NEWBIT

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

ISSUE 23 | SPRING 2014

We're GROWING

$5M ULTRA HIGH VACUUM (UHV) CLUSTER DEPOSITION LAB OPENS

UNIVERSITY OF WATERLOO | IQC Institute for Quantum Computing

NEWBIT | ISSUE 23 | SPRING 2014

IN this issue

SUPERCONDUCTING CIRCUITS IN SUPER-COOLED LAB

pg 04

We visit Chris Wilson's lab and explore his high-tech cooling system.

NEW IQC FACULTY

pg 06

Three new scientists join IQC.

SCIENTISTS PROVE QUANTUM NONLOCALITY

pg 07

IQC researchers demonstrate the distribution of three entangled photons at three locations.

ON THE COVER

The Ultra High Vacuum (UHV) Cluster Deposition lab in RAC 2.

Cover Photo by: *Light Imaging*

SPRING 2014

publisher
IQC COMMUNICATIONS & EXTERNAL RELATIONS

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

FROM THE EDITOR

We are delighted that IQC was awarded $15M in funding by the federal government in Budget 2014 announced in February. This tremendous show of support allows IQC to continue to excel in our research, outreach and education activities.

In this edition of *NewBIT*, we'll highlight some of our most recent activities. We participated in programming for senior public and high school students through ZOOM Information and Communications Technology Career Day, Waterloo Unlimited and Shad Valley. We also invited leading quantum information experts to IQC such as **JOHN R. KIRTLEY** as part of our Quantum Frontiers Distinguished Lecture series.

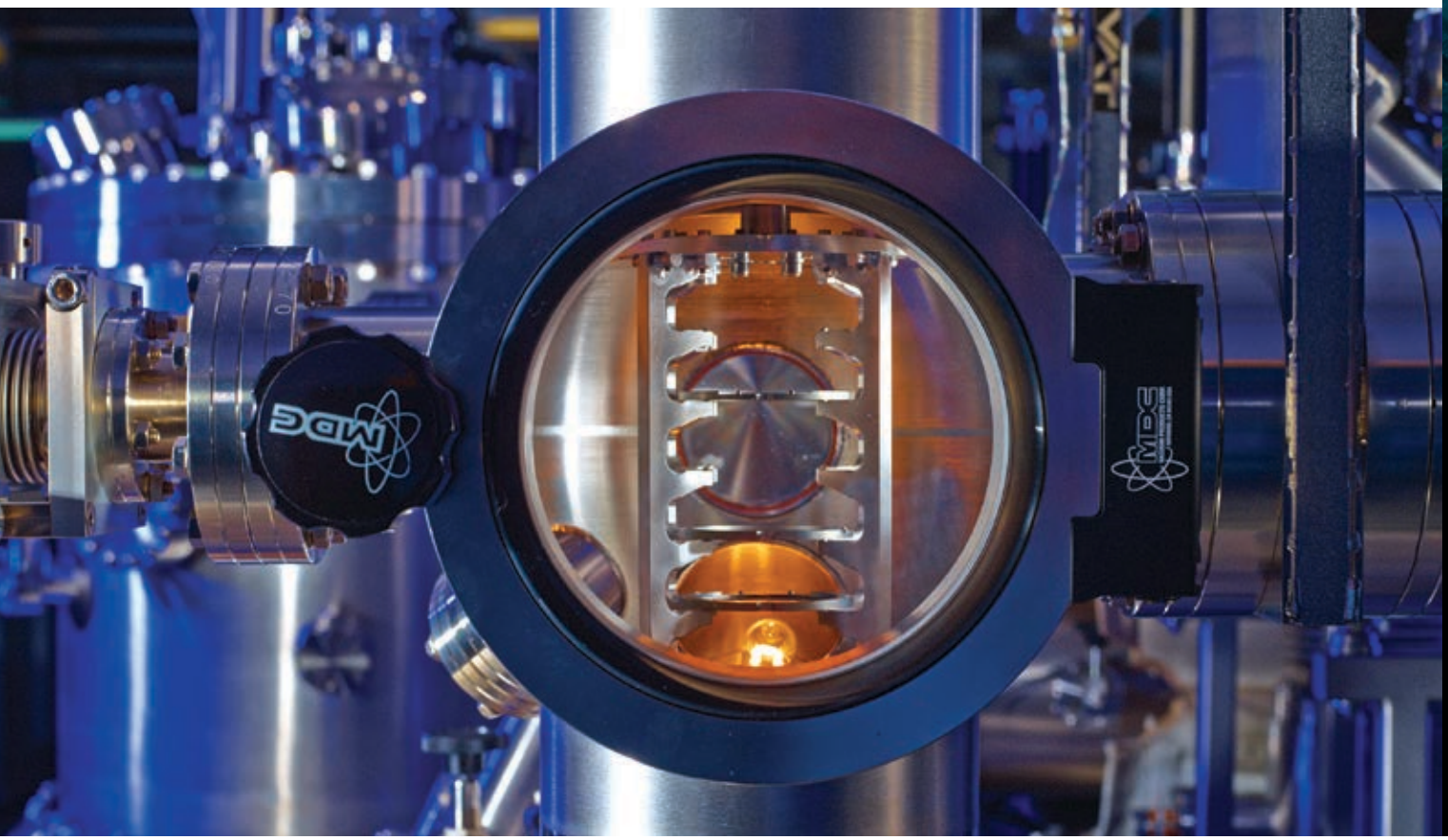
One of our highlights is the opening of a new Ultra High Vacuum (UHV) Cluster Deposition lab as part of **DAVID CORY**'s research activities. We also feature **CHRIS WILSON**'s lab in the Lazaridis Centre where experiments started in November. You'll read about our connections with industry, in particular talks on cryptography by **MICHELE MOSCA** and **MARTIN LAFOREST** at Manulife Financial during Data Privacy Month.

Our IQC members continue to be awarded grants, scholarships and prizes for their leading-edge work. We also continue to expand – we've added three more faculty members in the past term.

It's a busy place and we hope you enjoy reading about all the varied activities underway here at IQC.

JODI SZIMANSKI, *Senior Communications Manager*

Growing **quantum materials** to build quantum devices



December 12, 2013 saw the grand opening of a first-of-its-kind, world-class lab – a UHV cluster deposition lab built specifically for growing a variety of exotic quantum materials.

Quantum materials are needed as the building blocks of robust quantum devices. With a unique combination of molecular beam epitaxy and sputtering chambers, the new deposition system has the ability to carefully grow different types of materials in a layered fashion, such as topological insulators, superconductors, magnetic and non-magnetic metals, and oxides. The physics happening at the interfaces of such materials exhibit exotic behaviours and unconventional electrical properties that can then be harnessed to build quantum devices. The lab is home to **DAVID CORY**, Canada Excellence Research Chair in quantum information and **GUOXING MAO**.

"The Institute for Quantum Computing has made a significant investment in quantum materials science and the most promising direction for building quantum devices is quantum materials," said Cory.

MP HAROLD ALBRECHT and NSERC president **JANET WALDEN** were among the invited speakers along with Dr. **FERDINAND BARTELS** from Omicron NanoScience (Oxford Instruments), IQC Executive Director **RAYMOND LAFLAMME**, Cory and **GEOFF McBOYLE** vice-president, academic & provost of the University of Waterloo. ■

FEATURE ARTICLE

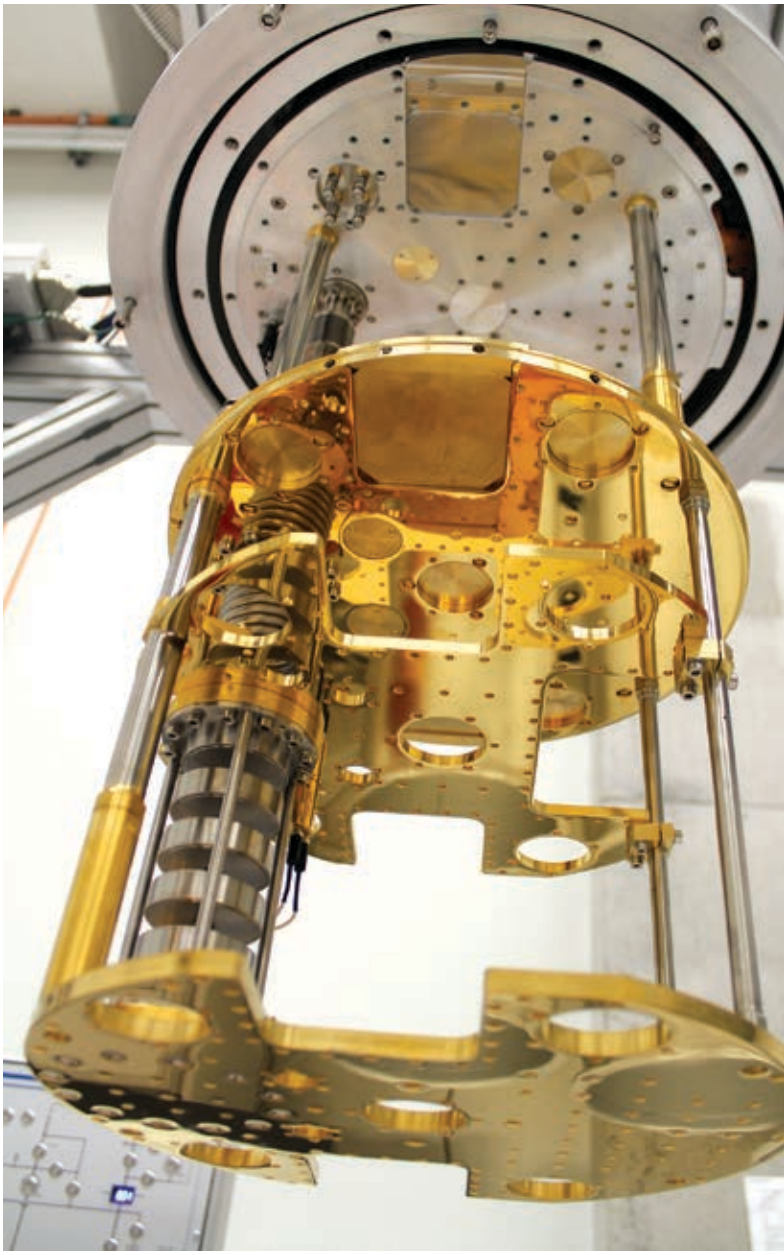
Superconducting circuits in super-cooled lab

Upon entering **CHRIS WILSON**'s lab, the first thing you hear is a high-pitched, repetitive squeak. That squeak is the pump driving liquid helium into the cooling systems so that samples can be cooled down to the order of 10mK. (How cold is 10mK? About 250 times colder than deep space.) These liquid helium cryostats (also known as dilution refrigerators) are used for experiments in superconducting qubits.

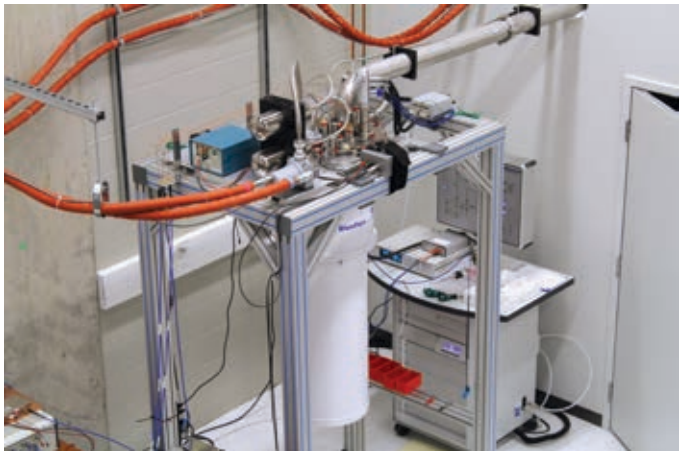
Wilson and his team are exploring how quantum microwaves can be used as a resource for future quantum communication networks. They use superconducting qubits, which are engineered electronic circuits that exhibit quantum properties, to generate quantum microwave states.

By cooling the circuits to the order of 10mK, the circuits behave quantum mechanically and act as artificial atoms. Where many researchers work with "natural quantum systems" such as ions, atoms, molecules and photons as qubits, Wilson's work with these artificial qubits opens the door to more control. They can be made from almost any physical system that has two levels (0 and 1) that behave quantum mechanically, can be initialized, controlled and measured. According to Wilson, "it allows us to do a lot of interesting physics."

This area of study was developed out of 30 years of research in mesoscopic physics studying quantum effects in solid states. Researchers learned how to make nanoelectric circuits that could behave as artificial atoms or could have quantized energy levels. By creating artificial atoms researchers have the freedom to engineer the energy splitting of the levels. By tuning the energy levels of qubits, researchers can make them work in different regimes instead of having nature choose the regime.



The inside of a dilution refrigerator in Wilson's lab.



« Wilson's lab features two dilution fridges supplied with liquid helium.

» An open dilution fridge with layered canisters that seal and secure the vacuum when in use.

Facts about dilution fridges

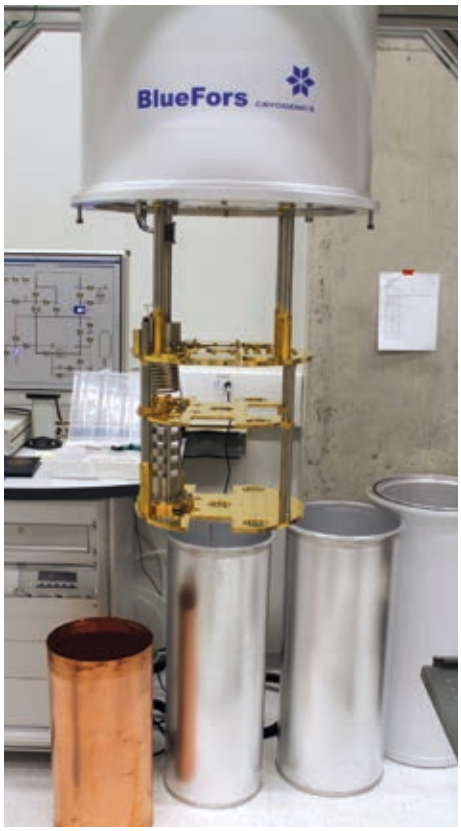
- Can cool materials to the order of 10mK
- Takes 24 hours to cool down to base temperatures
- Uses liquid helium to refrigerate materials
- Measures <0.1 µm on all experimental flanges – very low vibration levels
- Push one button to initiate fully automated cooldown sequence from room to base temperature.

For Wilson's research in quantum communications, the energy levels need to be converted to a microwave frequency of 5 GHz – the frequency of wireless communications. There are two major advantages to working at this frequency: cost efficiency (the higher the frequency, the more expensive it is) and the tremendous amount of technology already available at this frequency - allowing researchers to piggyback on electronic developments already established by industry.

One particular area of interest is how superconducting qubits can be used as quantum repeaters in communications. Traditional repeaters allow today's networks to span the globe. But repeaters would disrupt quantum communications (if a quantum system is observed, it's perturbed). By preparing quantum states of microwave light, the superconducting circuits can be a resource for quantum communications. Wilson envisions a quantum communication network that's a hybrid network using optical or telecomm photons for extended distances and superconducting circuits for local processing.

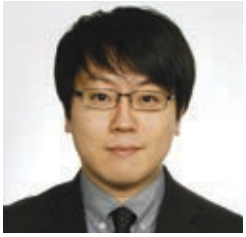
In another experiment, one of Wilson's students is attempting to create tripartite entanglement between three different microwave fields. By using three entangled qubits that are far apart on a chip, entangled microwave photons could be generated and distributed for information processing.

Wilson's is one of the first labs to be outfitted in the Mike & Ophelia Lazaridis Quantum-Nano Centre. ■



Welcome

Three new faculty members have joined IQC since January 2014.



KYUNG CHOI

Assistant Professor **KYUNG CHOI** joins IQC and the Department of Physics and Astronomy from the Korea Institute of Science and Technology where he is a senior scientist and group leader since 2011. He completed his PhD and a postdoctoral fellowship at the California Institute of Technology.

He currently holds the Presidential Early Career Award for Scientists and Engineers from the Republic of Korea. His research will focus on the development and application of advanced techniques in cold atom physics and quantum optics to probe the fundamental nature of the quantum world.

MICHAL BAJCSY

Having just completed a postdoctoral fellowship at Ginzton Laboratory at Stanford University, Assistant Professor **MICHAL BAJCSY** joined IQC and the Department of Electrical Engineering in January. Bajcsy received both his BSc and PhD from Harvard University's School of Engineering and Applied Science and spent several years as a visiting student at the Massachusetts Institute of Technology.

At IQC, Bajcsy's research focuses on scalable photonic devices and quantum optics experimental platforms based on quantum emitters such as cooled atoms, quantum dots and colour centers, coupled to nanophotonic structures.

RAFFI BUDAKIAN

RAFFI BUDAKIAN will join IQC as the Nanotechnology (WIN) Endowed Chair in Superconductivity in Waterloo's Physics and Astronomy department. After earning his bachelor's, master's and PhD degrees in physics from the University of California, Los Angeles, Budakian was a visiting scientist at the IBM Almaden Research Centre.

The World Technology Network awarded him the World Technology Award in 2005 for his work in the detection and manipulation of quantum spins. That same year Budakian joined the University of Illinois at Urbana-Champaign. In July, Budakian joins IQC to continue his research in the use of spins, one of the promising approaches being applied to quantum information processing. ■

SCIENCE HIGHLIGHTS

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

Proving quantum nonlocality with the distribution of three entangled photons

NATURE PHOTONICS 8 (2014)

For the first time, IQC researchers have demonstrated the distribution of three entangled photons at three different locations several hundreds of metres apart proving quantum nonlocality. The findings of the experiment, *Experimental Three-Particle Quantum Nonlocality under Strict Locality Conditions*, were published in *Nature Photonics* in March. Former PhD student **CHRIS ERVEN** (University of Bristol) was the lead author along with PhD students **EVAN MEYER-SCOTT**, **KENT FISHER**, **JONATHAN LAVOIE**, **CHRISTOPHER PUGH**, **JEAN-PHILIPPE BOURGOIN**, Master's student **NICKOLAY GIGOV**; undergraduate research assistant **LAURA RICHARDS**; postdoctoral fellows **BRENDON HIGGINS**, **ROBERT PREVEDEL** (Max F. Perutz Laboratories), **ZHIZHONG YAN** (Macquarie University) and **KRISTER SHALM** (National Institute of Standards and Technology); Associate Professors **THOMAS JENNEWEIN** and **KEVIN RESCH**; IQC Executive Director **RAYMOND LAFLAMME**; and former faculty member **GREGOR WEIHS** (University of Innsbruck).

The project team studied the correlations of three photons in a Greenberger-Horne-Zeilinger (GHZ) state – a type of entangled quantum state involving at least three particles. First, photon triplets were generated in Resch's lab. Then, the first photon was delayed in a 580m optical fibre in the lab while the two other photons travelled up 85m of optical fibre to the rooftop. Both photons were then sent through two telescopes to two trailers about 700m away from the source and from each other.

Photons generated in the lab were beamed to separate trailers in a field on the University of Waterloo campus.

Each trailer contained detectors, time-tagging devices developed by IQC spin off Universal Quantum Devices (UQD), and quantum random number generators. To ensure the locality loophole was closed, the random number generators determined how the photon at each trailer would be measured independently. The UQD time tagging devices also ensured the measurements happened in a very small time window (three nanoseconds), meaning that no information could possibly be transmitted from one location to the other during the measurement period – a critical condition to prove the non-locality of entanglement.

This three photon entanglement leads to interesting possibilities for multi-party quantum communication protocols including Quantum Key Distribution (QKD), third man cryptography and quantum secret sharing.

WEB **http://bit.ly/1hqe1R4**

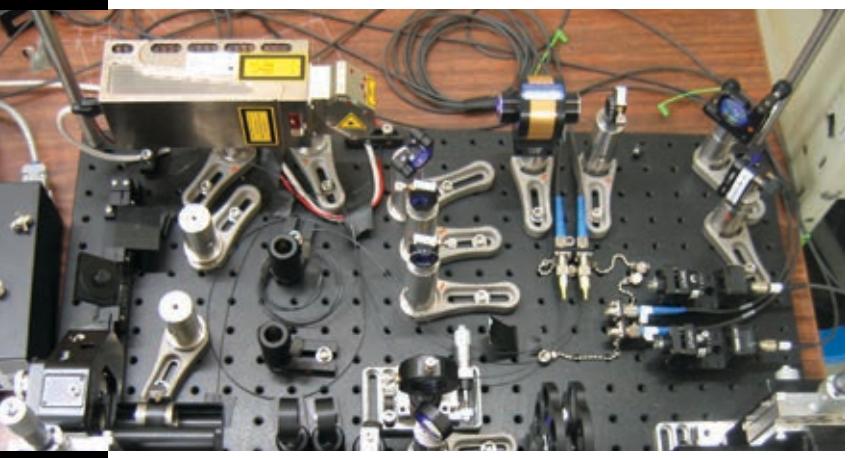
SCIENCE
HIGHLIGHTS

Protecting people doing business with others they may not trust

NATURE COMMUNICATIONS 5: 3418 (2014)

Experiments performed by IQC researchers **CHRIS ERVEN** (now a postdoc at the University of Bristol), **NICK GIGOV**, **RAYMOND LAFLAMME** and **GREGOR WEIHS** (now at the University of Innsbruck) deployed quantum-entangled photons so that Alice could share information with Bob while meeting stringent restrictions. In the experiment, Bob requests access to one or the other of two sets of information that Alice holds. Alice needs to send it to Bob without knowing which set he's asked for and Bob can't know about the other set. Known as the 1-2 random oblivious transfer (ROT), this protocol was developed by **STEPHANIE WEHNER** and **NELLY NG** of the Center for Quantum Technologies, National University of Singapore. ROT is a building block for more complicated schemes that could have applications in secure identification. The paper, *An experimental implementation of oblivious transfer in the noisy storage model* was published in March in *Nature Communications*.

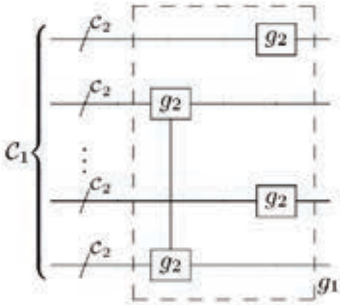
WEB **http://bit.ly/1tHrmtH**



The experiment's Alice and Bob communicated with entangled photons produced in this setup. Such apparatus could be miniaturised using techniques from integrated optics.

REDUCING OVERHEAD IN QUANTUM ERROR CORRECTION

PHYS. REV. LETT. 112 010505 (2014)



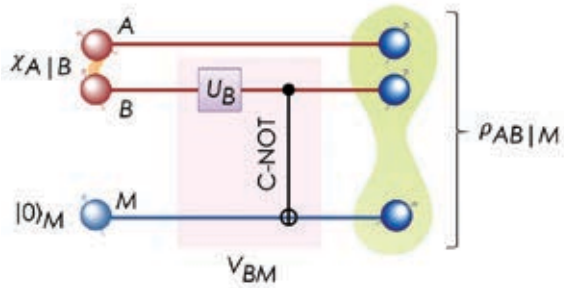
General construction of a logical gate for a concatenated error correction scheme.

In the development of scalable quantum computing systems, it is necessary to understand and to control sources of noise during the manipulation of quantum systems. The theory of fault-tolerant quantum error correction address these issues. However, the overhead in schemes such as magic state distillation have proven to be prohibitive. To address this issue, PhD student **TOMAS JOCHYM-O'CONNOR** and **RAYMOND LAFLAMME** proposed a scheme that uses two different quantum error correcting codes in concatenation. By sacrificing the full distance of the concatenated scheme, a universal set of quantum gates is established that are robust to errors. Because this scheme requires no special ancillary state preparation to achieve universality, it provides an alternative to other state distillation schemes that have high overhead. The paper, *Using concentrate quantum codes for universal fault-tolerant quantum gates*, was published in *Physical Review Letters* in January.

WEB **http://bit.ly/1rp7APt**

THE GENERATION OF ENTANGLEMENT

PHYS. REV. A 89, 010302 (2014)
PHYS. REV. LETT. 112, 140501 (2014)



Circuit model for the activation protocol.

Research Assistant Professor **MARCO PIANI** has recently published two papers on the generation of quantum entanglement. In a new approach to Heisenberg's uncertainty principle, Piani and his collaborator **PATRICK J. COLES** (University of Singapore) explored complementarity of physical observables by relating it to entanglement. Their paper, *Complementary sequential measurements generate entanglement*, was selected as Editor's suggestion, and published in *Physical Review Rapid Communications* in January 2014. The paper outlines a new paradigm for capturing and quantifying the complementarity of two observables, based on the interaction and the entanglement created between an observed system and the two measurement devices used to sequentially measure the two observables. This work connects, in a fundamental way, complementarity and entanglement, and provides bounds on the usefulness of sequential bipartite operations for entanglement production.

WEB **http://bit.ly/1lKnMtb**

Piani's second paper, *Experimental entanglement activation from discord in a programmable quantum measurement*, deals with the experimental verification of a predicted qualitative and quantitative theoretical mapping from discord to entanglement. Quantum discord constitutes a form of nonclassical correlations more general and less fragile than entanglement, and a potential resource in the development of information processing and quantum communication protocols. Yet, discord is less understood than entanglement. In the experiment, Piani and collaborators **GERARDO ADESSO** (University of Nottingham), **VINCENZO D'AMBROSIO**, **ELEONAORA NAGALI**, and **FABIO SCIARRINO** (Sapienza University of Rome), created and manipulated a three-qubit system – playing the role of a composite system *AB* and a measurement apparatus *M* – using a flexible two-photon setup. They demonstrated that, in the presence of discord between *A* and *B*, any measurement interaction between *B* and *M* leads to the creation of useful and better understood entanglement between *AB* and *M*. The paper was published in *Physical Review Letters* in April.

WEB **http://bit.ly/QBPI8U** ■

ANNE BROADBENT

KENT FISHER

KEEPING PRIVATE DATA PRIVATE

NATURE COMMUNICATIONS 5: 3074 (2014)

IQC researchers have been studying how to keep your private data just that – private, even when performing remote quantum computation on it. PhD student **KENT FISHER** and alumna **ANNE BROADBENT** (now at University of Ottawa) set out to determine how arbitrary quantum computations could be carried out on encrypted quantum data. They proved that an untrusted server can implement a universal set of quantum gates on encrypted qubits without learning any information about inputs, while the client, who knows the decryption key, can easily decrypt the results of the computation. The results of this research will play a key role in enabling the development of secure distributed quantum computing. Contributors to the paper, *Quantum computing on encrypted data*, include IQC alumni **KRISTER SHALM** (National Institute of Standards and Technology); **ZHIZHONG YAN** (University of Sydney); **JONATHAN LAVOIE**, (University of Geneva); and **ROBERT PREVEDEL** (Research Institute of Molecular Pathology). This work was supervised by Associate Professors **THOMAS JENNEWEIN** and **KEVIN RESCH** and published in *Nature Communications* in January.

WEB **http://bit.ly/1mJkAIv** ■

SCIENCE
HIGHLIGHTS

TALKS

Exotic quantum phenomena explored at Quantum Frontiers Distinguished Lecture

JOHN R. KIRTLEY, physical research science associate at the Center for Probing the Nanoscale in the Department of Applied Physics at Stanford University, kicked off the 2014 Quantum Frontiers Distinguished Lecture series on March 20.

Kirtley's lecture explored the results of research conducted at Stanford, led by **KATHRYN A. MOLER**, published in March of 2013: *Scanning SQUID Microscopy of Topological Insulators*. The research team used a scanning SQUID microscope to image the bulk and edge currents in mercury telleride (HgTe) quantum well, one of few known topological insulators. Topological insulators (TI) are recently discovered materials that under certain conditions are insulating in the bulk but conducting on their surfaces with quantized, spin polarized currents. Proximity of a topological insulator to a superconductor (S) is predicted to give rise to exotic quantum phenomena and unconventional electrical properties. ■

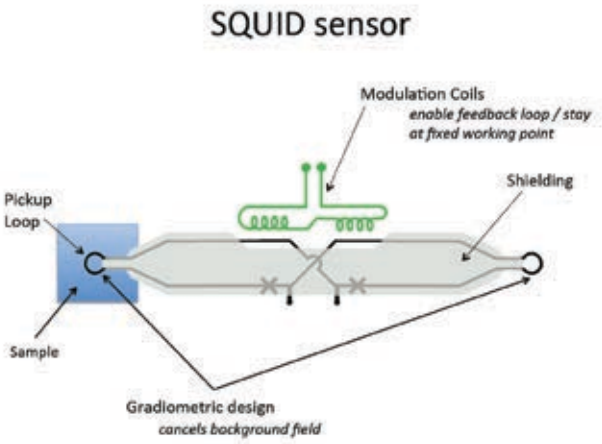


Diagram of the SQUID microscope.

CONFERENCES

On the global stage at AAAS in Chicago

The world's largest general scientific society, AAAS, held their annual meeting in Chicago in February. With the theme of *Meeting Global Challenges: Discovery and Innovation*, Executive Director **RAYMOND LAFLAMME** moderated a panel on Quantum Information Technologies sharing insights into how quantum information will shape our future. Panelists included:

- **DAVID CORY**, Canada Excellence Research Chair in quantum information, discussed two ways in which quantum mechanics leads to more powerful devices
- **GREGOIRE RIBORDY** of ID Quantique presented the opportunities and challenges for commercial quantum cryptography
- **MICHEL DEVORET** of Yale University discussed superconducting microwave circuits serving as qubits and known strategies for error corrections

WEB For a full description of the panel, go to **http://bit.ly/1rp7Qy8** ■

Quantum Innovators welcomes promising young postdocs and grad students

January 17-20, 2014

The Quantum Innovators workshop brought together the most promising young postdoctoral fellows and senior graduate students in quantum physics and engineering for a three-day conference aimed at exploring the frontiers of our field. Each researcher accepted to the program delivered a 30-minute talk on their research.

Keynotes included **LUMING DUAN**, University of Michigan and one of our newest faculty members **MICHAL BAJCSY**. ■

Strong IQC presence at APS March Meeting

Over a dozen IQC researchers shared their research findings at this year's APS meeting in Denver, Colorado the week of March 3rd.

Invited speakers included Associate Professor **JOSEPH EMERSON**, Professor **NORBERT LÜTKENHAUS**, PhD student **TOMAS JOCHYM-O'CONNOR** and IQC Affiliate **DANIEL GOTTESMAN**. The following papers were also presented:

- *Tunable coupling in atom-mirror system* by Associate Professor **CHRIS WILSON** and colleagues from Chalmers University of Technology
- *Nuclear Spin Polarization of Phosphorus Donors in Silicon. Direct Evidence from 31P-Nuclear Magnetic Resonance* by Postdoctoral Fellows **PATRYK GUMANN** and **OSAMA MOUSSA**, Masters student **OM PATANGE**, Canada Excellence Research Chair **DAVID CORY** and colleagues from Dartmouth College, Simon Fraser University, Liebniz-Institut fuer Kristallzuechtung, PTB Braunschweig, Keio University and VITCON Projectconsult GmbH
- *Decoherence of superconducting flux qubits in copianar waveguide resonators* by Assistant Professor **ADRIAN LUPASCU**, PhD student **JEAN-LUC ORGIAZZI**, Undergraduate Research Assistant **DAVID LAYDEN**, and former IQC researchers **RYAN MARCHILDON**, **MUSTAFA BAL**, **CHUNQING DENG**, and **FLORIAN ONG**
- *Fourier space encoding techniques applied to magnetic resonance imaging using NV centers in diamond* by IQC Associate **AMIR YACOBY** and his colleagues from Harvard
- *Fibre bundle framework for quantum fault tolerance* by IQC Affiliate **DANIEL GOTTESMAN** and his colleague from the University of Toronto
- *Efficient characterization of spurious two-level systems in superconducting qubits under non-ideal conditions* by PhD student **YUVAL R. SANDERS** and colleagues from Saarland University
- *Characterization of the temperature dependence of dielectic loss at microwave frequencies in Al_2O_3 and TiO_2 films grown by atomic layer deposition* by Lupascu, Orgiazzi, Deng and Masters student **MARTIN OTTO**
- *Proximity effect in a Nb_inAs-Nb nanowire junction* by Assistant Professor **JONATHAN BAUGH**, PhD students **KAVEH GHARAVI** and **GREG HOLLOWAY**, Postdoctoral Fellow **CHRIS HAAPAMAKI** and a colleague from McMaster University

WEB Watch the feature on IQC produced by APS TV shown on this year's conference channel: **http://bit.ly/1mEsFVW** ■

IQC OUTREACH

LAFLAMME TALKS ABOUT THE QUANTUM QUEST

Executive Director **RAYMOND LAFLAMME** addressed the Canadian Club of Ottawa on February 18th at the Chateau Laurier. Laflamme described how quantum information will shape the future by harnessing quantum phenomena. Government, industry leaders and academics from the Ottawa area attended the talk entitled *The quest for the quantum "holy grail"*. ■

CONNECTING WITH THE INSURANCE INDUSTRY

IQC was invited to take part in one of the special events Manulife Financial planned to promote Data Privacy Month. Deputy Director, Academic, **MICHELE MOSCA** presented *Toward Quantum Safe Cryptography* for a group of Manulife staff, and **MARTIN LAFOREST**, senior manager of scientific outreach hosted an interactive, hands-on cryptography demonstration with PhD students **CHRISTOPHER PUGH**, **AIMEE GUNTHER** and **JOHN DONOHUE**. ■

ZOOMING INTO QUANTUM CRYPTOGRAPHY

This year's ZOOM Information and Communications Technology (ICT) Career Day took place at the Perimeter Institute for Theoretical Physics on February 26. IQC Postdoctoral Fellow **MARCO PIANI** held an interactive session on quantum computing, specifically quantum cryptography. Piani discussed classical and quantum cryptography and had the students create a simple message and decrypt it. He also demonstrated quantum effects through the polarization of light. ZOOM Career Days are organized by Communitech's Business & Education Partnership for grades 11 and 12 students to learn from ICT professionals and explore career options.

WEB For more information on the ZOOM ICT Career Day, see CTV's coverage: **http://bit.ly/1gUDmis** ■

Acknowledging women in science

PhD students **COREY RAE MCRAE** and **AIMEE GUNTHER** joined the Laurier Centre for Women in Science for an International Women's Day event on Saturday, March 8. The family-friendly event featured cool science demonstrations, hands-on activities and games. Other partners included the Kitchener Public Library, Desire2Learn, Kwartzlab, Diyode, Savvy Planet, Nerd Nite KW and Brick Works Academy. ■

KEEPING UP with MARTIN »

IQC's senior manager of outreach, **MARTIN LAFOREST**, has been busy inspiring others by encouraging curiosity and discovery.

Encouraging scientific study and discovery

More than 160 grade seven and eight students from Waterloo Region participated in Shad Valley's "Design Your Future" event on March 24. In an effort to pique the interest of elementary school students in careers in science, technology, engineering, and mathematics (STEM), **MARTIN LAFOREST**, presented *Where does Technology Come From?* He emphasized the role that scientific study and curiosity-based discovery plays in the development of new and exciting technology. IQC and Shad Valley have a long history of partnership in promoting STEM careers to youth, and this is the third year that IQC has participated in the Engineering Week event. ■

Inspiring curiosity in Colorado

MARTIN LAFOREST kicked off the 2014 Collegiate Forum Peaks lecture series on March 6 in Buena Vista, Colorado. Now in its 11th season, the lecture series brings national and international experts in science, religion and philosophy to the Upper Arkansas Valley. Laforest's presentation, *How extremely tiny is becoming extremely huge*, introduced 200 attendees to the world of quantum research and its impact on the fields of communication, sensing and computing. ■

High school students discover the design of cryptography

Waterloo Unlimited is a transdisciplinary, week-long high school enrichment program for students in grades 10 through 12. In March of 2014, 20 grade 11 students participated in the "design" program, where they spent a week exploring design from the point of view of engineering, environment, science fiction, virtual reality and more. **MARTIN LAFOREST** gave a 90-minute interactive workshop on the design of classical and quantum cryptography. IQC has worked with the students of Waterloo Unlimited for many years, exposing them to the varied opportunities that exist within the study of quantum science. ■

» A pop-up research park because research matters

RAYMOND LAFLAMME represented IQC at a pop-up research park at Queen's Park as part of the Council of Ontario University's (COU) Research Matters initiative. The event invited researchers from across the province to share their research at Queen's Park and was kicked off with an address from Minister of Research and Innovation, **REZA MORIDI**. ■

« **RAYMOND LAFLAMME** shares IQC research at Research Matters.

IQC OUTREACH

A TRIP TO DEVELOP SCIENTIFIC COLLABORATIONS WITH TECHNION

In March, President and Vice-Chancellor **FERIDUN HAMDULLAHPUR** led a delegation of University of Waterloo researchers to Israel. Seven IQC researchers participated in a quantum information symposium hosted by the Technion-Israel Institute of Technology in Haifa, Israel. Faculty members **MICHAL BAJCSY**, **JONATHAN BAUGH**, **ROBERT KOENIG**, **RAYMOND LAFLAMME** and **ADRIAN LUPASCU**, along with Postdoctoral Fellow **AHARON BRODUTCH** and PhD student **ZAK WEBB** presented their research. The Qubit Symposium was part of the University of Waterloo's visit to Technion where the two institutes signed a memorandum of understanding for future research initiatives. ■

Participants in the Qubit Symposium at the Technion-Israel Institute of Technology.

UPCOMING EVENTS

Undergraduate School on Experimental Quantum Information Processing (USEQIP)

IQC, May 26-June 6

WEB **https://uwaterloo/iqc/useqip**

Algebraic Combinatorics: Spectral Graph Theory, Erdös-Ko-Rado Theorems and Quantum Information Theory

A conference to celebrate the work of Chris Godsil by The Fields Institute

University of Waterloo, June 23-27

WEB **http://bit.ly/1rp8fk5**

Quantum Cryptography School for Young Students (QCSYS)

IQC, August 11-15

WEB **https://uwaterloo.ca/qcsys/**

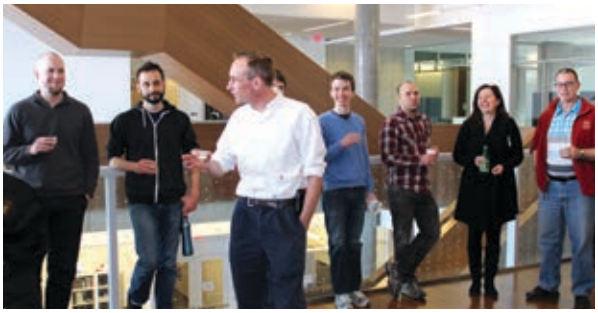
Quantum-Safe-Crypto Workshop

Ottawa, October 6-7

WEB **http://bit.ly/Pxgjmm** ■

Around the INSTITUTE

Executive Director **RAYMOND LAFLAMME** congratulates the team.



ANNOUNCEMENTS

Renewed funding by the Government of Canada

On February 11, the Government of Canada announced its Economic Action Plan 2014 and in it IQC received $15 million over the next three years. This funding will help IQC achieve its goal to become the world leader in the field of quantum information science and to develop the technologies that will fundamentally impact the ways in which we work, communicate and live. The Government of Canada first partnered with IQC in 2009 with an investment of $50 million.

WEB MP Harold Albrecht speaks about what we do at IQC following the budget (at 7:51): **http://bit.ly/1hqgmLO**

Funding to build a compact prototype QKD Receiver for space

Associate Professor **THOMAS JENNEWEIN** and Research Assistant Professor **VADIM MAKAROV** received a $600,000 contract from the Canadian Space Agency to design and build a compact prototype Quantum Key Distribution Receiver (QKDR) suitable for a low-cost microsatellite mission. With a number of industry partners, the IQC team will refine the requirements for a QKDR, select an instrument concept, develop the design, quantify photon detectors for the space radiation environment, assemble and test the prototype and conduct an end-to-end test to simulate a long-distance QKD experiment.

MARS ANYONE?

IQC alumnus, **BEN CRIGER**, may one day call the planet Mars home. Criger, a former PhD student, has made the first cut of applicants to the Mars One project, which hopes to establish a permanent human settlement on the red planet. He is one of approximately 1,000 applicants selected from a pool of more than 200,000 to move onto the next stage of the selection process. The one-way trip to Mars, scheduled for April of 2024, will include a team of four people – and Criger hopes to be among them.

Around THE INSTITUTE

Celebrating the holidays, IQC style

Jolly Old St. Nick made an appearance at IQC on December 12, to the delight of IQC members and their families. The annual holiday gathering, a tradition at IQC, featured fun, food and entertainment including a gingerbread decorating station for children and adults alike. And in the spirit of holiday giving, IQC members donated 220 pounds of food and $620 to the Waterloo Region Food Bank. ■

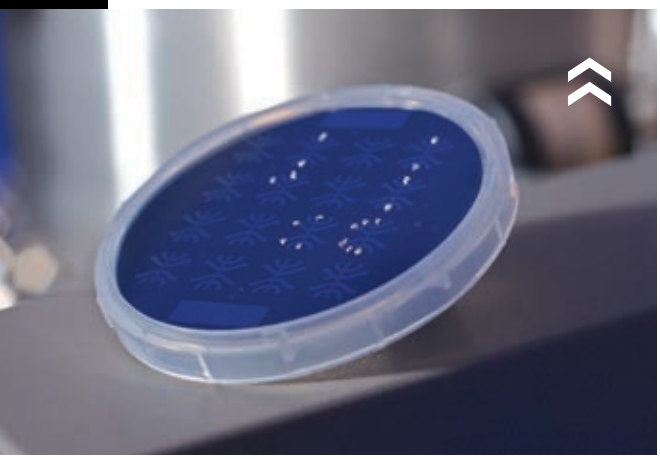
» Santa Claus makes an appearance at the holiday party.

IN THE NEWS

New lab to create novel quantum materials

The Chemical Institute of Canada (and several other media outlets) wrote about the opening of the UHV lab in December at RAC 2. The story, *New quantum laboratory opens at University of Waterloo*, by Tim Lougheed focused on the future use of the quantum materials that Professor **DAVID CORY** and his team will engineer in the lab for information processing. By using the new equipment to create the raw materials, Lougheed suggests that this will jumpstart a new era of increased computer processing speed and information storage.

WEB **http://bit.ly/1mEtyha** ■



Quantum Valley INVESTMENTS

Betting on tech not yet invented

It's not if, it's when, says **MIKE LAZARIDIS**, about the possibility of quantum technologies transforming Canada in the same fashion that silicon did for America in the *National Post* article *The quantum computing revolution: BlackBerry billionaire Mike Lazaridis is betting on tech that hasn't been invented... yet*. Lazaridis shared his belief that his investments in the Perimeter Institute for Theoretical Physics and the Institute for Quantum Computing are sure to spur a quantum revolution. With his newest venture, Quantum Valley Investments, Lazaridis plans on enabling the quantum revolution by bringing the science to market.

WEB **http://bit.ly/1bDsfKu** ■

Can quantum cryptography help protect our data?

Whether people acknowledge it or not, we use encryption all the time, says **DYLAN LOVE** in his piece for *Business Insider: You've Never Heard of Quantum Encryption, But It's The Technology That 'Keeps Our Digital World Running Smoothly'*. Love interviewed Research Assistant Professor **VADIM MAKAROV**, who re-iterated Love's statement that encryption is all around us. Makarov warned that in the future we'll need something more than the mathematical methods we use today as computing power increases and future technology advances. Quantum cryptography is a likely alternative, but to most users, they'll never know what's happening behind the scenes.

» VADIM MAKAROV

WEB **http://read.bi/1lJDngV** ■

AWARDS AND FELLOWSHIPS

Support for engineered quantum systems

Associate Professor **CHRIS WILSON** was awarded the John R. Evans Leaders Fund grant in January. The $50,000 in funding from Canada Foundation for Innovation (CFI) will support Wilson's work in engineered quantum systems. Wilson and his team are exploring how quantum microwaves can be used as a resource for future quantum communication networks. They use superconducting qubits, which are engineered electronic circuits that exhibit quantum properties, to generate quantum microwave states. See page 4 for an article on Wilson's lab. ■

Prestigious honour for an IQC Master's student

Master's student **JEAN-PHILIPPE MACLEAN** was awarded the prestigious 2013 André Hamer Postgraduate Prize from NSERC. His research uses carefully stretched pulses of light called chirped laser pulses to study entanglement, resulting in advancement of cryptography and quantum computing. ■

Photo credit: Diana Askhatova

2014 IQC Achievement Award winner

VADYM KLIUCHNIKOV was awarded a Winter 2014 IQC Achievement Award. Valued at $5,000, the award is presented to an IQC student based on their exceptional achievements in research in quantum information. A PhD candidate, Kliuchnikov's research focuses on quantum circuit synthesis and optimization. ■

Scholastic excellence awarded

PhD student **STACEY JEFFREY** was awarded a Type 1 David R. Cheriton Scholarship valued at $20,000 over two years. The Cheriton awards are given to the top University of Waterloo students based on scholastic excellence and research interests in designing and implementing efficient and reliable computing systems. Jeffrey works with Deputy Director, Academic **MICHELE MOSCA** to develop frameworks for the construction of quantum algorithms, which make it easier to create new quantum algorithms. ■

FROM THE IQC GSA

The IQC Graduate Student Association (IQC GSA) has recently hosted a handful of events for IQC members, friends and family. Grad students have flooded the second floor of the Lazaridis Centre for game nights to play board games ranging from the classics such as *Settlers of Catan* to the more obscure *Two Rooms and a Boom* (and sometimes even a game of *Dungeons and Dragons* thrown in). There was indoor paintball, as well as an IQC exclusive screening of the film *Gravity* on April 2, followed by a Q&A by celebrated Canadian astronaut and IQC Associate **STEVE MACLEAN**.

Corey Rae McRae ■

« Grad students taking a break from research for some games.

Around
THE INSTITUTE

ARRIVALS

Faculty

Michal Bajcsy
Kyung Choi

Staff

Scott McManus
Brooke Mulder

Students

Nigar Sultana

Long-Term Visitors

Robin Côte
Bo Wen
Michaël Simoen
Xuan Wang
Chi-Kwong Li
Barry Sanders
Simon Forest

Postdocs*

Pol Forn-Diaz
Francois Fillion-Gourdeau
Vlad Gheorghiu
Mark Howard
Catherine Lefebvre
Ryo Namiki
Zlatko Papic
Daryoush Shiri
Fang Song
Joel Wallman
Huan Yang
Hui Zhang
Yanbao Zhang

* *In the last NewBit we did not mention the newest postdoctoral fellows. Our apologies.* ■

Visitors to IQC 2013

168 total visitors

36 LONG TERM VISITORS

132 SHORT TERM VISITORS

IQC received visitors from 25 different countries last year.

111 Universities from around the world collaborated on

65 Guest lectures at IQC last year ensured true interdisciplinary research.

25 research papers to help increase IQC's ever-growing academic network.

Publications written with visitors

WEB See the interactive version of the infographic at: **http://bit.ly/RMrHwp** ■

Summer schools AT IQC

USEQIP
UNDERGRADUATE SCHOOL ON EXPERIMENTAL QUANTUM INFORMATION PROCESSING

May 26-June 6

Undergraduate students have the chance to discover the field of quantum information processing

The Undergraduate School on Experimental Quantum Information Processing (USEQIP) is a two-week program on both the theoretical and experimental study of quantum information. Geared towards students completing their third year in engineering, physics, chemistry, mathematics and computer science, USEQIP features:

- Lectures with IQC faculty and visitors
- Hands-on time in the labs
- A chance to complete a summer research opportunity

WEB **uwaterloo.ca/iqc/useqip**

QCSYS
QUANTUM CRYPTOGRAPHY SCHOOL FOR YOUNG STUDENTS

August 11-15

Introducing high school students to the fascinating laws of quantum mechanics to develop encryption

The Quantum Cryptography School for Young Students (QCSYS) gives students in grades 11 and 12 the opportunity to discover how the physics and mathematics of quantum mechanics and cryptography merge into quantum cryptography.

Students will:

- Attend lectures
- Experience hands-on experiments
- Meet and collaborate with IQC researchers

WEB **uwaterloo.ca/qcsys-at-iqc**

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

PQCrypto 2014

6th International Conference on Post-Quantum Cryptography

October 1-3

Join us for this year's PQCrypto at the Mike & Ophelia Lazaridis Quantum-Nano Centre at the University of Waterloo.

» Submit your paper by May 20
» Attend the two-day summer school September 29-30
» Register soon to attend the conference October 1-3

In cooperation with the International Association for Cryptologic Research.

WEB **https://pqcrypto2014.uwaterloo.ca/**

Sponsors and partners: IQC Institute for Quantum Computing, Microsoft Research, Institut Tutte Institute

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

UNIVERSITY OF WATERLOO | IQC Institute for Quantum Computing | Ontario | Canada