Roetteler is a Senior Researcher at Microsoft Research Redmond and member of the Quantum Architectures and Computation (QuArC) group. His research has focused on quantum algorithms, quantum error-correction, quantum circuits, and digital signal processing. More recently he has begun exploring quantum programming languages, quantum circuit synthesis and a compiler system that can break down higher-level algorithms into elementary gate sequences that can also perform resource estimation for a variety of physical machine descriptions.

Peter Zoller is currently a professor of physics at the Institute for Theoretical Physics, University of Innsbruck in Austria. Zoller, a pioneer in quantum computing and communication research, is known for bridging quantum optics and solid state physics. While visiting IQC in December 2014, Zoller delivered a talk on *New frontiers of quantum simulation with atoms and ions* for students and faculty, discussing quantum simulation of lattice gauge theories both from a condensed matter and a high-energy physics point of view. He also addressed system quantum simulation, quantum dynamics and realization with quantum optical systems.

Objective D

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

Expected Outcomes for 2014/2015

- Host two major undergraduate and high school summer schools
- Host three Quantum Frontiers Distinguished Lectures
- Establish and plan for a major open house event in 2015
- Establish relationships with key strategic partners to further share IQC's research discoveries
- Establish a new teacher/student outreach program
- Continue to share IQC's research through publications, web and social media outlets

Highlighted Results for 2014/2015

- Hosted two major summer schools for undergraduate and high school students
- Hosted two Quantum Frontier Distinguished Lectures
- Established a new teacher/student outreach program
- Participated in 46 outreach activities, reaching a minimum of 2600 participants
- Grew online social media activity

Progress Achieved in 2014/2015

Host two major undergraduate and high school summer schools

In order to continue IQC's efforts of public education and outreach activities to effectively promote quantum information science and to continue to attract world-class talent, IQC hosted two summer schools to engage high school and undergraduate students.

Undergraduate School on Quantum Information Processing (USEQIP) May 26-June 6, 2014

IQC hosted 21 undergraduate students from institutions from nine countries for two weeks. USEQIP gives undergraduate students the chance to learn and discuss the theoretical and experimental study of quantum information. Not only did students get to spend over 25 hours of time working with IQC members on experiments in various state-of-the-art labs, they also had the opportunity to attend lectures by IQC faculty Raymond Laflamme, David Cory, Michele Mosca, Michal Bajcsy, Jonathan Baugh, Andre Childs, Thomas Jennewein, Kevin Resch and Christopher Wilson. 12 of the participants spent the remainder of the summer performing research at IQC.

Quantum Cryptography School for Young Students (QCSYS) August 11-15, 2014

QCSYS welcomed 42 students from grades 11 and 12, along with a few exceptional students from grade 10 for a week long enrichment program focused on quantum mechanics, advanced mathematics, information security and quantum cryptography. Students had the opportunity to learn about the cutting-edge field of quantum cryptography through lectures and demonstrations. Internationally renowned faculty and students get involved in the program each year to make it one of the most prestigious programs in the field. The 17 young women and 25 young men represented the global reach of IQC with participants from six Canadian provinces and five different countries, including Canada, Latvia, Romania, the United States, and South Africa.

Host three Quantum Frontiers Distinguished Lectures

In 2014, IQC is proud to have hosted two globally acknowledged researchers for the Quantum Frontiers Distinguished Lecture series. This series was established to bring world-leading researchers to share research knowledge with students and faculty at IQC and the University of Waterloo.

K. Birgitta Whaley (University of California, Berkeley and Lawrence Berkeley National Laboratory) delivered her lecture *What role does Quantum Mechanics play in Biology?* on September 15, 2014. She described how the development of quantum mechanics in the early years of the twentieth century transformed both physics and chemistry, providing a new understanding of the microscopic behaviour of atoms and molecules. The development of novel probes of living cells and the possible role of quantum mechanics in biological phenomena, such as photosynthesis, are being driven by advances in both quantum sciences and nanotechnology.

Alain Aspect (Augustin Fresnel Professor at Institut d'Optique, Professor at École Polytechnique, and a CNRS Distinguished Scientist (Director of Research)) is known for performing a series of experiments decisively demonstrating that one of the most remarkable predictions of quantum mechanics – quantum entanglement – was true, in 1982. This forced a complete change in our understanding of the universe. In his Quantum Frontiers Distinguished Lecture titled *From Einstein to Wheeler: wave particle duality for a photon* on October 23, Aspect presented experiments he and his team realized with a true single photon source demonstrating that photons behave both like a wave and a particle. Such single photon sources are now an important resource in the domain of quantum information.

Sajeev John (University of Toronto) delivered the next Quantum Frontier Distinguished Lecture on April 30, 2015 on *Photonic band gap materials: semiconductors of light*. Dr. John is a pioneering theoretician in photonic band gap (PBG) materials and the Canada Research Chair in Optical Sciences.

Establish and plan for a major open house event in 2015

Plans are currently underway to host an open house event on October 3, 2015 for the community as part of the University of Waterloo's Reunion celebration. Raymond Laflamme will give a public lecture and a kids-zone will feature interactive, educational outreach activities for youth.

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

IQC continues to encourage scientific study and discovery, inspire curiosity, share the science and raise awareness of quantum information research among youth, the community and the general public. Almost 2,000 youth participated in a hands-on workshop or were engaged through a lecture in the past year with an IQC member. Below are some highlights of outreach activities conducted between April 1, 2014 and March 31, 2015. See the table below for a complete list of outreach activities.

SHAD Uncommon Purpose – July 2014

PhD students Sarah Kaiser and John Donohue led 15 high school students through a six-hour workshop on "Peering into the fantastic world of quantum mechanics". The workshop, part of the SHAD enrichment program for exceptional students and leaders of tomorrow, focused on the fundamentals of quantum mechanics and its applications. The workshop included a Bell test experiment for the students to perform, a famous experiment that measures the strangeness and surprising consequences of quantum entanglement.

The Centre for Education in Mathematics and Computing (CEMC) – May 29, 2014

The University of Waterloo's Centre for Education in Mathematics and Computing invited Senior Manager, Scientific Outreach, Martin Laforest to speak at two workshops about quantum mechanics and the impact of quantum information in computer science and society.

Peel District Science and Tech Inquiry Symposium – October 18, 2014

Martin Laforest gave the keynote lecture on quantum technology to 120 K-12 science educators at the Peel District Science and Tech Inquiry symposium. He demonstrated simple experiments that teachers can perform in the classroom to show the principles of superposition and uncertainty and how they can lead to powerful technology.

Community public lectures – Fall 2014

Martin Laforest, Senior Manager, Scientific Outreach, gave two public lectures:

- *Quantum Information: The Future of Technology* October 29 for 150 members of Third Age Learning in Guelph
- *The Quantum Revolution* November 26 at the Kitchener Public Library as part of the IDEAS & ISSUES lecture series.

School visits – December 2014

IQC hosted a workshop for 94 high school students from the Ontario Science Centre Science School, The Study Academy as well as Uxbridge and Woodlands secondary schools in December. Laforest delivered an engaging lecture on quantum information, science and technology (QIST) and exposed the students to hands-on exploration of quantum key distribution, superconductivity and a lab tour at IQC.

Cybersecurity in a quantum world: will we be ready? – March 10, 2015

IQC hosted 150 members of the community on March 10 for a public lecture by co-founder and faculty member, Michele Mosca about cybersecurity in a quantum world. As quantum technologies emerge and change the way online information is stored and secured, new security challenges arise leaving us vulnerable to viruses, fraud and identity theft. Mosca cautioned that the time to plan is now to become quantum-safe and cyber-safe.

All Public Outreach (including undergraduate students)

Senior Manager, Scientific Outreach Martin Laforest and IQC students excited more than 2,500 students and community members about quantum information science through interactive, hands-on activities, lectures, building and lab tours.

Group	Date	# of participants
OCE Discovery	13-May-14	60
OCE Discovery	13-May-14	60
Undergraduate School on Experimental Quantum Information Processing (USEQIP)	26-May-14 to 06-June-14	21

Group	Date	# of participants
Canadian Association of Physicist Teachers Day	17-Jun-14	20
EinsteinPlus	08-Jul-14	45
Peel District School Board Science and Technology Inquiry Symposium	18-Oct-14	100
Canadian Undergraduate Physics Conference at Queen's University	25-Oct-14	200
Third-Age Learning (Guelph)	24-Oct-14	70
IDEAS & ISSUES Public lecture	29-Nov-14	30
Canadian Conference for Undergraduate Women in Physics	10-Jan-15	70
Laurentian University Science communication students	05-Feb-15	12
Atlantic Universities Physics and Astronomy Conference	07-Feb-15	100
QIC 750: Implementation of QIP	26-Feb-15	20
Lansdowne Lecture - Quantum Information Science: Why the quantum age is closer than you think	02-Mar-15	200

Youth Outreach Group	Date	# of participants
QIP class	01-Apr-14	40
Woodland High School	01-Apr-14	40
Sir John A. MacDonald High School Science Club	02-May-14	26
Girls in Computer Science (CEMC)	29-May-14	50
Engineering Science Quest	June to August 2014	200
Auckland Workshop (CEMC)	03-Jun-14	60
Catalyst	07-Jul-14	45
ISSYP	21-Jul-14	45
Quantum Cryptography School for Young Students	11-Aug to 15-Aug-14	42
Waterloo Ideas	17-Jul-14	8
Woodlands Secondary School	24-Oct-14	40
Waterloo Unlimited	13-Nov-14	15
Study Academy	20-Nov-14	20
Louise Arbour High School	04-Dec-14	84
Uxbridge High School	10-Dec-14	45
Girls in Computer Science (CEMC)	12-Dec-14	60
Ontario Science Centre Science School	17-Dec-14	30
Assumption College School	04-Feb-15	150
Science Expo	20-Feb-15	160
Cegep de Levis-Lauzon	02-Mar-15	50
Turner Fenton Secondary School	05-Mar-15	35
Waterloo Unlimited	19-Mar-15	27
Cegep de Riviere-du-Loup	31-Mar-15	70

Government and industry tours

Providing tours of IQC facilities is an important aspect of IQC's outreach program. Tours are offered at the new Lazaridis Quantum-Nano Centre, RAC I and RAC II. Approximately 2,500 visitors toured IQC in the past year – almost 500 of those were government or business partners. For a full list of tours, see Appendix M. Below are select highlights of Group and Industry Tours.

Government Tours

Group	Date	# of Visitors
Israeli Ambassador to CanadaRafaêl Barak, D. J. Schneeweiss, Consul General of Israel to Toronto	May 20, 2014	5
South Korean Delegation	May 22, 2014	4
Nova Scotian Premier	May 30, 2014	24
National Research Council: Duncan Stewart (General Manager, Security and disruptive Technologies) Ben Sussman (Principal Investigator, Quantum Technologies)	September 4, 2014	2
Treasury Board /CIO visit: Corinne Charette (Chief Information Officer) Benoit Long, (Senior Assistant Deputy Minister) Toni Moffa (Deputy Chief IT Security) Dave Adamson (Deputy Chief Information Officer) Dan Couillard (Senior Director, Cyber Security) Serge Caron (Senior Director IT Architecture)	September 4 & 5, 2014	12
Konstantinos Georgaras, Industry Canada Intellectual Property Office	October 10, 2014	1
India ICT visit	November 13, 2014	8
The Honourable Ed Holder, MP Peter Braid and MP Harold Albrecht	January 22, 2015	6

Business/Industry Tours

Group	Date	# of Visitors
TrustPoint	June 2, 2014	7
Ronald Rivest, RSA	June 13, 2014	2
Eugene Roman, CTO Canadian Tire	July 25, 2014	4
Lockheed Martin: Charles Bouchard (CEO) and Duncan Hills (Government Relations)	September 15, 2014	2
Ranovus	March 9, 2015	3

Establish a new teacher/student outreach program

The *Quantum Technology for Students and Educators (QTSE)* will support hands-on learning experiences for young students and their teachers. On March 18, Martin Laforest, Senior Manager, Outreach, received a $9,500 NSERC PromoScience grant for QTSE that will initiate its implementation at IQC to encourage and develop the future generation of scientists, mathematicians and engineers. QTSE includes three programs:

1. *Quantum Cryptography School for Young Students (QCSYS)* has been extended by two days to include more hands-on activities, enhancing the student experience and providing further exploration of quantum cryptography and quantum entanglement.
2. *Teaching Quantum Technology (TQT),* a new workshop for high school science and technology educators to enable educators to convey the power of quantum information technology to their own students as part of the grade 12 physics curriculum or as part of extra-curricular activities.
3. *Quantum Experience for Young Students,* a new program for groups of senior high school students and their teachers to design and build quantum experiments at IQC.

NSERC's PromoScience Program offers financial support for organizations working with young Canadians to promote an understanding of science and engineering (including mathematics and technology).

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

IQC regularly publishes communications materials to share research success and highlight IQC achievements with a worldwide audience. These publications are shared in print and available online.

Communications Materials

Publications share research success and highlight IQC achievements. They reach a varied audience and are accessible in both print and online.

Publication	Publication Cycle
Annual report	Yearly; 2011, 2012, 2013
"NewBit" newsletter	Semesterly; January, May, September
"One Pagers"	Yearly
Graduate brochure/poster	Yearly
USEQIP/QCSYS brochure/poster	Yearly
Industry Canada Annual Report	Yearly; 2010, 2011, 2012, 2013, 2014
Industry Canada Corporate Plan	Yearly; 2015
Quarterly Progress Reports – provincial government	Quarterly; April, July, October, January

Website

IQC's website is a key medium in sharing IQC's knowledge, research and success. Visit www.uwaterloo.ca/iqc. Over the last year, the website moved over to a new content management system – Web Content Management System (WCMS) – to improve web consistency across the university, ease of use and maintenance. The traffic to the IQC website has increased significantly – the IQC homepage (uwaterloo.ca/iqc) has an average of 353 visitors per day. Almost two-thirds (59%) of website traffic is from outside of Canada. *Data represented is from May 5, 2014 – March 31, 2015.*

Social Media

Social media tools are integral today in communicating with a wide global audience. IQC's social media include active Twitter and Facebook, along with various other tools.

Twitter

On Twitter, IQC's 4,300+ followers include students, other educational and quantum institutions and those with an interest in quantum. Generally, IQC tweets three times each day with links to articles, videos, news, scientific history and to promote talks at IQC.

Twitter – April 1, 2014 to March 31, 2015	
Total # of followers	4,345
# new followers since April 2014	953
Total # tweets	2,167
Total # retweets	917
Link clicks	3,325
# tweets favourited	929
# of impressions	1,066,800

Facebook

The majority of IQC's 3,000+ followers are 18-24 years old. News, events, reminders, videos and science facts is posted every 2-3 days.

Facebook – April 1, 2014 to March 31, 2015	
Total # of like	3,029
# new likes since April 2014	523
Engagements	8,263
# of impressions	74,966

YouTube

The number of YouTube postings has increased as additional lectures are filmed. Interviews and small educational pieces are also posted. New content is promoted through Twitter and Facebook.

YouTube – April 1, 2014 to March 31, 2015	
Total # of subscribers	4,962
# new subscribers since April 2014	1,798
# of views	173,707
# of minutes watched	1,373,652
# of likes	1,000

Earned Media

IQC news receiving regional, national and global media coverage last year included faculty awards, high-profile published papers, the government investment announcement and the growing interest in quantum cryptography. Media highlights are listed below. For a full list, see Appendix N.

Date	Media Outlet	Reference/Specific	Media Tier
April 4, 2014	The Waterloo Region Record	Specific – Quantum, Early Researcher Awards	Regional
April 22, 2014	Sing Tao newspaper	Specific – IQC, mission to China	National
May 22, 2014	CBC	Reference – IQC, Michele Mosca	National
June 11, 2014	Nature	Specific - Contextuality paper; Joseph Emerson; Mark Howard, Joel Wallman; IQC	International Science
June 13, 2014	Canada Journal	Specific - Contextuality paper; Joseph Emerson; Mark Howard, Joel Wallman; IQC	National
June 19, 2014	National Post	Reference – IQC, Raymond Laflamme	National
June 26, 2014	Globe & Mail ROB	Reference - Mike Lazaridis, IQC; quantum valley	National
Sept 11, 2014	New Scientist	Specific – Raymond Laflamme, IQC	International Science
Oct 2014 issue	Discover magazine	Reference – Michele Mosca, IQC	International Science
Sept 14, 2014	Science Daily	Specific – Three-photon entanglement paper, Hamel, Jennewein & Resch	International Science

Date	Media Outlet	Reference/Specific	Media Tier
Sept 26, 2014	MIT Technology Review	Reference – One of Raymond's experiments in 2001 ("an obscure group of theoretical physicists proved a remarkable result")	National Science
Oct 8, 2014	IT World Canada	Reference – IQC/ETSI event	National Science
Nov 3, 2014	The Waterloo Region Record	Specific – IQC, Raymond Laflamme, Rolf Horn	Regional
Nov 4, 2014	CBC	Reference – IQC, Mike Lazaridis	National
Nov 13, 2014	The Waterloo Region Record	Reference – IQC, Mike Lazaridis	Regional
Nov 17, 2014	The Waterloo Region Record	Specific – Eduardo Martin-Martinez, Polanyi Prize	Regional
Nov 19, 2014	CBC Kitchener Radio	Specific – Eduardo Martin-Martinez, Polanyi Prize	Regional
Dec 19, 2014	International Business Times	Specific - Wave-particle duality/uncertainty paper, Patrick Coles	International
Dec 24, 2014	Huffington Post	Specific - Wave-particle duality/uncertainty paper, Patrick Coles	National
Jan 14, 2015	National Post	Reference – Waterloo region, IQC	National
Jan 21, 2015	Globe & Mail ROB	Reference - IQC, Raymond Laflamme, Quantum Valley	National
Jan 22, 2015	New Scientist	Specific - Eduardo Martin-Martinez, early universe	International Science
Jan 22, 2015	CTV	Specific – IQC, budget	Regional
Feb 16, 2015	CBC	Reference – Ben Criger, IQC, Mars One	National

Objective E

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

Expected Outcomes for 2014-2015

- Host commercialization workshops for IQC researchers
- Host industry workshop for industry partners to showcase opportunities in quantum technologies

Highlighted Results for 2014-2015

- Postdoctoral fellow Rolf Horn developed a quantum light source device
- Hosted a commercialization and entrepreneurship workshop in partnership with CryptoWorks21

Progress Achieved in 2014-2015

In November, IQC was highlighted in Waterloo Region Record's 2014 *Technology Spotlight*. Executive Director Raymond Laflamme shared IQC's world-class research in quantum information science and its future impact: "Behind IQC there is this vision that the work we do on quantum will have a fundamental impact. There are incredible opportunities for commercialization."

Spinoff technologies are already being realized, such as Universal Quantum Devices (UQD), a company founded by faculty member Thomas Jennewein, Laflamme, and former IQC Chief Operating Officer Steve MacDonald, that manufactures specialized quantum measurement devices for use in sophisticated optics labs. Postdoctoral fellow Rolf Horn developed a quantum light source device with the potential to spin off into another company. Looking ahead to a quantum future, the challenge becomes understanding the application of quantum technology and moving through the process of commercialization.

IQC continues to pursue opportunities to educate and assist researchers through the commercialization process.

Host commercialization workshops for IQC researchers

IQC hosted a commercialization and entrepreneurship workshop in partnership with CryptoWorks21 July 24-25, 2014. CryptoWorks21 offered a series of workshops throughout July. To build students' professional skills, one of the workshops focused on intellectual property and management, as well as commercialization and entrepreneurship.

In addition, the IQC GSA/CryptoWorks21 hosted a talk by Dr. Jonathan Hodges (as part of the Quantum Industry Lecture Series) on May 6, 2014. Hodges walked the students through six steps of commercialization for the audience.

Host industry workshop for industry partners to showcase opportunities in quantum technologies

Planning is currently underway to host the first quantum industry workshop in the fall of 2015. The workshop will run over several days and will be offered to and customized for managers of research and development areas of hardware companies. The goal will be to introduce them to the underlying science of quantum information technology and the potential applications for commercialization. IQC's Deputy Director, Research and Canada Excellence Research Chair, David Cory and Senior Manager, Scientific Outreach, Martin Laforest are planning the workshop. It will consist of a mix of lectures, hands-on experiments and group discussion.

Patents, Licences and Spinoffs

In addition to active research agendas, IQC researchers have a strong track record of entrepreneurship and commercialization success. Five IQC faculty hold 37 patents and have worked with industry to commercialize or license technologies. IQC researchers have partnered with companies such as Quantum Valley Investments, COM DEV, Lockheed-Martin, BBN, Schlumberger, Teledyne-Dalsa, Single Quantum, Google, IDQuantique and others. Additionally, IQC is now home to three startup companies: Universal Quantum Devices (UQD), HQT and evolutionQ. This activity – along with the entrepreneurial and commercialization activities of the broader Waterloo innovation ecosystem – supports Waterloo Region's reputation as the Quantum Valley, where the next generation of technologies based on quantum information science will drive economic growth for Ontario.

Note: The University of Waterloo's Intellectual Property policy (Policy #73) states that intellectual property is owned by the discoverer. Researchers are not required to report on patents or commercialization activities. With this in mind, the number of patents and or licences may actually be higher.

APPENDICES

A. Risk Assessment & Mitigation Strategies

B.

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

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

C. Financial statements

See attached audited statement

D. IQC Faculty Members and IQC Research Assistant Professors

IQC Faculty Members as of March 31, 2015

1. Michal Bajcsy
2. Jonathan Baugh
3. Raffi Budakian
4. Andrew Childs (on leave)
5. Richard Cleve
6. Kyung Choi
7. David Cory
8. Joseph Emerson
9. Thomas Jennewein
10. Robert Koenig (partial year)
11. Raymond Laflamme
12. Debbie Leung
13. Adrian Lupascu
14. Norbert Lutkenhaus
15. Hamid Majedi (partial year)
16. Matteo Mariantoni
17. Guoxing Miao
18. Michele Mosca
19. Ashwin Nayak
20. Michael Reimer
21. Kevin Resch
22. John Watrous
23. Christopher Wilson

IQC Research Assistant Professors as of March 31, 2015

1. Vadim Makarov
2. Eduardo Martin- Martinez
3. Marco Piani (currently on leave)
4. Dmitry Pushin

E. Supervisory Privileges

Supervisor (IQC Faculty member)	Supervisory privileges	Quantum information research interests
Michal Bajcsy	Electrical and Computer Engineering	Nanophotonics and quantum optics Atom cooling and trapping on chips Cavity quantum electrodynamics Quantum memory and dark-state polaritons
Jonathan Baugh	Chemistry Physics and Astronomy	Experimental investigation of spin qubits in quantum dots Electron spin resonance Nuclear magnetic resonance (NMR)
Raffi Budakian	Physics and Astronomy	Coupling spins and nanomechanical oscillators Nanometer scale magnetic resonance imaging Exploring nanometer scale quantum phenomena in condensed matter systems
Andrew Childs	Combinatorics and Optimization Computer Science Physics and Astronomy	Theory of quantum information Quantum algorithms Quantum complexity theory
Kyung Soo Choi	Physics and Astronomy	Experimental & theoretical quantum optics Atomic, molecular, optical physics Cold atom physics Cavity quantum electrodynamics
Richard Cleve	Combinatorics and Optimization Computer Science	Quantum algorithms Quantum complexity theory Quantum cryptography
David Cory	 Applied Mathematics Chemistry Electrical and Computer Engineering	Experimental application quantum information processing (QIP) Magnetic resonance and its applications Quantum sensors and actuators

Supervisor (IQC Faculty member)	Supervisory privileges	Quantum information research interests
	Physics and Astronomy	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
Thomas Jennewein	Physics and Astronomy	Experimental quantum communication and cryptography Global satellite-based quantum communication Entangled photon sources
Robert Koenig	Applied Mathematics	Quantum information theory Quantum cryptography Quantum many-body physics Mathematical physics
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
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

Supervisor (IQC Faculty member)	Supervisory privileges	Quantum information research interests
		Theory of linear optics implementations of QIP
Vadim Makarov	Physics and Astronomy	Quantum hacking (practical security of quantum cryptography) Experimental quantum communication and cryptography Single photon detectors
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
Eduardo Martin-Martinez	Applied Mathematics	General relativistic quantum physics Relativistic quantum information Quantum discord Cosmology and the early universe
Guo-Xing 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

Supervisor (IQC Faculty member)	Supervisory privileges	Quantum information research interests
		Quantum algorithms Theory of quantum information Quantum communication
Kevin Resch	Physics and Astronomy	Experimental optical implementation of QIP Photon entanglement Nonlinear optics Interferometry
Michael Reimer	Electrical and Computer Engineering	
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
Chris Wilson	Electrical and Computer Engineering	Microwave quantum optics Superconducting qubits Nonlinear dynamics

Supervisor (IQC Associate member)	Supervisory privileges	Quantum information research interests
Bei Zeng (University of Guelph)	Physics and Astronomy	Quantum information theory Coding theory Quantum computation Theory of quantum entanglement Mathematical physics
David Jao	Combinatorics and Optimization	
Achim Kempf	Applied Mathematics Physics and Astronomy	Quantum information applied to quantum gravity/cosmology/computing Data compression
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
Anthony Leggett (Illinois)	Physics and Astronomy	Theory of quantum measurement Condensed matter theory
Robert Mann	Physics and Astronomy	Quantum information applied to gravity
James Martin	Physics and Astronomy	Experimental atomic implementations of QIP
Bill Power	Chemistry	Experimental NMR implementations of QIP

Supervisor (IQC Affiliate member)	Supervisory privileges	Quantum information research interests
Christopher Fuchs (PI)	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 (WLU)	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 (PI)	Combinatorics and Optimization Physics and Astronomy	Quantum cryptography Quantum complexity theory Fault-tolerant quantum error-correction
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
Roger Melko	Physics and Astronomy	Theory of strongly-correlated many-body systems
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	Physics and Astronomy	Quantum information pertaining to the foundations of quantum theory

F. Publications

The following list of citations represents papers published in 2014 and from January 1 through March 31, 2015.

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Vermeyden, L., Ma, X., Lavoie, J., Bonsma, M., Sinha, U., Laflamme, R., et al. (2015). Experimental test of environment-assisted invariance. PHYSICAL REVIEW A, 91(1).
Zhang, J., Burgarth, D., Laflamme, R., & Suter, D. (2015). Experimental implementation of quantum gates through actuator qubits. PHYSICAL REVIEW A, 91(1).

G. IQC Postdoctoral Fellows

IQC Postdoctoral Fellows at March 31, 2015

1. Jean-Francois Biasse
2. Troy Borneman
3. Jean-Philippe Bourgoin
4. Aharon Brodutch
5. Patrick Coles
6. Joshua Combes
7. Electra Eleftheiradou
8. Guanru Feng
9. Francois Fillion-Gourdeau
10. Pol Forn-Diaz
11. Denis Gagnon
12. Vlad Gheorghiu
13. Patryk Gumann
14. Gus Gutoski
15. Christopher Haapamaki
16. Chris Herdman
17. Brendon Higgins
18. Rolf Horn
19. Mark Howard
20. Zhengfeng Ji
21. Jeongwan Jin
22. Nathaniel Johnston
23. Kassem Kalach
24. Milad Khoshnegar
25. Sangil Kwon
26. Catherine Lefevre
27. Ying Liu
28. Chang Liu
29. Dawei Lu
30. Filippo Miatto
31. Taisiya Mineeva
32. Osama Moussa
33. Ryo Namiki
34. George Nichols
35. Robabeh Rahimi Darabad
36. Daryoush Shiri
37. Fang Song
38. Rainer Stohr
39. Toeno van der Sar
40. Joel Wallman
41. Guoming Wang
42. Huan Yang
43. Taehyun Yoon
44. Nengkun Yu
45. Yanbao Zhang
46. Hui Zhang

H. IQC Graduate Students

IQC Graduate Students 2014-2015

Sascha Agne
Thomas Alexander

Elena Anisimova
Srinivasan Arunachalam
Marie Barnhill
Marian Berek
Steven Casagrande
Paulina Corona Ugalde
Chunqing Deng
John Donohue
Jeremy Flannery
Naimeh Ghafarian
Nicolas Gonzalez
Peter Groszkowski
Holger Haas
Ian Hincks
Darryl Hoving
Amir Jafari Salim
Tomas Jochym-O'Connor
Shitikanth Kashyap
Maria Kieferova
Robin Kothari
Stephane Labruyere
Lin Li
Kevin Liu
David Luong
Michael Mazurek
Evan Meyer-Scott
Takafumi Nakano
Matthew Novenstern
Martin Otto
Jihyun Park
Hammam Qassim
Nayeli Azucena Rodriguez Briones
Shihan Sajeed
Dusan Sarenac
Ala Shayeghi
William Stacey
Alexander Valtchev
Sean Walker
Zak Webb
Yihang Yang

Megan Agnew
Omar Alshehri

Razieh Annabestani
Shima Bab Hadiashar
Ryan Barrage
Jason Boisselle
Poompong Chaiwongkhot
Alessandro Cosentino
Rahul Deshpande
Carolyn Earnest
Honghao Fu
Kaveh Gharavi
Christopher Granade
Aimee Gunther
Minyang Han
Catherine Holloway
Anqi Huang
Stacey Jeffery
Oleg Kabernik
Hemant Katiyar
Feyruz Kitapli
Anirudh Krishna
David Layden
Madelaine Liddy
Li Liu
Xian Ma
Thomas McConkey
Maryam Mirkamali
Tyler Nighswander
Joachim Nsofini
Alex Parent
Chris Pugh
Sadegh Raeisi
Ansis Rosmanis

Jeff Salvail
John Schanck
Feiruo Shen
Nigar Sultana
Guillaume Verdon-Akzam
Zimeng Wang
Kyle Willick
Joshua Young

Rubayet Al Maruf
Vadiraj Ananthapadmanabha Rao
Juan Miguel Arrazola
Golam Bappi
Jeremy Bejanin
Arnaud Carignan-Dugas
Chung Wai Sandbo Chang
Hillary Dawkins
Olivia Di Matteo
Kent Fisher
Zhiwei Gao
Mirmojtaba Gharibi
Matthew Graydon
Vibhu Gupta
Fatin Haque
Gregory Holloway
Vinay Iyer
Yuantao Ji
Sarah Kaiser
Sumeet Khatri
Vadym Kliuchnikov
Meenu Kumari
Han Le
Piers Lillystone
Xingliang (David) Lou
Jean-Philippe Maclean
Corey Rae McRae
Hamidreza Nafissi
Mohamad Niknam
Jean-Luc F.X Orgiazzi
Kyungdoeck Park
Daniel Puzzuoli
John Rinehart
Vincent Russo

Yuval Sanders
Behrooz Semnani
Sumit Sijher
Yongchao Tang
Lydia Vermeyden
Chunhao Wang
Christopher Wood
Muhammet Yurtalan

I. Seminars and Colloquia

Title of Seminar or Colloquium	Presented By	Date
Using dissipation for quantum information processing.	Fernando Pastawski	07-Apr-14
Topological Quantum Compiling with Fractional Quantum Hall States	Layla Hormozi	07-Apr-14
Quantum receivers beyond the stand quantum limit of coherent optical communications	Jingyun Fan	08-Apr-14
Algorithms and Complexity for Quantum Computing	Joseph F. Traub	09-Apr-14
Operationally-Motivated Uncertainty Relations for Joint Measurability and the Error-Disturbance Tradeoff	Volkher Scholz	09-Apr-14
Exponential improvement in precision for simulating sparse Hamiltonians	Robin Kothari	17-Apr-14
Superconducting Nanostructures for Quantum Detection of Electromagnetic Radiation	Amir Jafari-Salim	17-Apr-14
NMR as a low energy probe of condensed matter	Takashi Imai	21-Apr-14
Graphene growth and characterization for device applications	Michael Hilke	22-Apr-14
Ultimate communication capacity of quantum optical channels	Raul Garcia-Patron	28-Apr-14
Quantum state engineering of multiphoton quantum superpositions	Magdalena Stobinska	28-Apr-14
Quantum Information, Surfaces, and Interfaces	David P. Pappas	05-May-14
Achieving the limits of the bounded/noisy quantum-storage model	Omar Fawzi	12-May-14
Analysis of a rate-adaptive reconciliation protocol	David Elkouss	21-May-14
Spin and pseudospins in 2D semiconductors	Xiaodong Xu	26-May-14
Superconducting qubit circuits under extreme conditions:	Sahel Ashhab	27-May-14
Ground state connectivity of local Hamiltonians	Sevag Gharibian	02-Jun-14
Exploiting relativity in quantum technologies and how a macroscopic clock can make you younger	Ivette Fuentes	05-Jun-14
Unbounded entanglement can be needed to achieve the optimal success probability	Laura Mancinska	09-Jun-14
Quantum random number generation from untrusted devices	Carl A. Miller	16-Jun-14
Quantum non-Gaussian and Gaussian States at Multiple Side-band Frequencies	Katanya Kuntz	18-Jun-14
Physical Randomness Extractors	Yaoyun Shi	19-Jun-14
Repeat-Until-Success: a new tool for quantum circuit synthesis	Martin Roetteler	19-Jun-14
Quantum-inspired photonic structures	Ramy El Ganainy	26-Jun-14
Jordan's Lemma and quantum computing	Robin Kothari	03-Jul-14
Quantum position verification (Crypto 2014)	Dominique Unruh	07-Jul-14
Genuinely multipartite entangled states, orthogonal arrays and Hadamard matrices.	Karol Zyczkowski	15-Jul-14
Monte Carlo simulation of stoquastic Hamiltonians	Sergey Bravyi	17-Jul-14

Title of Seminar or Colloquium	Presented By	Date
Laser-written integrated photonic quantum circuits	Alexander Szameit	21-Jul-14
Single Crystal Growth and Physical Property of Various Superconductor Materials.	Genda Gu	24-Jul-14
Quantum algorithms based on quantum walks	Jérémie Roland	28-Jul-14
Nonclassical light from semiconductor quantum dots	Gregor Weihs	28-Jul-14
Practical side-channel-free quantum key distribution	Feihu Xu	07-Aug-14
Generation and application of narrow-band biphotons in cold atom ensembles	Chang Liu	04-Sep-14
Spin controlled electronic devices for the next generation electronics	Joonyeon Chang	08-Sep-14
Cold atoms coupled to photonic crystals: a platform for tunable long-range interactions	Darrick Chang	22-Sep-14
Overview of quantum optics experiments in ANU	Julien Bernu	23-Sep-14
Quantum chromatic numbers	Vern Paulsen	23-Sep-14
Quantum optics experiments in Russian Quantum Center	Yury Kurochkin	30-Sep-14
Towards reliable quantum computing: Protecting quantum information against environmental noise and experimental imperfections	Dieter Suter	01-Oct-14
Nanowire quantum dots for quantum optics	Val Zwiller	06-Oct-14
Quantum arithmetic and numerical analysis using Repeat-Until-Success circuits	Nathan Wiebe	14-Oct-14
Metrology for QKD systems	Christopher Chunnilall	16-Oct-14
Limitations on separable measurements by convex optimization	Alessandro Cosentino	16-Oct-14
A quantum algorithm for computing the unit group of an arbitrary degree number field	Sean Hallgren	20-Oct-14
Multi-Source and Network Extractors in the Presence of Quantum Side Information	Kai-Min Chung	23-Oct-14
Back-reaction Effects in Optomechanical Cavities	Eyal Buks	27-Oct-14
Probabilistic Quantum Circuit Decomposition	Krysta Svore	30-Oct-14
Improved Semidefinite Programming Hierarchy for Entanglement Testing, with tools from Algebraic Geometry.	Xiaodi Wu	17-Nov-14
Back-action driven transport of Bloch oscillating atoms in ring cavities and Transient Quantum Fluctuation Theorems	Prasanna Venkatesh	18-Nov-14
Engineering event evidencing for legal documents using cryptography Framework, algorithms and standards	Leon Pintsov	19-Nov-14
New Frontiers of Quantum Simulation with Atoms and Ions	Peter Zoller	01-Dec-14
One component quantum dynamics and control	Lianao Wu	03-Dec-14
Controlling spin qubits in silicon in silicon using electric fields and light	John Morton	08-Dec-14
Excitation Energy Transfer in Ultra-Cold Rydberg Gases	Torsten Scholak	09-Dec-14

Title of Seminar or Colloquium	Presented By	Date
Contextuality supplies the magic for Quantum Computation	Joel Wallman	15-Dec-14
Topological Quantum Phenomena of Superfluid 3He	Seamus Davis	12-Jan-15
High-frequency EPR and DEER spectroscopy to study impurities in nanodiamonds	Franklin Cho	12-Jan-15
Synchronous Games and Traces	Vern Paulsen	15-Jan-15
Quantum Experiments with Twisted Photons	Robert Fickler	16-Jan-15
Nanoscale quantum systems with single atoms and photons	Jeff Thompson	02-Feb-15
An ultrahigh-resolution quantum optical coherence tomography with dispersion-tolerance	Masayuki Okano	06-Feb-15
Open-system quantum simulation with photons	Jens Koch	09-Feb-15
Coupling single quantum systems to spin baths	Swati Singh	09-Feb-15
Diamond nanophotonics for solid state quantum optics	Nathalie de Leon	10-Feb-15
On computation with 'probabilities' modulo k	Niel de Beaudrap	12-Feb-15
High contrast interactions and photonic qubits using multimode cavity QED	David McKay	13-Feb-15
Ancilla mediated quantum gates	Viv Kendon	19-Feb-15
Quantum Energy Teleportation: Strong Local Passivity vs. LOCC	Masahiro Hotta	23-Feb-15
Weakly Bound and Strongly Interacting: 1T-TaS2 in the Two-Dimensional Limit	Adam Tsen	24-Feb-15
Testing gravity with photons and satellites.	Aharon Brodutch	02-Mar-15
Quantum Photonic Devices Based on Single Dopants in Solids	Thomas Babinec	02-Mar-15
Light-Matter Interactions in Semiconductors: An Endless Playground for Fundamental Physics and Applications	Konstantinos Lagoudakis	09-Mar-15
The Oxford Questions – and some answers	Andrew Briggs	09-Mar-15
Carbon Nanotube Transport and Exciton-Polariton Condensation	Na Young Kim	16-Mar-15
Schrodinger cat states in separable Hilbert space: optimal branch distinguishability and algebras for metrological usefulness	Ty Volkoff	18-Mar-15
Quantum control of single spins in diamond for quantum information and sensing applications	Viatcheslav Dobrovitski	30-Mar-15

J. Collaborations

The following chart identifies examples of current and ongoing collaborations that IQC faculty members have with other researchers or organizations.

Faculty Member	Additional Collaborations/ Research Networks	
Budakian, Raffi	Magnetic Force Microscopy	University of Illinois
Cory, David	Satellite QKD Project	Canadian Space Agency
		COM DEV
		RIM
	CIFAR	
	Associate	Perimeter Institute for Theoretical Physics
	Consultant	Goodyear
	Consultant	Schlumberger Doll Research Laboratory
	Consultant	Infinite Potential Group
	Member of Scientific Advisory Board	Brockhouse Institute, McMaster University
	Member of Scientific Advisory Board	Shanghai Center for Complex Physics
	Chair of Scientific Advisory Board	Quantum Valley Investments
	Founder	High Q
Emerson, Joseph	Researcher	CIFAR
	Affliiate	Perimeter Institute for Theoretical Physics
	Affliate	University of Guelph
	Sub-grant holder	University of Innsbruck
	Sub-grant holder	Complutense University of Madrid
	Sub-grant holder	University of Sydney
Laflamme, Raymond	Quantum Information Processing	CIFAR
		Department of Defence, Canada
		Communication Security Establishment, Canada
	CSO	Universal Quantum Devices
	Quantum Encryption and Science Satellite	Canadian Space Agency
	Associate Faculty	Perimeter Institute for Theoretical Physics
	Scientific Advsiory Committee	Quantum Investment Funds
	Consultant	Infinite Potential Inc
		Com Dev
		Technion University, Israel

Faculty Member	Additional Collaborations/ Research Networks	
	Participant in Quantum Symphony	Indianapolis Symphony
	Participant in Quantum Symphony	Ottawa Symphony
Lupascu, Adrian	Affiliate	Perimeter Institute for Theoretical Physics
	Member	Guelph-Waterloo Physics Institute
	Sahel Ashhab	RIKEN and University of Michigan
	Jay Gambetta	IBM Watson Research Centre, Yorktown Heights, NY, USA
	Jonathan Baugh	Institute for Quantum Computing - University of Waterloo, Waterloo, Ontario, Canada
	Hans Mooij	TU Delft (Delft University of Technology), Postbus 5 2600 AA Delft The Netherlands
	Gates for coupled superconducting quantum bits	collaboration with Delft University of Technology & RIKEN Japan
	Juan Jose Garcia Ripoll	Instituto de Física Fundamental Serrano, 113b Room 107 Madrid 28006 (Spain)
	Tony Leggett	IQC/ University of Illinois at Urbana-Champaign
	Debbie Leung	IQC
	Chris Wilson	IQC
	Matteo Mariantoni	IQC
	David Cooke	McGill
Leung, Debbie	Affiliate Member	Perimeter Institute, Waterloo
	Fellow, Quantum Information Science Program	Canadian Institute for Advanced Research
	Affliate member, Center for Quantum Information and Quantum Control	University of Toronto
	Quantum Communication Complexity in Zero-Error regime	Cambridge University - Will Matthews (Former IQC Member), Harry Burhmann (and his students)
Lutkenhaus, Norbert	Quantum Digital Signatures	Heriot-Wiatt University
	Collaboration with Mohsen Razavi	
Makarov, Vadim	Radiophysics laboratory at State Pedagogical University, Moscow, Russia	
	Center for quantum information and quantum control at University of Toronto, Canada	

Faculty Member	Additional Collaborations/ Research Networks	
	Department of engineering physics at École Polytechnique de Montréal, Canada	
	ID Quantique SA in Geneva, Switzerland	
	Max Planck institute for the science of light in Erlangen, Germany	
Mosca, Michele	CryptoWorks 21	NSERC CREATE
	Quantum Cryptography	European Telecommunications Standards Institute (ETSI)
	Quantum Cryptography	Institute for Quantum Science and Technology (IQST), University of Calgary
	Quantum Cryptography	Université de Montréal
	Quantum Cryptography	Tech Capital Partners
	Quantum Cryptography	Amazon
	Quantum Cryptography	McGill University
	Quantum Cryptography	ComDev
	Quantum Cryptography	Perimeter institute
	Quantum Cryptography	National Institute of Standards and Technology (NIST)
	Quantum Cryptography	Swiss Federal institute of Technology in Zurich (ETHZ)
	Quantum Cryptography	ID Quantique
	Quantum Cryptography	Institute for Security, Privacy and Information Assurance
	Quantum Cryptography	Centre for Quantum Technologies (CQT), NUS
	Quantum Cryptography	Security Innovations
	Quantum Cryptography	Tutte Institute for Mathematics and Computing
	Quantum Cryptography	Ontario Centres of Excellence
	Quantum Cryptography	MITACS
	Quantum Cryptography	CIBC
	Quantum Cryptography	Trustpoint
	Smart CybERsEcurity Network	SERENE
	Security, Cryptography, Privacy	Economical Insurance
	Security, Cryptography, Privacy	Blackberry
	Quantum Cryptography	Approach Infinity inc.
	Quantum Cryptography	University of Ottawa

Faculty Member	Additional Collaborations/ Research Networks	
	Pulbic Works Government Services Canada	Government of Canada
	Quantum Cryptography	BBN Technologies
	Quantum Cryptography	InfoSec Global
	Quantum Cryptography	SignitSure Inc
Miao, Guoxing		Prof. Changgan Zeng, Prof. Zhenyu Zhang, Hefei National Laboratory for Physical Sciences at the Microscale, University of Science and Technology of China
		Dr. Jagadeesh Moodera, Francis Bitter Magnet Laboratory, Massachusetts Institute of Technology
		Prof. John Wei, Department of Physics, University of Toronto
Pushin, Dmitry	Affliate	National Institute of Standards and Technology
	Affliate	University of Maryland, College Park
Resch, Kevin	Affiliate	Perimeter Institute for Theoretical Physics
	Adjunct	University of Guelph
	Member	Guelph-Waterloo Physics Institute
	Other: Collaborators listed on Website	
	Name:	Institution:
	Steven Bartlett	University of Sydney
	Dida Bizheva	University of Waterloo
	Sarah Croke	Perimeter Institute for Theoretical Physics
	Alessandro Fedrizzi	University of Queensland
	David Kribs	University of Guelph
	Terry Rudolph	Imperial College
	Gregor Weihs	University of Innsbruck
	Andrew White	University of Queensland
	Bei Zeng	IQC/University of Guelph
	Will Matthews	IQC (Has left now)
	Collaborative Quantum Optics	University of Toronto (Centre for Quantum Information and Quantum Control, Institue for Optical Sciences, Department of Physics): Aephraim Steinberg
	Thomas Jennewein	IQC
	Raymond Laflamme	IQC

Faculty Member	Additional Collaborations/ Research Networks	
	Norbert Lutkenhaus	IQC
	Marco Piani	IQC
	Matt Pusey	Perimeter Institute for Theoretical Physics
	Michael Reimer	IQC
	Rob Spekkens	Perimeter Institute for Theoretical Physics
	Aephraim Steinberg	University of Toronto
Wilson, Chris	Workpackage Leader – European Union FP7 integrated project SOLID, which supported research in solid-state quantum information at 12 universities in 8 countries.	
	Conference Organizer – 2015 Quantum Simulations Conference, Benasque, Spain.	

K. Invited Talks and Conference Attendance

Faculty	Date	Title/Subject	Institution	Location
Bajcsy, Michal	Oct 19-23/14	Towards few-photon optoelectronics with photonic crystal devices," Frontiers in Optics/Laser Science	Conference - gave talk	Tucson, AZ, USA
	March 26/15	"Nanophotonic platforms for implementing photon-photon interactions," Condensed Matter and Optics Seminar, Queen's University Physics Department	Queen's University, Physics Department	Kingston, ON
	Feb 24/15	"Making photons interact: Basic principles and assorted experimental platforms," Undergraduate Physics Seminar, University of Waterloo, February 24, 2015, Waterloo, ON	University of Waterloo, Undergrad Physics Seminar	Waterloo, ON
	May 29/14	"Quantum Nonlinear Optics: Controlling photon-photon interactions (preferably on a chip),	Undergraduate School on Experimental Quantum Information Processing	Waterloo, ON
Budakian, Raffi	30-Jun-14	Nanoscale Magnetic Resoance Imaging	European Magnetic Resonance Conference	Zürich, Switzerland
	15-Oct-14	Nanoscale Magnetic Resoance Imaging	Univeristy of Illinois at Urbana-Champaign	Urbana, Illinois, US
Baugh, Jonathan	January 2015	Quantum control in a hyperfine coupled electron-nuclear system: algorithmic cooling", Quantum Cybernetics and Control		Nottingham, UK
	October 2014	Novel Josephson interference due to orbital states in a nanowire SNS junction	University of Buffalo Quantum Computing Workshop	Buffalo, USA

Faculty	Date	Title/Subject	Institution	Location
	June 2014	Quantum transport in semiconductor nanowires: normal and superconducting regimes	RQMP seminar, Ecole Polytechnique de Montreal	Montreal, Canada
Childs, Andrew	24-Feb-2015	Quantum algorithms for simulating quantum mechanics	University of Maryland	College Park, Maryland, USA
	27-Feb-2015	Quantum algorithms for simulating quantum mechanics	Standford Institute for Theoretical Physics (SITP)	California, USA
	17-Feb-2015	From quantum simulation to quantum algorithms for linear algebra	ASCR Workshop on Quantum Computing for Science	Washington DC, USA
	12-Feb-2015	Hamiltonian simulation with nearly optimal dependence on all parameters	NSF Conference on Mathematical Sciences Challenges in Quantum Information	Arlington VA, USA
	30-May-2014	Exponential improvement in precision for simulating sparse Hamiltonians	Tutte Seminar, University of Waterloo	Waterloo, ON
	11-Apr-2014	The computational power of quantum walk	Perimeter Institute	Waterloo, ON
Choi, Kyung	June 2014	Building exotic quantum systems with atoms and photons." (Colloquium)	Department of Physics, POSTECH	Pohang, Korea
	June 2014	Building exotic quantum systems with atoms and photons." (Invited Speaker)	AMP Workshop, APCTP	Pohang, Korea
	November 2014	"Building exotic quantum systems with atoms and photons." (Seminar)	Quantum Information Division, Oak Ridge National Laboratory	P.O. Box 2008, Oak Ridge, TN 37831
Cleve, Richard	01-Mar-15	Near-linear construction of exact unitary 2-designs	Massachusetts Institute of Technology	Massachusetts, USA

Faculty	Date	Title/Subject	Institution	Location
	01-Oct-14	Two basic quantum paradigms: eigenvalue estimation and amplitude amplification	Fields Institute	Toronto, ON
	01-Nov-14	Near-linear construction of exact unitary 2-designs	Canadian Institute for Advanced Research	Waterloo, ON
	01-Aug-14	Efficiently simulating Hamiltonian evolution	University of Tokyo	Tokyo, Japan
Cory, David	15-Apr-14	Quantum Devices	CERC Conference, University of Laval	Quebec, Quebec, Canada
	23-Apr-14	Quantum Computers	Louisiana State University	Baton Rouge, Louisiana
	24-Sep-14	Quantum Materials and Devices	Bring the Nanoworld Together by Oxford Instruments	Beijing, China
	05-Mar-15	Cavity Cooling for Ensemble Spin Systems	American Physical Scoiety March Meeting	San Antonio, Texas, USA
Emerson, Joseph	01-Jul-14	Contextuality supplies the magic for quantum computing	Institute for Theoretical Physics, ETH-Zurich	Zurich, Switzerland
	12-Aug-14	Certified Topological Computation with Trapped Ions	CETO program meeting	Arlington, Washington, USA
	17-Sep-14	From Pure Science to Today's Technologies	Canarie National Summit	Toronto, Ontario, Canada
	11-Nov-14	Negative Quasi-probability, Contextuality and the Power of Quantum Computation	INTRIQ Workshop	Chateau Bromont, Canada
	01-Oct-14	Negative Quasi-probability, Contextuality and the Power of Quantum Computation	Dartmouth University	Hanover, New Hampshire, USA
	02-Dec-14	Negative Quasi-probability, Contextuality and the Power of Quantum Computation	EQuS Workshop: Engineered	Sydney, Australia

Faculty	Date	Title/Subject	Institution	Location
			Quantum Systems	
Jennewein, Thomas	30-Oct-14	Towards a global quantum internet. Schawlow-Townes Symposium	organized by the NRC and UofOttawa	Ottawa, Canada
	10-Oct-14	Towards Quantum Receiver Satellites in Space	Seminar at ITS, Lisbon, Portugal	Lisbon, Portugal
		Optical Implementations of Quantum Communications	Lecture within the “Advanced Doctorate Program on Quantum Information Science" funded by the European Commission, held at the ITS, Lisbon, Portugal	Lisbon, Portugal
	22-Sep-14	Progress towards QEYSSAt: a quantum receiver in space	Invited Keynote Talk: SPIE, Defence and Security, Amsterdam	Amsterdam, Netherlands
		Quantum Science Experiments in Space	Invited Technical Seminar: International Space University, Montreal	Montreal, Quebec, Canada
		Quantum Communications in Space, towards a quantum internet	Invited Public Lecture: International Space University, Montreal, Canada	International Space University, Montreal, Canada

Faculty	Date	Title/Subject	Institution	Location
	17-Apr-13	Quantum entanglement enabled applications and technologies	Seminar at the Department of Electrical Engineering, MIT., Cambridge, United States	Cambridge, MA, United States
Laflamme, Raymond	16-Oct-14	Colloquia; From Quantum Science to Quantum Technologies	Raman Institute	Bangalore, India
	21-May-14	Colloquia; Testing Born's rule	Center for Theoretical Physics, Polish Academy of Science	Warsaw, Poland
	20-May-14	Colloquia; Quantum Science and Technology	Jagelonian University	Krakov, Poland
	17-Oct-14	Quantum Error Correction	India Institute of Science	Bengaluru, Karnataka, India
	23-May-14	Experimental Quantum Error Correction	KCIK conference	Sopot, Poland
	19-May-14	Fault tolerance without transversal gates	Jagelonian University	Krakov, Poland
	02-Mar-15	Lansdowne Lecture series; Quantum Information Science	University of Victoria	Victoria, BC, Canada
	17-Feb-15	Experimental Quantum Error Correction	Los Alamos National Laboratory	Los Alamos, NM, USA
Lupascu, Adrian	22nd-24th, Oct 2014	Decoherence of superconducting flux qubits	The 4th International Workshop on Entanglement, Decoherence, and Quantum Control (EDQC2014)	Buffalo, NY, USA
	17th, Sept 2014	Artificial atoms based on superconductors: from quantum information to measurements of noise in solid-state mesoscopic systems	McMaster Physics Colloquium, McMaster University	McMaster, Hamilton, Ontario, Canada

Faculty	Date	Title/Subject	Institution	Location
	1st - 5th, Sept 2014	Decoherence of superconducting flux qubits	Advanced many-body and statistical methods in mesoscopic systems II	Brasov, Romania
Leung, Debbie	June 16-20, 2014	"The little we know of quantum nonlocality"	2014 Canadian Association of Physicists Congress	Laurentian University, Sudbury, Canada
	June 4-6, 2014. Talk given June 04, 2014	"Maximal privacy without coherence"	CIFAR Quantum Information Processing program meeting	Quebec City, Canada
	March 31 - April 1, 2014	"Maximal privacy without coherence"	NIST-UMD Workshop on Quantum Information and Computer Science, QuICS	University of Maryland
Mariantoni, Matteo	07-Nov-14	The Truly Scalable Quantum Bit	University of Waterloo	Waterloo, ON N2L 3G1
	01-Oct-14	Building a Superconducting Quantum Computer	6th International Conference on Post-Quantum Cryptography, University of Waterloo	Waterloo, ON N2L 3G1
Martin-Martinez, Eduardo	30-Jun-14	The echo of the Early Universe	University of seoul	South Korea
	30-Jun-14	The (Anti-)Unruh effect in non-equillibrium scenarios	University of Seoul	South Korea
	02-Dec-14	Processing quantum information with relativistic motion of atoms	University of Queensland	Brisbane, Australia
Lutkenhaus, Norbert	27-May-14	Beating Classical Communication Resources by Quantum Communication	Quantum 2014	Torino, Italy

Faculty	Date	Title/Subject	Institution	Location
	20-Oct-14	Quantitative Quantum Communication: Practical Realizations of Exponential Quantum Advantage	Fio/LS	Tuscon, Arizona
	09-May-14	Beating Classical Communication Resources by Quantum Communication	University of Toronto	Toronto, Ontario
	31-Oct-14	Could Gaussian regenerative stations act as quantum repeaters?	Tsignhua Univeristy	Tsignha, China
Makarov, Vadim	07-Oct-14	Testing QKD systems	ETSI	Ottawa, Ontario
Mosca, Michele	10-Mar-15	Public lecture; Cybersecurity in a quantum world: will Canada be ready?	IQC, University of Waterloo	Waterloo, Ontario, Canada
	03-Feb-15	Industry Outreach; Towards Quantum-Safe Cryptography	Canadian Bankers Association	Toronto, Ontario, Canada
	12-Jan-15	Moving towards a quantum-safe cryptographic infrastructure	DIMACS Workshop on The Mathematics of Post-Quantum Cryptography	New Brunswick, New Jersey, United States
	14-Aug-14	Towards Quantum-Safe Cryptography	National Technical University	Singapore
	16-Jul-14	Workshop on Quantum Algorithms and Devices-Part 4	Microsoft QUArC workshop 2014	Virginia, Washington, United States
	22-Jul-14	Planery talk; Towards Quantum-Safe Cryptography	Internet Research Task Force(IRTF)open meeting	Toronto, Ontario, Canada
	06-May-14	Quantum software and quantum-safe cryptography	Institut Transdisciplinaire d'Information Quantique (INTRIQ) meeting,	Bromont, Quebec, Canada

Faculty	Date	Title/Subject	Institution	Location
	11-Apr-14	Quantum Computing and Cryptography	CIFAR Lunch and Learn	Toronto, Ontario, Canada
	22-May-14	Panelist; Cybersecurity - Issues and Opportunities	Ontario Centre of Excellence (OCE) Discovery Conference	Toronto, Ontario, Canada
Miao, Guoxing	30-Oct-14	Flitering spins for spintronics	3rd International Conference of Asian Union of Magnetics Societies (IcAUMS)	Haikou, China
	24-Sep-14	Exchange Induced Interfacial Field from Magnetic Insulators	Nanotechnology Seminar, Institute of Physics at the Chinese Academy of Sciences	Beijing, China
	29-Sep-14	Exchange Induced Interfacial Field from Magnetic Insulators	Qingdao University	Qingdao, China
	03-Nov-14	Exchange Induced Interfacial Field from Magnetic Insulators	East China Jiaotong University	Nanchang, China
	17-Nov-14	Magnetic Insulators for Spin Information Processing	McMaster University	Hamilton, Onatio, Canada
	27-Jan-15	Spin Information Processing with Magnetic Semiconductors	Institute of Physics, Chinese Academy of Science	Beijing, China
	06-Feb-15	Spin Information Processing with Magnetic Semiconductors	Suzhou Institute of Nano-Tech and Nano-BionicsChinese Academy of Science	Suzhou, China
	25-Feb-15	Spin Manipulation thorugh Tunable Magnetic Semiconductors	University of Toronto	Toronto, Ontario

Faculty	Date	Title/Subject	Institution	Location
Pushin, Dmitry	15-Feb-15	Quantum Correlations in a Noisy Neutron Interferometer	AAAS Annual Meeting	San Jose, California, USA
	30-Oct-14	Neutron Interferometry and Coherence	IQUISE Seminar Series	Cambridge, Massachusetts, USA
	06-Oct-14	Quantum Information and Neutron Interferometry	10th World Conference on Neutron Radiography	Grindelwald, Switzerland
	04-Jun-14	Neutron Interferometry and Coherence	Radiation Physics Seminar, National Institute of Standards and Technology	Gaithersburg, Maryland, USA
Resch, Kevin	Jun 16 - 20, 2014	Canadian Summer School on Quantum Information	University of Guelph	Guelph, Ontario, Canada
	2014	Quantum nonlocality with entangled triplets (so...what are those trailers doing in the North Campus cornfields?)	University of Waterloo, Undergrad Physics Seminar	Waterloo, Ontario, Canada
Reimer, Michael	27-Mar-15	New nanoscale source of on-demand entangled photon pairs,	13th European/French Israeli Symposium on Nonlinear and Quantum Optics	Aussois, France

L. Co-authored Papers

Publication title	External collaborators	Collaborating Institutions	Location
Non-classical higher-order photon correlations with a quantum dot strongly coupled to a photonic-crystal nanocavity	Armand Rundquist	Stanford University	California, USA
	Arka Majumdar	Stanford University	California, USA
	Thomas Sarmiento	Stanford University	California, USA
	Kevin Fischer	Stanford University	California, USA
	Konstantinos G. Lagoudakis	Stanford University	California, USA
	Sonia Buckley	Stanford University	California, USA
	Alexander Y. Piggott	Stanford University	California, USA
	Jelena Vuckovic	Stanford University	California, USA
Photooxidative tuning of individual and coupled GaAs Photonic Crystal Cavities	Alexander Y. Piggott	Stanford University	California, USA
	Konstantinos G. Lagoudakis	Stanford University	California, USA
	Thomas Sarmiento	Stanford University	California, USA
	Gary Shambat	Stanford University	California, USA
	Jelena Vuckovic	Stanford University	California, USA
Magnetoconductance signatures of subband structure in semiconductor nanowires	Ray R. LaPierre	McMaster University	Ontario, CA
Few-Qubit Magnetic Resonance Quantum Information Processors: Simulating Chemistry and Physics	B Criger	RWTH Aachen University	Aachen, Germany
Atom-Light Interactions in Photonic Crystals	A. Goban	California Institute of Technology	California, USA
	C.-L. Hung	California Institute of Technology	California, USA
	S.-P. Yu	California Institute of Technology	California, USA
	J.D. Hood	California Institute of Technology	California, USA
	J.A. Muniz	California Institute of Technology	California, USA
	J.H. Lee	California Institute of Technology	California, USA
	M.J. Martin	California Institute of Technology	California, USA
	A.C. McClung	California Institute of Technology	California, USA
	D.E. Chang	ICFO—Institut de Ciencies Fotoniques	Barcelona, Spain

Publication title	External collaborators	Collaborating Institutions	Location
	O.Painter	California Institute of Technology	California, USA
	H.J. Kimble	California Institute of Technology	California, USA
Simulating Hamiltonian dynamics with a truncated Taylor series	Berry, Dominic	Macquarie University	Sydney, Australia
	Somma, Rolando	Los Alamos National Laboratory	New Mexico, USA
Accelerated randomized benchmarking	Christopher Ferrie	University of New Mexico	New Mexico, USA
Inductive Measurement of Optically Hyperpolarized Phosphorous Donor Nuclei in an Isotopically Enriched Silicon-28 Crystal	Patryk Gumann	Harvard University	Massachusetts, USA
	Chandrashekar Ramanathan	Dartmouth College	NewHampshire, USA
	M.L.W. Thewalt	Simon Fraser University	British Columbia, CA
	H. Riemann	Leibniz Institute for Crystal Growth	Berlin, Germany
	N.V. Abrosimov	Leibniz Institute for Crystal Growth	Berlin, Germany
	P. Becker	PTB Braunschweig	Braunschweig, Germany
	H.-J. Pohl	VITCON	Jena, Germany
	K.M. Itoh	Keio University	Hiyoshi, Japan
Neutron Interferometry at the National Institute of Standards and Technology	M Arif	National Institute of Standards and Technology	Maryland, USA
	M Huber	National Institute of Standards and Technology	Maryland, USA
	C.B. Shahi	Tulane University	Louisiana, USA
Quantum correlations in a noisy neutron interferometer	Mohamed O. Abutaleb	Massachusetts Institute of Technology	Massachusetts, USA
	Michael G. Huber	National Institute of Standards and Technology	Maryland, USA
	Muhammad Arif	National Institute of Standards and Technology	Maryland, USA
Quantum Bootstrapping via Compressed Quantum Hamiltonian Learning	Nathan Wiebe	Microsoft Research	Washington, USA
Hamiltonian learning and certification using quantum resources	Nathan Wiebe	Microsoft Research	Washington, USA
	Christopher Ferrie	University of New Mexico	New Mexico, USA
	Nathan Wiebe	Microsoft Research	Washington, USA

Publication title	External collaborators	Collaborating Institutions	Location
Quantum Hamiltonian learning using imperfect quantum resources	Christopher Ferrie	University of New Mexico	New Mexico, USA
Contextuality supplies the "magic" for quantum computation	Mark Howard	National University of Ireland	Maynooth, Ireland
	Victor Veitch	University of Toronto	Ontario, CA
Direct generation of three-photon polarization entanglement	Deny R. Hamel	Université de Moncton	New Brunswick, CA
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	Hannes Hübel	Stockholm University	Stockholm, Sweden
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	Varun B. Verma	National Institute of Standards and Technology	Colorado, USA
	Richard P. Mirin	National Institute of Standards and Technology	Colorado, USA
	Sae Woo Nam	National Institute of Standards and Technology	Colorado, USA
Is wave-particle objectivity compatible with determinism and locality	Radu Ionicioiu	National Institute of Physics and Nuclear Engineering	Bucharest, Romania
		University Politehnica of Bucharest	Bucharest, Romania
	Daniel R. Terno	Macquarie University	Sydney, Australia
Space-time effects on satellite-based quantum communications	David Edward Bruschi	University of Leeds	Leeds, UK
	Timothy C. Ralph	University of Queensland	Queensland, Australia
	Ivette Fuentes	University of Nottingham	Nottingham, UK
	Mohsen Razavi	University of Leeds	Leeds, UK
Demonstration of spectral correlation control in a source of polarization entangled photon pairs at telecom wavelength	Thomas Lutz	Institut für Quantenmaterie, Universität Ulm	Ulm, Germany
	Piotr Kolenderski	Nicolaus Copernicus University	Torun, Poland

Publication title	External collaborators	Collaborating Institutions	Location
Experimental Three-Photon Quantum Nonlocality under Strict Locality Conditions. Nature Photonics	C. Erven	University of Bristol	Bristol, UK
	Z. Yan	Macquarie University	Sydney, Australia
	R. Prevedel	Research Institute of Molecular Pathology and Max F. Perutz Laboratories GmbH	Vienna, Austria
	L. K. Shalm	National Institute of Standards and Technology	Colorado, USA
	G. Weihs	Universitat Innsbruck	Innsbruck, Austria
The NanoQEY Mission: Ground to Space Quantum Key and Entanglement Distribution Using a Nanosatellite	C. Grant	Space Flight Laboratory, University of Toronto Institute for Aerospace Studies	Ontario, CA
	H. Hakima	Space Flight Laboratory, University of Toronto Institute for Aerospace Studies	Ontario, CA
	R. Zee	Space Flight Laboratory, University of Toronto Institute for Aerospace Studies	Ontario, CA
Quantum control in foundational experiments	Lucas C. Céleri	Universidade Federal de Goiás	Goiânia, GO, Brazil
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Qeyssat: a mission proposal for a quantum receiver in space	J. P. Bourgoin	COMDEV Canada	Ontario, CA
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Time and spectrum-resolving multiphoton	Piotr Kolenderski	Nicolaus Copernicus University	Torun, Poland

Publication title	External collaborators	Collaborating Institutions	Location
correlator for 300-900 nm	Carmelo Scarcella	Politecnico di Milano	Milano, Italy
	Alberto Tosi	Politecnico di Milano	Milano, Italy
Converting one photon into two via four-wave mixing in optical fibers	Raja Ahmad	McGill University	Quebec, CA
	Martin Rochette	McGill University	Quebec, CA
Time-resolved double-slit interference pattern measurement with entangled photons	Piotr Kolenderski	Nicolaus Copernicus University	Torun, Poland
	Carmelo Scarcella	Politecnico di Milano	Milano, Italy
	Lynden K. Shalm	National Institute of Standards and Technology	Colorado, USA
	Simone Tisa	Micro Photon Device	Bolzano, Italy
	Alberto Tosi	Politecnico di Milano	Milano, Italy
Experimental estimation of average fidelity of a clifford gate on a 7-qubit quantum processor	Guilu Long	Tsinghua University	Beijing, China
An experimental test of envariance	Jonathan Lavoie	University of Geneva	Geneva, Switzerland
Chiral quantum walks	Jacob D. Biamonte	ISI Foundation	Torino, Italy
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Experimental implementation of quantum gates through actuator qubits	Jingfu Zhang	Technische Universita ¨t Dortmund	Dortmund, Germany
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	Dieter Suter	Technische Universita ¨t Dortmund	Dortmund, Germany
Experimental three-photon quantum nonlocality under strict locality conditions	Gregor Weihs	Universita ¨t Innsbruck	Innsbruck, Austria
Quantum Subsystems: Exploring the Complementarity of Quantum Privacy and Error Correction	Sarah Plosker	Brandon University	Winnipeg, Manitoba
Experimental implementation of	Jingfu Zhang	Technische Universität Dortmund	Dortmund, Germany

Publication title	External collaborators	Collaborating Institutions	Location
quantum gates through actuator qubit	Daniel Burgarth	Aberystwyth University	Aberystwyth, Wales
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Experimental test of environment-assisted invariance	Jonathan Lavoie	University of Geneva	Geneva, Switzerland
Hyperfine spin qubits in irradiated malonic acid: heat-bath algorithmic cooling	Taiki Shibata	Tsukuba University	Tsukuba, Japan
	Shigeaki Nakazawa	Osaka University	Suita, Japan
	Kazunobu Sato	Osaka University	Suita, Japan
	Takeji Takui	Osaka University	Suita, Japan
Controlled Open Quantum Systems: Application to Quantum State Engineering	Jun Li	University of Science and Technology of China	Hefei, Chiina
	Xinhua Peng	University of Science and Technology of China	Hefei, Chiina
	Jiangfeng Du	University of Science and Technology of China	Hefei, Chiina
Characteristics of universal embezzling families	Bingjie Wang	University of Cambridge	Cambridgeshire, UK
Maximal Privacy Without Coherence	Ke Li	IBM T. J. Watson Research Center	New York, USA
	Graeme Smith	Massachusetts Institute of Technology	Massachusetts, USA
	John A. Smolin	Massachusetts Institute of Technology	Massachusetts, USA
When asymptotic LOCC offers no advantage over finite LOCC	Laura Mancinska	Centre for Quantum Technologies, National University of Singapore	Singapore
Everything You Always Wanted to Know About LOCC (But Were Afraid to Ask)	Eric Chitambar	Southern Illinois University	Illinois, USA
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Simulating Weak Localization Using Superconducting Quantum Circuits	Yu Chen	University of California	California, USA
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Particle detectors and the zero mode of a quantum field	Jorma Louko	University of Nottingham	Nottingham, UK
Quantum Seismology	Nicolas C. Menicucci	University of Sydney	Sydney, Australia
Entanglement in curved spacetimes and Cosmology	Nicolas C. Menicucci	University of Sydney	Sydney, Australia
Ultrafast and fault-tolerant quantum communication across long distances	Sreraman Muralidharan	Yale University	Connecticut, USA
	Jungsang Kim	Duke University	North Carolina, USA
	Mikhail D. Lukin	Harvard University	Massachusetts, USA
	Liang Jiang	Yale University	Connecticut, USA
Using quantum key distriution for cryptographic purposes: a survey	R. Alleaume	Telecom ParisTech & CNRS LTCI	Paris, France
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	N. Gisin	University of Geneva	Geneva, Switzerland
	M. Godfrey	University of Bristol	Bristol, UK
	P. Grangier	CNRS, Institut d'Optique	Palaiseau, France
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Publication title	External collaborators	Collaborating Institutions	Location
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	A. Shields	Toshiba Research Europe Ltd.	Cambridge, UK
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	A. Zeilinger	University of Vienna	Vienna, Austria
Symmetric extension of two-qubit states	Jianxin Chen	University of Guelph	Ontario, CA
	Zhenfeng Ji	Chinese Academy of Sciences	Beijing, China
	David Kribs	University of Guelph	Ontario, CA
	Bei Zeng	University of Guelph	Ontario, CA
Security of quantum key distribution using a simplified trusted relay	Xiongfeng Ma	Tsinghau University	Beijing, China
Trojan-horse attacks threaten the security of practical quantum cryptography	Nitin Jain	Max Planck Institute for the Science of Light	Erlangen, Germany
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Publication title	External collaborators	Collaborating Institutions	Location
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Practical approximation of single-qubit unitaries by single-qubit quantum Clifford and T circuits	Vadym Kliuchnikov	National Science Foundation	Virginia, USA
	Dmitri Maslov	National Science Foundation	Virginia, USA
Finding shortest lattice vectors faster using quantum search	Thijs Laarhoven	Eindhoven University of Technology	Eindhoven, Netherlands
	Joop van Pol	University of Bristol	Bristol, UK
On the Robustness of Bucket Brigade Quantum RAM	Srinivasan Arunachalam	Centrum Wiskunde & Informatica (CWI)	Amsterdam, The Netherlands
	Priyaa Varshinee Srinivasan	University of Calgary	Alberta, CA
Polynomial-time T-depth Optimization of Clifford+T circuits via Matroid Partitioning	Matthew Amy	University of Toronto	Ontario, CA
	Dmitri Marslov	National Science Foundation	Virginia, USA
Spin manipulation with magnetic semiconductor barriers	Jagadeesh S. Moodera	Massachusetts Institute of Technology	Massachusetts, USA
Epitaxial growth of NaCl on Fe (100) and characterization of Fe/NaCl/Fe magnetic tunnel junctions	Qiang Li	Virginia Tech	Virginia, USA
Spin regulation in composite spin-filter barrier devices	Joonyeon Chang	Korea Institute of Science and Technology	Seoul, South Korea
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	Donald Heiman	Northeastern University	Massachusetts, USA
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Quantumness of correlations, quantumness of ensembles and quantum data hiding	V. Narasimhachar	University of Calgary	Alberta, CA
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Role of correlations in the two-body-marginal problem	Lin Chen	Singapore University of Technology and Design	Singapore
	Oleg Gittsovich	University of Innsbruck	Innsbruck, Austria

Publication title	External collaborators	Collaborating Institutions	Location
	K. Modi	Monash University	Melbourne, Australia
Proposal for a Quantum Delayed-Choice Experiment	Daniel R. Terno	Macquarie University	Sydney, Australia
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A sensitive search for dark energy through chameleon scalar fields using neutron interferometry	WM Snow	Indiana University	Indiana, USA
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	B Heacock	North Carolina State University	North Carolina, USA
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Neutron Interferometry at the National Institute of Standards and Technology	M Huber	National Institute of Standards and Technology	Colorado, USA
	M Arif	National Institute of Standards and Technology	Colorado, USA
	C.B. Shahi	Tulane University	Louisiana, USA
Neutron interferometric measurement of the scattering length difference between the triplet and singlet states of n– He 3	M Huber	National Institute of Standards and Technology	Colorado, USA
	M Arif	National Institute of Standards and Technology	Colorado, USA
	W.C. Chen	National Institute of Standards and Technology	Colorado, USA
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Publication title	External collaborators	Collaborating Institutions	Location
Experimental search for long-range forces in neutron scattering via a gravitational spectrometer	A.P. Serebrov	Petersburg Nuclear Physics Institute	Gatchina, Russia
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	V.E. Varlamov	Petersburg Nuclear Physics Institute	Gatchina, Russia
	A.V. Vassiljev	Petersburg Nuclear Physics Institute	Gatchina, Russia
	M.S. Lasakov	Petersburg Nuclear Physics Institute	Gatchina, Russia
	I.A. Krasnoschekova	Petersburg Nuclear Physics Institute	Gatchina, Russia
	S.N. Ivanov	Institute Laue Langevin	Grenoble, France
Quantum correlations in a noisy neutron interferometer	Mohamed O. Abutaleb	Massachusetts Institute of Technology	Massachusetts, USA
	Michael G. Huber	National Institute of Standards and Technology	Colorado, USA
	Muhammad Arif	National Institute of Standards and Technology	Colorado, USA
A quantum advantage for inferring causal structure	Katja Ried	Perimeter Institute for Theoretical Physics	Ontario, CA
	Dominik Janzing	Max Planck Institute for Intelligent Systems	Tübingen, Germany
	Robert W. Spekkens	Perimeter Institute for Theoretical Physics	Ontario, CA
Storage and Retrieval of THz-Bandwidth Single Photons Using a Room-Temperature Diamond Quantum Memory	Duncan G. England	National Research Council of Canada	Ontario, CA
	Philip J. Bustard	National Research Council of Canada	Ontario, CA
	Rune Lausten	National Research Council of Canada	Ontario, CA
	Benjamin J. Sussman	National Research Council of Canada	Ontario, CA
Experimental test of environment-assisted invariance	J. Lavoie	University of Geneva	Geneva, Switzerland
	U. Sinha	Raman Research Institute	Bangalore, India
Ultrafast time-division demultiplexing of polarization-entangled photons	Jonathan Lavoie	University of Geneva	Geneva, Switzerland
	Deny R. Hamel	Université de Moncton	New Brunswick, CA

Publication title	External collaborators	Collaborating Institutions	Location
Direct generation of three-photon polarization entanglement	Lynden K. Shalm	National Institute of Standards and Technology	Colorado, USA
	Hannes Hübel	Stockholm University	Stockholm, Sweden
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Discriminating Single-Photon States Unambiguously in High Dimensions	Megan Agnew	Heriot-Watt University	Edinburgh, UK
	Eliot Bolduc	Heriot-Watt University	Edinburgh, UK
	Sonja Franke-Arnold	University of Glasgow	Glasgow, UK
	Jonathan Leach	Heriot-Watt University	Edinburgh, UK
Time-resolved double-slit interference pattern measurement with entangled photons	Piotr Kolenderski	Nicolaus Copernicus University	Torun, Poland
	Carmelo Scarcella	Politecnico di Milano	Milano, Italy
	Lynden K. Shalm	National Institute of Standards and Technology	Colorado, USA
	Simone Tisa	Micro Photon Device	Bolzano, Italy
	Alberto Tosi	Politecnico di Milano	Milano, Italy
Experimental Three-Photon Quantum Nonlocality under Strict Locality Conditions	C. Erven	University of Bristol	Bristol, UK
	Z. Yan	Macquarie University	Sydney, Australia
	R. Prevedel	Research Institute of Molecular Pathology and Max F. Perutz Laboratories GmbH	Vienna, Austria
	L. K. Shalm	National Institute of Standards and Technology	Colorado, USA
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Quantum Nondemolition	Sankar R Sathyamoorthy	Chalmers University of Technology	Gothenburg, Sweden

Publication title	External collaborators	Collaborating Institutions	Location
Detection of a Propagating Microwave Photon	L. Tornberg	Chalmers University of Technology	Gothenburg, Sweden
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Christopher Chamberland	McGill University, Canada
Christopher Chunnilall	National Physical Laboratory, United Kingdom
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Mary Beth Ruskai	Tufts University, USA
Masahiro Hotta	Tohoku University, Japan
Masayuki Okano	Kyoto University, Japan
Matthieu Nannini	McGill University, Canada
Michael Hilke	McGill University, Canada
Mitchell Brickson	Goshen College, Indiana, USA
Na Young Kim	Stanford University, USA
Nathalie de Leon	Harvard University, USA
Nathan Wiebe	University of Calgary, Canada
Nicolas C. Menicucci	University of Sydney, Australia
Nicolas Menicucci	The University of Sydney, Australia
Niel de Beaudrap	Centrum Wiskunde and Informatica, Netherlands
Omar Fawzi	Institute for Theoretical Physics ETH Zurich, Switzerland
Or Sattath	University of California, Berkeley, USA
Ozgur E. Mustecaplioglu	Koç Üniversitesi, Turkey
Paola Cappellaro	Massachusetts Institute of Technology, USA
Peter Hoyer	University of Calgary, Canada
Peter Zoller	University of Innsbruck, Austria
Petros Wallden	Heriot-Watt University, Institute of Photonics and Quantum Sciences, United Kingdom
Phil Kaye	Government of Canada, Canada
Piotr Kolenderski	Nicolaus Copernicus University, Poland
Pragya Shukla	Indian Institute of Technology Kharagpur, India
Prasanna Venkatesh	Pohang Universit of Science and Technology, South Korea
Raja Ahmad	McGill University, Canada
Ramy El Ganainy	Michigan Technological University, USA
Raul Garcia-Patron	Université Libre de Bruxelles, Belgium

Visitor Name	Visitor Affiliation
Robert Fickler	University of Vienna, Austria
Robert Raussendorf	The University of British Columbia, Canada
Robin Kothari	Massachusetts Institute of Technology, USA
Rolando Somma	Los Alamos National Laboratory, USA
Romain Ruhlmann	McGill University, Canada
Sahel Ashhab	Qatar Environment and Energy Research Institute, Qatar Foundation, Qatar
Seamus Davis	Cornell University, USA
Sean Hallgren	The Pennsylvania State University, USA
Sergey Bravyi	IBM Research, USA
Sevag Gharibian	University of California, Berkeley, USA
Shrobana Bagchi	Harish-Chandra Research Institute, Allahabad, India
Shuanping Du	University of Guelph, Canada
Som Bandyopadhyay	Bose Institute, Kolkata, Inda
Stacey Jeffery	California Institute of Technology, USA
Steve Bartlett	Imperial College London, UK
Sun Kyung Lee	Korea Advanced Institute of Science and Technology, South Korea
Swati Singh	Harvard University, USA
Tae Hee Kim	Ewha Womans University, South Korea
Takashi Imai	McMaster University, Canada
Terry Rudolph	Imperial College London, UK
Thijs Laarhoven	Eindhoven University of Technology, Netherlands
Thomas Babinec	Stanford University, USA
Tom Lai	McGill University, Canada
Torsten Scholak	University of Toronto, Canada
Ty Volkoff	University of California, Berkeley, USA
Val Zwiller	Delft University of Technology, Netherlands
Valentin Nguyen	Université De Montréal, Canada
Vern Paulsen	University of Houston, USA
Viatcheslav Dobrovitski	The Ames Laboratory, Iowa State University, USA
Vinzenz Gangl	UCP Plasma Technologies, Liechtenstein
Viv Kendon	Joint Quantum Centre, Durham-Newcastle, UK
Volkher Scholz	Institute for Theoretical Physics ETH Zurich, Switzerland
Xiaodi Wu	Massachusetts Institute of Technology, USA

Visitor Name	Visitor Affiliation
Xiaodong Xu	The University of Washington, USA
Xiaofei Qi	Shanxi University, China
Yaoyun Shi	University of Michigan, Ann Arbor, USA
Long Term Visitors	
Koon Tong Goh	Centre for Quantum Technologies, Singapore
Laura Mancinska	Centre for Quantum Technologies, Singapore
Paulo Vinicius Pereira Pinheiro	Federal University of Ceara, Ceara - Brazil
Krtin Kumar	Indian Institute of Technology, Guwahati, India
Ben Criger	Institut für Quanteninformation RWTH Aachen, Germany
Kai-Min Chung	Institute of Information Science, Academia Sinica, Taiwan
Aixi Chen	Jiao Tong University, Shanghai
Kyung Soo Choi	Korea Institute of Science and Technology, South Korea
Marta Palucka	Nicolaus Copernicus University, Poland
Hyeran Kong	Pohang University of Science & Technology, South Korea
Yury Kurochkin	Russian Quantum Center in Skolkovo, Moscow, Russia
Eyal Buks	Technion Israel Institute of Technology, Israel
Rui Chao	Tsinghua University, China
Tao Xin	Tsinghua University, China
Mehmet Canturk	Turgut Özal University, Turkey
Dominique Pouliot	University of Illinois at Urbana-Champaign, USA
Tony Leggett	University of Illinois at Urbana-Champaign, USA
Gregor Weihs	University of Innsbruck, Austria
Moshen Razavi	University of Leeds, UK
Katanya Kuntz	University of New South Wales, Canberra, Australia
Xinhua Peng	University of Science and Technology, China
Callum Croal	University of St. Andrews, Scotland
Zhaofang Bai	Xi'an Jiaotong University, China

N. Tours – Industry, Government and Academic

Group	Date	# of Participants
Academic		
QIP class	01-Apr-14	40
AIMS Tour	02-Jun-14	30
Delegation of Saudi Students	02-Jun-14	25
Central China Normal University	27-Aug-14	6
Perimeter Scholar International students	29-Aug-14	20
Korean Delegation	25-Sep-14	40
Aboriginal Education Centre's Directions Conference	05-May-14	20
Physics Undergraduate Students	29-Jul-14	10
International Conference for Woman in Physics	07-Aug-14	80
Soochow University Taiwan	27-Aug-14	16
Students from QIC 750	26-Feb-15	20
CASE Europe Study Tour	21-May-14	25
Government		
UKTI Delegation	15-May-14	12
Israeli Ambassador to Canada, Rafaêl Barak; D. J. Schneeweiss, Consul General of Israel to Toronto	20-May-14	5
Austrian Ambassador	20-May-14	5
South Korean Delegation	22-May-14	4
Indonesia Group	23-May-14	25
Nova Scotian Premiere	30-May-14	24
South Korea delegation	05-Aug-14	15
National Research Council: Duncan Stewart (General Manager, Security and disruptive Technologies) Ben Sussman (Principle Investigator, Quantum Technologies)	04-Sep-14	2
GOI Mr. Lal	04-Sep-14	3
CSA Martin Lihou, Danya Hudson, Marleen, Martin Bergeron, Mak	09-Sep-14	6
Leader Liberal party: Justin Trudeau	10-Sep-14	1
Konstantinos Georgaras, Industry Canada Intellectual Property Office	10-Oct-14	1
Giles Gherson, deputy minister economic development and MRI	27-Nov-14	1
US State Officials: Jane Humphreys Political-Economic Specialist U.S. Consulate General Toronto Andrea Gorog. Foreign Service Officer Washington DC Metro Area US Department of State Ryan Mousney, City of Waterloo	12-Mar-15	3
Treasury Board /CIO visit: Corinne Charette (Chief Information Officer) Benoit Long, (Senior Assistant Deputy	04/05-Sept-14	12

Group	Date	# of Participants
Minister) Toni Moffa (Deputy Chief IT Security) Dave Adamson (Deputy Chief Information Officer) Dan Couillard (Senior Director, Cyber Security) Serge Caron (Senior Director IT Architecture)		
Cassie J. Doyle: Canadian Consul General for Northern California, Nevada, Hawaii and Guam	21-Oct-14	1
Consul General UK	23-Oct-14	3
French Delegation	06-Nov-14	20
India ICT Visit	13-Nov-14	8
Privy Council Office: Janice Charette	18-Nov-14	3
Korean Ambassador	21-Nov-14	7
Political Representatives from Newfoundland and Labrador	28-Nov-14	3
The Honourable Ed holder, MP Peter Braid and MP Harold Albrecht	22-Jan-15	6
Dale Forbes - Industry Canada	04-Feb-15	3
Tom Teahen, Chief of Staff for Kathleen Wynne	09-Feb-15	2
Dutch Delegation	12-Feb-15	8
Richard Taraofsky: Senior Trade Officer Canadian Embassy Berlin	27-Feb-15	2
Honourable Deborah Matthews (Deputy Minister), Daiene Vernile MPP Kitchener Centre	27-Feb-15	3
Industry		
TrustPoint Group	02-Jun-14	7
Farzad Hussein	24-Jul-14	1
Eugene Roman- CTO Canadian Tire	25-Jul-14	4
Ronald Rivest, RSA	13-Jun-14	2
Lockheed Martin: Charles Bouchard (CEO) and Duncan Hills (Government Relations	15-Sep-14	2
Globe and Mail/Thompson Visit	04-Dec-14	5
Ranovus	09-Mar-15	3
Dan Falk, Journalist	11-Mar-15	1
Hongwei Liu and Mitchell Butler, Founders of Mapped In	13-Mar-15	3
Michael Dunn, Editor, EDN Design Ideas	26-Mar-15	1
	Total on tour:	556

O. Earned Media

Date	Media Outlet	Title	URL
04-04-2014	The Record	$3.5M for communications, market hijinks studies	http://www.therecord.com/news-story/4449663--3-5m-for-communications-market-hijinks-studies/?&article_id=17309654111
04-05-2014	Frankfurter Allgemeine Wissen	Drei Photonen treiben seltsamen Spuk	http://www.faz.net/aktuell/wissen/physik-chemie/einsteins-fernwirkung-drei-photonen-treiben-seltsamen-spuk-12873620.html
04-08-2014	Waterloo Chronicle	IQC displays quantum cryptography	http://www.waterloochronicle.ca/news/iqc-displays-quantum-cryptography/
04-10-2014	"@uwaterloo - your alumni enewsletter"	Quantum talk: Moving from the possibility of two people to a network of people	http://alumni.uwaterloo.ca/alumni/e-newsletter/2014/apr/
01/04/2014	CIFAR Knowledge Circle	Towards three-party quantum communication	http://knowledgecircle.cifar.ca/towards-secure-three-party-quantum-communications/
04-15-2014	Quartz	Why nobody can tell whether the world's biggest quantum computer is a quantum computer	http://qz.com/194738/why-nobody-can-tell-whether-the-worlds-biggest-quantum-computer-is-a-quantum-computer/
Spring 2014	Innovators Magazine	Institute for Quantum Computing - Theoretical & Experimental Quantum Information Research	
04-17-2014	Harvard Gazette	MRI, on a molecular scale	http://news.harvard.edu/gazette/story/2014/04/mri-on-a-molecular-scale/
04-21-2014	Nanotechnology Now	University of Waterloo Visits China to Strengthen Bonds With Research Partners	http://www.nanotech-now.com/news.cgi?story_id=49366
04-22-2014	Sing Tao newspaper	(in Chinese)	http://news.singtao.ca/toronto/2014-04-22/city1398146597d5017119.html
04-23-2014	Nuvo	Quantum theory and classical music	http://www.nuvo.net/indianapolis/quantum-theory-computer-music-and-the-iso/Content?oid=2815762#.U1gPG_ldV8E?

Date	Media Outlet	Title	URL
05-30-2014	Waterloo Chronicle	Another affirmation	http://www.waterloochronicle.ca/opinion/another-affirmation/
05-01-2014	Digital Journal	Ontario Budget Supports Quantum Research at Waterloo	http://www.digitaljournal.com/pr/1890805
05-01-2014	Waterloo Stories	Ontario Budget Supports Quantum Research at Waterloo	https://uwaterloo.ca/stories/ontario-budget-supports-quantum-research-waterloo
05-01-2014	SPIE.	Progress toward a quantum communication satellite	http://spie.org/x108085.xml?highlight=x2414&ArticleID=x108085
05-01-2014	CIFAR	Global Scholars launch projects on women in science, quantum mechanics by the stars	http://www.cifar.ca/global-scholars-launch-projects-on-women-in-science-quantum-mechanics-by-the-stars
05-01-2014	Imprint	Budget supports Quantum Computing but offers no surprises for post-secondary students	http://www.uwimprint.ca/article/4265-ontario-budget-promises-25-million-to
05-02-2014	Daily Bulletin	Budget supports quantum research at Waterloo	http://www.bulletin.uwaterloo.ca//2014/may/02fr.html
05-02-2014	Morning Post Exchange	Ontario budget supports quantum research at Waterloo	http://www.exchangemagazine.com/morningpost/2014/week17/Friday/14050203.htm#anchor
05-02-2014	uWaterloo Research News	$25 million allotted to Waterloo's IQC over five years	https://uwaterloo.ca/research/news/25-million-allotted-waterloos-iqc-over-five-years
05-07-2014	Machine Intelligence Research Institute	Harry Buhrman on quantum algorithms and cryptography	http://intelligence.org/2014/05/07/harry-buhrman/
05-08-2014	Canada's Technology Triangle	Ontario Budget Supports Quantum Research at Waterloo	http://www.scoop.it/t/canada-s-technology-triangle/p/4020972558/2014/05/08/ontario-budget-supports-quantum-research-at-waterloo
05-08-2014	Daily Bulletin	Campus summer camps, collected	http://www.bulletin.uwaterloo.ca//2014/may/08th.html
05-11-2014	cognitive-computing	The origins of Quantum Teleportation - Charles Bennett	http://cognitive-computing.info/?cat=30
05-12-2014	Daily Bulletin	Town Hall today and other notes	http://www.bulletin.uwaterloo.ca//2014/may/12mo.html

Date	Media Outlet	Title	URL
05-15-2014	YourIs.com	Andris Ambainis - The road to quantum computing	http://www.youris.com/Society/Interviews/Andris-Ambainis---The-Road-To-Quantum-Computing.kl
05-22-2014	CBC	EBay hack underscores need for a more secure internet	http://www.cbc.ca/news/technology/ebay-hack-underscores-need-for-a-more-secure-internet-1.2650400?cmp=rss
05-23-2014	Daily Bulletin	Crow named interim VP University Relations	http://www.bulletin.uwaterloo.ca//2014/may/23fr.html
05-26-2014	Daily Bulletin	Monday's notes	http://www.bulletin.uwaterloo.ca//2014/may/26mo.html
05-26-2014	Blog	Summer 2014	http://pgokhale.quora.com/Summer-Begins
05-28-2014	Daily Bulletin	Outstanding Performance winners named	http://www.bulletin.uwaterloo.ca//2014/may/28we.html
05-29-2014	Re$earch Money	People	http://researchmoneyinc.com/display.php?issue=28-8&id=16713
06-02-2014	Daily Bulletin	Quantum satellite one step closer to launch	http://www.bulletin.uwaterloo.ca/2014/jun/02mo.html
Jun-14	Exchange Magazine	Waterloo Researchers Finding Innovative Solutions to Global Challenges	http://www.exchangemagazine.com/currentissue/ExchangeVol31No6/ExchangeVol31No6.pdf
Spring 2014	Inside the Perimeter	Mike Lazaridis made Royal Society Fellow	http://pitp.ca/newsletter/2014/spring/#/4/zoomed
06-11-2014	EurekAlert!	Contextuality puts the 'magic' in quantum computing	http://www.eurekalert.org/pub_releases/2014-06/cifa-cpt061114.php
06-11-2014	Nature	Quantum computing: Powered by magic	http://www.nature.com/nature/journal/vaop/ncurrent/full/nature13504.html
06-11-2014	Waterloo Stories	Waterloo researchers find “magic” ingredient for quantum computing	https://uwaterloo.ca/stories/waterloo-researchers-find-magic-ingredient-quantum-computing
06-11-2014	Perimeter website	Researchers find “magic” ingredient for quantum computing	https://www.perimeterinstitute.ca/node/93995
06-11-2014	CrazyChucks.com News	Study finds weird magic ingredient for quantum computing	http://crazychucks.com/news/Study+finds+weird+magic+ingredient+for+quantum+computing

Date	Media Outlet	Title	URL
06-11-2014	Phys.org	Study finds weird magic ingredient for quantum computing	http://phys.org/news/2014-06-weird-magic-ingredient-quantum.html
06-11-2014	Jersey Tribune	Researchers find weird magic ingredient for quantum computing	http://jerseytribune.com/2014/06/11/researchers-find-weird-magic-ingredient-for-quantum-computing/
06-11-2014	Science Daily	Weird 'magic' ingredient for quantum computing: Contextuality	http://www.sciencedaily.com/releases/2014/06/140611131858.htm
06-11-2014	Science Codex	Researchers find weird magic ingredient for quantum computing	http://www.sciencecodex.com/researchers_find_weird_magic_ingredient_for_quantum_computing-135476
06-11-2014	Science Newsline	Researchers Find Weird Magic Ingredient for Quantum Computing	http://www.sciencenewsline.com/summary/2014061118420077.html
06-11-2014	NanoWerk	Contextuality puts the 'magic' in quantum computing	http://www.nanowerk.com/nanotechnology-news/newsid=36003.php
06-12-2014	La Ciencia de la Mula Francis	La contextualidad y el secreto del poder de los ordenadores cuánticos	http://francis.naukas.com/2014/06/12/la-contextualidad-como-secreto-del-poder-de-la-computacion-cuantica/?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+naukas%2Ffrancis+%28La+Ciencia+de+la+Mula+Francis%29
06-12-2014	Before It's News	Contextuality puts the 'MAGIC' in quantum computing, researchers say	http://beforeitsnews.com/alternative/2014/06/contextuality-puts-the-magic-in-quantum-computing-researchers-say-2973462.html
06-12-2014	RedOrbit	Quantum Contextuality Needed To Achieve "Magic" Required For Universal Quantum Computation	http://www.redorbit.com/news/technology/1113168455/quantum-theory-magic-061214/
06-12-2014	e! Science news	Researchers find weird magic ingredient for quantum computing	http://esciencenews.com/articles/2014/06/12/researchers.find.weird.magic.ingredient.quantum.computing
06-12-2014	Science Newsline	Contextuality Puts the 'Magic' in Quantum Computing	http://www.sciencenewsline.com/summary/2014061118420011.html

Date	Media Outlet	Title	URL
06-12-2014	NVONews	Magic ingredient for quantum computing means magic-state distillation	http://nvonews.com/magic-ingredient-for-quantum-computing-means-magic-state-distillation/
06-12-2014	HNGN	Quantum Computing's 'Weird Magical Ingredient' Revealed	http://www.hngn.com/articles/33616/20140612/quantum-computings-weird-magical-ingredient-revealed.htm
06-12-2014	Google News	Quantum Computing's 'Weird Magical Ingredient' Revealed	https://twitter.com/juniwiese/status/477396452067385344
06-12-2014	Free Republic	Quantum Computing's 'Weird Magical Ingredient' Revealed	http://www.freerepublic.com/focus/chat/3167091/posts?page=4
06-12-2014	Quantum Computing Frontiers - G+	Contextuality the missing ingredient for universal quantum computing	https://plus.google.com/+AbleLawrence/posts/BM1KxejtZmj
06-12-2014	SciTechDaily	Researchers Discover “Magic” Ingredient for Quantum Computing	http://scitechdaily.com/researchers-discover-magic-ingredient-quantum-computing/
06-12-2014	Technology.org	Study finds weird magic ingredient for quantum computing	http://www.technology.org/2014/06/12/study-finds-weird-magic-ingredient-quantum-computing/
06-13-2014	The Register	Boffins discover 'practical requirements' of 'realistic' QUANTUM COMPUTER	http://www.theregister.co.uk/2014/06/13/quantum_computing_contextuality_magic_states_university_waterloo/
06-13-2014	Canada Journal	Scientists Find Weird Magic Ingredient for Quantum Computing	http://canadajournal.net/science/scientists-find-weird-magic-ingredient-quantum-computing-10047-2014/
06-13-2014	Nature World News	Contextuality Essential in Making Quantum Computers a Reality, Researchers Say	http://www.natureworldnews.com/articles/7555/20140613/contextuality-essential-making-quantum-computers-reality-researchers.htm
06-13-2014	boson.ws	Quantum computing has a magic word – contextuality – Tech Times	http://www.boson.ws/news-and-updates/boson-god-particle-news-updates/quantum-computing-has-a-magic-word-contextuality-tech-times-7/?utm_source=dlvr.it&utm_medium=twitter

Date	Media Outlet	Title	URL
06-13-2014	Tech Times	Quantum computing has a magic word – contextuality – Tech Times	http://www.techtimes.com/articles/8412/20140612/quantum-computing-magic-word-contextuality.htm
06-13-2014	Newslicious	Scientists Find Weird Magic Ingredient for Quantum Computing - Canada News	http://newslicous.blogspot.ca/2014/06/scientists-find-weird-magic-ingredient_13.html
06-13-2014	WasOut	Quantum Contextuality Needed To Achieve "Magic" Required For Universal	http://wasout.com/blog/2014/06/13/quantum-contextuality-needed-to-achieve-magic-required-for-universal-quantum-computation/
06-13-2014	DesignLance	Quantum computing has a magic word – contextuality – Tech Times	http://design-lance.com/quantum-computing-has-a-magic-word-contextuality-tech-times/
06-13-2014	popbuzz.me	Quantum Weirdness a Key Ingredient for Building Quantum Computer - Scientific Computing	http://www.popbuzz.me/ca/p/3718110/
06-13-2014	Datacentre Management.org	Quantum computing has a sorcery word – contextuality	http://www.datacentremanagement.org/2014/06/quantum-computing-has-a-magic-word-contextuality/
06-13-2014	The Reference Frame	Quantum contextuality is just another fancy word for Bohr's complementarity	http://motls.blogspot.ca/2014/06/quantum-contextuality-is-just-another.html?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed:+LuboMotlsReferenceFrame+%28Lubos+Motl%27s+reference+frame%29
06-15-2014	Electronic Products and News	Researchers find weird magic ingredient for quantum computing	http://www.ept.ca/news/researchers-find-weird-magic-ingredient-for-quantum-computing/1003111849/?&er=NA
06-16-2014	Space Mart	Researchers find weird magic ingredient for quantum computing	http://www.spacemart.com/reports/Researchers_find_weird_magic_ingredient_for_quantum_computing_999.html
06-16-2014	One Page News	Researchers find weird magic ingredient for quantum computing	www.onenewspage.us/n/Science/750hnyc97/Researchers-find-weird-magic-ingredient-for-quantum-computing.htm

Date	Media Outlet	Title	URL
06-16-2014	Phys.org	Best of Last Week	http://phys.org/news/2014-06-week-universe-violent-history.html
06-19-2014	Daily Bulletin	Reading the tea leaves after the election	http://www.bulletin.uwaterloo.ca//2014/jun/19th.html
06-19-2014	National Post	Cutting-edge, Canadian-made quantum computer on wave of the future, but new tests say it is too slow	http://news.nationalpost.com/2014/06/19/cutting-edge-canadian-made-quantum-computer-on-wave-of-the-future-but-new-tests-say-it-is-too-slow/
06-23-2014	Daily Bulletin	Conference honours work of math professor	http://www.bulletin.uwaterloo.ca//2014/jun/23mo.html
06-26-2014	Globe & Mail ROB	The Interview: Mike Lazaridis on Canada's next computing revolution	http://www.theglobeandmail.com/report-on-business/rob-magazine/the-interview-mike-lazaridis-on-the-next-computing-revolution/article19216874/
07-01-2014	Azonano	Speakers Announced for Oxford Instruments Seminar at IOP in Beijing	http://www.azonano.com/news.aspx?newsID=30528
07-02-2014	FrogHeart	Bringing the Nanoworld Together Workshop in Beijing, China, Sept. 24 – 25, 2014	http://www.frogheart.ca/?tag=institute-for-quantum-computing
07-03-2014	Science Codex	From pencil marks to quantum computers	http://www.sciencecodex.com/from_pencil_marks_to_quantum_computers-136949
07-04-2014	Semiconductor Today	Oxford Instruments' Nanotechnology Seminar at China's Institute of Semiconductors to start with 2D materials sessions	http://www.semiconductor-today.com/news_items/2014/JUL/OXFORDINSTRUMENTS_040714.shtml
07-04-2014	Debra's blog	Quantum Computer Science: An Introduction book	http://rizomyqocu.bloger.index.hr/post/quantum-computer-science-an-introduction-book/26302464.aspx
07-07-2014	Engineering.com	From pencil marks to quantum computers	http://www.engineering.com/DesignerEdge/DesignerEdgeArticles/ArticleID/7959/From-Pencil-Marks-To-Quantum-Computers.aspx
07-07-2014	Joint Quantum institute	You are here Home News JQI publications in 2014 Google Scholar Metrics	http://jqi.umd.edu/news/jqi-publications-2014-google-scholar-metrics

Date	Media Outlet	Title	URL
Jul-14	"@Waterloo" - alumni newsletter	Waterloo researchers find "magic" ingredient for quantum computing	http://alumni.uwaterloo.ca/alumni/e-newsletter/2014/jul/
07-09-2014	Space Daily	From pencil marks to quantum computers	http://www.spacedaily.com/reports/From_Pencil_Marks_To_Quantum_Computers_999.html
07-13-2014	William Shatner's Weird or What	Potential for human teleportation	Television
07-15-2014	Morning Post Exchange	Ontario budget supports quantum research at Waterloo	http://www.exchangemagazine.com/morningpost/2014/week28/Tuesday/14071504.htm#anchor
07-15-2014	Daily Bulletin	NSERC funding for researchers on the brink	http://www.bulletin.uwaterloo.ca//2014/jul/15tu.html
07-16-2014	Scribd.	Contextuality Supplies the Magic for Quantum Computation	http://www.scribd.com/doc/233992425/Contextuality-Supplies-the-Magic-for-Quantum-Computation
07-17-2014	Morning Post Exchange	Funding announcement to accelerate scientific discovery at the University of Waterloo	http://www.exchangemagazine.com/morningpost/2014/week28/Thursday/14071711.htm
07-17-2014	Math News	NSERC Discovery Grants announcement	https://math.uwaterloo.ca/math/news/nserc-discovery-grants-announcement
07-18-2014	Daily Bulletin	Summer camps, the Waterloo Way	http://www.bulletin.uwaterloo.ca//2014/jul/18fr.html
07-23-2014	The Commercial Space Blog	Space Activities at the University of Waterloo	http://acuriousguy.blogspot.ca/2014/07/space-activities-at-university-of.html
07-25-2014	Daily Bulletin	Celebrating Canada, breakthrough research; remembering Andrei Anghel	http://www.bulletin.uwaterloo.ca//2014/jul/25fr.html
07-28-2014	Canadian Space Society - The Gazette Weekly	Space at Waterloo, past and future	saved in docket folder 10080
Spring 2014	REACH (CIFAR)	How to build a quantum computer	http://www.cifar.ca/cifar-reach-spring-2014/$file/CIFAR%20REACH%20BOOK-ENG_r_single.pdf and docket folder 10080
08-05-2014	Daily Bulletin	Women in Physics Conference this Week	http://www.bulletin.uwaterloo.ca//2014/aug/05tu.html
08-10-2014	Newswatch	Raymond in Weird or What re-run	https://www.youtube.com/watch?v=MPreZFwm1dg

Date	Media Outlet	Title	URL
08-11-2014	Daily Bulletin	Students get their crypto fix at summer school	http://www.bulletin.uwaterloo.ca/2014/aug/11mo.html
08-27-2014	Waterloo News	Major awards will help fund transformational research at Waterloo	https://uwaterloo.ca/news/news/major-awards-will-help-fund-transformational-research
09-01-2014	physicsworld.com	Fine-tuning quantum features to develop future technologies	http://blog.physicsworld.com/2014/09/01/fine-tuning-quantum-features-to-develop-future-technologies/
09-05-2014	TechNewsWorld	Google Ratchets Up Quantum Computing Efforts	http://www.technewsworld.com/story/80997.html
09-06-2014	Tech Cheat Sheet	What Is a Quantum Computer, and Why Is Google Building One?	http://wallstcheatsheet.com/technology/what-is-a-quantum-computer-and-why-is-google-building-one.html/?a=viewall
09-07-2014	Great Local News: Boston	Google Ratchets Up Quantum Computing Efforts	http://boston.greatlocalnews.info/?p=26342
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03-12-2014	Nature.com	Physics: Quantum computer quest	http://www.nature.com/news/physics-quantum-computer-quest-1.16457
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17-02-2015	Waterloo Region Record	UW grad shortlisted for one-way Mars mission	http://www.therecord.com/news-story/5341116-uw-grad-shortlisted-for-one-way-mars-mission/
17-02-2015	uWaterloo Stories	Waterloo grad shortlisted for one-way trip to Mars	https://uwaterloo.ca/stories/waterloo-grad-shortlisted-one-way-trip-mars
18-02-2015	University Affairs	Waterloo shines a light on Canadian innovation at AAAS	http://www.universityaffairs.ca/opinion/margin-notes/waterloo-shines-light-canadian-innovation-aaas/?utm_source=newsletterfeb18_15&utm_medium=email&utm_content=MN_AAAS&utm_campaign=ataglanceEN&utm_source=University+Affairs+e-newsletter&utm_campaign=80b3a0e936-At_a_Glance_Feb18&utm_medium=email&utm_term=0_314bc2ee29-80b3a0e936-425253017
18-02-2015	www.SEOFactorFiction	From molecular biology to quantum computing – Charles H. Bennett	http://www.seofactorfiction.com/quantum-computers/from-molecular-biology-to-quantum-computing-charles-h-bennett/
25-02-2015	Computerworld	Emerging enterprise techs to watch	http://www.computerworld.com/article/2885580/emerging-enterprise-techs-to-watch.html?nsdr=true
25-02-2015	Waterloo Chronicle	Another step closer to Mars	http://www.waterloochronicle.ca/news/another-step-closer-to-mars/
02-03-2015	Phys.org	Light, meet matter: Single-photon quantum memorey in diamond optical phonons at room temperature	http://phys.org/news/2015-03-single-photon-quantum-memory-diamond-optical.html
03-05-2015	Daily Bulletin	Grad makes one-way Mars trip's shortlist	http://www.bulletin.uwaterloo.ca//2015/mar/05th.html

Date	Media Outlet	Title	URL
03-10-2015	Exchange Morning Post	How to be cyber-safe in a quantum world	http://www.exchangemagazine.com/morningpost/2015/week10/Tuesday/15031010.htm
10-Mar-15	Student Science	How to pick up messages after they're gone	https://student.societyforscience.org/article/how-pick-messages-after-they%E2%80%99re-gone
03-12-2015	Waterloo Region Record	Online risks in a quantum world	http://m.therecord.com/news-story/5474935-online-risks-in-a-quantum-world/
03-12-2015	.@uwaterloo alumni newsletter	Embracing the Spirit of Experimentation	https://uwaterloo.ca/alumni/node/2587
03-13-2015	Canadian Jewish News	Hamilton native wants to live on Mars	http://www.cjnews.com/amy-grief-special-cjn/hamilton-native-wants-live-mars?&article_id=20714980009
03-19-2015	Quartz India	These ten guys aced the IIT entrance exam. Here's what they're doing after graduation	http://qz.com/363388/these-ten-guys-aced-the-iit-entrance-exam-heres-what-theyre-doing-after-graduation/?article_id=20770964842
03-23-2015	Phys.org	Quantum correlation can imply causation	http://phys.org/news/2015-03-quantum-imply-causation.html
03-23-2015	newswise	Quantum Cause and Effect	http://www.newswise.com/articles/quantum-cause-and-effect
03-23-2015	e-science news	Quantum correlation can imply causation	http://esciencenews.com/articles/2015/03/23/quantum.correlation.can.imply.causation
03-23-2015	Perimeter website	Quantum Cause and Effect	https://perimeterinstitute.ca/news/quantum-cause-and-effect
03-23-2015	Photonics Online	Quantum Correlation Can Imply Causation	http://www.photonicsonline.com/doc/quantum-correlation-can-imply-causation-0001
03-24-2015	Exchange Morning Post	Quantum correlation can imply causation	http://www.exchangemagazine.com/morningpost/2015/week12/Tuesday/15032406.htm
03-27-2015	Exchange Morning Post	A global index of wellbeing one goal of new Canadian Queen Elizabeth II Diamond Jubilee Scholarships	http://www.exchangemagazine.com/morningpost/2015/week12/Friday/15032703.htm

Date	Media Outlet	Title	URL
03-27-2015	Simcoe.com	Oro-Medonte teen goes asteroid hunting	http://www.simcoe.com/news-story/5528429-oro-medonte-teen-goes-asteroid-hunting/
03-29-2015	infodimanche.com	Conférence sur les technologies de l'information quantique	http://www.infodimanche.com/actualites/societe/215250/conference-sur-les-technologies-de-linformation-quantique
03-30-2015	physicsworld.com	Entangled photons cast a new light on cause and effect	http://physicsworld.com/cws/article/news/2015/mar/30/entangled-photons-cast-a-new-light-on-cause-and-effect
03-31-2015	Phys.org	Photon 'afterglow' could transmit information without transmitting energy	http://phys.org/news/2015-03-photon-afterglow-transmit-transmitting-energy.html#ajTabs

P. IQC Governance

Executive Committee

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

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.

Ian Goulden, Dean, Faculty of Mathematics, University of Waterloo

Ian Goulden obtained his BMath degree from the University of Waterloo in 1976, graduating with the inaugural Alumni Gold Medal for highest academic achievement. He remained at Waterloo for an MMath (1977) and PhD (1979), followed by an NSERC Postdoctoral Fellowship. He joined the Department of Combinatorics and Optimization as a faculty member in 1980, becoming a full professor in 1990. Dr. Goulden served as Department Chair during 1988-93, 1996-98, and 2009-10, and as Director of the Faculty of Mathematics Business programs in the late 1990's. Dr. Goulden is now serving as Dean, Faculty of Mathematics for a five year term which started July 1, 2010. Dr. Goulden became a Fellow of the Royal Society of Canada in 2010 and is well known for his research in algebraic combinatorics. Dr. Goulden is also highly regarded as an instructor, and was a winner of the Faculty of Mathematics Award for Distinction in Teaching in 2009. He lives in Waterloo with his wife Susan, and daughters Jennifer and Karen.

Raymond Laflamme, Executive Director, Institute for Quantum Computing

Raymond Laflamme was born in Quebec City and did his undergraduate studies in Physics at Universite Laval. He then moved to Cambridge, England, where he survived Part III of Mathematical Tripos before earning his PhD in the Department of Applied Mathematics and Theoretical Physics (DAMTP) under the direction of Stephen Hawking. Laflamme and Don Page are responsible for having changed Hawking's mind on the direction of time in a contracting Universe (as described in Hawking's best-seller "A Brief History of Time"). After his PhD, Laflamme became a Killam post-doctoral fellow at the University of British Columbia, where he met his future wife Janice Gregson. He moved back to Cambridge in 1990 as a Research Fellow at Peterhouse. He finally settled down for nine years at Los Alamos National Laboratory. He arrived as a postdoctoral fellow, then became an Oppenheimer Fellow in 1994, just after the birth of his son Patrick. His daughter Jocelyne was born in 1995. In 2001 he joined the Perimeter Institute for Theoretical Physics as a

founding member. He has founded the Institute for Quantum Computing with Michele Mosca and has been its Executive Director since 2002.

Terry McMahon, Dean, Faculty of Science, University of Waterloo

Terry McMahon obtained his B.Sc (Hons.) degree in Chemistry from the University of Alberta and his Ph.D. in Physical Chemistry from the California Institute of Technology. Following a period on the faculty of the University of New Brunswick he moved to the University of Waterloo as a Full Professor in 1984. He served as the Director of the Guelph-Waterloo Centre for Graduate Work in Chemistry, $(GWC)^2$, from 1988 to 1991 and as Chair of the Department of Chemistry from 1995 to 1998 and again from 2000 to 2007. In July 2007 he became Dean of Science. He has published ~180 articles in his research area of structure, energetics and reaction dynamics of gaseous ions. In recognition of his research accomplishments he has received the E.W.R. Steacie Fellowship and the Barringer Award of the Spectroscopy Society of Canada. In 2005 he was installed as University Professor, the University of Waterloo's top academic honour.

Michele Mosca, Deputy Director, Academic, Institute for Quantum Computing

Michele Mosca obtained a BMath at Waterloo in 1995 and was recipient of the Mathematics Faculty Alumni Gold Medal. He went to Wolfson College, University of Oxford, on a Commonwealth Scholarship, and received an MSc in Mathematics and the Foundations of Computer Science (with Distinction) in 1996. He continued at Oxford on a UK Communications-Electronic Security Group scholarship, obtaining a DPhil in quantum computer algorithms in 1999 while holding the Robin Gandy Junior Research Fellowship.

He is a co-founder and the Deputy Director of the Institute for Quantum Computing, and a founding member of the Perimeter Institute for Theoretical Physics. Since 1999 he has been a faculty member in the Combinatorics & Optimization department of the University of Waterloo, and a member of the Centre for Applied Cryptographic Research, with cross-appointments in Computer Science and Physics. Dr. Mosca has made major contributions to the theory and practice of quantum information processing, particularly in the areas of quantum algorithms, techniques for studying the limitations of quantum computers, quantum self-testing and private quantum channels. Together with collaborators at Oxford, he realized several of the first implementations of quantum algorithms using Nuclear Magnetic Resonance. He has made major contributions to the phase estimation approach to quantum algorithms, including the hidden subgroup problems, and quantum searching and counting. In the area of quantum security, he helped define the notion of private quantum channels and develop optimal methods for encrypting quantum information using classical keys.

Pearl Sullivan, Dean, Faculty of Engineering, University of Waterloo

Pearl Sullivan received her BEng with distinction (1985) and MASc (1986) degrees from the Technical University of Nova Scotia in metallurgical engineering. In 1990, she earned a PhD from the University of British Columbia in materials engineering, specializing in the failure of

carbon-fibre reinforced composite materials. Dr. Sulliv an started her academic career at Nanyang Technological University, Singapore, in 1991 before returning to Canada in 1994 to join the Department of Mechanical Engineering at the University of New Brunswick. She was twice honoured with the UNB Faculty Merit Award for Excellence.

In 2004, Dr. Sullivan became a faculty member of the University of Waterloo's Department of Mechanical and Mechatronics Engineering and served as its Department Chair from 2006 to 2011. She was recognized with the university's Outstanding Performance Award in 2009. A strong believer in interdisciplinary research, she was the founding Director of the collaborative graduate program in Nanotechnology within the university's Faculties of Engineering and Science. Dr. Sullivan began her term as Dean of Engineering in July 2012. She currently serves on the Ontario Research Fund Advisory Board, and remains active in research of degradation and failure of polymers and their composites due to aging and moisture.

Board of Directors

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

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.

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

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

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

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.

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

Complete biography listed under Executive Committee.

Robert Crow, Executive in Residence, Institute for Quantum Computing

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

Bob's career includes lengthy service in the private, Non Governmental Organization, and university sectors as an executive, consultant, and teacher. He is especially known as a strategic thinker and builder of organizational capacity in settings where technology and public policy intersect. A frequent speaker, Bob is an informed and articulate advocate for his organizations and their missions.

Bob is the former Vice-President for Industry, Government and University Relations at Research In Motion Limited (RIM), where he built and led RIM's global programs in government relations, community relations, corporate responsibility, market intelligence and university research. Bob's teams supported RIM's rapid international expansion from 2001 – 2011 and were especially noted for their ability to create and defend access to foreign markets, often under challenging circumstances.

Prior to joining RIM in July 2001, Bob was Vice-President Policy at the Information Technology Association of Canada (ITAC) where he successfully positioned ITAC as a business association of credibility and influence in the Canadian policy milieu. Prior to this, he served from 1975 – 1998 at Ryerson University in Toronto as both professor of planning and senior administrator in a wide variety of roles including Information and Communication Technology strategy development, establishment of a technology centre, and leader of Ryerson's advancement activities.

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

Cosimo Fiorenza, VP and General Consul, Quantum Valley Investments

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

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

Mark Pecen, CEO, Approach Infinity Inc.

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

Peter Hackett, Professor, University of Alberta

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

David Fransen, Former Consul General Canadian Consulate in Los Angeles

David Fransen worked from 1985 to 1988 at the Privy Council Office, where he provided policy advice related to such developments as the Green Plan in 1990, the drafting of the Canadian Environmental Assessment Act and the Canadian Environmental Protection Act, and the creation of the Canadian Environmental Assessment Agency. He then became Director of Economic Framework Policies in the Strategic Policy Branch of Industry Canada. In 1999, David became the Director General of the Centre for Healthy Human Development at Health Canada. He became Assistant Deputy Minister of the Industry Sector in 2003, where he was primarily responsible for providing policy advice and delivering programs related to some of Canada's key economic sectors. He became executive director of the Institute for Quantum Computing in 2006. He was most recently the Consul General, Canadian Consulate General in Los Angeles.

Peter E. Brown, Senior Practice Partner, Deloitte Canada

Peter E. Brown, CPA CA, ICD.D., is a Senior Practice Partner in Deloitte Canada. Peter has close to 30 years' experience in public accounting, serving clients in both the public and private sectors. He has gained significant international experience in assurance and advisory services and has extensive experience with business advisory services. Peter served as Managing Partner for Deloitte's Atlantic Practice until 2008 when Peter relocated to Toronto to assume the role of Managing Partner and National Leader for Private Company Services. In 2011, Peter's responsibilities were expanded to include the entire middle market for Deloitte Canada. In 2013 Peter relinquished these responsibilities and was appointed to Deloitte Canada's Client Cabinet which is comprised of senior leaders with firm wide market responsibilities.

Peter is the co-author of The Power of The Best, published in September 2012, the sequel to Building the Best - Inside Canada's Best Managed Companies. Peter is a frequent speaker on topics of entrepreneurship and what makes Best Managed companies unique. Peter has also served on the Board of Directors for Deloitte Canada.

Peter has a broad range of expertise in issues unique to entrepreneurs in privately held companies and to globally oriented mid-market companies. He also has extensive experience in leadership, strategic planning, mergers and acquisitions, and succession planning. His clients ranged from family owned businesses to global organizations in various industries, including transportation, consumer business, technology, real estate, professional services, and mining services. Peter's current portfolio of clients includes Fortis, Hatch, Stikeman Elliott LLP, Smart Centres, Spin Master and Major Drilling Group International Inc.

Peter has been involved in United Way both in the Atlantic Region and Toronto, in Chambers of Commerce throughout Atlantic Canada, and is a member of the Advisory Board for the Sobeys School of Business. Peter is also involved in Habitat for Humanity and served as part of a Deloitte Humanitarian Team that travelled to Brazil in October of 2011 to build homes and meet with local business leaders.

Peter is a graduate of St. Mary's University and is a member of the Canadian and Ontario Institutes of Chartered Accountants and a CPA (Illinois). Peter is a graduate of the Directors Education Program offered by the Institute of Corporate Directors and Rotman School of Management.

Scientific Advisory Committee

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

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

One of the highlights in the work of Buhrman is the article co-authored with Richard Cleve (University of Waterloo, Canada) 'Quantum Entanglement and Communication Complexity'. They demonstrated that with quantum entanglement certain communication tasks can be solved more efficiently. He also co-developed a general method to establish the limitations of quantum computers. He has written more than 100 scientific publications.

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

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

Prof. Gerard Milburn, University of Queensland

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.

Prof. Chris Monroe, University of Maryland

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

Umesh Vazarani, University of California

Umesh Vazirani is a professor in the Computer Science Division of the Department of Electrical Engineering and Computer Sciences at the University of California, Berkeley.

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

Prof. Anton Zeilinger, University of Vienna

Anton Zeilinger is a professor of physics at the University of Vienna (previously Innsbruck). Professor Zeilinger is known for multiple experiments in the realm of quantum interferometry and the demonstration of quantum teleportation. His work influenced the experimental progress in a new sub-field of physics, quantum information theory. He has contributed to theoretical physics and the foundations of quantum mechanics — he has showed an amplification of the Einstein-Podolsky-Rosen paradox, where one considers three, instead of just two, entangled particles.

Prof. Wojciech Zurek, Los Alamos National Laboratory

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

Q. IQC Administrative Staff

IQC Administrative Staff – 2014-2015

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