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NewBit

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05 | Bright new minds come to IQC

Largest-ever summer schools lead into fall term



UNIVERSITY OF UNIVERSITY OF UNIVERSITY OF UNIVERSITY OF Computing



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IQC.UWATERLOO.CA

Institute for Quantum Computing 200 University Avenue West

Waterloo, Ontario, Canada N2L 3G1 iqc.uwaterloo.ca

> Phone: 1 - 519 - 888 - 4021 Fax: 1 - 519 - 888 - 7610 E-mail: iqc@uwaterloo.ca

>> Welcome to NewBit

Autumn is always an exciting time of year, as it brings with it a new group of exceptional young minds to the Institute for Quantum Computing.

Last fall, IQC collaborated with Waterloo's Math, Science and Engineering Faculties to launch the quantum information graduate studies program, which offers an unprecedented breadth of study in this cutting-edge field.

I'm delighted to welcome all the new scholars who have come to Waterloo from around the world to pursue quantum information science. I would also like to thank the exceptional students who made the inaugural year of the graduate program a great success.

Because quantum information is still a relatively new branch of science, the young researchers who are pursuing it today will make pioneering discoveries that will shape the technologies of tomorrow.

The biggest breakthroughs in quantum information have yet to be made. Our goal at IQC is to give young scientists an unrivaled education, the best tools and the collaborative opportunities needed to take the field in exciting new directions.

Raymond Laflamme | Executive Director, IQC

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ON THE COVER

Participants in the Undergraduate School on Experimental Quantum Information Processing (USEQIP) got hands-on experience in IQC labs this summer.

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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 their cutting-edge research published recently in leading academic journals.

>>> Optics team tests new uncertainty principle

EXPERIMENTAL INVESTIGATION OF THE UNCERTAINTY PRINCIPLE IN THE PRESENCE OF QUANTUM MEMORY AND ITS APPLICATION TO WITNESSING ENTANGLEMENT, *NATURE PHYSICS* (JULY 24, 2011).

In a recent issue of *Nature Physics*, IQC optics researchers explained how they experimentally tested a novel variant of a cornerstone principle in physics — and discovered a useful new application for it.

The researchers tested a new uncertainty principle (a variation of the famous Heisenberg Uncertainty Principle) and verified its theoretical predictions. What's more, they showed that the new relation described by the uncertainty principle can be used as an effective "entanglement witness."



"In physics it is always important to test theoretical predictions, especially ones that are as fundamentally important as this one, because it might have widespread implications in the future," said IQC postdoctoral fellow **ROBERT PREVEDEL**, who conducted the experiments with IQC researchers **DENY HAMEL** and **KENT FISHER**, along with Perimeter Institute's **ROBERT COLBECK**, in the IQC optics lab of **PROF. KEVIN RESCH.**

RESEARCHERS TEST "QUANTUMNESS" OF DEVICES

STRONG QUANTITATIVE BENCHMARKING OF QUANTUM OPTICAL DEVICES, *PHYSICAL REVIEW A* 83, (MAY 20, 2011)

IQC researchers **NATHAN KILLORAN** and **PROF. NORBERT LÜTKENHAUS** have devised a method to determine whether a device, in spite of inherent imperfections, maintains enough "quantumness" to perform meaningful quantum communication.

In a paper published recently in *Physical Review A*, they describe a new benchmarking strategy to determine whether an optical quantum communications device is operating within the "quantum domain."



Useful quantum communication requires quantum entanglement — the strong correlation between particles such as photons — and the IQC researchers were able to get a clear picture of how well communication devices preserve entanglement.

"Everything is based on the idea that truly quantum communication devices will preserve entanglement," said Killoran, a PhD student at IQC. "Our recent paper takes this one step further, showing that we can, with minimal resources, quantify how much entanglement is lost or preserved in a device."



POSTDOC SHAKES THE QUANTUM BOX



Photo by Peter Lee courtesy of the Waterloo Region Record

IQC postdoc KRISTER SHALM described an experiment he conducted with University of Toronto colleagues as akin to shaking a wrapped Christmas present in hopes of discerning its contents.

Shalm and his colleagues discerned the hidden goings-on within a classic "double-slit" experiment without actually looking inside the experiment. The ingenuity of their technique, which they described in *Science*, garnered attention from plenty of media, including CBC Radio's popular science program *Quirks and Quarks*. "Some new work by Dr. Krister Shalm and his colleagues may have shown a way to outsmart nature a little," host Bob McDonald said during an on-air interview with Shalm.

FALL COURSES

THE FOLLOWING COURSES WILL BE OFFERED AT IQC DURING THE FALL SEMESTER.

QIC 710 Quantum Information Processing

Instructor: Prof. Richard Cleve (0.5 credit)

Quantum Information Processing seeks to harness the strange power of quantum mechanics to provide a qualitatively different and more powerful way of processing information than "classical" physics seems to allow. The objective of this course is to introduce this multidisciplinary subject at the graduate level.

QIC 880 Nanoelectronics for Quantum Information Processing

Instructor: Prof. Adrian Lupaşcu (0.5 credit)

Electrodynamics of superconductors, BCS theory and tunnel junctions, the Josephson effect, flux and fluxoid quantization, quantization of electric circuits, the basic types of superconducting qubits, decoherence in the solid state, circuit quantum electrodynamics, readout of nanoscale qubits, fabrication of gubit devices, and measurement techniques.

QIC 820 Theory of Quantum Information

Instructor: Prof. John Watrous (0.5 credit)

This course presents a mathematical treatment of the theory of quantum information, with a focus on the development of concepts and methods that are fundamental to a broad range of studies in quantum algorithms and complexity, quantum cryptography, and quantum Shannon theory. The course is intended for graduate students at the Masters or PhD level that have previously taken an introductory course (at the undergraduate or graduate level) in quantum computation.

QIC 890 Design in Quantum Systems

Instructor: Prof. David Cory (0.5 credit)

This course is aimed at students interested in learning how to integrate quantum information processing into design of quantum devices. The course will start with an example design for a quantum random number generator.

Check out Shalm's blog at **quantumpie.com** for more information.



✓ Leggett to return for five more years

For the fifth consecutive summer, Nobel Prize-winner **SIR ANTHONY LEGGETT** delivered a lecture series at IQC spanning fundamental questions of quantum mechanics to applications of quantum information. IQC is thrilled to announce that Leggett has renewed his visiting professorship at IQC and will continue to spend his summers teaching, collaborating and mentoring at the institute.

Video recordings of Leggett's 2011 lecture series are posted on the QuantumIQC YouTube Channel at **youtube.com/quantumiqc**.

Leggett (right) pictured with IQC executive director Raymond Laflamme.

QUANTUM FRONTIERS DISTINGUISHED LECTURE SERIES

DR. RALPH MERKLE, a pioneer in molecular nanotechnology, delivered the second installment of the *Quantum Frontiers Distinguished Lecture Series* on June 24, 2011. Merkle, who is based at Singularity

University and the Institute for Molecular Manufacturing, focused his talk on an intriguing question: if you could arrange atoms exactly as you wanted, how would you arrange them? The answers proved a fascinating glimpse into nanotechnology research.



¥ Freeman Dyson

Renowned theoretical physicist and mathematician **FREEMAN DYSON** visited IQC on June 2, the day after he delivered a Perimeter Institute Public Lecture. Dyson, whose wide-ranging interests span everything from space travel to nuclear disarmament, toured IQC labs and met with professors **MICHELE MOSCA**, **RAYMOND LAFLAMME** and IQC Board Chair **TOM BRZUSTOWSKI**.





✓ SCHREITER WINS VANIER FELLOWSHIP

Congratulations to IQC graduate student **KURT SCHREITER**, who has been awarded the prestigious Vanier Canada Graduate Fellowship, valued at \$50,000 annually over three years. The award will help Schreiter, whose graduate work has focused on chirped-pulse interferometry for non-invasive biomedical imaging, pursue his doctoral studies.





FOUR IQC FACULTY WIN EARLY RESEARCHER AWARDS





Ontario's Ministry of Research and Innovation recognized the importance of quantum information science by awarding four IQC faculty members with Early Researcher Awards. Professors JONATHAN BAUGH, ANDREW CHILDS, THOMAS JENNEWEIN and ADRIAN LUPAŞCU received the awards, which are valued at \$100,000, with a matching \$50,000 from a home/partner institution and an additional \$40,000 for indirect costs. Jennewein received an additional \$125,000 from the ministry's "Research Infrastructure" program for his work in quantum photonics devices. These awards will help these four faculty members continue their pioneering work in quantum information, spanning algorithms, computation and communications.

IQC 05

Questions & Answers

Get to know IQC people

Get to know: Vito Logiudice | Director of Operations, Fabrication Facility



Hometown?

I was born in beautiful Montreal.

What first intrigued you about quantum science?

I became interested in the subject after reading *Surely You're Joking, Mr. Feynman!* by Richard Feynman. Curiously, I met our own Raymond Laflamme soon after reading the book. Although I struggled with the very abstract concepts (and still do!), I was hooked the minute Raymond described the exciting things happening here. I'd been following Moore's Law and was intrigued by what lay beyond the "wall" predicted by Moore.

What are you currently working on?

My team and I are juggling the day-to-day operational demands of the RAC I temporary fabrication facility with the many tasks associated with implementing the state-of-the-art Quantum Nano Fabrication Facility in our future home on campus.

What scientist (past or present) inspires you, and why?

There are several, but three definitely stand out. I owe a huge debt of gratitude to my masters' thesis advisor, Les Landsberger, my mentor and friend. I'd probably still be wandering aimlessly in downtown Montreal were it not for Les' guidance and encouragement (long story). Also, Claude Jean of Teledyne Dalsa taught me much about work ethic, integrity, communication skills and equity in the workplace. He's Executive VP and GM of Teledyne Dalsa's foundry operations but remains a physicist at heart (I'm sure he secretly envies me for having met Stephen Hawking). Finally, Richard Feynman inspired me with his ability to explain incredibly complex concepts in simple terms and interact with people of vastly different backgrounds.

How would you briefly describe what you do to a layperson?

I bring together competent, hard-working people, and we implement and refine the infrastructure and technologies our researchers need to build devices that will result in meaningful, positive impacts on society.

What hobbies/interests do you have away from IQC?

With my family in tow, I enjoy exploring this great region we now call home as well as our vast and diverse country. I've recently taken up an old love, cycling, after 20 years of neglect, and I continue to thoroughly enjoy tinkering with all things mechanical.

What continues to pique your curiosity, scientifically or

otherwise? The beauty and power of the natural world as well as the great expanse of space. I vaguely remember seeing the first moon walk on a fuzzy black & white TV and, having seen both the first and last space shuttle launches live, I wonder what lies ahead for human space travel. Finally, I'm both stunned and thrilled at the pace of change of technology all around us.



Get to know: Brendon Higgins

Postdoctoral Fellow

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Hometown? A little rural town called Murwillumbah, near the easternmost tip of Australia. It's nestled under Mt. Warning, which sees the first beams of sunlight on Australian soil every morning.

What first intrigued you about quantum science?

Its counterintuitiveness, although probably everyone says that. Of course I'm used to it now, but only in the sense that I expect quantum mechanics to surprise me every now and then.

What are you currently investigating? I'm part of a project aiming to put a quantum receiver onto an orbiting satellite, so most of my time is spent looking into the various issues involved with that (as well as the inescapable paperwork that comes with it).

What scientist (past or present) inspires you, and why? This will sound like a cop-out, but I couldn't possibly narrow it down to one. Every scientist inspires me, at least in some way. I find science itself an inherently inspiring process for its powerful devotion to truth, in spite of superstition and authority.

How would you briefly describe quantum information science to a complete layperson? The universe is basically a very big, very powerful information processing system. But the language it uses is very strange, with limited vocabulary and unusual grammar. Quantum mechanics has taught us what this language is. Quantum information science is about figuring out what can be said in this new language, and how to go about saying it.

What hobbies/interests do you have away from IQC? I'm interested in a bunch of things, some I indulge in more often than others — technology, games, art, music, and photography (particularly if it involves cute critters of some kind)... I'd be interested in more things if I had the time.

What continues to pique your curiosity, scientifically or otherwise? All sorts of things. I suppose one of the bigger (though arguably philosophical) things that makes me ponder is the idea of information as a universal foundation. "It from bit", as Wheeler put it. The concept that, not only is our experience of the physical world limited by informational processes (defined by the restrictions of our physical senses), but that the physical universe itself can be viewed as operating on informational processes at its foundation, is something that I find wonderfully fascinating. I guess that goes some way to explain why I study quantum information.



Get to know: Sarah Sheldon

Graduate Student

Hometown? Gahanna, Ohio. It is a suburb of Columbus.

What first intrigued you about quantum science? Quantum science is just weird. It's nothing like the classical physics we experience in our everyday lives. At the same time it is very real, and exploring the quantum world has led to many new technologies and a different understanding of the rules that govern our world.

What are you currently investigating? My project is a magnetic resonance experiment that involves enhancing the signal of nuclear spins using their couplings to electrons in a solid crystal. Electrons are relatively easy to control while nuclei have smaller interactions with their environment and can thus store information for longer times. This work has applications in medical imaging as well as quantum information science.

What scientist (past or present) inspires you, and why?

While it is always interesting to read about old physicists like Faraday and Tesla tinkering in their labs and discovering amazing phenomena, the scientists who actually inspire me are the ones I work with every day. I learn the most from my fellow students and researchers, and their enthusiasm is so encouraging.

How would you briefly describe what you do to a layperson? I try to control quantum systems using the

interactions within the systems and limiting the influence of their environment. More specifically I use magnetic fields to control electrons and nuclei.

What hobbies/interests do you have away from IQC?

I love cooking and baking, and of course eating! I also enjoy running and having been taking boxing classes since I moved to Waterloo.

What continues to pique your curiosity, scientifically

or otherwise? I really just like solving puzzles — from the big mysteries of science to the everyday challenges of trying to figure out how to tackle some problem in the lab.

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The Quantum Library

Visit **pubs.iqc.uwaterloo.ca** and see our new publications database — home to hundreds of journal articles, conference proceedings and other publications by IQC researchers.





@QuantumIQC

Follow us on Twitter to find out what's happening at the institute today. We tweet about our current events, new publications, breakthroughs, conferences, what's coming up for IQC's 10th anniversary celebrations and more. Tag us **#QuantumIQC** in your tweets! =

From "campers" to collaborators

Visiting students stay for the summer and intern with faculty



This summer IQC hosted a pair of conferences aimed at introducing a new generation of students to theoretical and experimental approaches to quantum information science. The Undergraduate School on Experimental Quantum Information Processing (USEQIP) hosted 19 Canadian and international university students for two weeks spanning May and June. In August, IQC welcomed 40 exceptional high school students from around the world for the weeklong Quantum Cryptography School for Young Students (QCSYS). "Both programs were a huge success thanks to the curiosity and enthusiasm the students had for quantum science," said IQC's scientific outreach manager, Martin Laforest.

Many of the students from the camps stayed at IQC for the rest of the summer as interns, working alongside IQC faculty on a range of topics at the forefront of quantum research.

IQC's summer interns:

ANDREW McMULLEN 4th year Engineering Physics (Computing option), Queen's University

ARTUR CZERWINSKI 3rd year Theoretical Physics, Nicolaus Copernicus University, Torun, Poland

ALEX PARENT 4th year Physics (Computing option), University of Waterloo

DARYL CHULHO HYUN 4th year Applied Physics, University of Waterloo

DMITRI IOUCHTCHENKO 3rd year Computational Biochemistry, University of Waterloo

ERIKA JANITZ 4th year Electrical Engineering (Quantum Information option), University of Waterloo

MARILYNE THIBAULT 2nd year Physics, Laval University

JACOB PARKER 4th year Computer Science, University of Waterloo

JONATHAN ZUNG 4th year Mathematics, University of Toronto

JEAN MAILLARD 3rd year Theoretical Physics, Imperial College, London, UK

LOGAN WRIGHT 4th year Engineering Physics, Queen's University

ARUNACHALAM SRINIVASAN 4th year Electrical Engineering, National Institute for Technology Karnataka, Mangalore, India MIRIAM DIAMOND 4th year Physics, Carleton University

PHILIP REINHOLD 4th year Physics and Computer Science, University of Chicago

LAURA RICHARDS 1st year Master of Computer Science, University of Guelph

SHITIKANTH

4th year Computer Science and Engineering, Indian Institute of Technology, Kanpur, India

SHAUN SAWYER 3rd year Applied Mathematics, University of Waterloo

TAPASH J. SARKAR 3rd year Electrical Engineering, Physics and Mathematics, Rice University, Houston

MARCEL VAN HELDEN 4th year Physics, University of Waterloo



Inquisitive students participate in two successful summer schools hosted by IQC: QCSYS (above) and USEQIP (left).

IQC 09

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In the Community

» Cirque de la Science

More than 250 students at Waterloo's St. Matthew Elementary School got a hands-on look at the wonders of quantum science during a visit from IQC researchers on June 8.



More amazing than fiction



Proving that the truth can be stranger — and more amazing — than fiction, IQC postdoctoral fellow **KRISTER SHALM** and magician **DAN TROMMATER** presented "Quantum Physics and Harry Potter," two fascinating evenings of magic and science held at Waterloo's Princess Twin Cinemas on July 14 and 15.

SLITS AND RAILS

It was almost certainly the first of its kind: a human-sized re-creation of the classic double-slit quantum experiment — on a moving train. On June 24, IQC participated in the second annual Steel Rail Sessions, a moving mash-up of arts, science and culture that chugalugged between Waterloo and St. Jacobs. The IQC installation ushered human "photons" through a pair of large slits, and projectors captured images of the participants in unique ways that depicted (metaphorically) the wave-particle duality of light. Nearly 300 passengers walked through the installation, which was one of many eclectic and thought-provoking exhibits on the 10-car train.



>>> Arrivals

Research Assistant Professor Guo-Xing Miao

Postdoctoral Fellows

Lin Chen Silvano Garnarone Zhengfeng Ji Mustafa Muhammad

Graduate Students

Marcin Kotowski Michal Kotowski Jeremy Kroeker Alexandre Laplante Vadym Kliuchnikov Matthew Amy Antonio Scotland Juan Miguel Arrazola John Donohue Aimee Heinrichs Gregory Holloway Joseph Rebstock Denis-Alexandre Trottier Zak Webb Chris Pugh Takafumi Nakano Joshua Geller Sadegh Raeisi Joachim Nsofini Kaveh Gharavi Matthew Graydon Holger Haas

Research Assistants

Daryoush Shiri Allison MacDonald

Long-Term Visitor

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 or join us at flickr.com/quantumiqc =

Focus on Science



As part of IQC's 10th anniversary events, we will be hosting a slate of new academic conferences and workshops.

Distinguished

Lecture Series In collaboration with the Waterloo Institute for Nanotechnology, IQC continues its Quantum Frontiers Distinguished Lecture Series, featuring renowned experts from around the world.

Recent Progress in Quantum Algorithms April 11-13, 2012

Undergraduate School on Experimental Quantum Information Processing May 28-June 8, 2012 12th Annual Canadian Summer School on Quantum Information June 11-15, 2012

9th Canadian Student Conference & 2nd AQuA Student Congress on Quantum Information June 18-22, 2012

Tropical QKD July 25-29, 2012

Quantum Cryptography School for Young Students August 13-17, 2012

Quantum Information Processing with Spins and Superconductors Date to be determined

Marco Plani visiting Canmore, Alberta.

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Women in Physics Canada

More than 60 female physicists from across North America came to Waterloo in July for a conference that explored many of the deepest questions in physics — including the question of why women are so underrepresented in the field.

The *Women in Physics Canada* conference, developed and co-hosted by IQC and Perimeter Institute, featured three days of scientific lectures, workshops and networking sessions, as well as panel discussions about female involvement in a predominantly male field.

"The quality of the talks, the attitudes of the participants, the sharing and openness between them — it all created a great experience," said IQC postdoctoral fellow **ANNE BROADBENT**, who co-created the conference with Perimeter Institute postdoc **SARAH CROKE**. "There's a lot of enthusiasm for the conference to happen again, and we know there's a need for it."

Visit **flickr.com/quantumiqc** to see all of the photos from *Women in Physics Canada*.









LOOK FOR THE NEXT ISSUE OF NewBit COMING IN THE WINTER!











