

**03** SCIENCE  
HIGHLIGHTS

**06** GET TO KNOW IQC  
RESEARCHERS

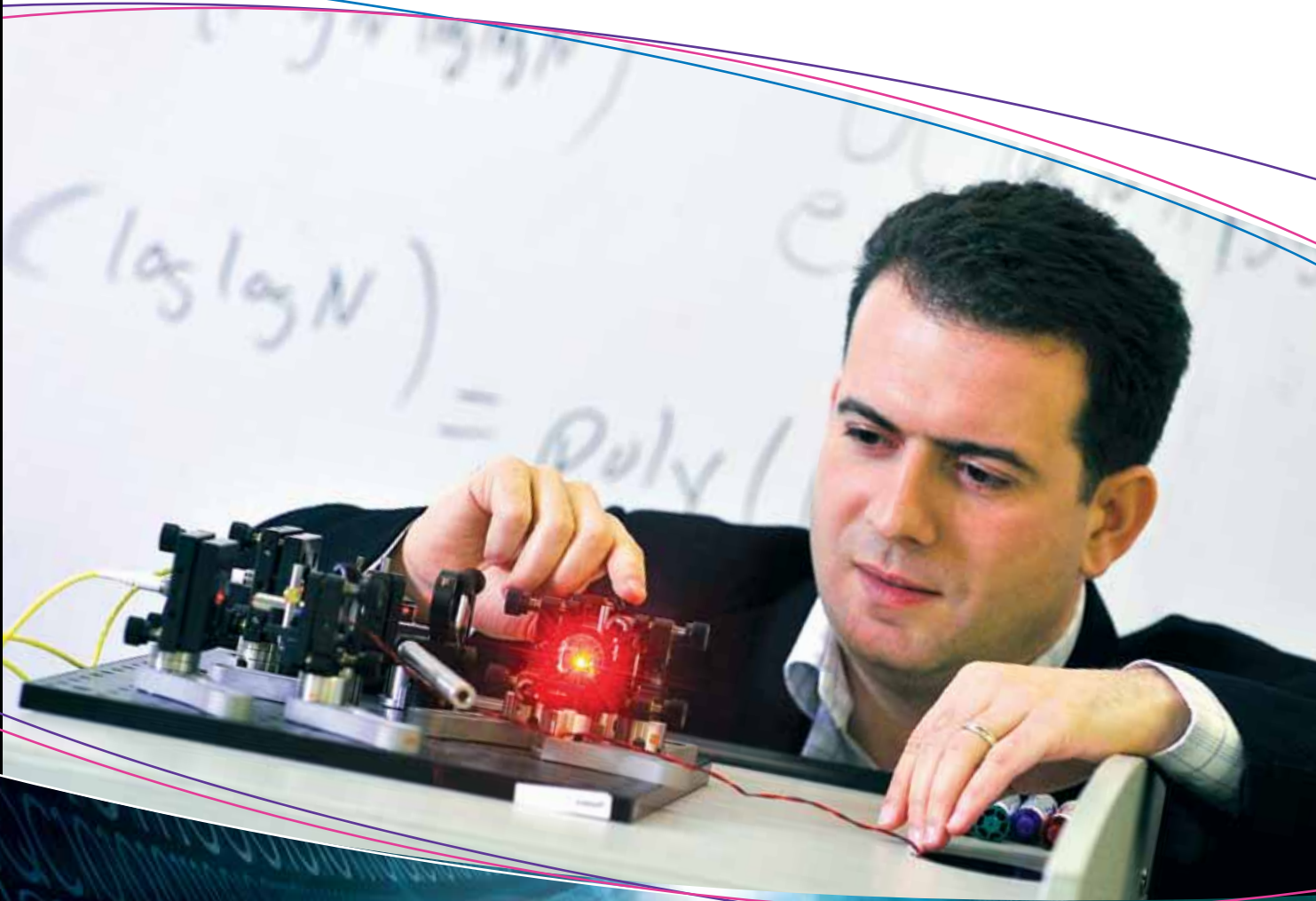
**08** QUANTUM  
CONNECTIONS

# NewBit

Issue 16 | Spring 2011

## **05 | Mosca wins national award**

IQC Deputy Director named among  
Canada's *Top 40 Under 40*



UNIVERSITY OF  
**WATERLOO**

**IQC** Institute for  
Quantum  
Computing

## » Welcome to NewBit

## Exciting, dramatic and life-changing

When Ontario's Lieutenant Governor David C. Onley visited the Institute for Quantum Computing recently, he described the research at IQC as "exciting, dramatic and life-changing."

It's satisfying for me to hear such feedback — and I hear it often — because it demonstrates the public is becoming increasingly aware of the remarkable work being done by our researchers, and how that research will benefit our society.

This newsletter encapsulates some of the great things that have been happening at IQC in recent months, and the people who have made them happen. You'll discover that faculty member Adrian Lupaşcu has earned a prestigious Sloan Fellowship — an honour that recognizes the exceptional scientific accomplishments Adrian has already made in his relatively young career. You'll read about Michele Mosca, who recently earned the wonderful honour of being counted among Canada's *Top 40 Under 40*. In the Q&A section, you'll learn more about what motivates, challenges and excites several of our researchers. You'll meet some of the distinguished guest lecturers who have travelled from around the world to meet and collaborate with IQC scientists. And you'll read about some of the recent breakthroughs and discoveries that are the *raison d'être* of IQC.

In short, this newsletter will give you a taste of what makes IQC's research "exciting, dramatic and life-changing."

Scientifiquement vôtre,

**Raymond Laflamme** | Executive Director, IQC ■



SPRING 2011

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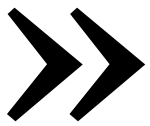
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## » Contents

ON THE COVER

**IQC Deputy Director  
Michele Mosca demonstrates  
an optics experiment.**

03	SCIENCE HIGHLIGHTS
06	GET TO KNOW IQC RESEARCHERS
08	QUANTUM CONNECTIONS
09	MEET OUR VISITING SCIENTISTS
11	QNC CONSTRUCTION UPDATE



# SCIENCE HIGHLIGHTS

IQC faculty, postdoctoral fellows and students have continued to set the global standard for quantum information research over the past term. Here is a sampling of the cutting-edge research published recently in leading academic journals.

## » Testing cryptography against quantum attacks

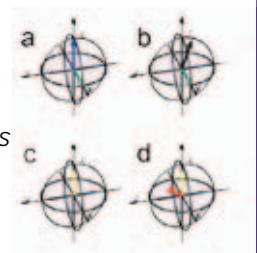
CONSTRUCTING ELLIPTIC CURVE ISOGENIES IN QUANTUM SUBEXPONENTIAL TIME, ARXIV:1012.4019V1 (DECEMBER 2010)

At the recent QIP Conference in Singapore, **ANDREW CHILDS** and collaborators presented a paper, currently under review for publication, which addresses a quantum attack on a certain kind of public-key cryptographic protocol. Childs, **DAVID JAO** and **VLADIMIR SOUKHAREV** address classical cryptography systems based on elliptical curves. While one such cryptosystem was already broken by Shor's famous algorithm, Childs and collaborators examined a cryptosystem that uses elliptic curves in a different way. While their result did not give a polynomial-time algorithm to break this system, they did find a significantly faster algorithm than the best-known classical algorithm, which suggests these cryptosystems may be susceptible to quantum attacks. ■



## RESEARCHERS ACHIEVE IMPORTANT BUILDING BLOCK IN ERROR CORRECTION

EXPERIMENTAL MAGIC STATE DISTILLATION FOR FAULT-TOLERANT QUANTUM COMPUTING, *NATURE COMMUNICATIONS* 2, 169 (2011)



An IQC research team recently implemented a novel way to cope with errors inherent to quantum systems. In a paper published last January in *Nature Communications*, the IQC researchers described how they implemented, for the time, the magic-state distillation. This quantum algorithm involves applying quantum operations to five imperfect magic states and distilling one with high-purity. "While there is still much more work to be done, this is an important building block in the implementation of quantum information processing," said **RAYMOND LAFLAMME**, who co-authored the paper with **JINGFU ZHANG**, **ALEXANDRE D'SOUZA** and **COLM RYAN**. ■

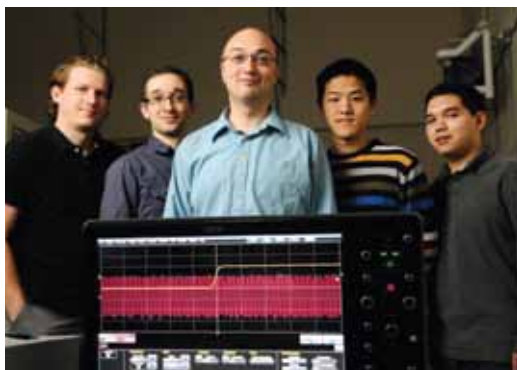
## ⤴ ENTANGLEMENT AS A GAME-CHANGER FOR COMMUNICATION

ENTANGLEMENT-ENHANCED CLASSICAL COMMUNICATION OVER A NOISY CLASSICAL CHANNEL, *PHYS. REV. LETT.* 106, 110505 (2011)

An IQC optics team recently demonstrated that quantum entanglement — the powerful correlation between particles — can significantly enhance the accuracy and efficacy of communication between parties. The team — **ROBERT PREVEDEL**, **YANG LU**, **RAINER KALTENBAEK**, **WILL MATTHEWS** and **KEVIN RESCH** — published their results in the March 14 edition of *Physical Review Letters*. They demonstrated that one can transmit information over a certain channel with higher success when using entanglement than with the means available in classical physics. ■



## AWARDS & HONOURS



### ADRIAN LUPAŞCU, Sloan Fellowship

Congratulations to IQC faculty member Adrian Lupaşcu, who has been awarded the prestigious Sloan Fellowship, which annually recognizes outstanding early-career scientists whose research pushes the boundaries of chemistry, computer science, physics and other fields. Lupaşcu, whose research focuses on superconductor-based approaches to quantum information, is among 118 scientists from across North America to earn the \$50,000 fellowship this year. Researchers who receive the fellowships “represent the very brightest rising stars of this generation of scholars,” said Paul L. Joskow, president of the Alfred P. Sloan foundation. Kudos to Adrian for this tremendous and well-deserved honour.



### JOSEPH EMERSON, Waterloo Region's 40 Under 40

Congratulations to Joseph Emerson, who has been honoured among Waterloo Region's 40 Under 40 — an annual award that recognizes remarkable people making a difference in the community. Emerson believes in the civic responsibility of scientists to share their work with the public, which led to his invaluable work as head writer, scientific advisor and co-star of the award-winning documentary, the *Quantum Tamers*. Emerson has also delivered several popular public lectures, most recently at the Royal Canadian Institute for the Advancement of Science. ■

## WINTER COURSES

THE FOLLOWING COURSES WERE OFFERED  
AT IQC DURING THE WINTER SEMESTER.

### QIC 750 Implementations of Quantum Information Processing

*Instructor: Frank Wilhelm*

An introduction to physical implementations of quantum computers with an emphasis on common and connecting themes.

### QIC 890 Spin-based Implementations

*Instructor: Jonathan Baugh*

An in-depth introduction to quantum information processing implementations based on nuclear and electron spin.

### QIC 885 Quantum Electronics and Photonics

*Instructor: Hamed Majedi*

For engineers who are interested to learn applied quantum mechanics to study quantum behaviours of electrons, photons and their interaction.

### QIC 845 Open Quantum Systems

*Instructor: Joseph Emerson*

Explores the theory of open quantum systems, which consists of a set of mathematical techniques and phenomenological models for describing generalized quantum dynamics and quantum measurements, and methods of quantum control.

### QIC 823 Quantum Algorithms

*Instructor: Andrew Childs*

An investigation of algorithms that allow quantum computers to solve problems faster than classical computers.

## SPRING COURSES

THE FOLLOWING COURSES ARE BEING OFFERED  
AT IQC DURING THE SPRING SEMESTER.

### QIC 890 Implementations of Quantum Communication

*Instructor: Thomas Jennewein*

### QIC 891 Sir Anthony Leggett Lecture Series

Foundations of Quantum Mechanics and Quantum Information

### QIC 890/891 Selected Advanced Topics in Quantum Information

*Course co-ordinator: Michele Mosca*

Instructors:

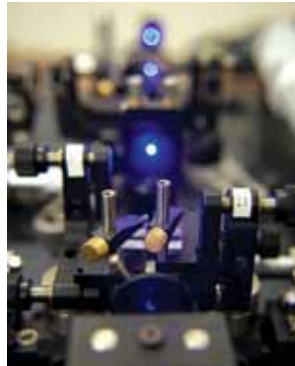
Ashwin Nayak (*IQC, Waterloo & Perimeter Institute*)  
Sarah Croke (*Perimeter Institute*)  
Giulio Chiribella (*Perimeter Institute*)  
Iman Marvian (*IQC, Waterloo & Perimeter Institute*)  
Rob Spekkens (*Perimeter Institute*)  
Rolf Horn (*IQC, Waterloo*)  
David Cory (*IQC, Waterloo & Perimeter Institute*)  
Jacob Biamonte (*Oxford*)  
Roger Colbeck (*Perimeter Institute*)  
Akimasa Miyake (*Perimeter Institute*) ■

## MOSCA AMONG CANADA'S TOP 40 UNDER 40

### » OPTICS GROUP ADVANCES MEASUREMENT-BASED QUANTUM COMPUTING

OPTICAL ONE-WAY QUANTUM COMPUTING WITH A SIMULATED VALENCE-BOND SOLID, *NATURE PHYSICS* 6, 850-854, (2010)

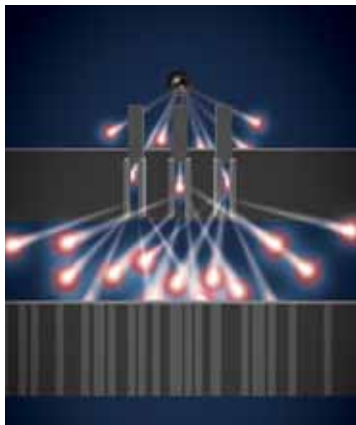
An IQC optics team described an important advancement they achieved in measurement-based quantum computing in an issue of *Nature Physics* published late last year. The team created and characterized, for the first time, a so-called AKLT (Affleck-Kennedy-Lieb-Tasaki) state, which can serve as a quantum processor.



The experiment “capitalized on the fact that photonic states can simulate other quantum systems,” summarized **JONATHAN LAVOIE**, who co-authored the paper with **KEVIN RESCH**, **BEI ZENG** and **RAINER KALTENBAEK**, along with **STEPHEN BARTLETT** of the University of Sydney. ■

### » IQC theorists shed light on three-slit experiments

THREE SLIT EXPERIMENTS AND THE STRUCTURE OF QUANTUM THEORY, *FOUNDATIONS OF PHYSICS* 3, VOL. 41, 398-405 (2011)



The famous two-slit experiment is known as one of the quintessential demonstrations of quantum phenomena. While the interference patterns resulting from the two-slit experiment are well documented, relatively little attention has been paid to what happens (or, more importantly, *doesn't* happen) when a third slit is introduced.

The absence of third-order

interference has been experimentally demonstrated, and recent work by IQC researchers **JOSEPH EMERSON** and **COZMIN UDUDEC**, along with **HOWARD BARNUM** of Perimeter Institute, seeks to better understand what is behind this absence. In the paper “Three Slit Experiments and the Structure of Quantum Theory,” published recently in *Foundations of Physics*, the team characterized a broad class of theories that, like quantum mechanics, predict no three-slit interference. ■



» “I feel very lucky and thankful to be counted among this remarkable group of people,” said Mosca. “This award helps bring together people from different sectors, who can work together to effect changes not achievable within one sector alone.”

For his tremendous contributions to science in Canada, IQC’s Deputy Director Michele Mosca has been named among the country’s *Top 40 Under 40*.

The award celebrates young Canadians who are “outstanding leaders in their chosen fields and are shaping our country’s future” — a description that certainly applies to Mosca.

As one of the founding creators of the Institute for Quantum Computing, he has made incalculable contributions to establishing Waterloo as a globally recognized hub for quantum information research. Through his own research and leadership, and his efforts to create the University of Waterloo’s collaborative graduate program in quantum information, Mosca has helped establish Canada as a leader in the global quantum race.

Mosca and the 39 other winners were recognized in a special section of the *Globe and Mail* on April 28, and were honoured during a gala ceremony in Toronto on May 2. ■



# Questions & Answers

Get to know IQC researchers



**Get to know:**

**Ashwin Nayak** | Faculty

**Hometown?** I was born on the southwest coast of India, but grew up in several cities across the country. Last year, I broke my previous record (seven years) for the longest time I've lived in any city.

**What first intrigued you about quantum science?** The first time I encountered anything quantum was in high school. I remember being completely confused about how a particle could also be a wave.

**What are you currently investigating?** I am working on methods from information theory for studying problems in communication complexity.

**Which scientist (past or present) inspires you, and why?** It may sound corny, but it's the people around me — the research community at Waterloo and in the wider academic world — that are a constant source of inspiration. It's one thing to hear or read about brilliant minds, and something else to see them in action.

**How would you briefly describe quantum information science to a complete layperson?** Whenever friends ask me about my research area, I point to the goggles they've worn at the dentist, or to toys that use polarization of light in clever ways. Quantum information science takes that to a whole other level, in trying to make devices for more sophisticated tasks.

**What hobbies/interests do you have away from IQC?**

I enjoy reading and experimenting in the kitchen.

**What continues to pique your curiosity, scientifically or otherwise?**

I am fascinated by Indian philosophy and practices, especially yoga and meditation, and their perspective on well-being.

**Any random factoid about you or your scientific work?** My official name has five parts, and the first four initials formed my computer login name at IIT Kanpur. My friends from those days sometimes call me by these initials.

## » Get to know: Emily Pritchett | Postdoctoral Fellow



**Hometown?** Macon, Georgia (pop. ~100,000); home of The Allman Brothers Band, Little Richard and the International Cherry Blossom Festival.

**What first intrigued you about quantum science?** Schrödinger's equation. I took an applied course on partial differential equations as an undergraduate mathematics major. All of the examples were taken from physics, of course, but I was completely blown away that in some situations nature is described best with a probability distribution itself predicted by a wave equation.

**What are you currently investigating?** Quantum computing and quantum optics on superconducting circuits.

**Which scientist (past or present) inspires you, and why?** I have a lot of admiration for the small percentage of physicists who manage to do both theoretical and experimental work.

**How would you briefly describe quantum information science to a complete layperson?** We try to control and exploit quantum mechanics, which is a completely different set of rules that govern nature at a fundamental level probabilistically.

**What hobbies/interests do you have away from IQC?** Hanging out with my dog Pete, music of all kinds (I play piano), painting (artistically and decoratively), board games, gardening.

**What continues to pique your curiosity, scientifically or otherwise?**

I'm most interested in things I don't understand at all (yet).

**Any random factoid about you or your scientific work?**

I gave a "blackboard talk" on special relativity in grade four. I think our assignment was to present the biography of a famous person. I picked Einstein, and rather than discussing his life, I led a discussion on the postulates of special relativity. It took me 12 years more to realize I wanted to study physics.

## » Get to know: Jonathan Lavoie | Graduate Student



**Hometown?** Jonquière, QC.

**What are you currently investigating?** I work in a quantum optics lab. I mainly focus on the generation and manipulation of different kinds of multi-photon states, in order to investigate foundational ideas in quantum mechanics, implement quantum information protocols or even simulate other quantum systems.

**Which scientist (past or present) inspires you, and why?** Hubert Reeves, an astrophysicist born in Quebec, was my first serious contact with science. I enjoyed reading his books and they inspired me to study physics.

**How would you briefly describe quantum information science to a complete layperson?** I usually use an analogy about soup to explain quantum mechanics. Soup can be liquid or very chunky. You could use either a spoon or a fork to eat it. Obviously, you won't go very far using a fork for the liquid soup, but it does not matter for the chunky one. However, the spoon is the best tool for both consistencies. Classical physics here is the fork — a mathematical tool that predicts very well properties of "chunky matter," but fails to explain phenomena at a smaller scale. Quantum mechanics is the spoon — a more appropriate tool to understand and explain the properties of microscopic or even some macroscopic systems.

**What hobbies/interests do you have away from IQC?** Outside of counting photons, I find cooking very pleasant. When I have free time, I usually escape to a lake to do some fishing and stay up as late as possible in front of a campfire.

**What continues to pique your curiosity, scientifically or otherwise?** I enjoy reading about the history and the evolution of ideas in science, including books like "The Age of Entanglement: When Quantum Physics Was Reborn" by Louisa Gilder, "The Structure of Scientific Revolutions" by Thomas S. Kuhn, and "Du scribe au savant", by Y. Gingras, P. Keating and C. Limoges.

**Any random factoid about you or your scientific work?** My parents still spread the word that I am an astrophysicist studying in Toronto. I guess my explanations about quantum information science have to be improved. But first I should start with a geography lesson. ■

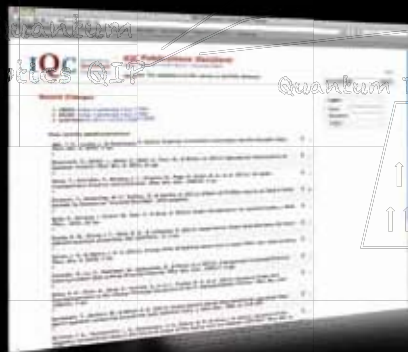


# Quantum Connections

## IQC Online

### The Quantum Library

Visit [pubs.iqc.ca](http://pubs.iqc.ca) and see our new publications database  
- home to hundreds of journal articles, conference proceedings and other publications by IQC researchers.



### The Quantum Factory Blog

Visit [quantumfactory.wordpress.com](http://quantumfactory.wordpress.com) to read the new blog spearheaded by IQC's communications and outreach team. The blog is home to a variety of posts including video interviews, news articles, travelogues and more. Interested in writing for the blog? Let us know! [iqc@uwaterloo.ca](mailto:iqc@uwaterloo.ca)



#### Twitter

Follow [@QuantumIQC](https://twitter.com/QuantumIQC) to see our tweets on events, quantum news, new publications and other fun stuff. Tag us [#quantumiqc](https://twitter.com/QuantumIQC) in your own tweets!



#### Facebook

Join our fan page at [facebook.com/quantumiqc](https://facebook.com/quantumiqc) for photos, news updates, event info and insight into social life at IQC.



#### Flickr

A picture is worth a thousand words. See photos from inside the construction site of the Mike & Ophelia Lazaridis Quantum-Nano Centre, our Open House, Stephen Hawking's visit and much more. ■





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# Meet our visiting scientists on



The IQC video library continues to grow, with nearly 25 videos posted to YouTube in recent months. Along with videos and animations explaining the research at IQC, the QuantumIQC YouTube channel features interviews with visiting scholars and collaborators including Andrew Cleland, Gilles Brassard, Tommaso Calarco and others. Find our YouTube channel at [youtube.com/quantumiqc](https://youtube.com/quantumiqc).



## Tommaso Calarco (from University of Ulm) on IQC

“ I'm very excited (to visit IQC) because this is one of the most successful examples of centres in quantum technologies worldwide. I'm very interested to learn how it's structured, how it works and what are the keys to its success. The drive that moves researchers here is to develop this beautiful vision of bringing quantum into our daily lives. ”

## Gilles Brassard (from University of Montreal) on the peculiar origins of quantum cryptography

“ The story is a bit unusual. I was in Puerto Rico...swimming in the ocean and minding my own business when a complete stranger swims up to me and tells me that he knows how to use quantum mechanics to make bank notes that would be impossible to counterfeit. Kind of strange. I listened to him politely, and by the time we swam back to shore I had found we can prove this idea. ”



## Andrew Cleland (from University of California) on the quantum mechanics of big things

“ Everybody thinks (quantum mechanics) is associated only with very, very small things — electrons, atoms, things of that nature — but if you really believe that quantum mechanics is the fundamental description, then it should apply to everything. But observing quantum effects in big things is quite challenging. What I've been trying to do is to find big physical systems that really can be shown to obey quantum mechanics. We built a mechanical system... which vibrates at a very, very high frequency which... makes it behave quantum-mechanically. ”



Join the growing list of subscribers to the QuantumIQC YouTube channel to see new videos as they're posted! ■

# Ontario Lieutenant Governor visits IQC

**Ontario Lieutenant Governor David C. Onley praised the “innovative science” and “leading-edge work” being done at IQC following his tour of the institute on April 11.**

“YOU WILL HAVE A REAL IMPACT THAT’S GOING TO AFFECT PEOPLE’S LIVES IN POSITIVE WAYS.”



» Their Honours with IQC Executive Director Raymond Laflamme (far left) and University of Waterloo President Feridun Hamdullahpur (far right).

“You will have a real impact that’s going to affect people’s lives in positive ways,” Onley told a group of IQC researchers during a lunch reception. “Don’t ever lose sight of that tremendous purpose.”

Onley’s interest in IQC was sparked last November, when he presented IQC postdoctoral fellow Anne Broadbent with the prestigious Polanyi Prize. While speaking with Broadbent and IQC Director Raymond Laflamme at the award ceremony, Onley asked if he could visit IQC for a behind-the-scenes tour — a request IQC was happy to oblige.

Following his tour of IQC, the Lieutenant Governor visited the University of Waterloo’s Adaptive Technology Centre and other sites on campus to learn about accessibility at the university. From there, he went to KidsAbility, where he met young students with disabilities and delivered a speech to supporters of the organization.

IQC was honoured to give the Lieutenant Governor a first-hand look at how Ontario is leading the quantum revolution. ■

## Nanotech pioneer delivers first Quantum Frontiers lecture

IQC launched its *Quantum Frontiers Distinguished Lecture Series* on April 1, with a fascinating, filled-to-capacity talk by nanotechnology pioneer Don Eigler. A fellow at the IBM Almaden Research Centre, Eigler is widely known for having spelled out I-B-M using 35 individual atoms of xenon. Eigler’s lecture, co-presented by IQC, the Waterloo Institute for Nanotechnology and CIFAR, explored how researchers are working to build and operate atomic-scale logic circuits that perform computation using only the spin degree of freedom. Each term, the *Quantum Frontiers Distinguished Lecture Series* will showcase a world-leading researcher whose work is at the forefront of quantum science. Visit the IQC website for a video of the full lecture, and for information about the next *Quantum Frontiers Distinguished Lecture*, to be delivered on June 24 by cryptography pioneer and nanotech expert Ralph Merkle. ■



# » Arrivals

## Postdocs

Olaf Benningshof  
Mustafa Bal  
Rajat Mittal  
Nathan Wiebe

## Graduate Students

Christian Konrad  
Michael Mazurek  
Juan Miguel Arrazola

## Long Term Visitors

Won-Young Hwang  
Yusuke Kondo  
Virginia Jauregui Villanueva

## Undergraduate Students

Rongjie Du  
Shazib Mahmood  
Erika Janitz  
David Pomaranski  
Natalie Sisombath  
Laura Richards  
Marilyne Thibault  
Alex Parent  
Shawn Sawyer  
Logan Wright  
Jacob Parker

## Staff

Sherry Hartung ■



## Where have you been?

Do you have a photo of yourself wearing an IQC hat or t-shirt somewhere outside of Waterloo? E-mail us at [iqc@uwaterloo.ca](mailto:iqc@uwaterloo.ca) or join us at [flickr.com/quantumiqc](https://www.flickr.com/photos/quantumiqc) ■



» Colin Hunter in Maine

# » Construction Update

IQC's permanent home, the Mike & Ophelia Lazaridis Quantum-Nano Centre is nearing completion. Check out recent construction and interior shots at [flickr.com/quantumiqc](https://www.flickr.com/photos/quantumiqc)



This shot looks out into the main entrance of the Mike & Ophelia Lazaridis Quantum-Nano Centre. To the left is the Waterloo Institute for Nanotechnology space, and to the right is the IQC space.



In this convertible space, there is a drop of about 15 feet that separates two rooms. In total, this space can be split into four separate rooms and also has retractable seating to accommodate almost 300 people. ■



UNIVERSITY OF  
**WATERLOO**

**IQC** Institute for  
Quantum  
Computing



As part of IQC's upcoming 10th anniversary celebrations, the institute is partnering with the Kitchener-Waterloo Symphony for a pair of concerts called

## **Quantum:** Music at the Frontier of Science

The concerts will explore, through music, sound and visuals, the fundamental concepts of quantum mechanics and quantum information science.

The concerts, to be held Feb. 23 and 24, 2012 at Kitchener's Conrad Centre for the Performing Arts, promise to entertain, educate and enthrall.

We want to hear your ideas! If you want to be involved in the creation of these concerts, or have any ideas about expressing quantum concepts through music, we'd love to hear from you!

[iqc@uwaterloo.ca](mailto:iqc@uwaterloo.ca) ■

Edwin Outwater,  
Music Director of  
the KW Symphony



LOOK FOR THE NEXT ISSUE OF **NewBit** COMING IN THE FALL!

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