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2013

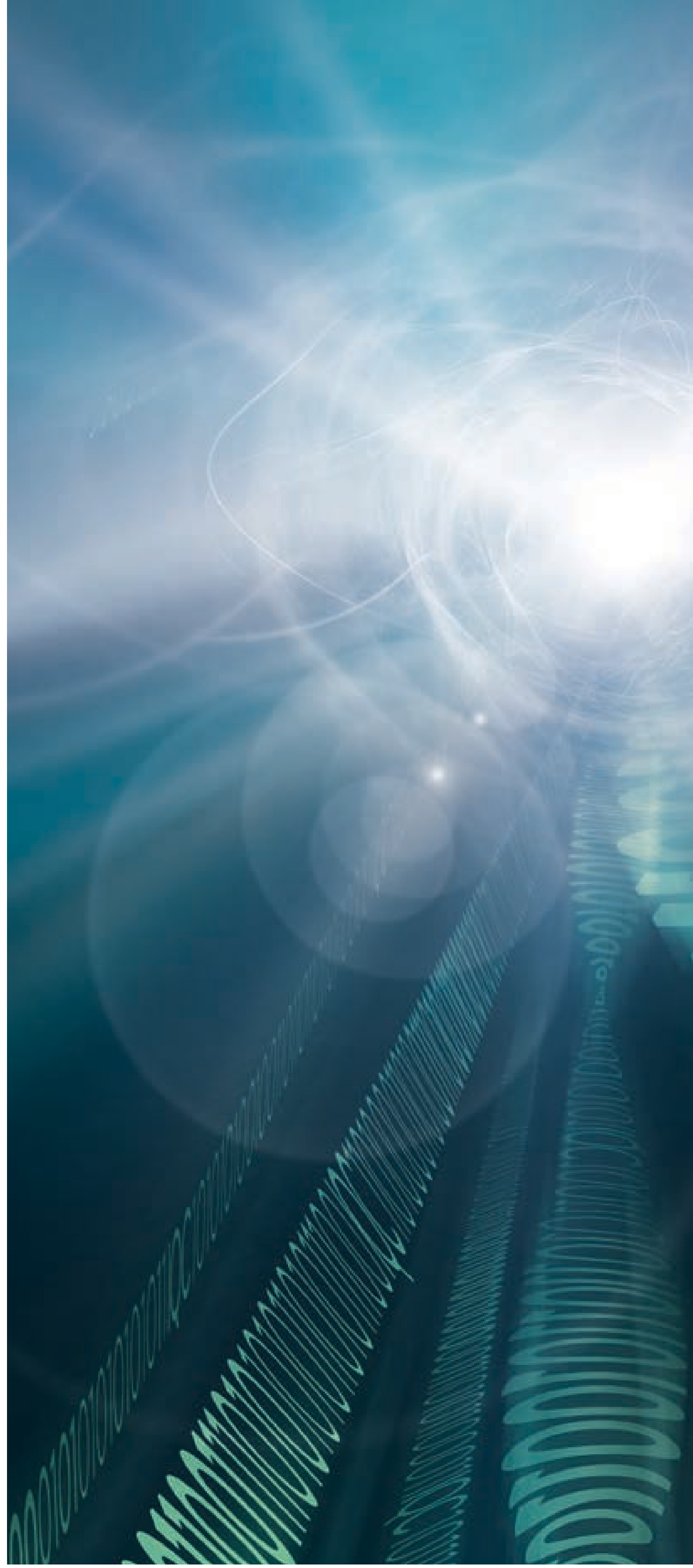
ANNUAL REPORT

THE QUANTUM REVOLUTION STARTS HERE

IQC Institute for Quantum Computing

"The Institute for Quantum Computing will advance our understanding of matter and movement, illuminating deep mysteries with the light of scientific discovery."

Professor Stephen Hawking



Quantum mechanics redefines reality at the atomic scale. In the quantum realm, the rules are different: objects can be in two states simultaneously and can be altered merely by observation. The interplay of atoms, molecules and photons at the quantum scale provides the blueprint for a technological revolution.

Researchers at the Institute for Quantum Computing are uncovering the reality of this microscopic world and harnessing the power of quantum mechanics to create next-generation technologies that promise to transform our world. Ultra-powerful computers, unbreakable cryptography, quantum devices, quantum materials and nanotechnologies of unprecedented precision are some of the discoveries being pioneered at IQC.

Welcome to the next quantum revolution.

Published by:
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2013

Annual Report

The drive for excellence and innovation

World-class science, world-class people

A magnet for the world's best

IQC to the world; the world to IQC

The year in review

IQC Institute for Quantum Computing

The drive for excellence and innovation

IQC's 10th anniversary last year was marked by the expansion into the Mike & Ophelia Lazaridis Quantum-Nano Centre. The Lazaridis Centre was designed with state-of-the-art technical facilities and collaboration spaces to provide the right environment for leading-edge quantum information research. Commissioning the labs in such a complex building is a very challenging task, but the work is on track and experimental research in the Lazaridis Centre is expanding steadily. The Board of Directors has nothing but praise for the IQC people involved.

The Board was very happy to note that the University of Waterloo has embraced IQC's vision, naming quantum information as one of the university's top three research priorities in its plan for the next five years. This is a very important step for both IQC and Waterloo. It emphasizes that this university, which values excellence, entrepreneurship and innovation, provides a most supportive culture for IQC's mission, namely to help outstanding students connect excellent research in quantum information with the development of revolutionary technologies.

It is always a pleasure to welcome new members to IQC. This year, I particularly wish to welcome Steve MacLean, former president of the Canadian Space Agency, who joins us as an associate member, and Harvard professor Amir Yacoby who is appointed IQC associate and Distinguished Chair in Condensed Matter. The experience and insight that these outstanding new colleagues bring to IQC will substantially enrich the capabilities of the IQC community.

As always, we are most happy to welcome new postdoctoral researchers and graduate students to the IQC community. These exceptional young researchers from all over the world arrive at IQC to contribute their talent, energy and thirst for knowledge to frontier research in quantum information. It is a measure of IQC research strength that the postdocs now total 46, and the graduate students 103. We are well on our way to reaching or surpassing our goal of 33 faculty members, 65 postdocs and 165 graduate students, a goal that seemed little more than a dream just a few years ago.

The Board of Directors has begun a process of renewal. On behalf of the Board of Directors, and of IQC as a whole, I wish to thank founding board members Douglas Barber and William Pulleyblank for their valued contributions. They have consistently raised important, and sometimes difficult, questions and offered perceptive insights, and have made IQC stronger as a result.

Finally, let me say once again that IQC would not be the success that it is without the visionary leadership of Executive Director Raymond Laflamme. He has led the growth of IQC in stature and accomplishment, and his own prominence has grown with it. I am proud to be associated with him, and with IQC.

Tom Brzustowski
Chair of the Board, IQC

2013

Curiosity is the driving force of innovation. Our desire to understand how the world around us operates leads us to the need to control that world and create technologies to benefit society. Today, we are harnessing the impressive power of even the smallest quanta of matter. As a result, technologies are emerging that will transform our everyday lives, technologies in computing, secure communications, medicine and beyond.

Over the past decade, IQC has been a leading force in the quantum revolution with significant advancements in quantum information research spanning the areas of quantum computation, communications and sensors that are the foundations for the years to come. Research results include the development of algorithms, control methods for quantum processors and laboratory demonstrations of quantum technologies. In the last year we have also built the infrastructure to develop quantum materials that we will use at the core of quantum devices. Fabrication and engineering of these new technologies will be a research focus in the coming years and IQC is well positioned at the forefront of new discoveries in this area.

Over the next decade, I'm excited by the opportunities our research presents. It's hard to imagine as I look back that today we have startup companies from IQC research, we have spin-off technologies already on the market and the future of quantum technologies is boundless. Our extraordinary people have driven the history of excellence here at IQC and will continue to set the global standard for quantum information research and commercialization.

The drive for excellence will see Waterloo leading the quantum revolution and building a new industry – a quantum technology industry. Canada's Quantum Valley vision will become a reality where our research will spark new technologies, employ future generations and change the way we live, work and play. The vision and philanthropic support of Mike and Ophelia Lazaridis along with generous federal and provincial funding makes this possible.

I look forward to the next phase of research and excellence here at IQC. To all the individuals and organizations whose support and guidance allow IQC to continue down this road and lead the quantum revolution...thank you.

Raymond Laflamme
Executive Director, IQC

The view from here

An overview of IQC

Our Vision: harnessing quantum mechanics will lead to transformational technologies that will benefit society and become a new engine of economic development in the 21st century.

IQC was officially created in 2002, sparked by the vision of **Mike Lazaridis**, to foster pioneering research into the next revolution in technology – quantum information science. Harnessing the quantum laws of nature promises powerful new advances in fields spanning computing, communications and sensors – and IQC was created to lead this charge.

Throughout history, humans have learned to tame and control natural phenomena – fire, steam and electromagnetism, for example – to improve their lives. IQC is now harnessing nature at its most fundamental level.

Building on the University of Waterloo's long-standing strengths in engineering, mathematics and computer science, IQC quickly recruited world-class researchers in the theory underlying quantum information, providing the nucleus of excellence to attract experimentalists. This year, Waterloo named quantum science as one of three top research areas with the greatest potential for world leadership.

Today, IQC is a highly successful partnership between the University of Waterloo, the private sector, and federal and provincial governments.

IQC has created a unique training program for postdoctoral fellows and graduate students, and is intensifying communication and outreach programs. IQC – and Canada – are becoming internationally recognized as leaders in the global quantum information revolution.

IQC expanded into the Mike & Ophelia Lazaridis Quantum-Nano Centre in September 2012. This remarkable facility features a state-of-the-art cleanroom, cutting-edge experimental infrastructure and innovative spaces designed to foster dialogue between researchers. The Lazaridis Centre will be instrumental in propelling research advancements and collaboration as we build the future of quantum information technologies. Already spin-off companies and commercialized applications of quantum devices are being realized; this is just the beginning.

With IQC as a world-leader in quantum information research, Waterloo and Canada are becoming known as "Quantum Valley" – the epicentre of the next information revolution.

Strategic Objectives

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

"Waterloo stands amongst the world's leaders in the revolutionary field of quantum science. IQC brings together internationally recognized researchers who are already developing our understanding of the quantum world."

Feridun Hamdullahpur,

President, University of Waterloo

Our Mission: 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.

Curiosity drives innovation

Curiosity drove the first quantum revolution enabling us to understand the quantum world.

Today, the researchers at the Institute for Quantum Computing collaborate to harness the quantum world to revolutionize technology and drive future economies. Ultra-powerful computers, unbreakable cryptography, quantum devices and nanotechnologies of unprecedented precision are some of the discoveries being pioneered at IQC, many of which are hitting the market today. IQC is leading the industry evolving from this research.

Welcome to the next quantum revolution; the future is bright.

Core areas of research

Quantum Information Theory

Understanding how to harness quantum mechanical phenomena for computing, communications, sensors and other technologies.

Quantum Algorithms

Developing instructions used by quantum information processors to perform computations.

Quantum Complexity

Identifying which problems quantum processors can – and cannot – handle efficiently.

Quantum Cryptography

Providing information security by capitalizing on quantum effects.

Quantum Error Correction & Fault Tolerance

Understanding how to control quantum systems in the presence of imperfections and imprecision.

Spin-based Quantum Information Processing

Developing quantum processors that use the "spins" of quantum particles such as electrons and atomic nuclei.

Nanoelectronics-based Quantum Information Processing

Using nano-scale technologies such as quantum dots or superconducting circuits to implement quantum processing.

Optical Quantum Information Processing

Using the properties of light particles, or photons, to carry and process quantum information.

Attracting world-class people

Amir Yacoby appointed IQC Associate

A new lab at IQC will focus on implementing quantum information processing in condensed matter systems. **Amir Yacoby**, a renowned experimental condensed matter physicist, has been appointed as an IQC associate and the Distinguished Research Chair in Condensed Matter.

A professor of condensed matter physics at Harvard University, Yacoby will spend three months each year as a visiting professor in Waterloo participating in research at IQC.

His research explores quantum phases of matter in reduced dimension and their applications towards quantum information science. One challenge in solid state implementations of quantum computation is coupling qubits over long distances, such as several microns, while maintaining their coherence. If long distance coupling can be achieved, this may lead to the integration of many qubits on a single chip.

"Most discoveries in science, including those that lead to societal impact, were never planned," says Yacoby. "I'm looking forward to the hidden surprises and discoveries that will happen here at IQC."

Steve MacLean goes back to his roots

One of the first six Canadian astronauts selected for training in the mid-eighties, **Steve MacLean** was the Program Manager for the Advanced Space Vision System and the Laser Camera System. A laser physicist, the former president of the Canadian Space Agency is now an associate member of IQC.

MacLean holds a PhD in Physics from York University. His research has covered electro-optics, laser-induced fluorescence of particles and crystals and multi-photon laser spectroscopy.

"I'm going back to my roots," says MacLean. "I've always been a physicist at heart. A change is coming in how we build useful devices using the ideas of quantum mechanics. I'm excited to be a part of that here at IQC."

MacLean's research at IQC will focus on the development of attosecond lasers. An attosecond is one quintillionth of a second. This type of laser would produce shorter and more powerful pulses of light, allowing for images as precise as the space between atoms to be captured.

Faculty

Research at IQC is fundamentally interdisciplinary, spanning theory and experiment to pursue every avenue of quantum information science. IQC fosters collaborations across the sciences and across borders. Our researchers are appointed to both IQC and one of six departments across three faculties at the University of Waterloo: Combinatorics and Optimization, Applied Mathematics or Computer Science in the Faculty of Mathematics; Physics and Astronomy or Chemistry in the Faculty of Science; and Electrical and Computer Engineering in the Faculty of Engineering.

Jonathan Baugh
Chemistry
IQC member since **2007**

Andrew Childs
Combinatorics and Optimization
IQC member since **2007**

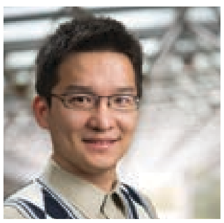
Richard Cleve
School of Computer Science
IQC member since **2004**

David Cory
Deputy Director, Research
Chemistry
IQC member since **2010**

Joseph Emerson
Applied Mathematics
IQC member since **2005**

Thomas Jennewein
Physics and Astronomy
IQC member since **2009**

Hamed Majedi
Electrical and Computer Engineering
IQC member since **2005**

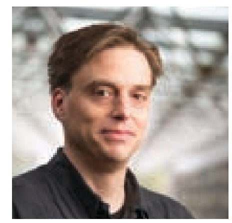


Guo-Xing Miao
Electrical and Computer Engineering
IQC member since **2011**

Michele Mosca
Deputy Director, Academic
Combinatorics and Optimization
IQC member since **2002**

Ashwin Nayak
Quantum Information Graduate Program Director
Combinatorics and Optimization
IQC member since **2002**

Kevin Resch
Physics and Astronomy
IQC member since **2006**



John Watrous
School of Computer Science
IQC member since **2006**

Robert Koenig
Applied Mathematics
IQC member since **2012**

Raymond Laflamme
Executive Director
Physics and Astronomy
IQC member since **2002**

Debbie Leung
Combinatorics and Optimization
IQC member since **2005**

Adrian Lupascu
Physics and Astronomy
IQC member since **2009**

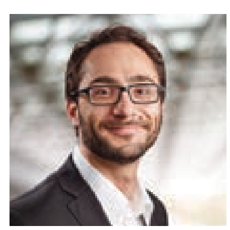
Norbert Lutkenhaus
Physics and Astronomy
IQC member since **2006**

Matteo Mariantoni
Physics and Astronomy
IQC member since **2012**

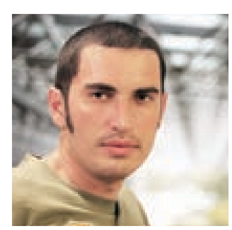
Christopher Wilson
Electrical and Computer Engineering
IQC member since **2012**

Research Assistant Professors

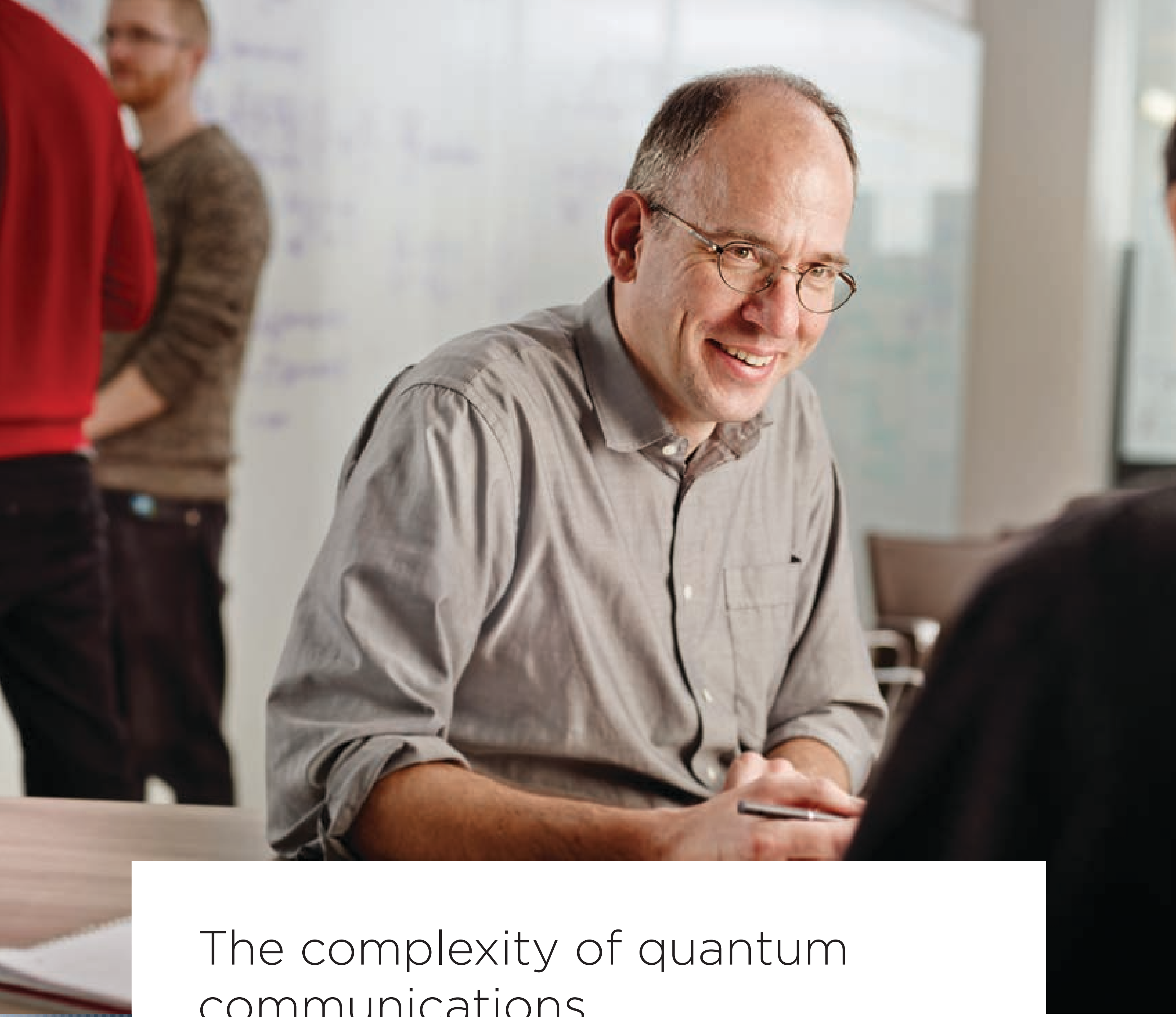
Vadim Makarov
Physics and Astronomy
IQC member since **2012**



Marco Piani
Physics and Astronomy
IQC member since **2010**



Dmitry Pushin
Physics and Astronomy
IQC member since **2010**



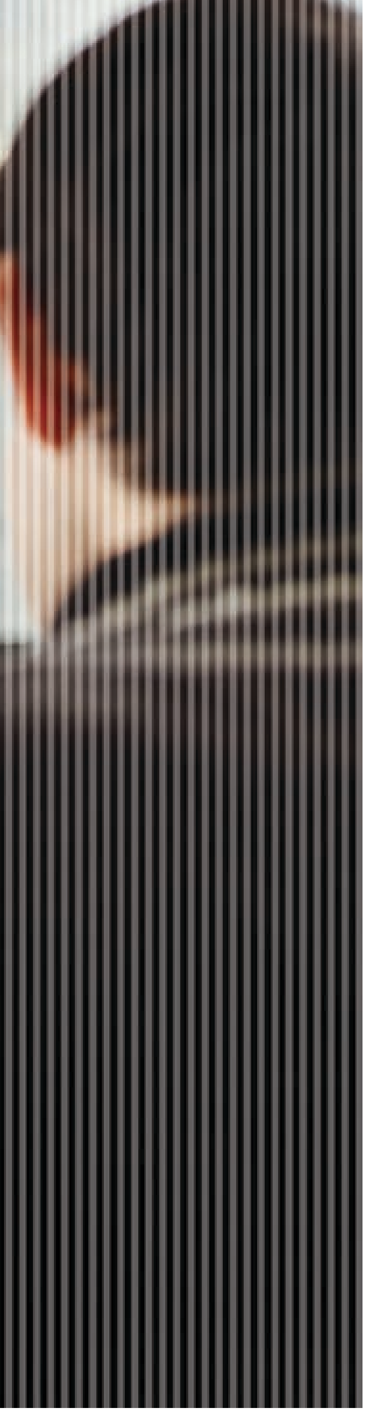
The complexity of quantum communications

IQC researcher and practical theorist Norbert Lutkenhaus is a big picture thinker.

When tackling a problem, he reflects on the entire spectrum from abstract theory to implementation design to experimentation. Developing theoretical ideas considering current technology and giving thought to the types of physical systems experimentalists are using in the lab often leads to results that can be realized in the short term.

Norbert Lutkenhaus (shown above) lends this perspective to his research in the area of quantum communications, investigating the interface between quantum information and optical implementation. Most recently, Lutkenhaus and PhD student **Juan Miguel Arrazola** (shown right), with support from IQC researcher **Richard Cleve**, have made progress in the field of communication complexity — the study of how much communication is required for two parties to accomplish certain common tasks, known as performing distributed computations.

Consider two separate parties who each receive a message, but need to convince a third, entrusted party that the messages are, in fact, the same. The two parties do not have a direct line of communication with each other and can only send input to the third party. How can this task be accomplished with the fewest resources possible?



Cleve and collaborators established that using quantum bits instead of classical bits to accomplish this task requires exponentially fewer resources. Now, Lutkenhaus and Arrazola have developed a protocol ready for implementation using the quantum mechanical properties of optical systems. They also show that experimental imperfections do not prevent the protocol from achieving the same results. Furthermore, in an ideal situation, the energy resource of the protocol is constant, no matter how large the message.

This protocol has practical applications for communication systems, but also for computer circuit and chip design, such as potential savings in energy and communication costs, and the technology needed to realize these results is currently available. When it comes to the unfamiliar, however, seeing is believing, says Lutkenhaus. The next step is to build a system that uses this quantum communication protocol. Once a physical system produces the observable exponential savings in communication resources, those who build communication infrastructures, such as optical communication engineers, may see the impressive potential of the protocol as quantum networks evolve.

Constant-Energy Quantum Fingerprinting
http://arxiv.org/abs/1309.5005

The promise of the unknown

As technology advances, the unknown applications that this quantum communication breakthrough could have in the future are just as promising as the short-term realizations. Quantum communication protocols could become the basis for new concepts in communication system design, or be useful in solving problems in other research areas.

A practical research approach bridges the gap between the theoretical and experimental perspectives of quantum information science. This complete perspective considers the future, starting from the theoretical proposal of an idea through to the implementation and commercialization of a proven concept. As Lutkenhaus puts it, building beyond the science is how the future of quantum communications will be realized.

Student profile: Juan Miguel Arrazola

The promise of uncertainty

IQC PhD student **Juan Miguel Arrazola** is fascinated by the interdisciplinary world of quantum information science. Complex problems that require the simplicity of creative thinking are the types of challenges he finds motivating. He recognizes collaboration with supervisor **Norbert Lutkenhaus** and other IQC faculty members, postdoctoral fellows and students from across all areas of quantum information science as a fundamental part of his research in communication complexity.

Although it is rewarding to see the implementation of his practical theory results, what Arrazola finds the most exciting about quantum information science is the promise of uncertainty. As quantum technologies advance, he sees research applications expanding and even permeating areas outside of quantum information science. While it's uncertain what impact this research will have, Arrazola is certain he wants to be a part of it.

Taking quantum into space

Privacy and data security are two of the hottest topics in the news today.

One opportunity for ultra-secure communication is Quantum Key Distribution (QKD). QKD utilizes the laws of quantum mechanics to establish a secure key between two parties – a key comprised of entangled photons, particles of light. Once this key is established, any attempt to intercept the key will be detected – quantum mechanics tell us that if you look at a quantum state you perturb it, so the state of the key will be disturbed. Unlike systems today where we don't know that systems are being intercepted, QKD establishes a truly secure network where you can continue to exchange keys until a secure channel is created.

Today's commercial QKD systems connect through fibre-optic cable, but are limited to less than 200 kilometres before the photons are absorbed into the fibre. With quantum repeaters still in the very early phases of research, the challenge becomes establishing a quantum network at global distances.

This is a challenge IQC faculty member **Thomas Jennewein** (below) and his team, postdoctoral fellow **Brendon Higgins** and PhD students **Jean-Philippe Bourgoin** (shown right), **Catherine Holloway**, and **Chris Pugh** have gladly accepted. Their research looks to create a global quantum communications network using satellites.

Jennewein's satellite mission proposal, **Quantum Encryption and Science Satellite project** (QEYSSAT), brings together the Canadian Space Agency and space hardware designer and manufacturer COM DEV for the development of a global satellite-based quantum communications network. In this satellite project, quantum information is generated and distributed using single or entangled photon sources located at a ground station and sent in a tight beam up towards the satellite receiver – called an "uplink". By keeping the photon source on the ground and sending the photons up, Jennewein and his team can manipulate the ground source – a more complex and fragile technology than the photon detectors on

the satellite – which allows flexibility for future experiments, expanding the potential possibilities of the project. With support from the Canadian Space Agency, Government of Canada's Federal Economic Development Agency for Southern Ontario and collaborators from Communitech's DATA.Base project, IQC is advancing the overall concept of the satellite mission proposal and showing the readiness of this quantum technology for space.

The next step in the project will be to demonstrate the satellite pointing system to track and maintain a link between a fixed ground station and a moving quantum receiver. The low-earth orbit satellite when in operation will be located about 500-600 kilometres from the ground and will move at speeds in excess of 25,000 kilometres per hour. In preliminary experiments, the quantum transmitter stationed on the Research Advancement Centre (RAC) on the north end of the University of Waterloo campus, the current home of Jennewein's lab, performs QKD with a receiver mounted to a moving vehicle. Eventually, the team will mount the receiver to a flying system, such as a hot air balloon or a plane, to further advance the evolution of quantum transmission between a ground station and a moving satellite in space.

Once the satellite pointing system is successfully proven, Jennewein looks forward to collaborating with research groups around the world to demonstrate several quantum transmissions, moving one step closer to establishing a global quantum communications network.

A collaborative approach

Collaboration with other IQC researchers contributes to the progress of the satellite project. Jennewein works with experimentalist **Vadim Makarov** and theorists **Norbert Lutkenhaus** and **Michele Mosca**, experts in quantum cryptography and security theory, to bring the fundamental theory of quantum communications to realization through the development of working quantum devices and real-world applications.

Envisioning the future of quantum communications

Jennewein is confident that the cutting-edge research happening in the field of quantum communications will change the way we send, receive and store our private data as quantum computers become more practical. What possibilities could a secure quantum communications network lead to? Jennewein predicts a global exchange of quantum information between many different users may be next, laying the possible framework for the realization of a global-scale exchange of quantum information – the quantum internet.

Three-photon energy-time entanglement

NATURE PHYSICS 9 (2013)

IQC faculty member **Thomas Jennewein**, in collaboration with fellow IQC faculty member **Kevin Resch**, IQC postdoctoral fellows **Krister Shalm**, **Zhizong Yan**, IQC PhD student **Deny Hamel**, and University of Calgary researcher **Christoph Simon**, demonstrated a new form of quantum entanglement using three particles.

This is the first time that entanglement of the continuous properties, time and energy, of three photons has been shown in the lab. It is possible due to a new process used by the team called cascaded down-conversion of photons, first proposed by Greenberger, Horne, Shimony and Zeilinger over twenty years ago. A single input photon is converted to three particles or photons that are correlated between the energies and emission times of the photons. This source for correlated photon triplets allows researchers to test new states of three-photon entanglement, and leads to further applications in quantum information processing.

http://www.nature.com/nphys/journal/v9/n1/full/nphys2492.html OR **http://arxiv.org/abs/1203.6315**

Student profile: Jean-Philippe Bourgoin

On the career path to industry

Before returning to the Austrian Academy of Sciences in Vienna, Austria to complete a senior postdoctoral fellowship, IQC faculty member **Thomas Jennewein** spent time working as an engineering consultant in the automotive industry in Germany. Jennewein gained valuable industry insight, an experience he often draws from in his role as supervisor to PhD and Master's students at IQC. He challenges his students to maintain a complete perspective of their research from theory to application while developing exceptional project management, critical thinking, problem solving, team collaboration and concise communication skills – all necessary for success in a future role within industry.

Jean-Philippe Bourgoin is one PhD student eager to learn from the wealth of industry knowledge that Jennewein incorporates into his research and teaching. Bourgoin has been working with Jennewein for the past four years, from the initial stages of the **Quantum Encryption and Science Satellite** (QEYSSAT) project. His first task was performing a detailed link analysis to demonstrate the feasibility of **Quantum Key Distribution** (QKD) via satellite. Since then, he has been working on the experimental demonstration of the QEYSSAT mission proposal, most recently including the moving satellite receiver.

Keeping the bigger picture in mind, Bourgoin sees the need for a secure quantum communications network as quantum computers evolve. He is motivated by the very real impact that the application of his experimental research will have in the future. Bourgoin plans to enter a career in industry where he can work on the commercialization of satellite QKD and build the quantum cryptography infrastructure of the future.

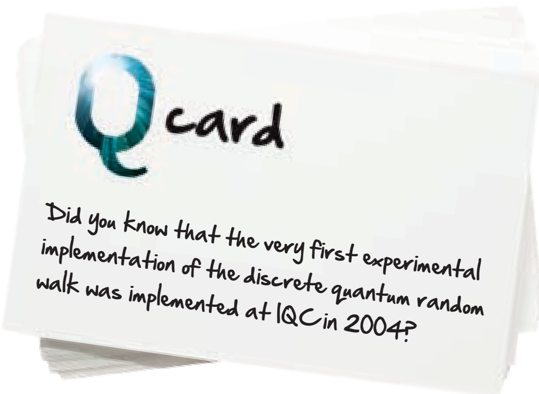
Taking a quantum walk with Andrew Childs

Can a quantum computer really solve problems more efficiently than a classical computer?

For some types of problems, the answer is yes. The ability of the quantum computer to use far fewer resources to solve a complex computational problem than a traditional, or classical, computer continues to fascinate scientists and engineers alike.

At the heart of a quantum computer is the quantum algorithm – a step-by-step procedure by which quantum information processors perform computations. IQC researcher **Andrew Childs** (shown above) and his team, postdoctoral fellow **David Gosset** (shown right) and PhD student **Zak Webb**, have made significant progress developing powerful quantum algorithm techniques based on multi-particle quantum walks that may lay the groundwork for finding new ways to program and build quantum computers in the future.

A quantum walk is a quantum-mechanical process that allows a quantum particle to investigate in superposition a graph, or a mathematical structure consisting of interconnected nodes. The multi-particle quantum walk model recently proposed by Childs and his team explores this concept even further, allowing for many interacting particles to investigate a graph simultaneously. In principle, any quantum algorithm can be cast into this model that can perform any computation possible by a quantum computer. It provides a framework for coming up with new quantum algorithms. Without the need to actively manipulate qubits during a computation, this model has the potential to be used as an architecture for a quantum computer.



Looking ahead...

Although it remains unclear what kinds of problems a quantum computer may be useful for in the future, there are some promising possibilities. For example, the ability to efficiently simulate quantum systems could lead to advancements in understanding chemical processes, developing drugs and designing new materials.

Childs sees a bright future for quantum computation and the progress that will be made in the area of quantum algorithms and the applications of quantum computers. As the nature of the power of quantum computers is pieced together in the coming years, the understanding of true quantum capabilities will come to light.

Investigating computational hardness

Childs and his team are currently investigating the computational hardness of finding the ground state – the state with the lowest possible energy – of a multi-particle quantum walk. Their most recent work provides evidence that the ground state problem for one particular kind of multi-particle quantum walk, the Bose-Hubbard model, is hard to solve. This has cross-disciplinary implications in areas of condensed matter physics, where properties of the ground state are relevant, and in the area of computer science called computational complexity theory.

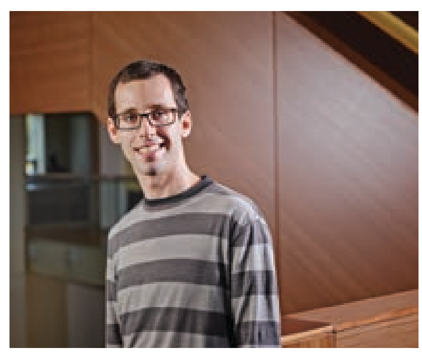
Quantum computation meets quantum communication

Communications in Mathematical Physics 323 (2013)

Collaboration between IQC faculty members **Andrew Childs**, a theorist in quantum computation, and **Debbie Leung**, a theorist in quantum communication, led to the discovery of a simpler proof of "nonlocality without entanglement." Imagine a scenario in which two different parties, Alice and Bob, each hold a quantum system. If their systems are entangled with each other, Alice and Bob may not be able to determine (with certainty) which quantum state they have using only local quantum operations and classical communication. Since entanglement cannot be created using only local quantum operations and classical communication, this result for entangled states is not so surprising. In fact, the same result can also occur even with unentangled states. This phenomenon, discovered by Bennett et al. in 1999, remains poorly understood.

Each bringing a unique perspective to the table, Childs and Leung, along with IQC PhD students **Laura Mancinska** and **Maris Ozols**, worked together to investigate this phenomenon, finding a simpler proof and extending it to cover more sets of states. Their paper *"A framework for bounding nonlocality of state discrimination"* appeared in *Communications in Mathematical Physics* 323 (2013).

[redacted] http://arxiv.org/abs/1206.5822
OR http://link.springer.com/article/10.1007%2Fs00220-013-1784-0



Postdoctoral Fellow: David Gosset

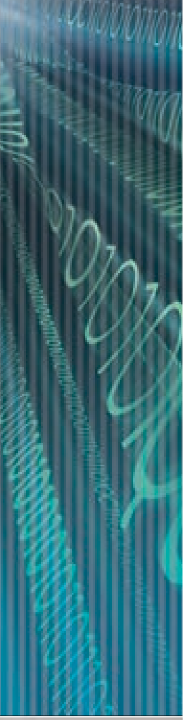
The next generation of leading researchers

It was reading the classic paper *"A quantum algorithm for the Hamiltonian NAND tree"* by Farhi, Goldstone and Gutmann during his first year of graduate school that piqued IQC postdoctoral fellow **David Gosset**'s interest in quantum computation.

Since then, his research in the areas of quantum algorithms and quantum complexity has contributed to the proposal of an entirely new way to perform quantum computation. This was the outcome of the right combination of new ideas and technical tools, explains Gosset, who collaborated with his supervisor **Andrew Childs** and PhD student **Zak Webb**. The resulting paper *"Universal computation by multi-particle walk"* appeared in *Science 339* (2013).

The experience he's gained working with supervisors Andrew Childs and **Michele Mosca**, as well as graduate and undergraduate students, has broadened Gosset's perspective of quantum information science. He describes IQC as a unique and amazing place to do research in this field. The incredible breadth of high impact, cutting-edge research is driven by the enthusiasm and interest of the leading quantum information researchers right here, says Gosset.

The environment has inspired Gosset to pursue a career in quantum computation research and teaching. It is an exciting time for quantum computation, he says. Gosset anticipates learning more about the computational power and complexity of realistic physical systems, and contributing to the many open questions in the field of Hamiltonian complexity.



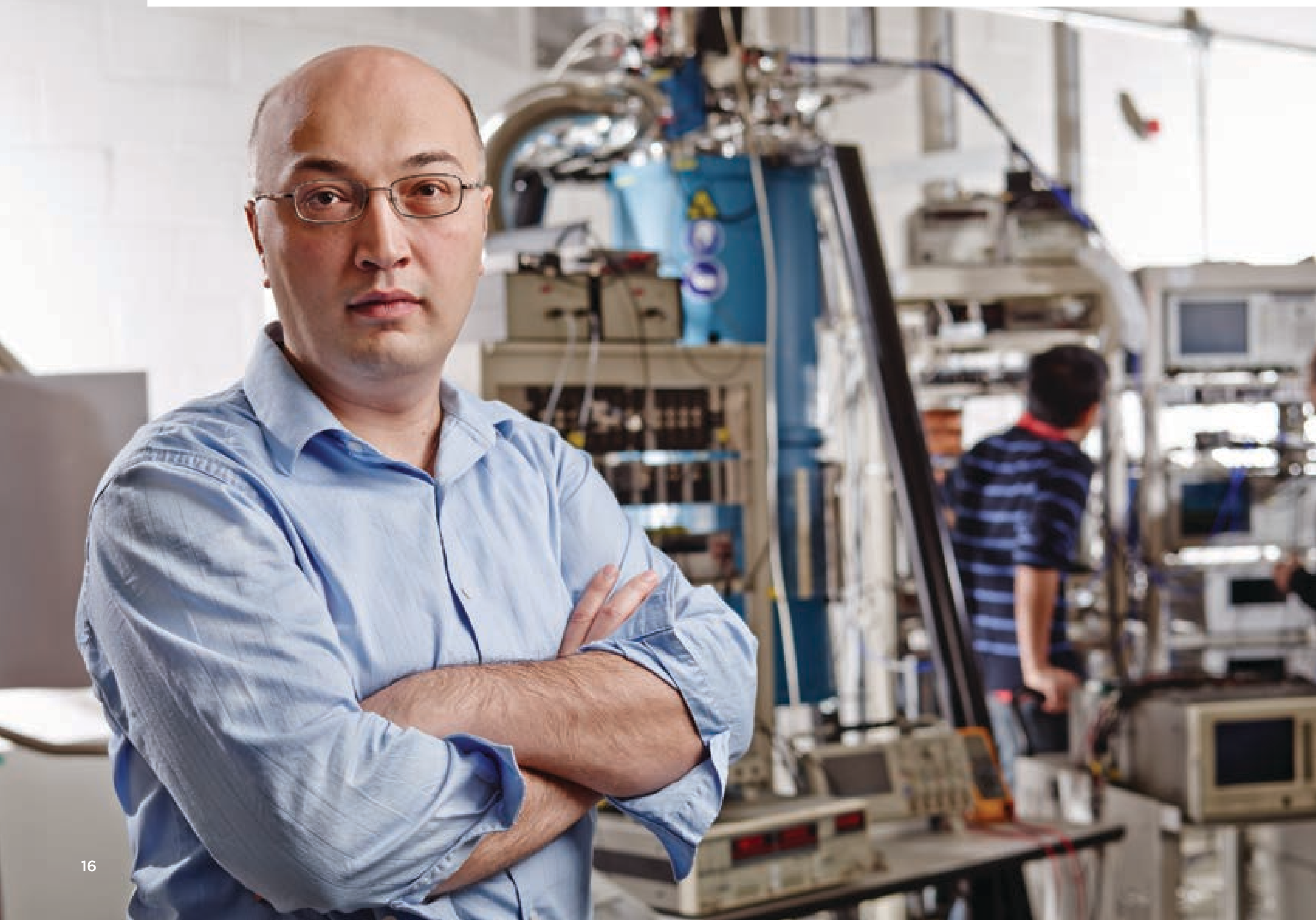
Building blocks of quantum technologies

Over the past decades, the understanding of quantum mechanics has led to research advancements in the manipulation and application of quantum devices.

This deepened comprehension of quantum devices provides new insight into the world of physics. The interplay between physics and its applications continues to intrigue IQC researcher **Adrian Lupascu** (shown below) and motivates his investigation in the area of superconducting quantum devices and sensors.

Using the properties of quantum mechanics, quantum sensors can reach the ultimate limits in resolution and sensitivity allowed by nature. This is useful in the detection of magnetic fields, a growing area of interest with many applications in science and technology, such as medical imaging, electrical measurement tools and material evaluation.

An effective quantum sensor depends on two parameters. The first is the coupling to the signal to be measured, such as a magnetic field, or the impact the signal has on the dynamics of the quantum sensor. The second is the decoherence of the system, or the process by which the information is lost due to interaction with its environment. Ideally, a quantum sensor provides strong coupling with slow decoherence, allowing a period of time for detection to occur. Typically, these parameters are contradictory to each other. Atomic systems tend to couple weakly to measurable signals, but preserve coherence for an extended period of time. Optimizing strong coupling and good coherence is a challenge when precision is required for the detection of a magnetic field.



Investigation by Lupascu and his research team, including postdoctoral fellows **Mustafa Bal** and **Florian Ong**, with PhD students **Chunqing Deng** and **Jean-Luc Orgiazzi**, led to the experimental demonstration of ultra-sensitive magnetic field detection using a single artificial atom. Lupascu and his team engineered an artificial atom from superconducting material, produced in IQC's fabrication facility. Lupascu and his team demonstrated that this quantum sensor compares favourably to other methods of detection, including superconducting quantum interference devices (SQUID) and atomic systems, when used to detect an oscillating magnetic field in the 100 kHz - 10 MHz frequency range. This initial proof-of-principle experiment opens the door to a significant increase in measurement precision compared to current techniques.

Building a quantum processor

Superconducting devices and quantum sensors will play a role in the future of quantum computing. The systems similar to the quantum sensors Lupascu's team is working on may be the future building blocks of quantum processors. Developments in this area will no doubt have an impact on advancing technology from how quantum devices are designed to what materials are used in their fabrication. Quantum information science is an interesting field, says Lupascu, with many surprises to come.

Student profile: Jean-Luc Orgiazzi

An interdisciplinary approach

The international path of IQC researcher **Adrian Lupascu**'s academic career began in his home country of Romania before taking him to the Netherlands, followed by France, where he studied with 2012 Nobel Prize for Physics co-recipient Serge Haroche. He then arrived in Canada to continue his research at IQC. Lupascu credits this global experience for his appreciation of working with a diverse group of researchers from various academic backgrounds. He encourages his students to seek these opportunities, recognizing collaboration as one of the key elements contributing to the progress his research group has made in the field of quantum sensors. The interdisciplinary character of quantum information science opens up new communication channels between chemistry, computer science, engineering, mathematics and physics.

PhD student **Jean-Luc Orgiazzi** (shown left) values the interdisciplinary and collaborative research experience at IQC and has been studying with Lupascu for the past four years. His engineering background drew him towards the experimental side of quantum information science. The quantum devices he works with at very low temperatures may be used towards the implementation of sensitive magnetic field sensors or even the basis of quantum processors in the future.

Recently, Orgiazzi has proposed the fabrication, design and characterization of a two-qubit platform circuit quantum electrodynamics (cQED) system with high coherence times – one requirement to achieve a scalable quantum computer. Inspired by these results, and seeing possible engineering solutions to other challenges of realizing a useable quantum processor, Orgiazzi plans to continue working in the field of quantum devices to be part of the development and discoveries.

Collaborative research drives towards 100 qubit system

In conversation with IQC researcher David Cory, Canada Excellence Research Chair

Quantum sensors, actuators, communication systems and computers will greatly impact our world. We have already seen quantum sensors provide more sensitivity and specificity than their classical counterparts. These quantum sensors are developed and deployed for important societal problems, for example, in relation to neutron studies of materials and to the oil industry for geological exploration. The sensors demonstrated so far use quantum algorithms and control methods with small quantum processors and find applications as far-reaching as metrology, fuel cell development, medicine and exploring Standard Model physics. Despite using only a single part of the overall quantum promise, these advances have been game changing.

These powerful advances are achieved with small systems and the quantum advantage is tied primarily to preserving coherence over a few qubits. The full impact of quantum information processing relies on having coherent control over larger systems of quantum particles where the Hilbert space is so complex that comparison to classical systems is meaningless. Recall that to fully simulate the dynamics of even 30 qubits is beyond the ability of any classical processor.

We are in the midst of a project to build a larger scale quantum processor by combining spin systems, superconducting electronics and qubits into one "hybrid" quantum processor. Nuclear and electron spin systems remain the most coherent and largest experimentally proven systems. Superconducting systems of qubits are the most flexible quantum systems and are open to easy engineering. Our research program aims to develop hybrid quantum processors where electron spins serve as quantum actuators, nuclear spins serve as qubits and superconducting circuits are the control and measurement apparatus for the electron spins. We plan for this processor to be about 100 physical qubits. It will enable us to explore how to control large processors, how to implement quantum error correction and provide a start to using quantum computers as non-trivial simulators of quantum physics.

The hybrid nature requires a broad range of expertise. Researchers are working together to explore the hybrid systems through experiments with low temperature and spin physics, as well as control theory and quantum information theory. This work brings together chemistry, physics, electrical engineering, math and computer science to effectively integrate this knowledge and apply it to one big goal – a 100 qubit quantum computer.

Graduate program

A message from the Quantum Information Graduate Program Director

Some of the most striking advances in quantum information have arisen from a confluence of ideas from different disciplines. The graduate program in quantum information at the University of Waterloo is designed to enable precisely such innovation by our young researchers. Offered as a collaborative effort by six academic units spanning three faculties (Engineering, Mathematics, Science), this multifaceted program exposes our students to a range of perspectives on the subject from the theoretical to the experimental. In fact, it includes the largest selection of courses in quantum information internationally. Beginning with foundational courses, bolstered by specialized ones, and culminating in research supervised by renowned researchers, the program provides the next generation of researchers with the resources and training to become leaders in the second quantum revolution.

IQC provides an unparalleled environment for quantum information research. We are home to one of the strongest and most diverse groups of faculty members in quantum computation, housed in a new building with state-of-the-art laboratories and design that engenders collaboration. Along with a weekly colloquium and informal institute-wide meetings, an active visitor and conference program, and a student exchange program with international partner institutions, this makes IQC a highly stimulating environment for scientific learning and discourse. We continue to attract brilliant students from a spectrum of academic and cultural backgrounds. Our students have won recognition in the form of prestigious scholarships and best paper awards at conferences. Many of our alumni are pursuing research at leading centres for quantum information worldwide.

I am excited and proud to have taken over the stewardship of the graduate program in early 2013. In less than four years, the program has grown from an ambitious dream to an exemplar in higher education. I can safely bet on our students to make ground-breaking discoveries during their stay at Waterloo, and later, as innovators in 21st century information technology.

Ashwin Nayak
Quantum Information Graduate Program Director

Courses

The University of Waterloo, in collaboration with the Institute for Quantum Computing, offers graduate students unique opportunities to learn about and engage in world-leading research in quantum information through a wide range of advanced research projects and advanced courses on the foundations, applications and implementation of quantum information processing.

Fall 2012

QIC 710
Quantum Information Processing

QIC 890
Theory of Quantum Communication

QIC 890
Magnetic Resonance and Spin-based Quantum Information Processing

QIC 890
Semidefinite Programming in Quantum Information

QIC 890
Design in Quantum Systems

Winter 2013

QIC 750
Implementation of Quantum Information Processing

QIC 890
Implementation of Quantum Communication

QIC 885
Quantum Electronics and Photonics

QIC 845
Open Quantum Systems

QIC 823
Quantum Algorithms

Spring 2013

PHYS 777
Sir Anthony Leggett Lecture Series

QIC 890/891
Selected Advanced Topics in Quantum Information

QIC 891
Topics in Quantum-Safe Cryptography

Graduate Students 2013

Megan Agnew
Matthew Amy
Elena Anisimova
Razeih Annabestani
Juan Miguel Arrazola
Srinivasan Arunachalam
Jason Boisselle
Jean-Philippe Bourgoin
Steven Casagrande
Grant Cleary
Alessandro Cosentino
Daniel Criger
Chunqing Deng
John Donohue
Amin Eftekharian
Agnes Ferenczi
Chris Ferrie
Kent Fisher
Joshua Geller
Naimeh Ghafarian
Kaveh Gharavi
Sevag Gharibian
Nickolay Gigov
Luke Govia
Christopher Granade
Matthew Graydon
Peter Groszkowski
Nupur Gupta
Vibhu Gupta
Holger Haas
Shima Bab Hadiashar
Deny Hamel
Minyang Han
Fatin Haque
Aimee Heinrichs
Ian Hincks
Catherine Holloway
Gregory Holloway
Erika Janitz
Stacey Jeffery
Tomas Jochym-O'Connor
Sarah Kaiser
Shitikanth Kashyap
Feyruz Kitapli
Vadym Kliuchnikov
Robin Kothari
Jeremy Kroeker
Stephane Labruyere
Alexandre Laplante
Jonathan Lavoie
Xian Ma
Easwar Magesan
Laura Mancinska
Iman Marvian
Michael Mazurek
Thomas McConkey
Corey Rae McRae
Evan Meyer-Scott
Maryam Mirkamali
Felix Motzoi
Hamidreza Nafissi
Takafumi Nakano
Mohamad Niknam
Joachim Nsofini
Jean-Luc Orgiazzi
Martin Otto
Yingkai Ouyang
Maris Ozols
Adam Paetznick
Kyungdeock Park
Om Patange
Chris Pugh
Daniel Puzzuoli
Farzad Qassemi
Wenling Qiao
Sadegh Raeisi
Ansis Rosmanis
Vincent Russo
Shihan Sajeed
Amir Jafari Salim
Yuval Sanders
Antonio Scotland
Milad Khoshnegar Shahrestani
Ala Shayeghi
Feiruo Shen
Jamie Sikora
Jamie Smith
William Stacey
Gelo Noel Tabia
Yongchao Tang
Denis-Alexandre Trottier
Cozmin Ududec
Paulina Corona Ugalde
Alexander Valtchev
Victor Veitch
Lydia Vermeyden
Zak Webb
Kyle Willick
Christopher Wood
Muhammet Yurtalan

Graduates

Congratulations to our 2013 graduates!

Matthew Amy
MMath Computer Science (Quantum Information)

Erika Janitz
MASc Electrical and Computer Engineering (Quantum Information)

Alexandre Laplante
MMath Computer Science

Jonathan Lavoie
PhD Physics

Laura Mancinska
PhD Combinatorics and Optimization (Quantum Information)

Michael Mazurek
MSc Physics

Christopher Pugh
MSc Physics (Quantum Information)

Gelo Tabia
PhD Physics (Quantum Information)

Denis-Alexandre Trottier
MSc Physics (Quantum Information)

Victor Veitch
MMath Applied Mathematics

Eric Webster
MMath Applied Mathematics (Quantum Information)

Postdoctoral Fellows

From May 1, 2012 to April 30, 2013

Mohammad Ansari
Mustafa Bal
Olaf Benningshof
Troy Borneman
Anne Broadbent
Aharon Brodutch
Jianxin Chen
Lin Chen
Robabeh Rahimi Darabad
Audrey Dot
Chris Erven
Silvano Garnerone
Oleg Gittsovich
David Gosset
Patryk Gumann
Gus Gutoski
Christopher Haapamaki
Brendon Higgins
Rolf Horn
Mark Howard
Zhengfeng Ji
Nathaniel Johnston
Piotr Kolenderski
Keith Lee
Ying Liu
Dawei Lu
Eduardo Martin-Martinez
Rajat Mittal
Hamid Mohebbi
Osama Moussa
Mustafa Muhammad
Florian Ong
Kazuto Otani
Zlatko Papic
Krister Shalm
Jon Tyson
Joel Wallman
Nathan Wiebe
Zizhong Yan

IQC alumni

Douglas Stebila
PhD 2009

After completing his PhD in 2009 with a focus on cryptographic key exchange protocols, IQC alumnus Douglas Stebila ventured down under to Brisbane, Australia for a postdoctoral fellowship at the Queensland University of Technology. Stebila is now a Senior Lecturer at QUT investigating provable security of real-world cryptographic protocols – specifically looking at the security properties of protocols used in web browsers and other online communications. As quantum computing evolves and impacts classical cryptography, Stebila hopes to contribute to the development of new standards for cryptographic protocols. When he's not exploring future possibilities of security protocols, Stebila enjoys scuba diving in the warm waters of the Pacific Ocean.

Gina Passante
PhD 2012

During her PhD studies at IQC, Gina Passante's research focused on detecting and measuring quantum correlations in a class of quantum computers known as Deterministic Quantum Computation with One Quantum Bit (DQC1), a type of system with "mixed qubits" – Passante's interest was in qubits that might not be entangled. She found that there are quantum correlations that go beyond what can be seen in the classical world in mixed state quantum computers.

Now working as a postdoctoral fellow at the University of Washington, Passante is part of the Physics Education Group where she is contributing to improving the education of future physicists. Passante explores how students learn quantum mechanics. "With the emergence of quantum technologies, it is more important than ever to better educate physics majors in this area," she says. She plans on continuing her research in this field and broadening her scope to include how a quantum mechanics curriculum might one day be incorporated into high school classrooms. As a creative outlet, Passante enjoys knitting and sewing, and is an active volleyball player.

Scott Aaronson
Postdoctoral Fellow 2007

After completing a postdoctoral fellowship at IQC in 2007, Scott Aaronson accepted the position of Associate Professor of Electrical Engineering and Computer Science at the Massachusetts Institute of Technology in Cambridge, Massachusetts. His research interests include the capabilities and limits of quantum computers and computational complexity theory. His recently published book *Quantum Computing since Democritus* provides insight and perspectives into "the deepest ideas of math, computer science and physics." Aaronson is also known for his blog *Shtetl-Optimized* about quantum computing and quantum information science. Aaronson credits his time at IQC for "bringing him out of his shell" and also where he learned to drive.

Watch an interview with Scott Aaronson: youtu.be/LzQAWsqV6ss

Jay Gambetta
Postdoctoral Fellow 2011

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

Awards & recognition

From May 1, 2012 to April 30, 2013

Faculty Awards & Grants

Jonathan Baugh
Discovery Grant Program, NSERC (April 2013)

Andrew Childs
Discovery Grant Program, NSERC (April 2013)

Richard Cleve
Discovery Grant Program, NSERC (April 2013)

Thomas Jennewein
- Canada Foundation for Innovation (CFI) Leading Edge Fund Grant (January 2013)
- Research Tool and Instruments Grant, NSERC (April 2013)

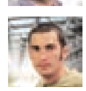
Robert Koenig
Discovery Grant Program, NSERC (April 2013)

Raymond Laflamme
Queen Elizabeth II Diamond Jubilee Medal (2013)

Vadim Makarov
Discovery Grant Program, NSERC (April 2013)

Matteo Mariantoni
- Sloan Research Fellowship (2013)
- Discovery Grant Program, NSERC (April 2013)
- Research Tools and Instruments Grant Program, NSERC (April 2013)

Michele Mosca
Queen Elizabeth II Diamond Jubilee Medal (2013)



Dmitry Pushin
Discovery Grant Program, NSERC (April 2013)

Kevin Resch
E.W.R. Steacie Fellowship, NSERC (2013)

Christopher Wilson
Discovery Grant Program, NSERC (April 2013)

Awards & recognition *continued*

Postdoctoral Fellows

David Gosset
NSERC Postdoctoral Fellowship (April 2013)

Student awards

Active student awards in the 2012-13 fiscal year.

David R. Cheriton Graduate Scholarship
Matthew Amy
Minyang Han
Stacey Jeffery
Robin Kothari
Ansis Rosmanis
Vincent Russo

IQC Achievement Award
Deny Hamel
Jonathan Lavoie
Laura Mancinska

IQC David Johnston Award for Scientific Outreach
Catherine Holloway
Evan Meyer-Scott
Chris Pugh
Farzad Qassemi

IQC Entrance Award
Megan Agnew
Maryam Mirkamali
Vincent Russo
Kyle Willick

Mike and Ophelia Lazaridis Fellowship
Juan Miguel Arrazola
Amin Eftekharian
Joshua Geller
Sarah Kaiser
Shitikanth Kashyap
Iman Marvian
Adam Paetznick
Ansis Rosmanis
Antonio Scotland

NSERC Alexander Graham Bell Canada Graduate Scholarship — Doctoral
Matthew Graydon
Stacey Jeffery
Jonathan Lavoie
Evan Meyer-Scott

NSERC Alexander Graham Bell Canada Graduate Scholarship — Masters
Megan Agnew
Minyang Han
Erika Janitz
Michael Mazurek
Chris Pugh
Joseph Rebstock
Denis-Alexandre Trottier
Kyle Willick

NSERC Postgraduate Scholarship — Doctoral
Robin Kothari
Felix Motzoi

NSERC Postgraduate Scholarship — Masters
William Stacey

NSERC Vanier Canada Graduate Scholarship
Kent Fisher
Deny Hamel

Ontario Graduate Scholarship
Daniel Criger
Chunqing Deng
Kent Fisher
Luke Govia
Fatin Haque
Catherine Holloway
Tomas Jochym-O'Connor
Alexandre Laplante
Jonathan Lavoie
Victor Veitch

Ontario Trillium Scholarship
Zak Webb

President's Graduate Scholarship
Megan Agnew
Daniel Criger
Chunqing Deng
Kent Fisher
Luke Govia
Matthew Graydon
Minyang Han
Fatin Haque
Catherine Holloway
Erika Janitz
Stacey Jeffery
Tomas Jochym-O'Connor
Robin Kothari
Alexandre Laplante
Jonathan Lavoie
Michael Mazurek
Evan Meyer-Scott
Felix Motzoi
Chris Pugh
Joseph Rebstock
William Stacey
Denis-Alexandre Trottier
Victor Veitch
Kyle Willick

QEII-Graduate Scholarship in Science and Technology
John Donohue

"In order to be cyber-safe, our information and communication infrastructure will need to be quantum-safe. We need to prepare the next generation workforce to design, implement, deploy and standardize these next-generation tools that will be secure in a world with quantum technologies."

Michele Mosca, Director, CryptoWorks21

CryptoWorks21

Training the cryptographic leaders of tomorrow

In our everyday lives, cryptography is one of the ways we maintain secure and reliable communications and information access.

Secret passwords, authentication protocols and encryption systems help to keep us safe from threats like viruses, fraud, and identity theft. Staying on the cutting-edge of cryptographic technology is a critical part of maintaining our online security as threats become more advanced.

A large-scale quantum computer will undermine core cryptographic tools we rely on for authentication and encryption. Emerging quantum technologies are bringing this threat closer and closer to reality. **Michele Mosca**, IQC researcher and Deputy Director, Academic, sees the urgent need to prepare our cryptographic infrastructures to be quantum-safe to protect against these new threats. This transition to a new quantum-safe infrastructure requires a workforce with the necessary specialized knowledge and skills.

"New cryptographic tools need to be designed, implemented, tested, deployed and standardized. History has shown that this task takes many years, even decades," says Mosca.

As a recipient of an NSERC-funded Collaborative Research and Training Experience (CREATE) grant last year, Mosca and his team launched **CryptoWorks21** – an IQC training program for building the workforce for the cryptographic infrastructure of the 21st century. The first CryptoWorks21 workshops were led at IQC this past summer through a collaboration with the University of Calgary, the Université de Montréal and industry organizations.

CryptoWorks21 encourages graduate students and postdoctoral fellows to expand their technical and professional skills through a series of workshops and courses. This innovative program out of IQC develops cryptographic experts with the ability to connect cutting-edge research to commercial innovation and bridge the gap between academia and industry.

cryptoworks21.ca

"Attending the ETSI Quantum-Safe-Crypto Workshop was terrific. Not only did I gain experience in presenting my research to academics and industry professionals, but I had the chance to meet and connect with others working in my field. This was invaluable as the exchange of ideas among researchers is of the utmost importance in generating new ideas and solving important problems."

Dieter Fishbein, University of Waterloo

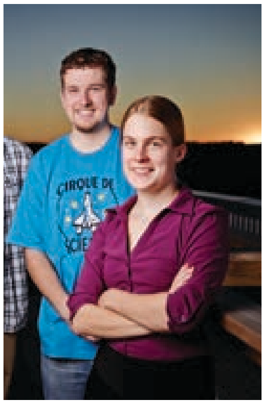
IQC to the world; the world to IQC

Great science cannot happen in isolation. It must be shared with the people who fuel it, support it, are fascinated by it and will ultimately benefit from it.

The Institute for Quantum Computing brings the intriguing world of quantum information science and research to the curious-minded through public lectures, community events, open houses, graduate fairs, building tours, summer schools for young students, conferences, publications, social media and unique outreach opportunities designed to share and explain the fascinating research that will ultimately change the way we live, work and play. Over the past decade and looking ahead to the next, outreach remains a fundamental aspect of IQC's objectives and operations. Our outreach efforts continue to expand and connect global audiences with the science and research at the forefront of the quantum information revolution.

Congratulations to Catherine Holloway and Christopher Pugh, winners of the IQC David Johnston Award for Scientific Outreach

Up to three awards valued at $2,500 each are given annually to current graduate students at IQC who have shown an outstanding commitment to scientific outreach and community engagement. This award was created to celebrate Canadian Governor General David Johnston's vital contributions to IQC, his passion for leadership and his enthusiasm for continuous learning, innovation and achievement. David Johnston was president of the University of Waterloo from 1999 to 2010. The award is funded by Industry Canada.



This year's recipients are **Catherine Holloway** and **Christopher Pugh**.

Scientific outreach

Quantum Innovators

September 6–9, 2012

The first Quantum Innovators was held at IQC, the University of Waterloo, and the Perimeter Institute for Theoretical Physics last fall. Twenty-five of the top young quantum experimentalists from around the world attended the workshop, giving scientific presentations and building relationships with established and emerging researchers over the three-day workshop. A panel of scientists who recently entered the work force shared their experiences and career paths with the young attendees. Panelists included academics **Paola Capellaro** (MIT), **Bill Coish** (McGill), industry **Colm Ryan** (BBN/ Raytheon), patent lawyer **Michael Henry** (Fish & Richardson) and an industrial entrepreneur **Grum Teklemariam** (XBO Medical Systems).

QFQI Conference – Wojciech Zurek's 60th Birthday "Decoherence & Friends"

May 20-23, 2013

Decoherence is a bridge between quantum and classical and an Achilles' heel of quantum computation. For the past 30 years, Wojciech Zurek led the development of the theory of decoherence and studied its implications for the foundations of quantum physics and its consequences for quantum information science and technology. To celebrate the 30-year anniversary of his seminal work, and coincidentally his 60th birthday, IQC hosted the *Decoherence & Friends* conference May 20-23, 2013.

Almost fifty of Zurek's collaborators and prominent contributors to the field traveled from around the world for the celebrations. Invited speakers included:

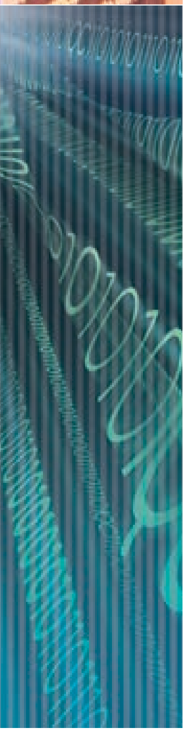
- **Charles Bennett**, IBM Research – co-founder of quantum cryptography
- **William Wootters**, Williams College – Proved the no cloning theorem, a cornerstone in quantum information research, in a joint paper with Zurek
- **Ben Schumacher**, Kenyon College – Coined the term "qubit"
- **David Wineland**, National Institute of Standards and Technology and Serge Haroche, Collège de France – Co-recipients of the 2012 Nobel Prize in physics

Hear from some of the *Decoherence & Friends* attendees on our YouTube Channel: http://bit.ly/qfqiconference

Quantum Computation and Complex Networks

May 24-26, 2013

This workshop brought together 16 researchers and students from diversified scientific areas to explore connections between quantum information and graph theory, such as quantum graph states, quantum expanders, and quantum walks on graphs.



Grand Opening of the Mike & Ophelia Lazaridis Quantum-Nano Centre

September 21, 2012

The celebration of the 10th anniversary of the Institute for Quantum Computing was marked by the expansion into the Mike & Ophelia Lazaridis Quantum-Nano Centre, the most scientifically sophisticated building at the University of Waterloo. This state-of-the-art facility controls vibration, temperature, humidity and electromagnetic radiation, enabling international excellence in quantum information research.

The Lazaridis Centre officially opened on September 21, 2012 with a ceremony attended by 1,200 guests and dignitaries, including world-renowned physicist Professor **Stephen Hawking**. According to Hawking, “this institution will advance our understanding of matter and movement, illuminating deep mysteries with the light of scientific discovery.”

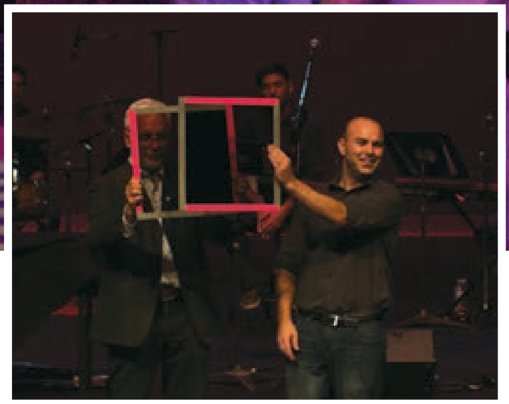
Visionary **Mike Lazaridis**, whose generous donation of more than $100 million supported the creation of the building, predicts “… the discoveries and innovations of the Quantum-Nano Centre [will] lead to the creation of companies that will lead to Waterloo Region becoming known as The Quantum Valley.”

Watch Professor Stephen Hawking, IQC Executive Director Raymond Laflamme, and Mike Lazaridis

bit.ly/lazaridiscentrego

“The work that will be done here will help transform the way we work, live and play.”

Mike Lazaridis



Mike & Ophelia Lazaridis Quantum-Nano Centre Public Open House

September 29, 2012

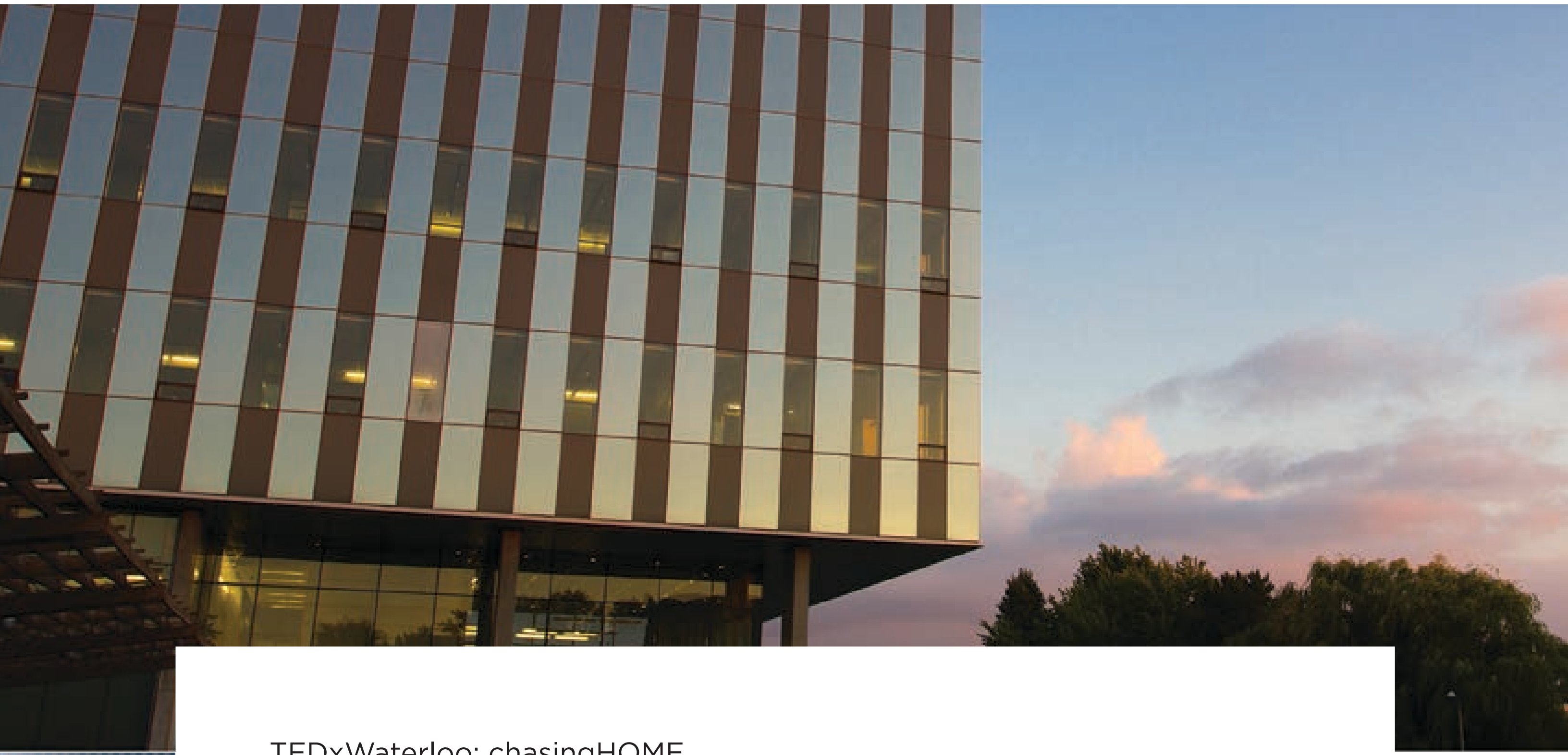
The Lazaridis Centre opened its doors to the public on September 29, 2012 to 3,000 visitors who explored the building and experienced quantum science through interactive exhibits, demonstrations and lab tours. Public lectures by science celebrities **Jay Ingram**, **Robert J. Sawyer** and **Chad Orzel** attracted 800 guests. A panel discussion with IQC Executive Director **Raymond Laflamme**, **Mike Lazaridis**, and other leading experts examined how science has reached the quantum frontier and explored the exciting new directions that research at the Lazaridis Centre will lead.

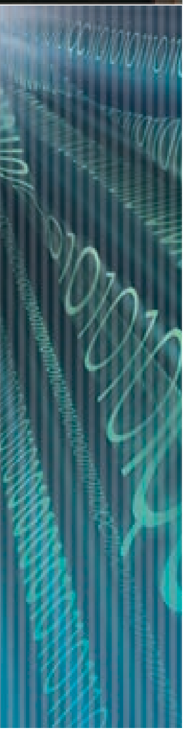
Canadian science writer and broadcaster Jay Ingram and his band **The Qubits** performed an interactive rock concert featuring onstage demonstrations of quantum mechanics for 350 guests. IQC's senior manager of scientific outreach, **Martin Laforest**, appeared on stage with Ingram to explain the principle of superposition and quantum computing, communication and cryptography.

Quantum: Music at the Frontier of Science

September 30, 2012

The Kitchener-Waterloo Symphony, conducted by musical director **Edwin Outwater**, performed "Quantum: Music at the Frontier of Science," a unique concert experience at the Lazaridis Centre on September 30, 2012. The orchestra performed pieces conveying the history and themes of quantum science by composers as diverse as Mozart and John Cage. The concert included narration, an eclectic musical program and an immersive visual experience. "Music and science are not as different as some people might think," explained IQC Executive Director Raymond Laflamme. "They both help us understand and interpret our world and ourselves. This concert shows how music and science are two sides of the same coin."





TEDxWaterloo: chasingHOME

March 27, 2013

IQC's executive director **Raymond Laflamme** returned to the TEDxWaterloo stage to take the audience into the world of quantum information science once more and talk about the progress in the field since his first visit in 2010. Laflamme talked about the rules of quantum mechanics and manipulating information at the atomic scale, IQC's expansion into the Mike & Ophelia Lazaridis Quantum-Nano Centre and how the Quantum Valley Investment fund will assist in commercializing some of the quantum technologies evolving from IQC. Laflamme also shared the biggest development made in terms of science: the ability to control atoms and molecules more precisely – a 100-fold change. Along the way to this control, other problems have been solved, leading to the development of quantum-enabled devices. Laflamme promised another update in 2016 that will include data about IQC's project on quantum communication using satellites.

Martin Laforest conducts an experiment with polarizers with the help of **Ramy Nassar**

Martin Laforest, senior manager of scientific outreach at IQC, was challenged by TEDxWaterloo organizers to teach quantum mechanics to 1,500 people with an interactive experiment in 5 minutes. Laforest lead the audience members through a polarization experiment showing the counter-intuitive effects of quantum mechanics on the properties of light.

Watch Raymond Laflamme's TEDxWaterloo talk: tedxwaterloo.com/speaker/laflamme

Learn about quantum mechanics from Martin Laforest at TEDxWaterloo: tedxwaterloo.com/speaker/laforest

Raymond Laflamme with a model of a satellite that will be used for quantum key distribution

Leadership in Innovation Conference (LINC) 2013

April 22-23, 2013

The Leadership in Innovation Conference (LINC) brought together 200 leaders, academics and policymakers for a two-day conference at the Mike & Ophelia Lazaridis Quantum-Nano Centre in April. The group was invited by University of Waterloo president **Feridun Hamdullahpur** to share ideas and policy options for building entrepreneurial ecosystems in Canada and around the world.

The focus of the second day of the conference was quantum computing and young entrepreneurs. **Mike Lazaridis** gave a keynote address and participated in a panel discussion entitled *"Why Will Quantum Information Science Transform Society?"* with IQC faculty member and Deputy Director, Research, **David Cory**, IQC executive director **Raymond Laflamme**, innovation and technology writer **Jon Gertner**, and Perimeter Institute for Theoretical Physics director **Neil Turok**. The panel was moderated by science journalist **Ivan Semeniuk**.

Random Walks: Music of Xenakis and Beyond

May 25, 2013

The Institute for Quantum Computing hosted *"Grains of Sound: A Concert of Electroacoustics, Video and Robotics Performers"* on Saturday, May 25, 2013, part of a two-day festival presented in partnership with the Perimeter Institute of Theoretical Physics and the Fields Institute. The festival included a contemporary string quartet, percussion and electroacoustic music, together with lectures and discussion on the impact of Xenakis' work. Xenakis is renowned for bringing together expertise in music, architecture and math in a remarkable collection of works. As one of the pioneers of computer music, Xenakis explored algorithmic approaches to composition and was known for expanding sound worlds of traditional ensembles (to the point of competing with electronic music), and especially for his expansive use of percussion instruments.

Cyber Security Symposia

September 2012 and May 2013

As the need for quantum-safe cyber solutions becomes more apparent, IQC lead two discussions on the future of cyber security – one in September 2012 and a second in May 2013. IQC brought together leaders from industry, academia and government to discuss the issues and opportunities for Canada's cyber security environment and to explore potential collaborative partnerships in a quantum world. IQC continues to lead discussions in this important area with the goal of making Canada a global leader in quantum-safe cryptography.

IQC online

iqc.uwaterloo.ca

IQC's website is home to all of the information and resources relevant to the institute's target audiences – from prospective students and faculty to government and the general public. The site is a news source, recruiting tool, learning resource and a gateway to IQC social media.

The Quantum Library

pubs.iqc.uwaterloo.ca

IQC's publications database, **pubs.iqc. uwaterloo.ca**,is home to hundreds of peer-reviewed journal articles, conference proceedings, commentaries and other publications by IQC researchers. Searchable by author, publication, subject, keywords and other criteria, the site is an online repository of IQC's leading contributions to quantum information science.

YouTube

youtube.com/quantumiqc

IQC's YouTube channel hosts more than 500 scientific talks, distinguished lectures and interviews with world-leading scientists. Watch our Quantum Researchers series featuring renowned researchers in the quantum information science field such as **Nicolas Gisin**, **Jane E. Norholdt**, **John Preskill** and **David Wineland**.

Social media

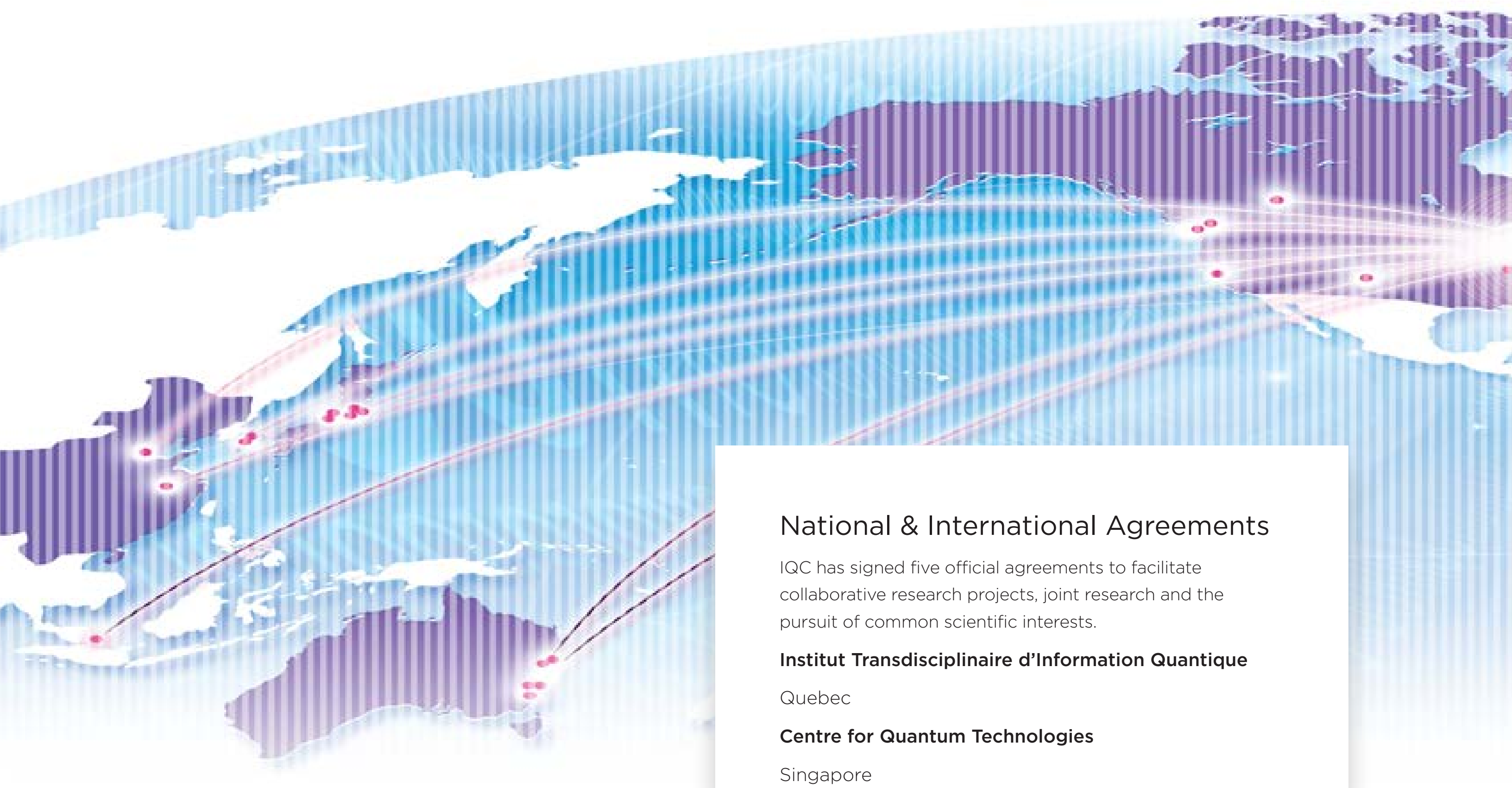
@QuantumIQC

facebook.com/quantumiqc

youtube.com/quantumiqc

flicker.com/quantumiqc

IQC's global reach



National & International Agreements

IQC has signed five official agreements to facilitate collaborative research projects, joint research and the pursuit of common scientific interests.

Institut Transdisciplinaire d'Information Quantique

Quebec

Centre for Quantum Technologies

Singapore

University of Science and Technology of China

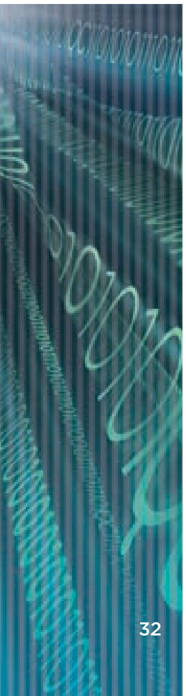
China

Tsinghua University

China

Raman Research Institute

India



The multidisciplinary nature of quantum information science brings together researchers from many areas of expertise. IQC researchers consider collaboration a catalyst for discovery, working closely with peers from organizations around the globe. Our international network continues to expand. These connections are laying the groundwork for exciting developments in the future.

International Exchange

The University of Waterloo supports exchange opportunities for IQC students, postdoctoral fellows and researchers that promote the advancement of education and research in quantum information processing through a student exchange agreement with the following institutions:

Université Paris Diderot

France

Friedrich-Alexander-Universität Erlangen-Nurnberg

Germany

Universität Innsbruck

Austria

École Normale Supérieure de Lyon

France

University of Latvia

Latvia

Annual Meeting of the American Association for the Advancement of Science (AAAS)

February 14-18, 2013

Researchers from IQC presented two talks at this year's annual meeting of the American Association for the Advancement of Science (AAAS) in Boston, Massachusetts, USA. IQC Canada Excellence Research Chair **David Cory** presented alongside **Amir Yacoby** from Harvard and **Raffi Budakian** of the University of Illinois at Urbana-Champaign. The panel highlighted three experimental approaches to quantum sensors: magnetic resonance force microscopy, scanning probe microscopy with a diamond tip, and neutron interferometry.

David Cory was also an invited panelist to the Canadian Media Breakfast at AAAS presented by the Canadian Foundation for Innovation (CFI). Cory presented his research on quantum devices and how they will drive Canadian innovation.

IQC Executive Director **Raymond Laflamme** represented Waterloo in a roundtable discussion called *Fostering Cultures of Innovation Through International Cooperation* hosted by the Canadian Consulate General in Boston.

In 2012-2013, IQC researchers collaborated with

221 external researchers

185 institutions

20 countries

Visitors

» (L-R) **Raymond Laflamme**, **Mike Lazaridis**, Premier **Kathleen Wynne**, **John Milloy** (MPP) and **David Cory**

Ontario Premier Kathleen Wynne

April 5, 2013

On Friday, April 5, 2013, Ontario Premier Kathleen Wynne toured the new Mike & Ophelia Lazaridis Quantum-Nano Centre at the University of Waterloo. Hosted by Mike Lazaridis and joined by IQC Executive Director Raymond Laflamme and IQC Deputy Director, Research David Cory, the Premier's visit was part of a tour of Waterloo Region. Laflamme and Cory shared IQC's history and research with Wynne, who was the first non-scientist to enter the Quantum NanoFab facility in the Lazaridis Centre.

Academic & scientific visitors

May 1, 2012 to April 30, 2013

Scott Aaronson, Massachusetts Institute of Technology
Markus Aspelmeyer, University of Vienna
Apoorva Athavale, Indian Institute of Technology Hyderabad
Michal Bajcsy, Stanford University
Konrad Banaszek, University of Warsaw
Julio Barreiro, Max Planck Institute of Quantum Optics & Ludwig Maximilian University of Munich, Germany
Jeremy Bejanin, McGill University
Charles H. Bennett, IBM TJ Watson Research Center
Steven Bennett, Harvard University
Dominic Berry, Macquarie University
Jacob Biamonte, Oxford University
Alexandre Blais, University of Sherbrooke
Thomas Blasi, Harvard University
Daniel David Bonior, Middle Tennessee State University
Sergey Bravyi, IBM Research
Jop Briët, Centrum Wiskunde & Informatica (CWI)
Thomas Brougham, University of Strathclyde
Ken Brown, Georgia Institute of Technology
Todd Brun, University of Southern California
Ian Burgess, Harvard
Robert Cameron, University of Strathclyde
Yudong Cao, Purdue University
Stefano Chesi, McGill University
Kyung Soo Choi, Korea Institute of Science and Technology
Matthias Christandl, Institute for Theoretical Physics ETH Zurich
Aashish Clerk, McGill University
Bill Coish, McGill University
Patrick Coles, Carnegie Mellon University
Wei Cui, University of Toronto
Pawel Dabkowski, Nicoalus Copernicus University & Czech Technical University Prague
Olivia Di Matteo, Lakehead University
Helen Fay Dowker, Imperial College London
Jiangfeng Du, University of Science and Technology, China

Carolyn Earnest, Portland State University
Chip Elliott, Raytheon-BBN Technologies
Klaus Ensslin, Swiss Federal Institute of Technology, Zurich
Mark A. Eriksson, University of Wisconsin, Madison
Pol Forn-Dìaz, California Institute of Technology
Sevag Gharibian, University of California, Berkeley
Vlad Gheorghiu, University of Calgary
Cecile Grezes, CEA-Saclay, France
Simon Groeblacher, California Institute of Technology
Otfried Guehne, Universität Siegen
Hartmut Haeffner, University of California, Berkeley
Mark Hillery, The City University of New York
Darryl Hoving, University of Toronto
Mark Howard, National University of Ireland, Maynooth
Xuedong Hu, University of Buffalo
Hannes Hubel, Stockholm University
Dan Hussey, National Institute of Standards and Technology
Daniel Jost Brod, Instituto de Física Universidade Federal Fluminense
Tae Hee Kim, Ewha Womans University, Korea
Yoon-Ho Kim, Pohang University of Science & Technology
Alexey Kovaleve, University of California, Riverside
Lindsey LeBlanc, National Institute of Standards and Technology
Kuret Loutfi, Université de Montréal
Riccardo Manenti, University of Milan, Italy
Vladimir Manucharyan, Harvard University Society of Fellows
Matteo Mariantoni, University of California, Santa Barbara
James Martin, University of Waterloo
Wen Masters, Office of Naval Research, USA
William Matthews, University of Cambridge
Nicolas C. Menicucci, University of Sydney
David Meyer, University of California, San Diego
Benjamin A. Milarch, United States National Intelligence University
Kavan Modi, University of Oxford
Christopher Monroe, University of Maryland
Ashley Montanaro, University of Cambridge
Sung Wook Moon, Korea Institute of Science and Technology
Tobias Moroder, Universität Siegen
Holger Muller, University of California, Berkeley
Daniel Nagaj, Slovak Academy of Sciences
Simon Nigg, Yale University
George Noid, Indiana University
Ryo Okamoto, Hokkaido University
Maris Ozols, IBM TJ Watson Research Center
Giuseppe Davide Paparo, University of Maryland
Annie Jihyun Park, University of British Columbia
Gerardo Paz, University of Southern California
Borja Peropadre, Instituto de Física Fundamental
Simon Phoenix, Khalifa University
Jaques Pienaar, University of Queensland
Trey Porto, National Institute of Standards and Technology
Katherine Quinn, McGill University
Sven Ramelov, University of Vienna
Mohsen Razavi, University of Leeds
Ben Reichardt, University of Southern California
John Rinehart, Washington State University, Spokane
Nayeli Azucena Rodriguez-Briones, Max Planck Institute of Quantum Optics in Garching, Germany
Andrey Rogachev, Cornell University
David Rosenbaum, University of Washington
Mary Beth Ruskai, Tufts University
Amir Safevi-Naeini, California Institute of Technology
Shihan Sajeed, University of Dhaka
Louis Salvail, Université de Montréal
Barry Sanders, University of Calgary
Ruediger Schack, Royal Holloway, University of London
Carey Schwartz, Office of Naval Research, USA
Guy Seguin, Canadian Space Agency
Feiruo Shen, Tsinghua University
Seung Woo Shin, University of California, Berkeley
Pragya Shukla, Indian Institute of Technology Kharagpur
Graeme Smith, IBM TJ Watson Research Center
W. Michael Snow, Indiana University Bloomington
Fang Song, Penn State University
Henriette Steiner, Eidgenössische Technische Hochschule Zurich
Rainer Steinwandt, Florida Atlantic University
Markku Stenberg, Saarland University
Michal Studzinski, Nicolaus Copernicus University
Krysta Svore, IBM
Mario Szegedy, Rutgers University
Barbara Terhal, RWTH Aachen University
Lin Tian, University of California, Merced
Peter Turner, University of Tokyo
Thomas Vidick, Massachusetts Institute of Technology
Denis Vion, CEA-Saclay, France
Christophe Vulliot, Université de Rennes
Joel Wallman, The University of Sydney
Jie Wang, University of Science and Technology, China
Xiaoya Wang, McGill University
Yingdan Wang, McGill University
Dan Wayner, National Research Council Canada
Sang Wook, Korea Institute of Science and Technology
Liu Ying, University of Wisconsin, Milwaukee
Anton Zeilinger, University of Vienna
Jingfu Zhang, Technische Universitat Dortmund
Yanbao Zhang, University of Colorado at Boulder
Zhenyu Zhang, University of Science and Technology, China
Zoltan Zimboras, UPV/EHU Bilbao
Karol Życzkowski, Jagiellonian University

IQC by the numbers

May 1, 2012 to April 30, 2013

Researchers at IQC

IQC is home to:

20 faculty members

3 research assistant professors

46 postdoctoral fellows

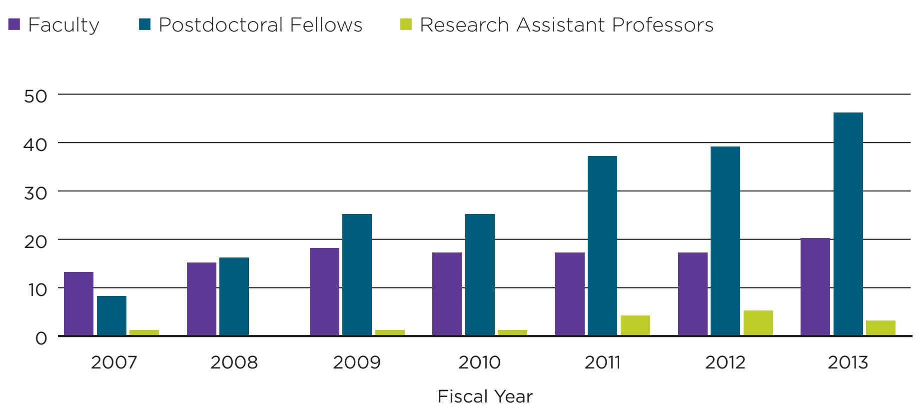
103 graduate students

34 long-term visitors

6 technical specialists

25 communications, information technology and administrative staff.

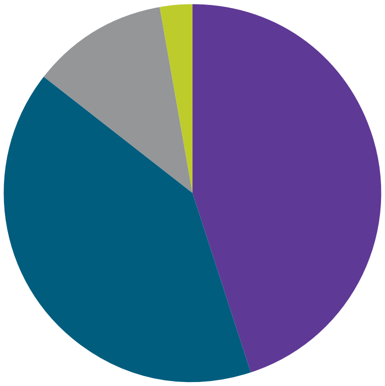
Faculty & Postdoctoral Fellows



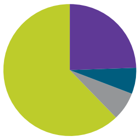
Long-Term Visitors

Vikram Sharad Athalye
Sam Bader
Amin Baumeler
Troy Borneman
Robin Cote
Tiago Debara
Audrey Dot
Jonathan Friedman
Daniel Gustaw
Melanie Jensenworth
Kelsey Johnsen
Daniel Jost Brod
Antti Karlsson
Maria Kieferova
Kevin Krsulich
Mehul Kumar
Srijita Kundu
Qiang Li
Hang Li
Thomas Lutz
Mhlambululi Mafu
Ryan Marchildon
Mayank Mishra
Keith Motes
Taesik Nam
Crystal Noel
Michal Papaj
Laura Piispanen
Dominique Pouliot
Sarah Sheldon
Hou Shiyao
Pragya Shukla
Christophe Vulliot
Fei Wang
Amir Yacoby

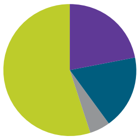
2012-2013 Expenditures



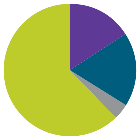
Salaries & Benefits	$ 9,698,252
Building, Equipment & Maintenance	$ 8,711,458
Other Expenses	$ 2,456,015
QNC Building	$ 657,464
TOTAL	**$ 21,523,189**



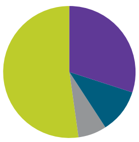
2011-2012
$37,151,910



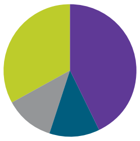
2010-2011
$35,442,930



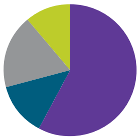
2009-2010
$37,610,287



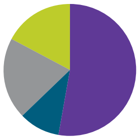
2008-2009
$17,530,346



2007-2008
$9,679,754



2006-2007
$5,931,616



2005-2006
$3,396,399

Publications

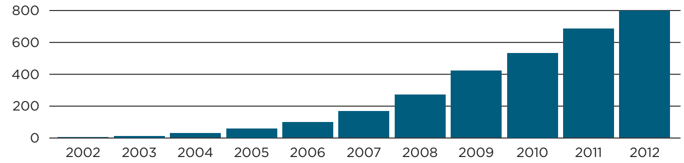
Notable publications in the journals *Nature*, *Nature Photonics*, *Nature Physics*, *Nature Communications*, *Physical Review Letters*, *Science*, *STOC*, *FOCS*, and the *Journal of Mathematical Physics* represent high-level, peer-reviewed discoveries by IQC researchers.

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

The publication distribution listed above is collected from Thomson Reuters' ISI Web of Knowledge.

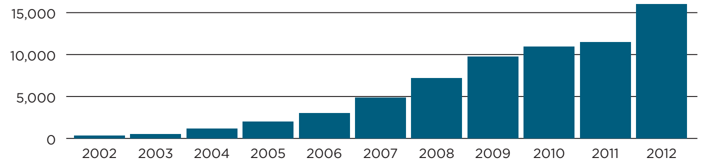
Cumulative Publications by IQC Researchers

172 publications by IQC researchers in 2012
796 publications by IQC researchers since 2002



Cumulative Citations of IQC Publications: Google Scholar

15,984 cumulative citations for all IQC publications since 2002



"We're all doing world-class research here and we're all building an industry. We're all contributing in different ways."

Bob Crow

Building a world-class research institution

Robert E. Crow, Executive in Residence

Establishing a world-class research institution requires a world-class administrative team.

Leading this team at the Institute for Quantum Computing is **Robert E. Crow (Bob)**, Executive in Residence. Crow joined IQC last year during the lead up to the grand opening of the Mike & Ophelia Lazaridis Quantum-Nano Centre. He recalls this event as a defining moment in the ten-year history of IQC – one that brought the research and science happening here into the global spotlight.

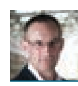
"We are building an industry here," says Crow. "IQC's central role in the Quantum Valley vision is to articulate research, create commercializable technologies, and continue to advance our understanding of the world around us. From these discoveries will come opportunities that were once unimaginable." Crow sees quantum information research and technology, technologies created here at IQC, as an opportunity for Canada to build a new worldwide industry that drives the future economy.

IQC Executive Director Raymond Laflamme recognized early that building this industry would take a strong team. With his past leadership experience in technology and public policy, Laflamme knew Crow was the right person to help grow the remarkable potential at IQC. Crow now leads the administrative team as Executive in Residence, supporting the operational success guided by three goals that align with the overall strategic direction of IQC:

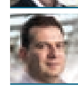
1. **Provide the world's best environment for scientific research** by our faculty, research staff, postdoctoral fellows and graduate students. "If the best environment is here, the rest will naturally fall into place," says Crow.
2. Run a scientific outreach program that enables all IQC members to interact with the **best and the brightest** from around the world, through our:
   - Visitor & conference programs;
   - Youth outreach activities that bring bright, young minds here from around the globe;
   - Communications and media relations efforts to share the stories and discoveries of IQC with the world.
3. Continue to **evolve and strive to be the best** administrative team that we can be.

The administrative team is a fundamental part of the future of IQC. Crow says, "We're all part of the team. We're all doing world-class research here and we're all building an industry. We're all contributing in different ways."

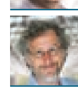
Senior Leadership



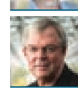
Raymond Laflamme
Executive Director



Michele Mosca
Deputy Director, Academic



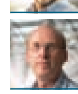
David Cory
Deputy Director, Research



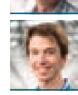
Robert E. Crow
Executive in Residence

Laboratory Support

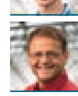
Vito Logiudice
Director of Operations, Quantum NanoFab



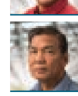
Brian Goddard
Senior Fabrication Equipment Technologist



Nathan Nelson-Fitzpatrick
Nanofabrication Process Specialist/Engineer



Roberto Romero
Senior Electronics Engineering Technologist and Health, Safety & Fire Evacuation Coordinator



Rodello Salandanan
Senior Fabrication Equipment Technologist

Ivar Taminiau
Laboratory Technician

IQC Board of Directors

Tom Brzustowski
(Chair), RBC Professor, Telfer School of Management

Douglas Barber
Distinguished Professor-in-Residence, McMaster University

Paul Corkum
University of Ottawa and National Research Council

Robert Crow
Executive in Residence, IQC

George Dixon
Vice-president, University Research, University of Waterloo

Cosimo Fiorenza
VP and General Counsel, Quantum Valley Investments

David Fransen
Consul General, Canadian Consulate General in Los Angeles

Peter Hackett
Executive Professor, School of Business at the University of Alberta & Fellow, National Institute for Nanotechnology

Raymond Laflamme
Executive Director, IQC

Mike Lazaridis
Co-Founder and Managing Partner, Quantum Valley Investments

Michele Mosca
Deputy Director, Academic, IQC

William R. Pulleyblank
Professor of Operations Research, United States Military Academy, West Point

Executive Committee

George Dixon
(Chair), Vice-president, University Research

Robert Crow
Executive in Residence, IQC

Ian Goulden
Dean, Faculty of Mathematics

Raymond Laflamme
Executive Director, IQC

Terry McMahon
Dean, Faculty of Science

Michele Mosca
Deputy Director, Academic, IQC

Pearl Sullivan
Dean, Faculty of Engineering

Scientific Advisory Committee

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(Chair), University of Queensland

Prof. Harry Buhman
Centrum voor Wiskunde en Informatica

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

Prof. Christopher Monroe
University of Maryland

Prof. Umesh Vazirani
University of Maryland

Prof. Anton Zellinger
University of Vienna

Prof. Wojciech Hubert Zurek
Los Alamos National Laboratory and Santa Fe Institute

Administration


Lorna Kropf
Assistant Director, Administration


Matt Schumacher
Associate Director, Finance

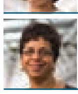

Andrew Dale
Administrative/Financial Assistant, Faculty Research Groups

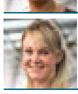

Monica Dey
CREATE & Graduate Program Coordinator


Melissa Floyd
Administrative/Financial Assistant, Faculty Research Groups

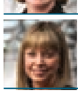

Matthew Fries
Visitor Coordinator

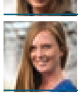

Chin Lee
Research Support Assistant, Deputy Director, Academic


Jessica Miranda
Administrative/Financial Coordinator, Faculty Research & Administration


Bethany Mulder
Receptionist/Office Assistant


Mary Lyn Payerl
Financial Officer


Wendy Reibel
Administrative Officer


Carly Turnbull
Administrative/Financial Assistant – CERC Chair

Communications and External Relations

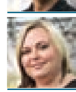

Tobi Day-Hamilton
Associate Director, Communications and External Relations


Sean Collins
Senior Manager, Research Development


Erin Cronin
External Relations Coordinator


Kathryn Fedy
Communications Officer

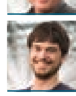

Martin Laforest
Senior Manager, Scientific Outreach

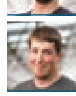

Kimberly Simmermaker
Events, Outreach & Communications Coordinator

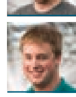

Jodi Szimanski
Senior Manager, Communications

Information Technology


Steve Weiss
Associate Director, Information Technology


Matthew Cooper
Client Support Specialist


Ryan Goggin
Computing Specialist


Dylan Totzke
Computing Support Specialist

Thank you

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