NEWBIT

A NEWSLETTER FROM THE INSTITUTE FOR QUANTUM COMPUTING, UNIVERSITY OF WATERLOO

ISSUE 21 | SUMMER 2013

Moving into the new LAZARIDIS CENTRE

UNIVERSITY OF WATERLOO | IQC Institute for Quantum Computing

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UNIVERSITY OF WATERLOO | IQC Institute for Quantum Computing

IN this issue

ON THE COVER

Cover Photo by: Jonathan Bielaski

The Mike & Ophelia Lazaridis Quantum-Nano Centre opened last fall solidifying Waterloo's growing reputation as "Quantum Valley"

SUMMER 2013

publisher
IQC COMMUNICATIONS & OUTREACH

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FROM THE EDITOR

Since the Grand Opening of the Mike & Ophelia Lazaridis Quantum-Nano Centre in September 2012, we have been busy at the Institute for Quantum Computing, not only with research, but also with conferences, workshops and visits.

We were fortunate to host:

- The premier of Ontario, Kathleen Wynne;
- Several pioneers in the field of quantum information, including both 2012 Nobel Laureates in Physics, during the Decoherence and Friends conference;
- Researchers and students from diversified scientific areas for the Quantum Computation and Complex Networks workshop;
- Leading entrepreneurs, venture capitalists, academics and policy-makers were invited for the first Leadership Innovation Conference.

The spring term brought several other conferences and camps to IQC:

- The Undergraduate School on Experimental Quantum Information Processing (USEQIP) accepted 26 engineering, physics, chemistry, computer science and math undergraduate students interested in the field of quantum information processing for a two-week workshop in June;
- Graduate students and young postdoctoral fellows from around the world joined us for the International Quantum Key Distribution (QKD) Summer School at the end of July;
- We hosted the third annual QCrypt August 5-9;
- From August 12 to 16, the Quantum Cryptography School for Young Students (QCSYS) introduced 42 exceptional students aged 15-17 to the intersection between computing, security and quantum mechanics.

Despite the busy summer, research continues at IQC, and several groups prepare to move their labs from the Research Advancement Centre (RAC) to the Mike & Ophelia Lazaridis Quantum-Nano Centre. We'll have more about use of the new space in upcoming issues.

JODI SZIMANSKI, *Senior Communications Manager*

FEATURE ARTICLE

A Celebration of Quantum Contributions

DECOHERENCE AND FRIENDS CONFERENCE

WOJCIECH ZUREK is a pioneer in quantum information research who is renowned for his work in the theory of decoherence in quantum systems. To celebrate the 30-year anniversary of his seminal work, and coincidentally his 60th birthday, IQC hosted the *Decoherence and Friends* conference May 20-23, 2013.

The organizing committee composed of IQC faculty member **JOSEPH EMERSON**, IQC Executive Director **RAYMOND LAFLAMME**, **JUAN PABLO PAZ** (University of Buenos Aires) and **JOSÉ IGNACIO LATORRE** (Universitat de Barcelona) invited Zurek's collaborators and prominent contributors to the field from around the world for the celebrations.

Invited guests and 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. ■

(L-R) **WOJCIECH ZUREK**, **RAYMOND LAFLAMME** and **DAVID WINELAND**

Nobel laureate lecture

2012 Nobel Prize co-recipient, **SERGE HAROCHE**, gave a public lecture to a full house during the *Decoherence and Friends* conference. Haroche spoke about his vast career, the impact of the Nobel Prize and the state of fundamental science funding.

FEATURE ARTICLE

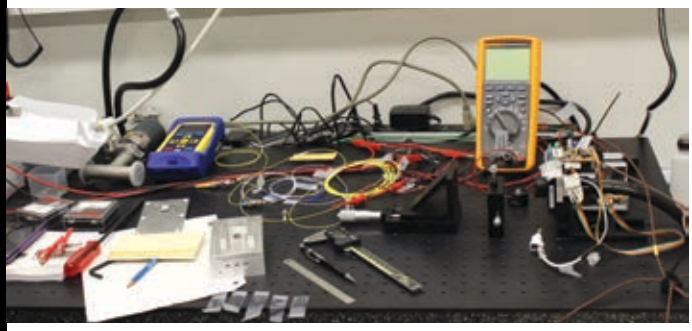
The Lazaridis Centre

MIKE & OPHELIA LAZARIDIS QUANTUM-NANO CENTRE

The first lab to be outfitted in the new Mike & Ophelia Lazaridis Quantum-Nano Centre focuses on the security of quantum communication. Research Assistant Professor **VADIM MAKAROV**, who was introduced in the last *NewBit*, and his team are testing commercial devices that perform quantum key distribution, a primitive for ultra-secure, quantum-enabled communication.

Makarov and his team are taking apart quantum key distribution machines currently sold by companies. The team looks at their functions and finds weaknesses that hackers can exploit.

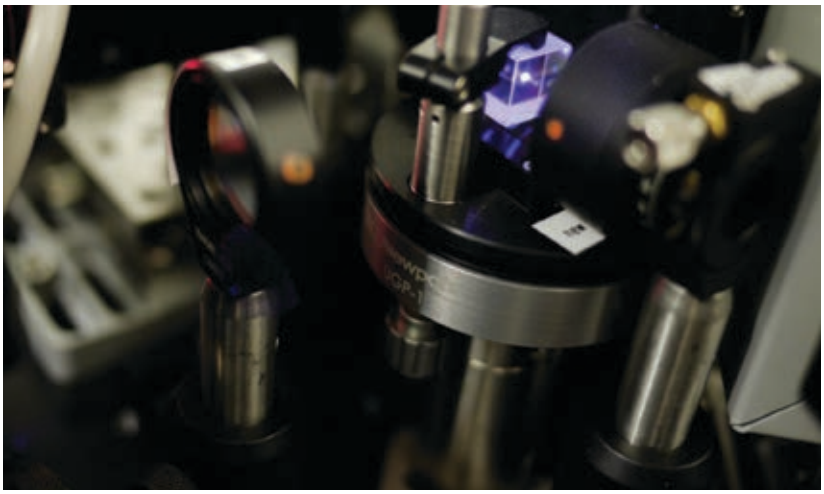
In theory, using quantum information for communication security is unbreakable, but when built into a physical machine there are many opportunities for imperfections. These imperfections unintentionally open backdoors for hackers. Typically, the problems are component deficiencies such as light reflecting off of a component instead of fully passing through — an imperfection similar to being able to see your own reflection in a window, even though the purpose of a window pane is merely to pass light. There can also be engineering mistakes not obvious to the designer of a cryptographic machine. Through their research, Makarov and his team verify that the implementation of the quantum elements remains secure.



Makarov and his team also build components in the lab including specialized optoelectronic devices. Recently, the team built a low-noise single-photon detector used in an experiment that achieved quantum teleportation over a record-breaking distance of 143 kilometres through free space between the Canary Islands of La Palma and Tenerife. ■

SCIENCE HIGHLIGHTS

IQC faculty, postdoctoral fellows and students continue to conduct internationally recognized research into quantum information science. Here is a sampling of their cutting-edge research published recently in academic journals over the past term.



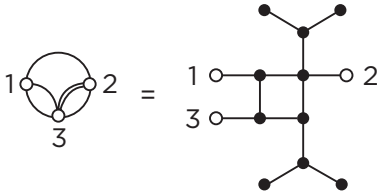
EXTENDING EINSTEIN

NATURE PHYSICS 9 (2012)

Ever since Einstein, Podolsky and Rosen (EPR) investigated the surprising behavior of two entangled particles in 1935, the phenomenon of quantum entanglement has fascinated, intrigued and puzzled physicists. Generating pairs of entangled photons is now routine and is currently used for quantum computing, quantum cryptography and quantum precision measurements.

A team, led by Associate Professor **THOMAS JENNEWEIN**, extended EPR's original ideas of two particles to three particles of light. Using this method to create three entangled photons leads to entanglement of the three photons' energies, which was not possible using the previous methods for generating three photons. This new form of creating quantum correlations between three photons from a single input photon may eventually allow for quantum mechanics to operate future communications networks, and could even lead to new advances in the development of quantum devices. **JENNEWEIN** and the team, **KRISTER SHALM** (National Institute of Standards and Technology), **DENY HAMEL** (PhD student), **ZHIZHONG YAN** (Macquarie University), **CHRISTOPH SIMON** (University of Calgary) and Assistant Professor **KEVIN RESCH** published their results in *Nature Physics* in November 2012. ■

A new model to build a scalable quantum computer



SCIENCE 389 6121 (2013)

Three IQC researchers proposed a new universal computation model. Their construction could potentially provide an architecture for building a scalable quantum computer without a need to actively manipulate qubits. Inspired by the quantum version of a random walk, Professor **ANDREW CHILDS**, along with postdoctoral fellow **DAVID GOSSET** and PhD candidate **ZAK WEBB** demonstrated that any desired quantum algorithm can be cast by judiciously configuring a graph of particle locations and letting multiple walkers "quantum walk" along the configuration for a given time. This model of computation is particularly well-suited for a variety of physical quantum systems currently under investigation, such as neutral atoms in optical lattices and photons in arrays of superconducting qubits. ■

SCIENCE HIGHLIGHTS

New frameworks, new assumptions

PHYS. REV. A 87, 042301 (2013)

While investigating different frameworks, new assumptions need to be made about the dynamics of an open system and its correlation with its environment in its initial state. Postdoctoral Fellow **AHARON BRODUTCH**, along with co-authors **ANIMESH DATTA** (University of Oxford), **KAVAN MODI** (National University of Singapore), **ANGEL RIVAS** (Universidad Complutense) and **CÉSAR A. RODRÍGUEZ-ROS ARIO** (Harvard), published the results of their research presenting a system-environment state with nonvanishing quantum discord that resulted in a completely positive map in a paper called *Vanishing quantum discord is not necessary for completely positive maps*. Using two different sets of assumptions about the relevant family of initial states, the co-authors set out to re-examine the connections between positivity and quantum discord. Their work invalidated an earlier claim that vanishing quantum discord was necessary for completely positive maps. ■

WITH A FOCUS ON THE THEORETICAL

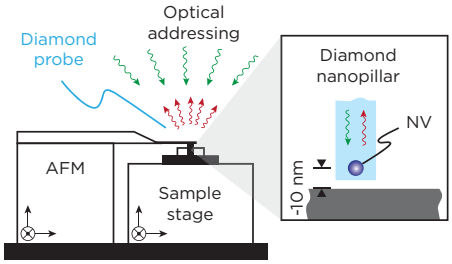
The 16th annual QIP conference took place at Tsinghua University in Beijing in January 2013. IQC members participated in five quantum information processing presentations — two of them featured talks.

- **ERIC CHITAMBAR** (University of Toronto) led a presentation with Assistant Professor **DEBBIE LEUNG**, PhD students **LAURA MANCINSKA** and **MARIS OZOLS**, and **ANDREAS WINTER** (Universitat Autònoma de Barcelona) on *Everything you always wanted to know about LOCC (but were afraid to ask)*.
- Assistant Professor **ANDREW CHILDS**, **DAVID GOSSET** (Postdoctoral Fellow) and **ZAK WEBB** (PhD student) presented their paper *Universal computation by multi-particle quantum walk*, which was published in *Science* in February.
- Associate Professor **JOSEPH EMERSON**, Master's student **VICTOR VEITCH**, **CHRIS FERRIE** (PhD student) and **DAVID GROSS** (University of California, Santa Barbara) spoke about their paper *Negative Quasi-Probability as a Resource for Quantum Computation*.
- Assistant Professor **ROBERT KOENIG** gave two featured talks: one with **SERGEY BRAVYI** (IBM T. J. Watson Research Center), *Classification of topologically protected gates for local stabilizer codes*; the other with **GRAEME SMITH** (IBM Thomas J. Watson Research Center), *Limits on classical communication from quantum entropy power equalities.* ■

IQC OUTREACH

IQC at AAAS

Researchers from IQC presented two talks at this year's annual meeting of the American Association for the Advancement of Science (AAAS) in Boston. IQC Canada Excellence Research Chair **DAVID CORY** presented alongside **AMIR YACOBY** (Harvard) and **RAFFI BUDAKIAN** (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 Canada Foundation for Innovation (CFI). Cory presented his research on quantum devices and how they will drive Canadian innovation.

While in Boston, 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. ■

Martin Laforest

Christopher Wilson

IQC ON TOUR

Associate Professor **CHRISTOPHER WILSON** and **MARTIN LAFOREST** toured 12 universities between January and April through a program organized by the Canadian Association of Physicists (CAP). The CAP Lecture Tour helps promote the study of physics in Canada and raise the level of excitement about new developments in the field.

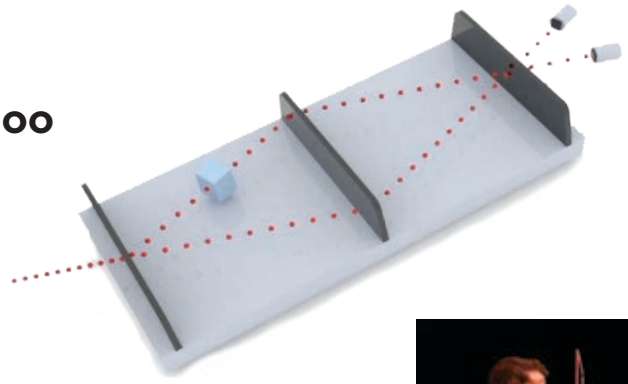
Laforest presented the basic concepts of quantum information science and technologies and how they're being applied to computing, communication and sensing at Carleton University, Concordia University, Simon Fraser University, the University of Ontario Institute of Technology, the University of Regina and the University of Saskatchewan. Wilson spoke about the dynamical Casimir effect that he demonstrated in 2011 and led to the experiment being named one of Physics World's 'Breakthrough' experiments. He presented at McGill University, Mount Allison University, St. Francis Xavier University, Université de Moncton, University of PEI and University of Windsor. ■

IQC OUTREACH

Returning to TEDxWaterloo

For this year's TEDxWaterloo, *chasingHOME*, **RAYMOND LAFLAMME** returned to talk about the progress in the field of quantum information since the last time he spoke in 2010. Laflamme discussed 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, we've also been able to solve other problems that have led 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.

The organizers of TEDxWaterloo challenged **MARTIN LAFOREST** with performing a quantum physics experiment with the entire audience. Laforest took up the challenge and performed an experiment to explain the rules of quantum mechanics. Using polarizers, Laforest showed an example of superposition and how if you attempt to measure a quantum system, you perturb it. ■



Neutron interferometer

RAYMOND LAFLAMME with a model of a satellite that will be used for quantum key exchange

MARTIN LAFOREST conducts an experiment with polarizers with the help of **RAMY NASSAR**

STUDENT CONFERENCE

Canadian-American-Mexican (CAM) Graduate Student Physics Conference

University of Waterloo

Monday, August 15 to Thursday, August 18 ■

Around the INSTITUTE

Premier tours Lazaridis Centre

The Honourable **KATHLEEN WYNNE** toured IQC on April 5, 2013 as part of her first visit to Waterloo Region as Premier of Ontario. **RAYMOND LAFLAMME** and **DAVID CORY** shared IQC's history and research and Premier Wynne was the first non-scientist to enter the Quantum NanoFab facility in the Lazaridis Centre. ■

» (L-R) **RAYMOND LAFLAMME**, **MIKE LAZARIDIS**, Premier **KATHLEEN WYNNE**, **JOHN MILLOY** (MPP) and **DAVID CORY**

Investments in Quantum Commercialization to build the Quantum Valley

On March 19, 2013, **MIKE LAZARIDIS** and **DOUG FREGIN** announced the $100M Quantum Valley Investment fund. Lazaridis and Fregin, who together founded BlackBerry, have partnered again to help grow the quantum information industry in Canada.

Investments from the fund will support the commercialization of research from IQC and other research institutes around the world.

WEB **quantumvalleyinvestments.com** ■

NEW COURSES & WORKSHOPS

CryptoWorks21

Cryptoworks21, a NSERC-funded training program for building the workforce for the cryptographic infrastructure of the 21st century introduced its first two courses in July. The collaboration between IQC, the University of Calgary and the Université de Montréal offered a Professional Development Session on Project Management, a workshop based on Mitacs Step Foundations of Project Management I and was hosted by IQC July 23-24. The workshop aimed to help CryptoWorks21 researchers interested in building their professional skills, strengthen working relationships and improve research results and impact. For the two days following, the second course, Standards & Certification, was open to CryptoWorks21 researchers as well as students in other programs. This course helped researchers understand the importance of certification and standardization for quantum cryptography technologies, including when they're introducing new technologies to the marketplace. ■

Around THE INSTITUTE

AWARDS AND FELLOWSHIPS

KEVIN RESCH

Associate Professor **KEVIN RESCH** was awarded the E.W.R. Steacie Fellowship from the Natural Sciences and Engineering Research Council of Canada (NSERC) valued at $250,000 over two years. This funding will support his work on the development of quantum sources of light and interferometric sensors.

MATTEO MARIANTONI

Assistant Professor **MATTEO MARIANTONI** was one of this year's recipients of the prestigious Sloan Fellowship. Mariantoni plans on using the monetary portion of the two-year fellowship to further build his state-of-the-art Digital Quantum Matter Lab. The lab focuses on designing, fabricating and manipulating nano-scale superconducting integrated circuits and controlling their quantum behaviour.

THOMAS JENNEWEIN

The Canada Foundation for Innovation (CFI) helps provide researchers with the facilities and equipment they require to innovate. Associate Professor **THOMAS JENNEWEIN** was awarded a CFI Leading Edge Fund grant worth $490,000 for his research in Global Quantum Communication and Security Certification.

LAURA MANCINSKA

PhD student **LAURA MANCINSKA** was awarded the $5,000 IQC Achievement Award for her research investigating the local quantum operations and classical communication framework. The work of Laura and her colleagues will be useful to others investigating new techniques used to answer open questions. She studies under the direction of **DEBBIE LEUNG** and **ANDREW CHILDS** and defended her thesis July 31. ■

Arrivals

Staff

Kathryn Fedy
Bronwyn Greavette
David Lu
Jessica Miranda
Jodi Szimanski
Dylan Totzke

Students

Feiruo Shen
Shihan Sajeed
Martin Otto
Hamidreza Nafissi
Chunhao Wang
John Rinehart

Long-Term Visitors

Mhlambululi Mafu
Qiang Li
Amir Yacoby
Qiang Li
Hang Li
Fei Wang
Daniel Jost Brod
Tiago Debara
Mouktik Raha ■

Investigating Quantum Cryptography

QCrypt 2013

August 5-9

Students and researchers gathered to discuss one of the most promising opportunities for future quantum cryptography. Researchers shared their results, industry partners showcased their current technologies and a student poster session highlighted recent work.

WEB **2013.qcrypt.net**

SPONSORS Institute for Quantum Computing, Centre for Quantum Technologies, Perimeter Institute, Swiss Federal Institute of Technology Zurich, Cryptoworks21, Telecom Paris Tech, IDQ, ComDev, Communitech, IDQ, OptoElectronic Components, Micro Photon Devices, PicoQuant, USTC-QuantumCTek, Austrian Institute of Technology, Institute for Quantum Technology at the University of Calgary, QaSKY, Single Quantum, SeQureNet, SCONTEL, Tektronix and Teledyne LeCroy.

QKD Summer School

July 29-August 2

Graduate students and postdoctoral fellows converged at IQC for the International Quantum Key Distribution (QKD) Summer School. The annual summer school is an opportunity for students to learn more about relevant approaches and techniques to further their own research in quantum cryptography.

WEB

iqc.uwaterloo.ca/conferences/qkd-2013

SPONSORS

Quantum Cryptography School for Young Students

August 12-16

QCSYS QUANTUM CRYPTOGRAPHY SCHOOL FOR YOUNG STUDENTS

This week-long enrichment program brought high school students to IQC for lectures, hands-on experiments and group work focused on quantum cryptography. QCSYS gives students the opportunity to not only learn about cryptography, but meet and collaborate with some the most renowned researchers in the field. ■

WEB

iqc.uwaterloo.ca/conferences/qcsys2013

SPONSOR

A NEWSLETTER FROM THE **INSTITUTE FOR QUANTUM COMPUTING**, **UNIVERSITY OF WATERLOO**, WATERLOO, ONTARIO, CANADA

You're invited

We're laying out the welcome mat!

We opened the doors of the Mike & Ophelia Lazaridis Quantum-Nano Centre last fall. On September 21, we will welcome the community once again as we participate in *Doors Open Waterloo Region*. Join us for a tour of this spectacular facility and discover for yourself the excitement of quantum physics.

WEB **iqc.uwaterloo.ca/news-events**

Doors Open Waterloo Region
September 21
10 a.m. to 5 p.m.

LOOK FOR THE NEXT ISSUE OF **NewBit** IN THE NEW YEAR

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Ontario

Industry Canada Industrie Canada
Canada