

NEWM BIT

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COOL ATOMS make photons interact

CHILLING RESEARCH FROM MICHAL BAJCSY'S LAB

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UNIVERSITY OF
WATERLOO

IQC

Institute for
Quantum
Computing



this issue

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Get all the chilling details about
 the research being done in
MICHAL BAJCSY's lab.

FORMER UW STUDENT WELCOMED AS NEW FACULTY MEMBER pg 06

Experimental physicist
MICHAEL REIMER joins IQC.

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A passion for problems and a
 love of exploration is what
 drives this young physicist.

ON THE COVER

MICHAL BAJCSY in his lab in the
 Mike & Ophelia Lazaridis
 Quantum-Nano Centre.

Cover Photo by: IQC

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FROM THE EDITOR

We had lots of cool things happen around the Institute for Quantum Computing during the winter term, and it wasn't just the weather. We started the year off welcoming the Minister of State (Science and Technology) **ED HOLDER** and MP for Kitchener-Waterloo **PETER BRAID** as they made the official announcement on IQC's \$15 million contribution from the 2014 Economic Action Plan.

It was followed by announcements of NSERC funding (page 18), satellite mission advancements (page 14), one of our alumni **BEN CRIGER** being shortlisted for the trip to Mars (page 15) and the addition of a new faculty member (page 6). And through all this, great research and collaborations continued with papers about quantum collect calls, quantum correlations implying causation and the use of diamonds as quantum memory.

Throughout the term, faculty member **MICHAL BAJCSY** was putting the final touches on his lab where he's cooling atoms with lasers. We hear of lasers as beams of light that heat and cut through materials like metal or in medical procedures, but Bajcsy explains in our feature *Cool atoms make photons interact* on page 4, how he uses lasers to chill the atoms and slow them down to help photons communicate with each other.

As the research continues, so do efforts to help our researchers take quantum information science and technologies out of the lab. That's why **MARK PECEN**, our Entrepreneur-in-Residence is here to help as you'll learn on the next page.

JODI SZIMANSKI, Senior Communications Manager



» New IQC board member and Entrepreneur-in-Residence, **MARK PECEN**.

MEET IQC'S Entrepreneur-in-Residence

MARK PECEN would describe himself as “a combination of business guy and researcher.” Here at the Institute for Quantum Computing, we now call him our Entrepreneur-in-Residence and board member.

Pecen joined IQC after he retired from BlackBerry (formerly RIM) where he was senior vice president, research and advanced technology and founder of the Advanced Technology Research Centre where much of the fundamental technology for LTE 4G wireless was invented.

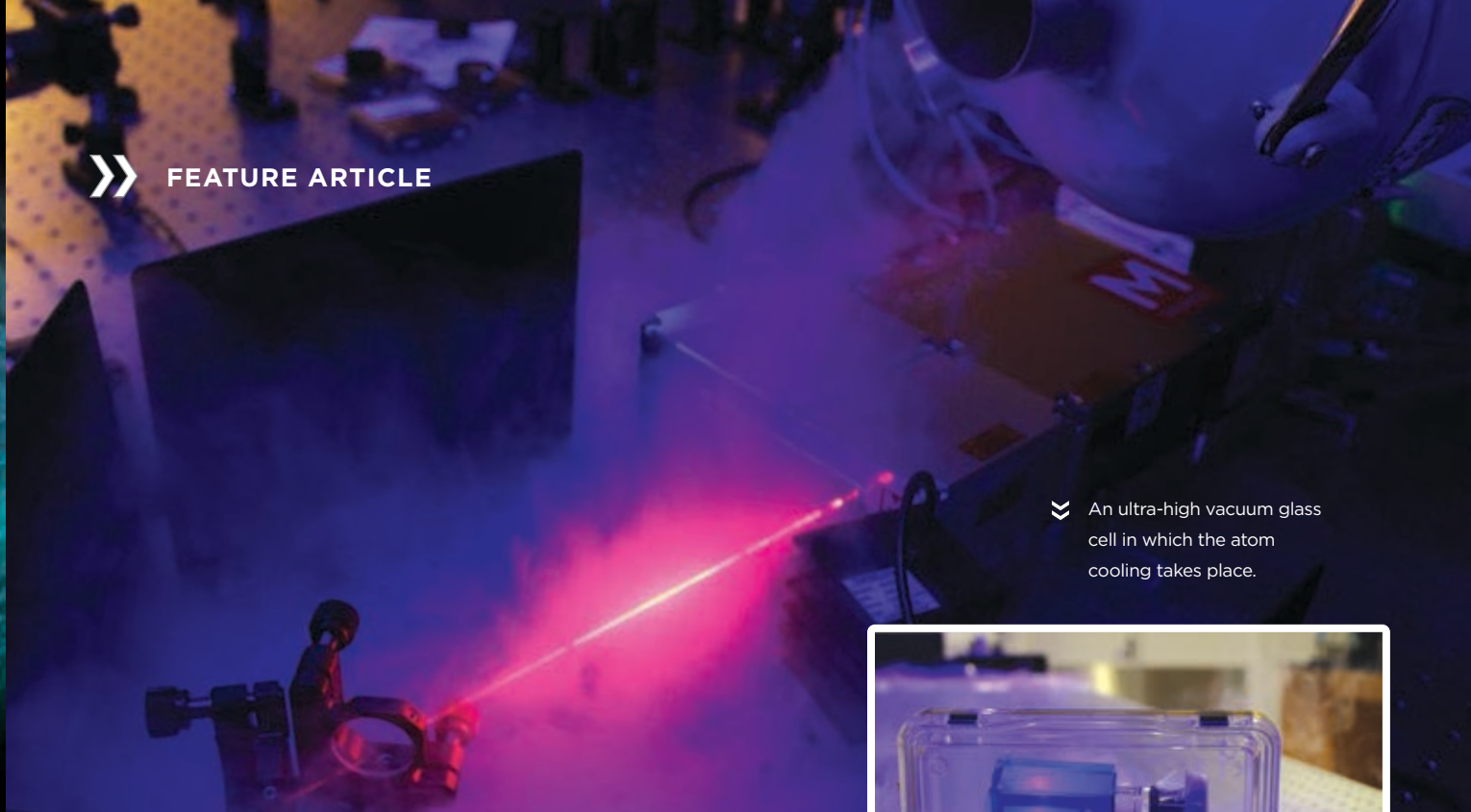
Prior to BlackBerry, Pecen was a researcher at Motorola where he was awarded the title of Distinguished Innovator and Science Advisor Board Member for his work in the development of 2G and 3G wireless technology and global standards.

Today, Pecen is CEO of Approach Infinity and serves as an advisor to several corporations and academic organizations as well as helping

to recently found the European Telecommunication Standards Institute (ETSI) Industry Standards Group for Quantum Safe Cryptography in Sophia Antipolis, France.

With years of experience bridging the path from theory in advanced technology to commercialization, Pecen knows how to start things and build them up. He understands commercial research and has the ability to always think a few steps ahead. He has invented a number of technologies and holds more than 100 fundamental patents in the areas of wireless communication, networking and computing. That knowledge and ability are pivotal for Pecen to help researchers determine their commercial landing zone.

Pecen advises students: “Consider working in industry. You may be surprised what you find there.” Pecen knows that only so many academic positions exist – and there are many more opportunities in industry, especially as an entrepreneur. Pecen believes that being an entrepreneur gives students the opportunity to create their own culture within a company, have the honour to innovate and do a lot of positive work. ■



An ultra-high vacuum glass cell in which the atom cooling takes place.



Cool atoms make photons interact

In his Nano-photonics and Quantum optics lab, **MICHAL BAJCSY** works with his team on development of chip-scale quantum optical devices based on laser-cooled atoms.

"Photons normally don't interact," says Bajcsy. "So we will use laser-cooled atoms to act as mediators for interactions between photons confined to nano-photonic structures."

Contrary to what one would expect based on scenes of light-saber duels in Star Wars, two laser beams, or two individual photons, will just pass through each other when their paths cross in space. Put an atom in their way and things become different. Under the right conditions, the first photon will change the optical properties of the atom, which will in turn affect the second photon. While this cartoon picture of atom-

mediated photon-photon interaction is essentially the basis of non-linear optics in general, implementing it at the quantum level with single photons remains a technological challenge.

If there are only two photons to work with, they both must hit the same atom. At room temperature though, atoms will either move at hundreds of metres per second if they are part of a gas cloud, or at least shake vigorously if they are embedded in a solid. The rapid movement turns aiming photons at a specific atom into a headache, not to mention the inevitable collisions and bounces that can make the atoms 'forget' their interaction with the first photon before the second photon arrives.

When cooled down to a few millionths of a degree above absolute zero, the atoms slow down to a crawl – a few centimetres per second or even less. At this speed, the atom is

an easier target for the photons and allows for trapping and manipulating of the atoms with tools such as optical tweezers or magnetic traps to prevent them from hitting any walls.

Since January 2014, Bajcsy and his group have been setting up their new laboratory and plan to implement photon-photon interactions enabled by laser-cooled atoms in integrated platforms, such as chips and optical fibres. Some of the team members, including postdoctoral fellows **CHRIS HAAPAMAKI** and **TAEHYUN YOON**, are building a laser-cooling setup to cool, trap and manipulate atoms, while other group members have been working in the Quantum Nanofab facility fabricating hollow-core waveguides, photonic crystals and other nano-scale structures to confine both photons and atoms into small spaces where the photons will be forced to interact.



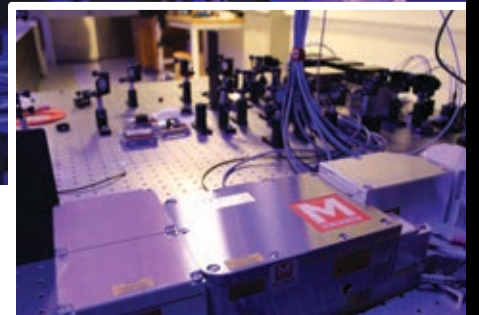
One of the first steps in the group's effort — cooling atoms with lasers — might seem a bit counterintuitive as laser beams — generally associated with having a lot of energy and thus being 'hot'. However, from the thermodynamics point of view, in which temperature can be seen as a measure of chaos in a system, lasers are actually extremely 'cold' as all photons in a laser beam are nearly identical.

A technique, based on the Doppler effect and three pairs of counter-propagating beams from carefully stabilized lasers tuned just below the frequency at which the atoms absorb light, has long been used for atom cooling experiments. Called optical molasses, this approach drains energy out of a cloud of atoms until the atoms' motion is slowed down to an equivalent in temperature of a few millionths of a degree above absolute zero.

Once the laser-cooled atoms are loaded and confined on a chip, one of the first goals of Bajcsy's group is

to demonstrate an alloptical quantum transistor. In this device, which would operate much like an electronic transistor, the presence or absence of a single photon controls the flow of many photons. The practical uses of such devices would range from the nondestructive detection of photons to being the building block for scalable networks for quantum information processing.

The group also plans to apply the quantum optical devices it is developing to lasers with ultra-narrow line-widths for quantum metrology, as well as quantum memories for quantum repeaters. The latter in particular is of crucial importance for wide deployment of quantum cryptography protocols in the future, as optical amplifiers used in classical telecommunications to compensate for signal loss in optical fibres will not work for long-distance quantum key distribution because of the 'No-cloning theorem' of quantum mechanics.



⤴ (top) **BAJCSY** adjusting the equipment in his lab.

(above) One of the laser setups on the optics table.

Over the past decade, many experiments relying on laser-cooled atoms have shrunk down to a shoebox size from their original optics-table scale. This evolution has transformed many of these experiments into portable turn-key systems that have been placed on submarines and even space satellites for navigation, precision time keeping and fundamental measurement applications. Research in Bajcsy's lab will push to further shrink these systems down to the size of a chip to improve their scalability as devices and to explore their new uses for quantum information processing and quantum technologies in general. ■



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.



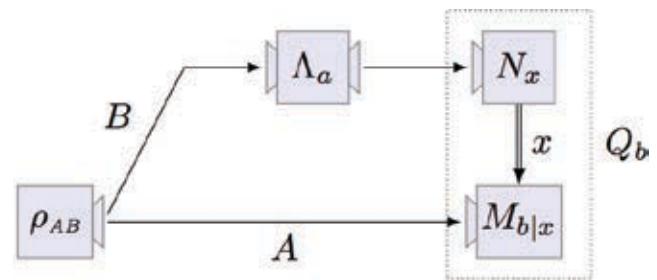
» Former Waterloo student returns as a faculty member

MICHAEL REIMER returned to Waterloo in February to join IQC — he was born and raised in Waterloo and is an alumnus of Waterloo's Physics & Astronomy department where he earned his BSc. His research at IQC will focus on the development of quantum photonic devices and optical approaches needed to advance quantum information science and technologies. He will also be testing fundamental questions in quantum photonics.

Prior to joining IQC and the Department of Electrical and Computer Engineering, Reimer completed a postdoctoral fellowship at the Quantum Optics Lab in Quantum Transport, Kavli Institute of Nanoscience at the Technical University of Delft in the Netherlands, where he was also part of a start-up called Single Quantum. The company developed highly efficient single-photon detectors based on superconducting nanowires. ■

» The impact of quantum steering

PHYS. REV. LETT. 114, 060404 (2015)



⌘ Using quantum steering in the discrimination of physical processes.

Research Assistant Professor **MARCO PIANI**, currently on leave at the University of Strathclyde, and faculty member **JOHN WATROUS** presented the results of their paper *Necessary and Sufficient Quantum Information Characterization of Einstein-Podolsky-Rosen Steering* at the 18th Conference on Quantum Information Processing in Sydney, Australia January 12-16. Their research, published in *Physical Review Letters*, involved analyzing the impact of quantum steering — a feature of quantum mechanics related to entanglement through which a measurement performed on a particle can affect another distant particle.

Piani and Watrous developed a method for precisely quantifying steering's impact and relating it to the task of distinguishing physical processes. They showed that the steering effect is the key to providing a specific advantage in this type of task. The results could be useful in fields such as quantum metrology and quantum cryptography, where secret keys are created between two parties to encrypt messages for private communication — for example, online banking.

WEB <http://bit.ly/quantum-steering> ■



WAVE-PARTICLE DUALITY IN DISGUISE

NATURE COMMUNICATIONS 5, 5814 (2014)

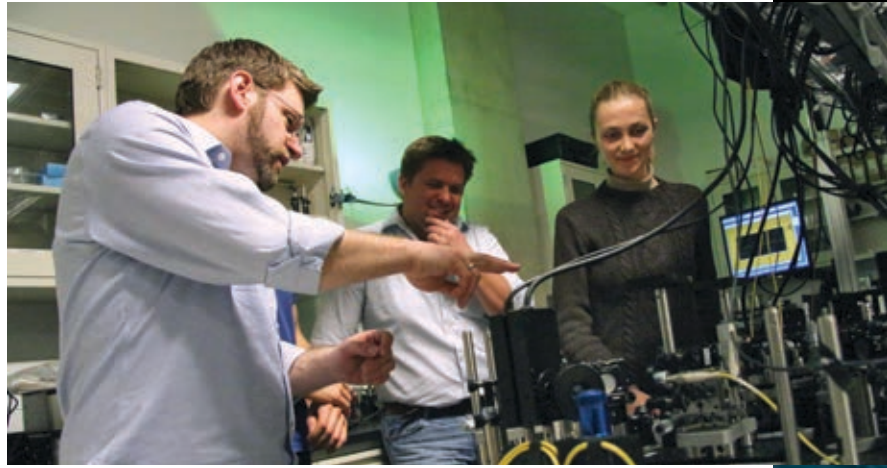


Image credit:
Timothy Yeo / CQT, National
University of Singapore

In quantum physics, wave-particle duality refers to the peculiar behaviour of particles that behave like waves and waves that behave as particles. Recently, postdoctoral fellow **PATRICK COLES** and collaborators from the National University of Singapore and Delft University of Technology in the Netherlands discovered that wave-particle duality is simply the uncertainty principle in disguise. The uncertainty principle states that it's impossible to know certain pairs of things, such as velocity and location at the same time about a quantum particle. The paper, *Equivalence of wave-particle duality to entropic uncertainty*, published in *Nature Communications* December 19, shows that how much one can learn about the wave versus the particle behaviour of a system is constrained in exactly the same way.

The team unifies these two fundamental concepts of quantum mechanics by showing that all mathematics previously used to describe wave-particle duality could be reformulated in terms of entropic uncertainty relations. These relations have been used in proving the security of quantum cryptography, suggesting that this work could also lead to the development of new cryptography protocols.

WEB <http://bit.ly/wave-particle-duality> ■



⤴ Rob Spekkens and Katja Ried of PI with Kevin Resch in Resch's Quantum Optics and Quantum Information Lab.

Quantum mechanics eliminates intervention

NATURE PHYSICS 11, 414-420 (2015)

Research from IQC and the Perimeter Institute for Theoretical Physics (PI) shows that in quantum mechanics, certain kinds of observations will let you distinguish whether there is a common cause or a cause-effect relation between two variables. The same is not true in classical physics.

Causal inference hinges on the distinction between correlation and causation. If A and B are correlated, then when you learn about A, you update your knowledge of B — this is inference. If A causes B, then by manipulating A, you can control B — this is influence. In quantum foundations, this distinction is key. Considering classical statistics, intervention is needed to determine whether the correlations are due to a cause-effect relation, a common cause relation, or a mix of both. The paper, *A quantum advantage for inferring causal structure* published in *Nature Physics* in March, demonstrates that quantum effects can eliminate the need for intervention.

Faculty member **KEVIN RESCH**, together with students **MEGAN AGNEW** and **LYDIA VERMEYDEN**, along with their colleagues at PI, built a photonic circuit that could switch between the two scenarios, allowing the causal structure realized by the experiment to vary. Their results confirmed that the quantum effects of entanglement and coherence provide an advantage for causal inference. These quantum effects can help to solve computational problems and make cryptography more secure, and could lead to other insights into the foundational possibilities of the quantum world.

WEB <http://bit.ly/quantum-advantage-causal-structure> ■



Innovation, information and imaging in San Jose

USING DIAMONDS AS A QUANTUM MEMORY

PHYS. REV. LETT. 114, 053602 (2015)

Canada Research Chair in Optical Quantum Technologies **KEVIN RESCH**, with students **KENT FISHER** and **JEAN-PHILIPPE MACLEAN**, in collaboration with colleagues at the National Research Council of Canada (NRC), found a novel way to manipulate properties of light and store it in a controllable way using diamond materials.

Instead of using a nitrogen-vacancy center, which acts as an artificial atom with well-defined resonance frequencies, the team used the vibrations of a diamond lattice as a quantum system. The accommodating and defect-free nature of the diamond lattice provides a very large bandwidth, which allows it to store and retrieve on demand quantum information in the vibrations — like a quantum memory. The memory is low noise, high speed and broadly tunable, promising the potential to be a versatile light-matter interface for local quantum processing applications.

The research paper *Storage and Retrieval of THz-Bandwidth Single Photons Using a Room-Temperature Diamond Quantum Memory* was the Editors' Suggestion in *Physical Review Letters* in February, and also featured in *Physics*.

WEB <http://bit.ly/diamond-quantum-memory> ■



» **Kate Lunau moderates the AAAS panel with Raymond Laflamme, Artur Ekert and Andrew Briggs**

To kick off this year's annual American Association for the Advancement of Science (AAAS) in San Jose, California February 12-16, the University of Waterloo invited AAAS guests to its Global Innovation Showcase where IQC shared its research.

IQC researchers also participated in two sessions.

KATE LUNAU of *Maclean's* magazine moderated the panel *Transformational Opportunities of Quantum Information Technologies*, featuring the directors of three leading research institutes:

- » **ANDREW BRIGGS**, Director of Quantum Information Processing Interdisciplinary Research Collaboration, England
- » **RAYMOND LAFLAMME**, Executive Director of the Institute for Quantum Computing (IQC)
- » **ARTUR EKERT**, Director of the Centre for Quantum Technologies (CQT), National University of Singapore

Research Assistant Professor **DMITRY PUSHIN** also participated in a symposium on *Wave-Particle Duality of Neutrons, Atoms and Molecules*, presenting his work on the uniquely quantum behaviour of a neutron interferometer.

WEB For a full description of the panel, see: http://bit.ly/AAAS2015_QIT ■

» IQC research presented at APS March Meeting

Almost 10,000 researchers gathered in San Antonio, Texas for the APS March Meeting held March 2-6. Faculty member and Canada Excellence Research Chair **DAVID CORY** was among the invited speakers. Twenty-one IQC researchers co-authored the following papers that were also presented:

- » *Cavity Cooling for Ensemble Spin Systems* by Postdoctoral Fellow **TROY BORNEMAN**, PhD student **CHRISTOPHER WOOD** and faculty member **DAVID CORY**
- » *Quantum Bootstrapping via Compressed Quantum Hamiltonian Learning* by PhD student **CHRISTOPHER GRANADE**, faculty member **DAVID CORY**, in collaboration with **NATHAN WIEBE** of Microsoft Research
- » *Josephson Interference due to Orbital States in Nanowire Proximity Effect Junctions* by PhD students **KAVEH GHARAVI**, **GREGORY HOLLOWAY**, Postdoctoral Fellows **CHRIS HAAPAMAKI**, **MOHAMMAD ANSARI**, **MUSTAFA MUHAMMAD**, **RAY LAPIERRE** (McMaster University) and faculty member **JONATHAN BAUGH**
- » *Heat bath algorithmic cooling using electron-nuclear spin ensemble in the solid state: characterization of the open quantum system control* by PhD Student **DANIEL (KYUNGDOECK) PARK**, Postdoctoral Fellows **ROBABEH DARABAD**, **GUANRU FENG**, Master's student **STEPHANE LABRUYERE** and faculty members **JONATHAN BAUGH** and **RAYMOND LAFLAMME**
- » *Single Molecule Magnetic Force Detection with a Carbon Nanotube Resonator* by PhD student **KYLE WILLICK**, Master's student **SEAN WALKER** and faculty member **JONATHAN BAUGH**
- » *Magnetoconductance signatures of subband structure in semiconductor nanowires* by PhD student **GREGORY HOLLOWAY**, Postdoctoral Fellow **CHRIS HAAPAMAKI**, **RAY LAPIERRE** (McMaster University) and faculty member **JONATHAN BAUGH**
- » *The temperature dependence of decoherence in superconducting flux qubits coupled to microwave resonators* by PhD students **CHUNQING DENG**, **JEAN-LUC ORGIAZZI**, Master's students **FEIRUO SHEN**, **NICOLAS GONZALEZ** and faculty member **ADRIAN LUPASCU**
- » *Fast control and floquet state dynamics of a strongly driven superconducting qubit* by PhD students **CHUNQING DENG**, **JEAN-LUC ORGIAZZI**, Master's student **FEIRUO SHEN**, **SAHEL ASHHAB** (Qatar Environment and Energy Research Institute) and faculty member **ADRIAN LUPASCU**
- » *Strong qubit-photon interactions in a superconducting 1D open space* by Postdoctoral Fellow **POL FORN-DIAZ**, PhD students **JEAN-LUC ORGIAZZI**, **MUHAMMET (ALI) YURTALAN**, Master's student **MARTIN OTTO**, **BORJA PEROPADRE** (Harvard University), **JUAN-JOSE GARCIA-RIPOLL** (Institut de Física Fundamental IFF-CSIC) and faculty member **ADRIAN LUPASCU**
- » *Perfect Zeno effect through imperfect measurements at a finite frequency* by Master's student **DAVID LAYDEN**, Research Assistant Professor **EDUARDO MARTIN-MARTINEZ** and associate member **ACHIM KEMPF**
- » *Quantum Collect Calling (published with the title Information Transmission Without Energy Exchange)* by PhD student **ROBERT JONSSON** (Department of Applied Mathematics, University of Waterloo), Research Assistant Professor **EDUARDO MARTIN-MARTINEZ** and associate member **ACHIM KEMPF**
- » *Casimir-Polder-like Effect in a Superconducting Circuit System* by PhD student **PETER GROSZKOWSKI**, Research Assistant Professor **EDUARDO MARTIN-MARTINEZ**, faculty member **CHRIS WILSON** and colleague **FRANK WILHELM** (Saarland University). ■

SCIENCE HIGHLIGHTS



GROWING THE FIELD OF QUANTUM SIMULATIONS

One hundred and fifty theoretical and experimental researchers on quantum simulations gathered at the Centro de Ciencias de Benasque Pedro Pascual in Benasque, Spain February 22-27 for the fourth annual Quantum Simulations workshop. Faculty member **CHRISTOPHER WILSON** was among the main organizers of the workshop, co-sponsored by IQC, that brought together leading scientists in the growing field of quantum simulations — the reproduction of quantum dynamics using engineered quantum systems that are, in theory and practice, more controllable and versatile.

WEB <http://bit.ly/quantum-simulations-2015> ■

Encouraging female undergrads at CCUWIP

PhD students **COREY RAE MCRAE** and **AIMEE GUNTHER** represented IQC at the 2015 Canadian Conference for Undergraduate Women in Physics (CCUWIP) graduate fair at Université Laval in Québec City January 9-11. McRae also participated in a panel about graduate studies, sharing her experience with female undergraduate students in a range of topics ranging from choosing which type of physics research to pursue at the graduate level to preparing for interviews with supervisors. ■

» TALKS



» Building a quantum computer in three steps

On January 23, Canada Excellence Research Chair **DAVID CORY** delivered the first Research Talks lecture, sponsored by Waterloo's Office of Research. Cory presented his three basic rules to build a quantum computer to over 200 Waterloo students, staff and faculty:

- » Keep quantum information hidden from the corrupting classical environment
- » Keep parts needed to model small, therefore use an array of nodes
- » Perform error correction in parallel; cool the quantum computer by removing accumulated noise to keep computations reliable.

While significant progress has been made in satisfying the first two rules, the third rule still needs to be written. "This rule is beyond our ability to simulate, we will never solve this problem on a classical computer," says Cory. "We do know how to solve it — we take this problem and run it on a quantum computer."

WEB [Watch the recorded talk:](http://bit.ly/build-a-quantum-computer-talk)
<http://bit.ly/build-a-quantum-computer-talk>
[Read the full story:](http://bit.ly/build-a-quantum-computer-story)
<http://bit.ly/build-a-quantum-computer-story> ■

» TALKS & TOURS

» Cybersecurity in a quantum world: will we be ready?



On March 10, IQC hosted 150 community members for a public lecture on being cyber-safe in a quantum world from faculty member **MICHELE MOSCA**. Mosca shared his predictions that with the realization of a quantum computer, possibly in 10 to 15 years, our current cybersecurity infrastructure won't keep our information safe and secure. He advised industry organizations to start planning for quantum-safe options and develop standards and quantum-safe tools. Mosca suggested that as individuals, we can share our security concerns with organizations that keep our data and ask questions about what is being done to keep our information secure — now and in the future.

WEB Watch the public lecture:

<http://bit.ly/cybersecurity-in-a-quantum-world-lecture> ■

» GIRLS EXPLORE QUANTUM INFORMATION SCIENCE

In January, nine girls aged 9 to 12 from the Canadian Association for Girls in Science (CAGIS) came to IQC to learn about quantum information science and technology. PhD students **CAROLYN EARNEST, COREY RAE MCRAE, SARAH KASIER** and **JOEL KLASSEN** guided the young science enthusiasts through interactive demonstrations exploring algorithms, search algorithm efficiency, optics and superconductors. Highlights of the visit included enjoying liquid nitrogen ice cream and playing with lasers. ■



Inspiring young minds and educators

IQC continues to educate and excite students about quantum information science and technology through hands-on workshops, lectures and lab tours including:

- » 160 high school students at Science Expo's Conference at the Ontario Science Centre, Toronto on February 21
- » 421 high school and Cégep students from Assumption College, Turner Fenton Secondary School, Cégep de Lévis-Lauzon, Cégep de Rivière-du-Loup, Sir Oliver Mowat Collegiate Institute, Barrie North Collegiate Institute, Rockway Mennonite Collegiate and North Park Secondary School
- » 27 high school students participating in *Waterloo Unlimited*, an enrichment program that brings together curious and motivated teenagers from across Canada ■

»» CONFERENCES



PUSHING THE BOUNDARIES OF RESEARCH AND INNOVATION AT CERC MEETING

The University of Waterloo was host to the 5th Canada Excellence Research Chairs (CERC) annual meeting April 13-14. Waterloo researchers **DAVID CORY**, CERC in Quantum Information Processing, and **PHILIPPE VAN CAPPELLEN**, CERC in Ecohydrology, chaired the meeting that brought CERCs from across the country together to discuss their research.

The meeting included plenary lectures by chair holders and a keynote by CERC Executive Director Michèle Boutin. A new addition for this year's meeting included outreach activities for young students. A group of elementary students learned about the importance of wetlands with Van Cappellen, while Cory and Senior Manager, Outreach **MARTIN LAFOREST** engaged a group of 27 high school students from Rockway Mennonite Collegiate with interactive quantum science experiments using water, milk, lasers and polarizers.

WEB To learn more about the CERC program go to:
<http://bit.ly/CERC-video> ■

»» UPCOMING CONFERENCES

- »» 3rd ETSI Quantum-Safe Cryptography Workshop in Partnership with the Institute for Quantum Computing

October 5-7, 2015
Seoul, Korea

WEB bit.ly/ETSI-2015

- »» 5th International Conference on Quantum Cryptography (QCrypt)

September 28-October 2, 2015
Tokyo, Japan

WEB 2015.qcrypt.net ■

≡≡ Around the INSTITUTE

» student PROFILE: XIAN MA

A passion for problems



XIAN MA, A PhD student in the physics and astronomy department, loves to explore. And he doesn't mind that exploration never ends. In fact, he seems more motivated while investigating a problem when more things to discover pop up.

Xian Ma's desire to explore many different interests started at a young age. After winning first prize in a competition in China that allowed him to bypass testing to enter university, he entered the Academic Talented program at Tsinghua University. This program allowed him to study both mathematics and physics for the first two years. "This was a really good program for me," said Ma. "I didn't really know what I wanted to do, so I chose the program because it allowed me to explore my career path."

During his studies at Tsinghua, he heard about quantum information and decided he wanted to learn more. He started working with Professor GuiLu Long's group on his first free space Quantum Key Distribution (QKD) prototype. Following graduation, he went to the University of Queensland to work with Tim Roth and Gerard Millburn investigating measurement-based quantum computation. For his PhD, Ma wanted to explore as many options as possible with a variety of experts so he applied to the Institute for Quantum Computing working with **RAYMOND LAFLAMME**.

One of the projects that Ma found interesting at IQC involved testing the foundations of quantum mechanics. Many people find that quantum mechanics isn't intuitive because it requires a lot of interpretation. Currently, he's tackling how to characterize a special quantum state and designing a protocol based on the characterization. Both of these projects have allowed him to work with Canada Research Chair in Optical Quantum Technologies **KEVIN RESCH** and his group to run experiments in Resch's experimental quantum optics lab.

Ma plans on always looking into these types of problems: "It's a lifetime enjoyment. Knowing that you're the first one to discover something, or the first to see something, or the only one thinking about something, the whole process to do the research — it's exciting." ■

Around THE INSTITUTE

»» TOURS/VISITS



GOVERNMENT OF CANADA ANNOUNCES SUPPORT OF QUANTUM RESEARCH

The Honourable **ED HOLDER**, Minister of State (Science and Technology) and MP for Kitchener-Waterloo **PETER BRAID** announced renewed support for IQC at the University of Waterloo on January 22. The Economic Action Plan 2014 included a contribution of \$15 million to IQC over three years. The 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.

"Through our updated science, technology and innovation strategy, our government is making the necessary investments to push the boundaries of knowledge, create jobs and prosperity, and improve the quality of life of Canadians," said Ed Holder, Minister of State (Science and Technology).

WEB <http://bit.ly/iqc-support-announcement> ■

»» ANNOUNCEMENTS

Quantum-safe cybersecurity spin-off

IQC co-founder **MICHELE MOSCA** and **NORBERT LÜTKENHAUS** have started a new company, **evolutionQ**. The company was founded in response to the need by industry and government to prepare for an era with quantum computers by helping organizations understand the quantum threat to cybersecurity, to assess their risk, and to design and implement appropriate solutions to mitigate their risk.

WEB evolutionq.com ■

Quantum satellite mission advanced by IQC researchers

An IQC team, led by faculty member **THOMAS JENNEWEIN**, completed a successful laboratory demonstration of a form, fit and function prototype of a Quantum Key Distribution Receiver (QKDR), a significant milestone in advancing the Quantum Encryption and Science Satellite (QEYSSAT) project. QEYSSAT is a collaborative project with the Canadian Space Agency (CSA), space hardware designer and manufacturer COM DEV and others for the development of a global satellite-based quantum communications network.

"By successfully validating the prototype QKDR in a lab environment, we've advanced the technologies to Technology Readiness Level Four (TRL4)," said Jennewein.

WEB http://bit.ly/QKDR_SatMission

Read about QEYSSAT in the 2013 Annual Report (pages 12-13):
<http://bit.ly/iqc-annual-report-2013> ■

» Can we build it? Yes we CanBuild!

In March, IQC students and staff were one of 16 participating teams in the University of Waterloo's CanBuild competition that collected 4,500 cans for the Federation of Students Food Bank and the Food Bank of Waterloo Region.

PhD students **JOHN DONOHUE**, **AIMEE GUNTHER**, Master's student **OLIVIA DI MATTEO**, and staff members **ERIN CRONIN** and **KIM KUNTZ** used 315 donated cans to build *Wave-Can Duality*, a replica of the double-slit experiment. ■

» Aimee Gunther, John Donohue, Olivia Di Matteo, Erin Cronin and Kim Kuntz



» **Wave-Can Duality:** Interference of light has been well understood since the early 1800s, but interference of particles is a considerably newer idea. Our construction represents the first known experiment demonstrating the interference of canned goods, as seen by the peaks in cantensity after passing through two narrow cereal canals. Our result clearly indicates that a donated good is not just a can or just a wave, but exists as both a wave and a can simultaneously.

» IN THE NEWS



On the way to Mars

IQC alumnus **BEN CRIGER** was chosen as one of 100 people — and among only seven Canadians — to move on to a third round of training for the Mars One mission aiming to establish a permanent human settlement on the red planet. Criger, currently a postdoctoral researcher at Rhine-Westphalia Institute of Technology (RWTH) Aachen University in Germany, graduated from the University of Waterloo with a PhD in Physics.

WEB <http://bit.ly/on-the-way-to-mars> ■

Around

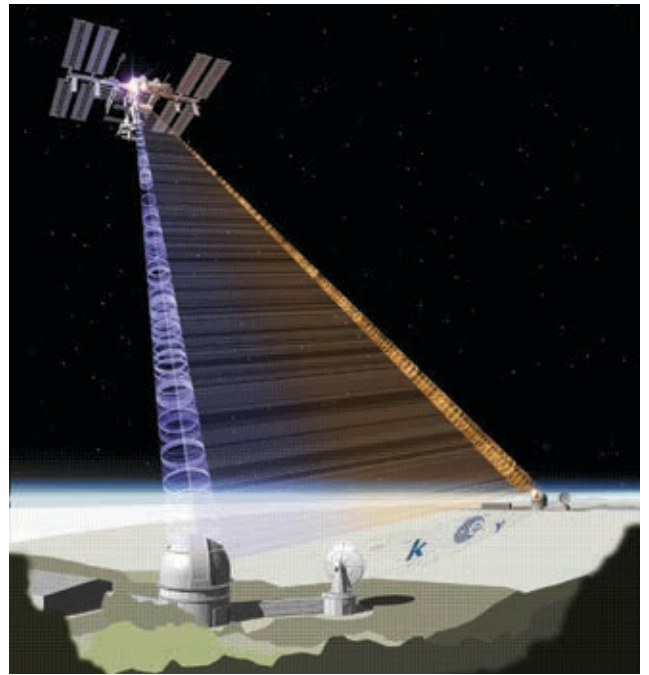
THE INSTITUTE

» QUANTUM COLLECT CALL MAY LEAD TO GLIMPSE OF THE EARLY UNIVERSE

Science News highlighted recent research by Research Assistant Professor **EDUARDO MARTIN-MARTINEZ** that was also presented March 2 at the APS March Meeting. Martin-Martinez, with collaborators from the Department of Mathematics, University of Waterloo, found a possible communication channel that does not require energy transmission from the sender to the receiver, but instead requires only the receiver to spend energy to run its detector, similar to a collect call. This kind of communication without energy exchange may be called “Quantum Collect Calling,” and makes it possible for the sender to transmit information without the receiver being present and without spending extra energy to broadcast to many receivers. The paper *Information Transmission Without Energy Exchange* was published in *Physical Review Letters* March 20.

In a second paper, also appearing in *Physical Review Letters* and featured in *New Scientist* and *Phys.org*, Martin-Martinez and collaborators from Universidad Complutense de Madrid, Spain and Radboud University Nijmegen, Netherlands, look more closely at the “Quantum Collect Call” communication channel to see if it can be used to access information from the early stages of the universe. Their fundamental results show that information transmitted through the echoes travels more resiliently than it would by light, only showing signs of decay over time. They also showed that the information does not decay at all as a function of distance between the sender and receiver. Echoes traveling from the very start of the universe could shed some light on this event, providing helpful insight for cosmologists.

“Information about background signals from the early universe will also be propagated through this echo. The challenge (now) is to figure out precisely what form the echoes will take and how to build receivers that can pick them up,” Martin-Martinez told *New Scientist* in January. ■



⤴ Quantum collect calling

WEB

Read the *Science News* article:

<http://bit.ly/martin-martinez-science-news>

Read the paper *Information Transmission Without Energy Exchange*:

<http://bit.ly/info-transmission-wout-energy>

New Scientist article:

<http://bit.ly/martin-martinez-new-scientist>

Phys.org article:

<http://bit.ly/martin-martinez-physorg>

Read the paper *Violation of the Strong Huygen's Principle and Timelike Signals from the Early Universe*:

<http://bit.ly/timelike-signals-early-universe>



Quantum-safe encryption: The need is now

Computerworld named quantum computing as one of six *Emerging enterprise techs to watch* in an insider feature by **LAMONT WOOD** on February 25. Faculty member **MICHELE MOSCA** explained that thanks to quantum mechanics, qubits can be in superposition — meaning that one qubit can be both a 1 and a 0 at the same time. This ability gives quantum computers the power to solve some types of problems more efficiently. Mosca predicts a significant possibility that a real quantum computer may be realized in just 10 to 15 years. With the possibility that quantum computers could crack algorithms once thought to be secure, online data could be vulnerable to attacks. “Security officials need to start looking for quantum-safe encryption now,” warned Mosca.

WEB <http://bit.ly/emerging-enterprise-techs-to-watch> ■



Leading Canada in the Quantum Valley race

Reminiscent of his grandfather’s stories of the very first airplane flights, executive director **RAYMOND LAFLAMME** shared the life-changing impact that quantum technologies may have on our society and Canada’s role in their realization in his Report on Business commentary profiled in *The Globe and Mail* on January 21.

Other countries are starting to realize the potential opportunities of quantum technologies and are increasing resources and investments towards quantum research and development. The good news for Canada, said Laflamme, is that thanks to visionary investing and strong political commitment, we fired the starting gun in this race 14 years ago. We are positioned to not only compete in the race, but to lead and win.

WEB <http://bit.ly/laflamme-globe-and-mail> ■



FROM THE IQC GSA

IQC Graduate Students Association winter events featured the second annual IQC Pub Crawl, in addition to regular features like our monthly board games night. IQC students, faculty and staff members raised 315 cans for the University of Waterloo can drive. The can drive concluded with an institute-wide chili cook-off, with professor **KEVIN RESCH** and graduate student **MADELAINE LIDDY** tying for the title of IQC Chili Champion. This term, the IQC Entrepreneurship Student Group met with IQC postdoctoral fellow and entrepreneur **ROLF HORN** who gave an introduction to business lingo, as well as Creative Destruction incubator associate director **NOOPUR PARMAR** and WatCo representative **GARY BROCK**.

Corey Rae McRae ■

» AWARDS AND FELLOWSHIPS

Scholarship funding supports student exchange



Faculty member and Quantum Information Graduate Program Director, **ASHWIN NAYAK**, received \$260,000 in Canadian Queen Elizabeth II Diamond Jubilee Scholarship funding announced March 25. The funding will be used to financially assist 24 Canadian undergraduate and graduate students from IQC to visit the National University of Singapore’s Centre for Quantum Technologies (CQT), and support 16 CQT students (Singaporean or from other Commonwealth countries) to visit IQC for a period of four months.

WEB <http://bit.ly/CQE-diamond-jubilee-scholarship> ■

Around THE INSTITUTE



NSERC PromoScience funding for IQC outreach programs

The National Sciences and Engineering Research Council of Canada (NSERC) announced its support March 18 for the expansion and proposal of scientific outreach programs at IQC. **MARTIN LAFOREST**, Senior Manager, Outreach, received a \$9,500 NSERC PromoScience grant for his project *Quantum Technology for Students and Educators (QTSE)*. The programs include:

- » Quantum Cryptography School for Young Students (QCSYS)
- » Teaching Quantum Technology (TQT)
- » Quantum Experience for Young Students (QEYS)

WEB <http://bit.ly/laforest-receives-NSERC-PromoScience-grant> ■

Gold & Silver for IQC publications

The IQC Communications and Strategic Initiatives team received two Council for Advancement and Support of Education (CASE) District II Accolades awards, announced in December:

- » *NewBit* (this newsletter) was awarded Gold in the Newsletters: Print category
- » *IQC 2013 Annual Report* was awarded Silver in the Annual or Institutional Reports: Print category

WEB <http://bit.ly/iqc-comm-awards> ■



» John Donohue



» Juan Miguel Arrazola

STUDENTS EARN IQC ACHIEVEMENT AWARD

PhD students **JOHN DONOHUE** and **JUAN MIGUEL ARRAZOLA** were awarded the Winter 2015 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.

Donohue works on the creation and manipulation of entangled photons on the sub-picosecond timescale. Arrazola's research focuses on the theory of optical implementations of quantum information and communication. ■

» ARRIVALS

Faculty

Michael Reimer

Staff

Corey Brown
Angela Olano
Matt Scott

Students

Vadiraj Ananthapadmanabha Rao
Jaff Salvail
Yihang Yang
Omar Alshehri

Visitors

Katanya Kuntz
Hyeran Kong
Moshen Razavi
Tao Xin ■



Quantum Key Distribution Summer School

August 17-21, 2015

Explore quantum key distribution



The QKD Summer School program for graduate students and young postdoctoral fellows focuses on theoretical and experimental aspects of quantum communication over five days. QKD experts will cover topics including classical cryptography, security analysis and optical implementation of QKD, and QKD in a cryptoworld. Attendees will:

- » Learn independent research techniques in quantum communication
- » Collaborate with renowned researchers ■



uwaterloo.ca/iqc/qkd

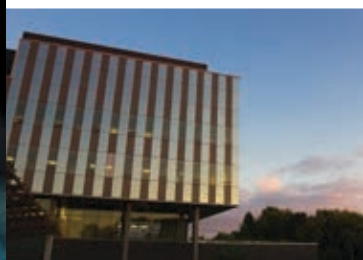


You're invited to the IQC Open House

**Saturday,
October 3, 2015
11-4 pm**

The Institute for Quantum Computing will open its doors to the community as part of Reunion at the University of Waterloo. Bring the whole family to discover the excitement of quantum mechanics and learn about the world-class research that is happening right here in our community!

- » Explore the Mike & Ophelia Lazaridis Quantum-Nano Centre.
- » Ask a scientist about IQC research and its applications.
- » Bring your kids to the Discovery Zone or the Q-Kids Science Show.
- » Hear Executive Director **RAYMOND LAFLAMME** talk about embracing the Quantum Revolution! ■



bit.ly/iqc-open-house-2015

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



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