NEWBIT

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

ISSUE 32

Revolutionary **materials**

UNIVERSITY OF WATERLOO | IQC Institute for Quantum Computing

UNIVERSITY OF WATERLOO | IQC Institute for Quantum Computing

IN this issue

ON THE COVER

In Na Young Kim's lab, a spectrometer is used to record and measure the light's spectrum for analysis.

Cover Photo by: IQC

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IQC COMMUNICATIONS & STRATEGIC INITIATIVES

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FROM THE EDITOR

Outreach activities continue to be an important part of what we do at the Institute for Quantum Computing (IQC). As a magnet for highly qualified personnel in our field, we also reach out to quantum enthusiasts of all ages.

Both *QUANTUM: The Exhibition* and the Quantum Cats game appeal to people of almost any age and serve as an excellent introduction to the field of quantum information science and technology. Many of our other activities concentrate on increasing diversity in STEM, including our participation in the March for Science, International Women's Day and the #ChooseScience campaign by Minister Duncan's office. Some of our activities even bring together art and science, such as Quantum Etude or the Quantum Shorts and Quantum Applications public talk.

Driving it all, is the ground-breaking research happening at IQC. From the theoretical to the experimental, IQC researchers continue to study fundamental science, collaborate with researchers around the world and develop innovative technologies to take us beyond the silicon age (see page 4).

We couldn't do any of this without the funding of our many generous supporters. We were extremely excited (and thankful!) to hear that the Government of Canada renewed their support in 2017. Thank you, Canada – we look forward to continue our leadership in this exciting field.

CHRISTINE BEZRUKI,

Senior Manager, Communications,
Institute for Quantum Computing

Federal government **INVESTS IN QUANTUM** science in Canada

IQC continues its work to become a 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, all thanks to renewed funding from the Government of Canada in Budget 2017.

IQC has continued to grow thanks to the support of the Government of Canada and generous supporters including the Province of Ontario, Mike and Ophelia Lazaridis and the University of Waterloo.

With the renewed funding of $10 million over two years, IQC continues research in quantum information science and technology, helping Canada to lead the transformation of markets, creation of new industries and the production of leading-edge jobs.

"Canada is positioned to take full advantage of the opportunities quantum technologies present, and this renewed investment ensures IQC continues its world-leading research," said IQC Executive Director **RAYMOND LAFLAMME**.

IQC's discoveries are already making important impacts in information technology, security, environmental monitoring and healthcare. The continued commitment to innovation demonstrated by the federal government ensures that IQC will be able to accomplish even more amazing breakthroughs in the years to come. ■

New **faculty** hire

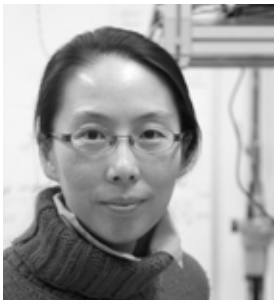
Before coming to IQC, **DMITRY PUSHIN**'s work at the Massachusetts Institute of Technology (MIT) and National Institute of Standards and Technology (NIST) led to the design and commissioning of a novel device: the decoherence-free subspace neutron interferometer. Later his team demonstrated for the first time the control of Orbital Angular Momentum (OAM) of a neutron beam, a new degree of freedom for massive particles. His work on neutron holography was selected as one of the American Physical Society's (APS) Top 10 Physics Newsmakers of 2016.

Now, as an Assistant Professor at IQC and the Department of Physics and Astronomy, he uses quantum information processing to further improve neutron interferometry. He's making it accessible to the general scientific community as a resource for studying fundamental questions of physics such as dark energy, gravity, neutrino oscillations; phase transitions in condensed matter, magnetic materials in functional devices, and materials science. ■

» FEATURE ARTICLE

Innovating

« Kim and Master's student **MATS POWLOWSKI** adjust optical elements between the liquid cryostat and spectrometer on the optical table.



IQC researcher NA YOUNG KIM foresees "the wall of the silicon age" fast approaching — if we're going to keep improving circuits at smaller and smaller scales, we're going to need even better materials. Kim and her team are working to find the next revolutionary semiconductor materials for the post-silicon age.

Characterizing the future

Semiconductors are solid materials that conduct electricity better than an insulator like rubber, but worse than a conductor like copper, usually because of some impurity. The conductivity of semiconductors can be controlled based on the current or voltage of electricity applied. This control makes semiconductors well suited for use in integrated circuits, like those in our phones, cameras and computers. While all these devices use silicon as their semiconductor, Kim foresees the need for new materials when silicon reaches its limits.

Kim is always looking toward new possibilities: the next big materials advancement, revolutionary applications of fundamental research, and the skills she will need to lead the way there.

Once Kim and her team have acquired a semiconductor material — either by creating it or obtaining an already existing one — they need to characterize it (measure its properties) to determine its usefulness.

There are three main kinds of characterization: electrical, chemical and optical. When Kim joined IQC and the Department of Electrical and Computer Engineering at the University of Waterloo as the Principal Investigator of the Quantum Innovation lab (QuIN) in March 2016, she began equipping her labs to perform all three, with the help of other IQC labs when necessary.

Kim calls the first lab the chemical/electrical lab. There, she and her research team will develop, process and chemically and electrically characterize semiconductor materials. These materials will then be taken to the second lab, the optics lab, to test their optical properties.

Assembling the tools for innovation

The QuIN lab was outfitted with millwork lab furniture, including optical tables for the optics lab, in September 2016. Soon after, additional lab equipment began to arrive. The chemical/electrical lab contains equipment new to Kim, who is a trained physicist — a fume hood, glove box, sonicator, centrifuge and analytical balance — all necessary for Kim's processes.

The tables in the optics lab were outfitted with elements like lenses, beam splitters and mirrors, as well as a continuous laser to excite material samples

for the post-silicon age

Building a multifunctional lab to produce multifunctional quantum devices

and a spectrometer to analyze those excitations. These analyses will reveal the optical properties of any given sample, helping researchers determine if they have a material useful for their applications.

Kim and her team completed their first experiments in January 2017, but outfitting the lab and modifying equipment is still a work in progress. One piece of equipment — a femtosecond pulse laser with tunable frequency – gives Kim new ways to excite samples. However she plans to modify it into a picosecond laser to better suit the narrow bandwidth required for her experiments.

The ability to modify, design and build her own equipment is a perk of academia crucial to Kim's research project; it is difficult to lead the field without tools specifically designed for the task. Even so, for Kim, the QuIN lab isn't just rooms filled with equipment — it's a place to enact her research philosophy.

"What I aim to do as a researcher is not just follow. I want to lead the field, and to be a leader, you need to be curious," said Kim. "If you're really curiosity-driven, you can't just stop."

« Samples are placed in this cryostat in the optics lab before a vacuum pump is used to remove the air. Liquid helium cools the chamber to about 4 Kelvin, and then lasers are used to excite the samples.

» Master's student **MATS POWLOWSKI** aligns optical elements in the lab.

Realizing the Quantum Age

Kim has big plans for the semiconductor materials developed and tested in the QuIN lab. The team is developing solid-state quantum processors that will probe elusive classes of problems from fields as diverse as medicine and particle physics. They are also working on scalable planar architecture for multifunctional integrated circuits that will surpass current technology in terms of electrical, optical, mechanical and thermal properties. More fundamentally, Kim hopes to tackle theoretical and experimental obstacles that lie in the way of building quantum information processing and quantum communications machines that will help discover the quantum secrets of nature and result in tangible products for the market.

"My dream would be to put some quantum technology in everyone's smartphones," said Kim. But it's not just about the technology. "It could be tangible products, but also the paradigm: people's thought processes, philosophy, some kind of positive lifestyle change. I want to be not only an engineer, but also a good thinker and educator. If I could be remembered like that, I would be honoured." ■

SCIENCE HIGHLIGHTS

IQC faculty, postdoctoral fellows and students continue to conduct internationally recognized quantum information science research. Here is a sampling of their research published in academic journals.

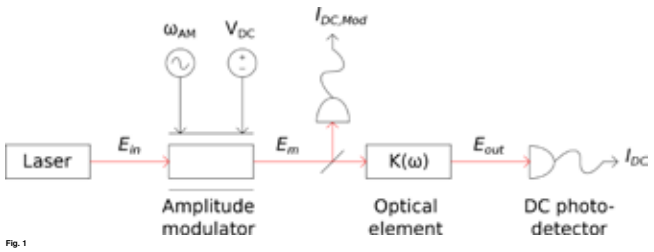


Fig. 1

Schematic representing the model of the proposed method to measure the frequency response of an optical system consisting of an optical cavity and an amplitude modulator.

ROBUST CAVITY CALIBRATION

Optics Express 25, 2, 573-586 (2017)

IQC postdoctoral fellow **KATANYA KUNTZ** led the discovery of a new technique for measuring the length of an optical cavity without any initial calibration published in *Optics Express* January 23. With potential applications for both classical and quantum research, the measurement technique could also be useful in the telecommunications industry for calibrating lasers to transmission channels.

An optical cavity is an arrangement of mirrors that allow a beam of light to circulate around a closed path. Cavities can be used for many tasks, including producing groups of entangled photons called cluster states that are useful for complex quantum computing tasks. However, it's necessary to know the cavity's free spectral range (FSR) before the cavity can be used. Until now, existing techniques for determining a cavity's FSR relied on equipment not readily accessible. The new technique detailed in *Ultra-wide frequency response measurement of an optical system with a DC photo-detector*, does not require any specialized equipment, or for the measurement components to be calibrated beforehand.

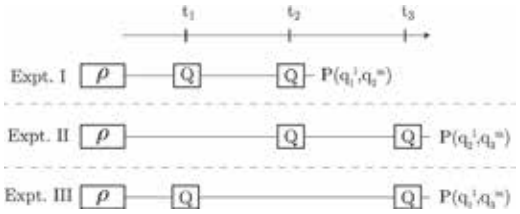
WEB **bit.ly/robust-cavity-calibration**

Pushing the upper bounds of a long-standing test

New Journal of Physics, 19, Feb 2017

IQC researchers performed the first experiment to violate the Leggett-Garg (LG) inequality on a three-level quantum system, demonstrating the possibility of larger violations than previously thought possible.

The LG test is meant to demonstrate a violation of macrorealism, the idea that macroscopic objects cannot exist in superposition of classically observable states. The test provides a fixed upper bound for a quantum system, but a recent discovery revealed that this quantum upper bound can be increased by testing systems that can exist in more than two states.



Scheme for LG test.

PhD student **HEMANT KATIYAR**, along with former IQC postdoctoral fellow **AHARON BRODUTCH**, postdoctoral fellow **DAWEI LU**, and Canada Research Chair in Quantum Information **RAYMOND LAFLAMME** created a three-level system to expand the upper bound beyond what has ever been experimentally achieved, giving a larger buffer for noise and experimental error. Their improvement in the methods of performing an LG test brings researchers one step closer to violating the inequality with a truly macroscopic object.

The results were published as *Experimental violation of the Leggett-Garg inequality in a 3-level system* in the *New Journal of Physics*.

WEB **bit.ly/upper-bounds**

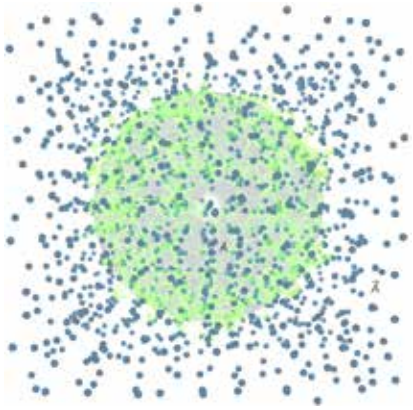
SCIENCE HIGHLIGHTS

Entanglement area law in a quantum fluid

Nature Physics 13, 556–558 (2017)

While entanglement is often thought of as occurring between two particles, the IQC researchers behind a recent experiment instead measured entanglement between particle-filled regions of space and demonstrated area law scaling of entanglement entropy in a real quantum fluid for the first time.

The researchers took a cubic box of superfluid helium-4 and divided it into a spherical sub-region and its complement. They then measured the entanglement entropy between the two regions at different system densities. The area law scaling of entanglement entropy describes the strength of the entanglement entropy as scaling with the bounding surface of two entangled regions.



Entanglement across a spherical boundary.

The paper *Entanglement area law in superfluid ^{4}He* published in *Nature Physics* March 13 showed that, counterintuitively, entanglement between the sphere and complement of superfluid helium was dominated by an area law, not a volume law. The researchers, led by postdoctoral fellow **CHRIS HERDMAN**, also demonstrated that they could control entanglement between the sub-regions by changing the pressure of the system, a simple variable for experimentalists to control.

WEB **bit.ly/entanglement-area-law**

TALKS

QUANTUM SHORTS AND QUANTUM APPLICATIONS

On February 23 IQC celebrated a night of film and science with 10 quantum-inspired films followed by a lecture about the applications of quantum devices. For the past two years, IQC has partnered with the Centre for Quantum Technologies in Singapore for their Quantum Shorts contest. This year, applicants from 50 countries submitted over 200 quantum physics-inspired short films. After the judges short-listed the top 10 films, they were shown around the world, including the Lazaridis Centre. To give the local audience an understanding of just what quantum might mean in their lives, Senior Manager, Scientific Outreach, **MARTIN LAFOREST** talked about what we know quantum devices will be used for (that will affect everyone) and where researchers are hoping they will be used in the future.

Congratulations to **THOMAS VANZ**, whose film *Novae* won the Quantum Shorts contest.

WEB **bit.ly/quantum-shorts-2017**

IQC OUTREACH

TALKS AND TOURS

INSPIRATION FOR THE NEXT QUANTUM GENERATION

One hundred high school students gathered at Assumption College, Brantford, April 5 to hear a keynote by IQC Scientific Outreach Officer **ELECTRA ELEFTHERIADOU**. She not only talked about quantum information science and technologies but also shared her own career path. "An Evening of STEM" inspired the students to consider their own potential quantum career paths in turn. ■

Visualizing quantum

How can quantum phenomena that occur outside the realm of perception be visualized? **MARTIN LAFOREST**, OCAD University faculty member **KARIN VON OMPTEDA**, independent artist **LAURA DE DECKER** and Ryerson University lecturer **JAY IRIZAWA** tackled this question in a panel discussion at OCAD University April 27. The panelists discussed their respective work dealing with quantum mechanics, and Laforest showcased some of the visualizations of quantum in *QUANTUM: The Exhibition*. The discussion was part of the Leonardo Art Science Evening Rendezvous (LASER) series that brings artists and scientists together for informal presentations and conversations. ■

QUANTUM in Vancouver

After the Second World War, Canada was in need of engineers and technicians to meet the needs of the growing economy. The institution that came to be known as the University of Waterloo was established in 1957 to fulfill this need. Sixty years later, hundreds of alumni congregated at TELUS World of Science in Vancouver to celebrate the stunning growth of their alma mater into a world-class institution constantly pushing the threshold of innovation.

IQC was present to demonstrate how Waterloo is leading the way in quantum science research and outreach on a global scale. Faculty member and Canada Excellence Research Chair Laureate **DAVID CORY** spoke about the fundamentals of quantum information science and the importance of research in this area for society at the event. Attendees had a sneak peak of *QUANTUM: The Exhibition* before its Vancouver debut to the public the next day. When looking at the progress 60 years has brought — becoming a world leader in the theory and practice of quantum computing just one of many great achievements — it is impossible not to wonder what the next 60 years have in store. ■

IQC OUTREACH

SHARING QUANTUM WITH SASKATOON

IQC received a lot of attention in Saskatoon when *QUANTUM: The Exhibition* arrived at the Western Development Museum. Senior Manager, Scientific Outreach **MARTIN LAFOREST** made multiple media appearances to spread word about the exhibition and Innovation150, including on CTV Saskatoon, Saskatchewan Radio-Canada radio and Saskatchewan Radio-Canada TV. Perimeter Institute for Theoretical Physics (PI) Manager of Special Projects **RJ TAYLOR** also made an appearance on CTV: this time live from the exhibition.

Over 16,000 people experienced the wonders of quantum information science and technology during the exhibition's stay in Saskatoon, including Waterloo alumni living in the city who had the chance to attend a private showing of *QUANTUM: The Exhibition* with Laforest presenting. ■

EVENTS

#ChooseScience

IQC joined the push for inclusivity in STEM fields online and in schools as part of a new campaign launched by the Honourable **KIRSTY DUNCAN**, Minister of Science, to encourage more young women, Indigenous peoples and otherwise underrepresented groups in research to choose science. In addition to a social media campaign highlighting Canadian science breakthroughs and opportunities marked with #ChooseScience, Duncan visited elementary schools, high schools and other venues to encourage young people to pursue their scientific ambitions.

Participating in the #ChooseScience campaign was only the latest effort in IQC's longstanding commitment to equity in science research. Past efforts have included establishing the IQC Equity and Inclusivity Committee, sponsoring FemPhys, Women in Science, hosting the 2017 Women in Physics Canada conference and more. At IQC, we want to encourage everyone with a passion for science to choose science.

WEB **bit.ly/choose-science-tweets** ■

The next science communicators

Outreach isn't just about sharing science with the public — it's also about helping the next generation of science communicators do the same. It's why each year Science Communication students from Laurentian University visit IQC to see how the Communications and Strategic Initiatives team does its work. This year, Senior Communications Manager **JODI SZIMANSKI** and Senior Manager, Scientific Outreach **MARTIN LAFOREST** spoke to the students about IQC and the types of communications challenges particular to the science done here. With this "case study" of real-world science communication, the students have one more example of how to translate theory into practice in their future careers. ■

JOINING THE MARCH FOR SCIENCE

IQC faculty members **DEBBIE LEUNG** and **JONATHAN BAUGH** spoke to hundreds at the March for Science rally that took place at Waterloo Town Square April 22. The rally celebrated passion for science and called for everyone to support and safeguard the scientific community, scientific research, and science-based policy. "The foundation of innovation is basic science," said **BOB LEMIEUX**, Dean of the Faculty of Science at the University of Waterloo. He spoke about the importance of the field and science advocacy at the event, which coincided with more than 500 Marches for Science taking place around the globe. ■

Quantum introductions and inspiration

Scientific outreach invests in future researchers, connects the general public with cutting-edge knowledge, and inspires some to see a path for themselves in the sciences that they didn't see before. The IQC Outreach team had a busy term – reaching out to high school and elementary school students and their parents with school visits and programs at the University of Waterloo. Through various programs and events like *Girls in STEM*, *Waterloo Unlimited* and *Physics Lab Days*, the Outreach team:

- introduced quantum concepts to 30 **teachers** participating in a workshop,
- revealed potential quantum careers paths to 40 **parents** of elementary students and
- inspired over 150 **elementary students** and 480 **high school students** with the fascination of quantum science this term. ■

QUANTUM ETUDE: Bringing the beauty of quantum science to the public with music

Dress rehearsal of *Does God Play Dice?*

The Kitchener-Waterloo (KW) Symphony, led by Musical Director **EDWIN OUTWATER**, collaborated with IQC Executive Director **RAYMOND LAFLAMME** to combine music and quantum science since the creation of *Quantum: Music at the Frontier of Science*, first performed in 2012 at the opening of the Lazaridis Centre. In his final quantum challenge before stepping down as Musical Director, Outwater collaborated with Laflamme to create *Quantum Etude*.

Quantum Etude debuted at the Conrad Centre for the Performing Arts April 20 as part of a concert entitled *Intersections Magnetar*, which also featured the pieces *Magnetar and The Rise of Exotic Computing*. An audience of 200 community members witnessed the unique and inspired intersection of art and quantum science.

The music of *Quantum Etude* encapsulates key concepts in quantum mechanics using both musical form and the performance method itself. During the performance of *Does God Play Dice?*, Outwater literally rolled the dice as a random number generator. Different groups of musicians were spread around the auditorium and assigned numbers and colours. When Outwater signalled a group's number and colour, they would begin to play their part, with this probabilistic performance representing the seemingly probabilistic nature of quantum phenomena.

The performance was a resounding success. Audience members heard quantum concepts as musical analogy and experienced the beauty of the quantum world in art, a kind of transcendent scientific outreach.

The collaboration was fruitful for Laflamme and Outwater as well, who cherished their collaboration between quantum and music.

"I've never seen somebody doing the process of creating a piece of music, and this, for me, was totally fascinating," said Laflamme.

"I can say that, as an artist, Raymond has made me go in a completely different direction, and inspired me, and made me open my mind to things that I didn't even think about in music," said Outwater. ■

CONFERENCES

IQC at QIP

Many IQC members travelled to Washington in January to take part in the 20th international conference on theoretical aspects of quantum computing, cryptography and information: Quantum Information Processing (QIP) 2017. It was an opportunity to join other researchers that are part of the theoretical quantum information community to present and discuss the latest ground-breaking work in the field.

Hosted by the The Quantum Architectures and Computation (QuArC) group at Microsoft Research in Redmond, Washington, and the University of Washington, QIP 2017 featured a tutorial program, plenary talks, contributed talks, and a poster session. Attendees witnessed some of the ground-breaking research being done at IQC when assistant professor **WILLIAM SLOFSTRA** presented a plenary talk discussing his work solving Tsirelson's problem. Faculty member **ASHWIN NAYAK** and postdoctoral fellow **DAVE TOUCHETTE** also gave a presentation while former postdoctoral fellows **SCOTT AARONSON**, **JEAN-FRANCOIS BIASSE**, **ANNE BROADBENT**, **DAVID GOSSET** and **DAVID POULIN** participated in the conference as well, showcasing the far-reaching impact of IQC on theoretical quantum computing. ■

UPCOMING CONFERENCES

Undergraduate School in Experimental Quantum Information Processing

May 28-June 8, 2018
IQC, University of Waterloo,
Waterloo, Ontario

Quantum Cryptography School for Young Students

August 10-17, 2018
IQC, University of Waterloo,
Waterloo, Ontario ■

MARCH MEETING OUTREACH

The American Physical Society's (APS) March Meeting 2017 invited IQC to participate in a workshop about outreach and the gamification of quantum mechanics. Senior Manager, Scientific Outreach **MARTIN LAFOREST** shared the creation process behind IQC's *QUANTUM: The Exhibition*, the first touring exhibition on quantum information science. PhD student **THOMAS GEORGE McCONKEY** also presented *Quantum Cats*, a simple app that introduces younger science enthusiasts to quantum information science through the concept of gamification.

IQC's presence at the APS March Meeting, which was hosted at the Ernest N. Morial Convention Center in New Orleans this year, extended beyond the outreach and gamification session:

- 4 Master's students,
- 20 PhD students,
- 6 postdoctoral fellows,
- 1 research assistant professor,
- 11 faculty members,
- 3 affiliates/associates,
- 1 long-term visitor and
- 2 research assistants presented
- 28 research papers at the conference ■

Around the INSTITUTE

Master's student PROFILE: MORGAN MASTROVICH

Broad vision creates many opportunities

MORGAN MASTROVICH thought she wanted to be a professional dancer, then a violinist, and then a biochemist. Now a Master's student studying Physics at IQC, she strives to maintain the same breadth of vision that led her from art to chemistry to quantum information science.

After a year and a half of studying computer science at Harvey Mudd College, Mastrovich realized she wanted to be on the forefront of computing, which inspired her to take courses in quantum physics. She applied to the Undergraduate School on Experimental Quantum Information Processing (USEQIP) and the Undergraduate Research Award (URA) program at IQC on the advice of an academic advisor, and was accepted to both.

"I was interested in quantum computing. This institute seemed like one of the biggest, and very cross-disciplinary," said Mastrovich of her decision to apply. She made lasting friendships at USEQIP and was exposed to a broad array of subject matter during the lectures. She began as an Undergraduate Research Assistant in faculty member **KEVIN RESCH**'s research group soon afterwards, and it was the quality of the group that convinced Mastrovich to apply to IQC for graduate studies.

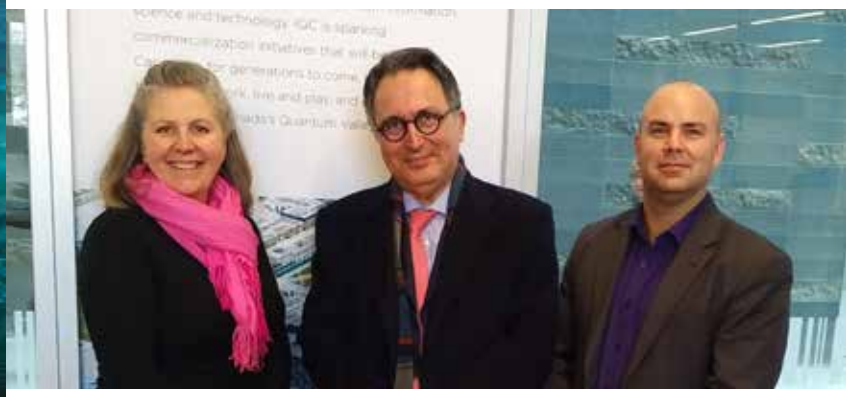
Now back in Resch's group on a Mike and Ophelia Lazaridis Fellowship, she is also collaborating with faculty member **MICHAEL REIMER**'s group. The two groups are making use of the high-quality single photon sources — quantum dots embedded in nanowires — in Reimer's lab, but for different purposes. Reimer and his team create these sources and test them in an attempt to create improved versions. Mastrovich, along with Reimer's group members, **ARASH AHMADI** and **SARA HOSSEINI**, is interested in exploring applications of these sources. They use an interferometer to delay photons from neighbouring light pulses, causing them to overlap at a beam splitter. "If we can get them to overlap, and give them the right polarizations, we can create entangled states of several photons," said Mastrovich.

This work is a proof-of-concept for efficiently creating entanglement with a quantum dot single photon source. The brightness of the quantum dot source allows experiments to be done faster than other methods, like spontaneous parametric down conversion.

Although Mastrovich acknowledges that it can be easy to have tunnel vision as a grad student, her collaboration with Reimer's group demonstrates the value of having a physical concentration of researchers in a broad number of fields. "We have this lovely building and a lot of different people in close proximity, so the barrier is lower to go up and talk to a computer scientist or a theorist." ■

Around
THE INSTITUTE

TOURS/VISITS



IQC AS AN EXAMPLE

HIS EXCELLENCY RAOUL DELCORDE, Ambassador of Belgium to Canada, visited IQC February 11. **MARTIN LAFOREST** showed him around the institute, and they discussed the strategy behind IQC's research and outreach agendas, the Belgian approach to nanoelectronics research and development, as well as Belgian innovation hubs. Declorde's visit is the latest in a line of European delegations to visit IQC since the European Union's spring 2016 announcement of the EU Flagship in Quantum Technologies, an initiative dedicated to advancing quantum research in Europe. ■

NEW COURSES/ WORKSHOPS

CryptoWorks21

Quantum IP

During the winter term CryptoWorks21 courses focused on the fundamentals of intellectual property. CryptoWorks21 is a supplementary Collaborative Research and Training Experience (CREATE) program by the Natural Sciences and Engineering Research Council (NSERC) for graduate students and postdoctoral fellows working in various aspects of cryptography and quantum computing. This year's program consisted of six seminars covering different aspects of intellectual property to help IQC researchers understand what to do with any devices, technologies and methods they invent during the course of their work. ■

ANNOUNCEMENTS

Satellite project achieves lift off

Economic Development Minister **NAVDEEP BAINS** and Transport Minister **MARC GARNEAU** announced $80.9 million in funding over five years for the Canadian Space Agency (CSA) April 27. The support will fund two major projects, including IQC's Quantum Encryption and Science Satellite (QEYSSat) project. IQC faculty member **THOMAS JENNEWEIN** and his team have developed a cost-effective, small-scale satellite mission to position Canada at the forefront of the effort to build a global, secure quantum communication network.

Read **RAYMOND LAFLAMME**'s statement: **bit.ly/IQC-statement** ■

THESIS DEFENCE

Congratulations to **VINCENT RUSSO** for successfully defending his PhD thesis *Extended nonlocal games* February 1. ■

IN THE NEWS

Quantum machine learning

After Google's AlphaGo defeated world champion Lee Sedol in Go, a game magnitudes more complex than chess, IQC Affiliate **ROGER MELKO** began to think about how machine learning and artificial intelligence could help solve the grand problems of physics — especially if implemented on a quantum computer. He wrote an article on the potential use of this quantum machine learning for *Quartz* entitled, "The most complex problem in physics could be solved by machines with brains" February 1.

WEB **bit.ly/quantum-machine-learning** ■

Airborne QKD

Wired published a piece about the first successful test of Quantum Key Distribution (QKD) from ground to airplane by IQC researchers. In "PHYSICISTS, LASERS, AND AN AIRPLANE: TAKING AIM AT QUANTUM CRYPTOGRAPHY," science writer **SOPHIA CHEN** described how the experiment was done and what it means in a way that can be easily understood by a general audience. She also discussed the future plans of faculty member **THOMAS JENNEWEIN**'s research group: beaming a quantum key 300 miles in the air to an orbiting satellite.

WEB **bit.ly/airborne-qkd** ■

Replicated results

Two separate research teams — one at IQC and one at the University of Oxford — independently observed genuine three-photon interference for the first time using different methods. *Physics World* reported on the twin discovery in an article entitled "Three-photon interference measured at long last" April 17. Editor **HAMISH JOHNSTON** described the results and noted the possible applications of three-photon interference in three-photon sharing, quantum sensing and a quantum computing technique called boson sampling.

WEB **bit.ly/3-photon-interference** ■

FROM THE IQC GSA

We tried to escape the winter blues through the chilly term by holding our annual chili cookoff. With over 10 great chilies to choose from — vegetarian to meat lovers to hot pepper-infused – it's safe to say the event was a resounding success. Professor **KEVIN RESCH** took home the award for the Best Omnivore Chili, while **CHRIS WARREN** won both the Best Vegetarian and the Spiciest. IQC members also enjoyed the annual social night, a video game night and escape room night. ■

Around
THE INSTITUTE

AWARDS AND FELLOWSHIPS

KICK-STARTING FUNDAMENTAL RESEARCH




The Government of Ontario announced **MICHAL BAJCSY**, **GUO-XING MIAO**, **MICHAEL REIMER** and **NA YOUNG KIM** – all faculty members at IQC and the Department of Electrical and Computer Engineering at the University of Waterloo – as winners of Early Researcher Awards.

These IQC researchers are pushing the boundaries of what is possible in quantum communication and quantum information processing. Their work in developing fault-tolerant quantum computing and ways for quantum processors to communicate remotely helps drive Ontario as a world-class leader of the second Quantum Revolution. ■

Rewarding a life of research excellence

Canada Research Chair in Quantum Information **RAYMOND LAFLAMME** won the prestigious CAP-CRM Prize for Theoretical and Mathematical Physics "for his groundbreaking contributions to quantum information." Laflamme has been innovating the field since before his tenure at IQC began back in 2002, with breakthroughs including the long-standing world record for universal control of the largest number of quantum bits, experimental implementation of heat-bath algorithmic cooling, experimental three-particle quantum nonlocality under strict locality conditions, and many more. The prize is jointly awarded by the Canadian Association of Physicists (CAP) and Canada's Centre de Recherches Mathématiques (CRM). ■

NSERC Discovery

IQC faculty member **KEVIN RESCH** received an NSERC Discovery grant worth over $148,000 for his project to create a single-photon counting CCD. Low-light-level imaging techniques using such a camera could have application in many diverse fields, ranging from biological sciences to security, as well as the exploration of fundamental quantum physics. ■

MARSLAND FAMILY AWARD

IQC and University of Waterloo Department of Electrical and Computer Engineering faculty member **CHRISTOPHER WILSON** received the 2016 Marsland Family Award — the top research award given at the department level — for his work on *Ultrastrong coupling of a single artificial atom to an electromagnetic continuum in the nonperturbative regime*, published in *Nature Physics* in 2016. The paper was a collaboration between the labs of Wilson and fellow IQC faculty member **ADRIAN LUPAȘCU**, and demonstrates light–matter interaction over an order of magnitude stronger than any previously reported. ■

Mike and Ophelia Lazaridis Fellowship

IQC aims to attract high quality researchers to help push the limits of quantum information science and quantum technologies. Master's student **YOUN SEOK LEE** received a Mike & Ophelia Lazaridis Fellowship for academic excellence and the potential for research in quantum information. Thanks to the generosity of Mike and Ophelia Lazaridis, graduate fellowships are available for international Master's students up to a maximum of $20,000 per year. ■

IQC ACHIEVEMENT AWARD

IQC Achievement Awards, valued at $5,000, were given to PhD students **MIKE MAZUREK** and **SHIHAN SAJEED** for their exceptional achievement in research. Mazurek played a crucial role in the experimental demonstration of the failure of noncontextuality in the lab by IQC researchers last year. Sajeed has done extensive work in quantum security, including quantum hacking, quantum key distribution, experimental quantum fingerprinting, and more. ■

Award-winning architecture

The Mike & Ophelia Lazaridis Quantum-Nano Centre designed by KPMB Architects won the Ontario Association of Architects (OAA) award for Design Excellence April 11. The Lazaridis Centre was one of 10 winners selected from more than 140 submissions, all judged by criteria including creativity, context, sustainability, good design, good business and legacy. ■

ARRIVALS

Faculty

Dmitry Pushin

Staff

Maren Butcher
Siobhan Stables
Steven (Chuqi) Wei

Postdoctoral fellows

Sara Hosseini
Jun Li
Zhihuang Luo
Pan Zheng

Students

Connor Paul-Paddock
Maria Papageorgiou
Ray Liu
Youn Seok Lee

Visitors

Yidun Wan
Xiaodong Ma
Bienvenu Irenge Ndagano
Shilin Huang
Anuj Shripad Apte
Li Deng
Qian Xue ■

PROFILE: **DINAH SHI**

QCSYS alumnus 2012

Cryptography, quantum theory and their intersection were among the new topics introduced to DINAH SHI at the Quantum Cryptography School for Young Students (QCSYS).

She was fascinated by the real implications of quantum cryptography on everyday life:

> **A quantum algorithm could render cryptography based on factoring large composite integers insecure, and that's dangerous." The lecturers, faculty members and graduate students, also inspired Shi. "They were clearly passionate about this niche, highly advanced subject. It made me want to discover a technical topic that I could get excited about and become a master at my craft."**

Now a fourth year undergraduate student studying software engineering at the University of Waterloo, Shi is well on her way to mastering her craft. She is interested in how technology affects end consumers and businesses, and plans to use her skills as a programmer. Today, Shi leads the Waterloo chapter of Women Who Code, a program that inspires women to excel in careers in technology by organizing tech talks, panels and networking events. Her advice for future QCSYS students: "Come ready to learn!" ■

#womeninscience

#womeninstem

#optezscience #womenscienceday #BeBoldForChange

#choosescience #wipc

593 LIKES 100 SHARES

+420

women and girls impacted by targeted science outreach and skills programs.

Almost

50%

of QCSYS and USEQIP participants are now female.

Women in STEM

YouTube Playlist

49
Videos

1,316,686
Minutes Watched

874 LIKES 445 SHARES

IQC SPONSORSHIPS

ORGANIZATIONS

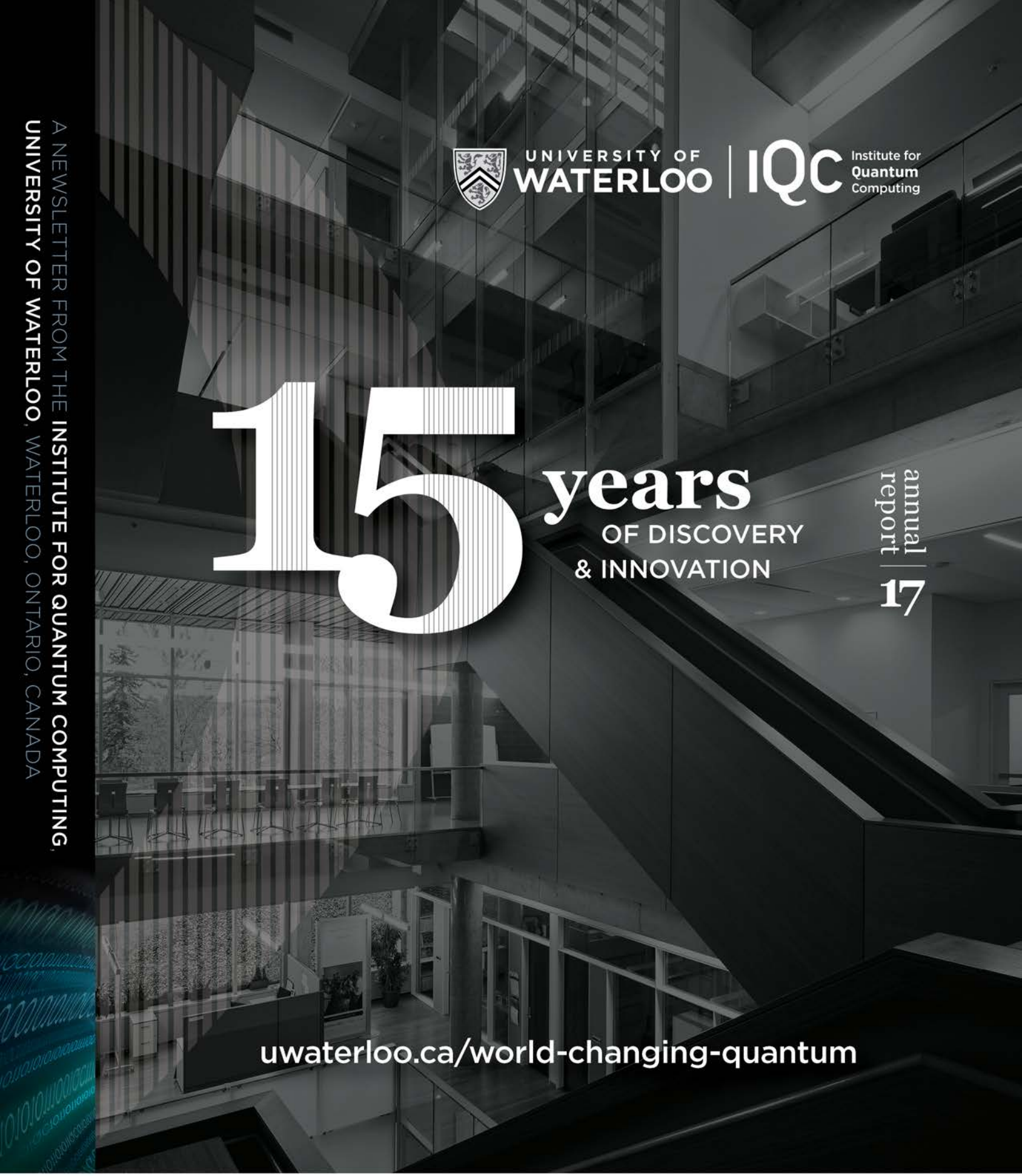
Women in Science Society

FemPhys

CONFERENCES

CCUWiP
Canadian Conference for Undergraduate Women in Physics

WIPC
Women in Physics Canada



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