The problem with

03 TRAINING THE NEXT GENERATION 07 SCIENCE HIGHLIGHTS 10 IQC OUTREACH

WATERLOO IQ

Institute for Quantum Computing



this issue

PLAYING MATHEMATICAL GAMES pg 04

WILLIAM SLOFSTRA has a problem with Tsirelson. Learn all about it as we explore his mathematical world.

COMPUTING A SECRET, UNBREAKABLE KEY pg 07

IQC researchers make key developments in Quantum Key Distribution protocol.

INNOVATION150 INITIATIVES pg 10

Celebrating *QUANTUM: The Exhibition* during a panel discussion in Vancouver.

ON THE COVER

Research Assistant Professor WILLIAM SLOFSTRA

Cover Photo by: IQC

FALL 2016

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FROM THE EDITOR

You'll notice something different about our main feature this issue – it doesn't contain photos of faculty and students in labs or photos of lab equipment. This issue we focus on the work of one IQC theorist, **WILLIAM SLOFSTRA**. Although we may think of theorists working alone with a whiteboard marker in hand, and sometimes they do, their collaborations often lead to thinking of new ways to solve a problem, as you'll see on page 4.

Collaborations between research groups, and even with other institutions, resulted in a number of papers over the last few months. In our *Science Highlights* section, we cover the publication of a paper by a group of theorists led by IQC affiliate **ROBERT SPEKKENS** and experimentalists led by Canada Research Chair in Optical Quantum Technologies and IQC faculty member **KEVIN RESCH**. There is also a paper resulting from collaboration with the Joint Quantum Institute at the University of Maryland and NIST.

Collaboration inspires new ideas. Often those new ideas come from different places – it's one of the reasons why IQC supports a strong visitor program and started the undergraduate research award. This award brings undergraduate students from around the world to work with a research group at IQC for a term. We interviewed one of those students, **DARIUSZ LASECKI**, who learned from his experience that research is where his future is leading.

Lasecki has seen first-hand how collaboration leads to better research, and we have a feeling that we'll hear more from him very soon – maybe even through a collaborative endeavor.

JODI SZIMANSKI, Senior Communications Manager

NEWBIT | ISSUE 30 | FALL 2016

Training the next generation of researchers

Undergraduate students join the quantum research community

The Undergraduate Research Award (URA) program trains the next generation of scientists, fundamentally supporting IQC's mission: to develop and advance quantum information science and technology at the highest international level.

A consistent part of IQC's research environment, undergraduate research assistants have contributed to scientific developments since IQC's founding in 2002. The URA program offers a fully-funded research experience at IQC for as many as 30 students annually. Participants in the two-week Undergraduate School on Experimental Quantum Information Processing (USEQIP) at IQC are also encouraged to apply to the URA program.

"The URA program exposes undergraduate students to quantum information, often for the first time," said **MARTIN LAFOREST**, Senior Manager, Scientific Outreach. "Introducing younger students to quantum information opens up a potential path for graduate studies."

The URA program gives undergraduates more than just a research experience: it is a community experience. Living together in university townhouses while at IQC, the students build relationships and work together. The students also become an integral part of the broader IQC research community, exposed to many facets of quantum information science and technology.

Laforest sees great value in the URA program for students and for the research community. "Exposing young students to the beauty and importance of quantum information science and technology may attract new quantum researchers to the field. These students will be the ones making groundbreaking discoveries in the future, finding new applications for quantum devices and proposing fresh ideas."



ff I certainly acquired skills that are vital for scientific research, like questioning and justifying your own research results, as well as working long term on a specific problem. **JJ**

DARIUSZ LASECKI, 2016 URA recipient

IQC 03



Playing mathematical

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Unfinished business

WILLIAM SLOFSTRA had some unfinished business when he started at the Institute for Quantum Computing (IQC) as a research assistant professor. For 10 years he had been curious about Tsirelson's problem.

He was first introduced to Tsirelson's problem while visiting IQC shortly after finishing his undergraduate studies in the departments of pure mathematics and combinatorics and optimization at the University of Waterloo. However, Slofstra's approach to the problem started with a much more recent visit to IQC in 2014, while a postdoctoral fellow at the University of California, Davis.

He met with $\ensuremath{\textbf{RICHARD}}$ $\ensuremath{\textbf{CLEVE}}$ and $\ensuremath{\textbf{JOHN}}$

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WATROUS, faculty of IQC and the David Cheriton School of Computer Science at the University of Waterloo. Through discussions with them, Slofstra learned about new algebraic approaches to the subject of non-local games proposed by Cleve and RAJAT MITTAL, now at ITT Kanpur.

Games and quantum mechanics

Alice and Bob are on a game show. They each sit in isolation booths at either end of the set and can't communicate in any way. The game show host asks a number of questions. Neither knows what questions are being asked, or the answers the other gives. The judges are shocked that they provide the exact same answer more often than they should. From the judges' perspectives, Alice and Bob appear to read each others' minds.

While this scenario is hypothetical, there are real-life situations where Alice and Bob do seem to answer questions exactly the same way in this scenario despite the fact that they cannot see each other or communicate. Quantum entanglement can explain the lack of mistakes – it does not actually allow Alice and Bob to read each others' minds, but it does potentially allow them to gain an advantage. Researchers call games built around these types of scenarios, like this hypothetical game show, "non-local games."

Entanglement describes how our knowledge of distant elements of a quantum state can change immediately once we learn the local outcome. It's not what we experience in our every day, but it is something that mathematicians, computer scientists and physicists study to discover if it can be used as a computational resource. Cleve and Watrous are two of the founding fathers of the idea that entanglement is a type of computational resource that can be used to succeed in non-local games more often than what would normally be possible.

Solving Tsirelson's problem

Although we know a lot about the mathematics of entanglement, there are still many questions about entanglement and non-local games that researchers don't know how to answer. Slofstra's work gets at the nature of how we model entanglement, and in the summer, he announced a solution for one of the main open problems in this area, the strong Tsirelson problem. The pre-print, Tsirelson's Problem and an embedding theorem for groups arising from non-local games, focuses on whether two ways of explaining, or modeling, Alice and Bob's actions in the game show are the same. More specifically, Tsirelson's problem asks whether commuting operator models for two-party quantum correlations are equivalent to tensor product models.

K Slofstra works through algebraic problems



TESTING THE RULES OF QUANTUM ENTANGLEMENT

Non-local games are test cases to gauge the power of entanglement. Researchers have been completing demonstrations of the properties of entanglement - known as Bell tests - since the 1970s. These tests allow researchers to experimentally test the hypothesis that nature is governed by local realism or whether, conversely, the effects predicted by quantum mechanics can occur. The success of these experiments is one of the reasons we believe that quantum mechanics successfully describes the physical world. The study of quantum entanglement is important to mathematicians and computer scientists because they would like to use it as a resource for quantum computing.

Slofstra's meeting with Cleve and Watrous in 2014 led to a new approach to Tsirelson's problem, but the path to the solution was not a straight one. Following his visit, he felt that the algebraic problems they had discussed would all have straightforward solutions. For a year, it was just one of Slofstra's research projects, but the methods he was applying didn't seem to work. Even once he joined IQC in August 2015, the problem remained unsolved.

Around December, Slofstra realized that his research in the area was not going the way he thought it was. However, he was able to make some progress through a collaborative paper on related issues with Cleve and PhD student LI LIU – *Perfect commuting-operator strategies for linear systems games* - which strengthened the algebra. This work, which was based on ideas from IQC faculty member VERN PAULSEN's work about commuting operators, was key to the realization that an algebraic approach to the problem could work.

Eventually, Slofstra recognized that the two models of entanglement, commuting operator and tensor-product, could be different. To show this was the case, he had to come up with a complicated game for Alice and Bob to play. If Alice and Bob are allowed to use the type of entanglement allowed in one set of models, the commuting operator models, then they can play this complicated game successfully. But they cannot win if they are restricted to the type of entanglement used in tensor-product models. This shows that the two types of models are not the same.

Furthering our understanding of entanglement

Currently, it's not clear where Slofstra's proof could lead. According to Slofstra, "We currently struggle to create systems with just a few qubits of entanglement, and we don't know if we'll ever be able to do an experiment where we observe the difference between these two models."

According to Watrous, "it's a step in answering one of the extremely difficult open questions in mathematics." Watrous explains by sharing **ANDREW WILES**' analogy of mathematics and walking around a dark mansion. Suppose you enter a dark room, and, after finding a light, you find a significant piece of furniture. This can help make assumptions about the mansion without getting the complete picture of the mansion.

Slofstra's findings can help mathematicians understand the possible ways in which two spatially separated systems behave. For now, as the paper moves through the standard peer review process, Slofstra is working with other mathematicians to explain and test the logic. "We now know that the commuting operator models and tensor product models are not the same," said Slofstra. "The main question becomes, is this something we could hypothetically test?"

06

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 over the past term.



Computing a secret, unbreakable key

A team of IQC researchers developed the first available MATLAB software to evaluate the security of any protocol for Quantum Key Distribution (QKD). The resulting paper, *Numerical approach for unstructured quantum key distribution*, published in *Nature Communications* on May 20 presented three findings. First, the researchers tested the software against previous results for known studied QKD protocols that allow for secure communication between two parties. Their results were in perfect agreement. They then studied protocols that had never been studied before. Finally, they developed a framework to inform users how to enter the data using a new protocol into the software.

Faculty member **NORBERT LÜTKENHAUS**, postdoctoral fellow **PATRICK COLES** and undergraduate research assistant **ERIC METODIEV** took a mathematical approach to calculate the allowed length of the final secret key for any given QKD protocol and the experimentally observed disturbance.

WEB http://bit.ly/numerical-QKD-software =

Testing noncontextuality in the lab

Noncontextual models assume that systems have definite properties and that two systems that are identical, as far as any experiment could tell, must have the same set of properties. It turns out that these seemingly reasonable assumptions are at odds with quantum mechanics; at least one of the theories must be wrong.

IQC affiliate **ROBERT SPEKKENS**, a faculty member at the Perimeter Institute for Theoretical Physics (PI) and the Department of Physics and Astronomy at the University of Waterloo, along with PI postdoctoral researcher **MATTHEW PUSEY** and **RAVI KUNJWAL** from The Institute of Mathematical Sciences, India, lifted the theoretical limitations that were previously not experimentally feasible and proposed an experiment that could test for noncontexuality, taking the realities of experiment into account.

IQC faculty member and Canada Research Chair in Optical Quantum Technologies **KEVIN RESCH** and his research group put the improved theory to the test. PhD student **MICHAEL MAZUREK** constructed the experimental setup out of single photon emitters and detectors. *Nature Communications* published the results, *An experimental test of noncontextuality without unphysical idealizations*, on June 13.

WEB http://bit.ly/testing-noncontextuality =

07

IOC

SCIENCE HIGHLIGHTS

SPIN-ORBIT STATES OF NEUTRON WAVE-PACKETS

Neutrons are massive, subatomic, electrically neutral particles that carry spin and have unique penetrating abilities, properties that make neutrons useful for probing matter and forces. A previous experiment led by IQC Research Assistant Professor **DMITRY PUSHIN** demonstrated that Orbital Angular Momentum (OAM) of the incoming neutron can be controlled to any specified value using a macroscopic spiral phase plate cut by a numerical controlled milling machine.

Now, Pushin, together with a team of researchers from IQC, the IBM T.J. Watson Research Center, the Perimeter Institute for Theoretical Physics, the National Institute of Standards and Technology, and the Joint Quantum Institute, has proposed a method for preparing an entangled spin-orbit state between the spin and the OAM degrees of freedom of a neutron wave packet.

The researchers designed an experimental set-up that passes neutrons through the center of a quadrupole magnetic field, providing a coupling between the neutron's spin and orbital degrees of freedom; this creates the spin-orbit state. The spinorbit state, in principle, could be used for applications in quantum metrology, such as chiral or helical materials. Other contributors from IQC included PhD students **JOACHIM NSOFINI**, **DUSAN SARENAC, CHRISTOPHER WOOD**, and faculty member and Canada Excellence Research Chair in Quantum Information Processing **DAVID CORY**. The paper *Spin-orbit states of neutron wave packets* appeared in *Physical Review A* on July 13.

WEB

http://bit.ly/spin-orbit-states-nwp



CONFERENCES

RQI-N 2016 at IQC

An interdisciplinary community of 80 researchers from 13 countries gathered at IQC June 21-24 for the 7th annual Relativistic Quantum Information North (RQI-N) conference. Eighteen invited speakers and 40 contributed talks focused discussion around the interface of quantum information science and relativity, including topics such as quantum information and black holes, quantum optics and implementations in optomechanical resonators, superconducting circuits, and static and dynamical Casimir effect. ■



Semi-Quantum Computing Workshop

IQC hosted 18 pioneers, representing 14 international institutes, in the field of semi-quantum computing for a two-day workshop in August. The workshop covered a number of semi (or sub-universal) quantum computing models including DQC1, Linear Optics and sub-universal quantum simulators/annealers.

\gg

TALKS

The detection of gravitational waves on earth

BILL UNRUH, University of British Columbia, presented a public lecture titled The detection of gravitational waves on earth on June 22 while in Waterloo for the RQI-N conference. Unruh's talk focused on the significance of the Laser Interferometer Gravitational-Wave Observatory's (LIGO) detection of gravitational waves on earth. He shared his expertise on the topic of gravitational radiation - what it is, how it is detected and how quantum mechanics plays a role in setting limits in the large (kilograms and kilometres) with a full house of 170 community members and conference attendees.



>>> IQC OUTREACH

TALKS & TOURS

Innovation150 initiatives to celebrate Canada's 150th anniversary in 2017



The 2016 Canadian Association of Science Centres (CASC) Conference was held at Science World at TELUS World of Science, Vancouver May 5-7. As a partner in Innovation150, CASC invited IQC to participate in a panel discussion on plans for Canada's sesquicentennial. **TOBI** DAY-HAMILTON, Director of Communications and Strategic Initiatives, presented plans for QUANTUM: The Exhibition alongside partners from the Perimeter Institute for Theoretical Physics, Actua, the Canada Science and Technology Museums Corporation and CASC. The exhibit is the first-ever travelling show on quantum information science and technology, and will tour Canadian cities throughout 2017 as part of Canada's 150th anniversary celebrations.



CONNECTING WITH CANADIAN SCIENCE WRITERS

What do Stephen Hawking, Angry Birds, museums and musical symphonies have in common? They are all access points to learning about quantum mechanics. Senior Communications Manager JODI SZIMANKSI and Communications Officer KATHRYN FEDY presented to a group of 60 science communicators at the 2016 Canadian Science Writers' Association Conference at the University of Guelph in June. In their presentation Reaching your unaudience: How to share your complex story with new markets, Szimanski and Fedy shared how science writers can use access points and meaningful frames of reference to bridge new audiences with complex messages for impactful storytelling, using examples from IQC's Communications and Strategic Initiatives team.



SHARING, EDUCATING, INSPIRING

Throughout the summer, **MARTIN LAFOREST** continued to share quantum information science and technology with young students and teachers. Almost 500 students participated in quantum workshops and 155 youth toured labs at IQC. Laforest inspired 140 teachers through interactive workshops and lab tours. He welcomed groups from:

- >>> Beijing Normal University
- ✗ Catalyst
- >> Capstone International
- CEMC Computer Science for Young Women
- >>> CEMC Auckland workshop
- >> Christ the King Catholic Secondary School
- >>> IDEAS Summer Program
- >> North Park Secondary School
- Ontario Association of Physics Teachers
- >>> PI's EinStein Plus program
- PI's International Summer School for Young Physicists
- >>> SHAD Valley



FROM INNOVATION TO COMMERCIALIZATION

Discovery, the Ontario Centres of Excellence (OCE) innovationto-commercialization conference, offers key players from industry, academia, government as well as investors, entrepreneurs and students the opportunity to network, collaborate, pursue partnerships and create prospects for business growth and commercialization. Representing IQC at *Discovery* were faculty member **JONATHAN BAUGH** and postdoctoral fellow **POL FORN-DIAZ**, who met with Lockheed Martin for a presentation on collaborative projects between IQC, OCE and Lockheed Martin. *Discovery* was held in Toronto at the Metro Toronto Convention Centre May 9-10.



Undergraduate students get hands-on during quantum bootcamp

Exceptional post-secondary students from around the globe travelled to IQC for the Undergraduate School on Experimental Quantum Information Processing (USEQIP) from May 30 to June 10. Through lectures by IQC faculty members and hands-on exploration in IQC's experimental facilities, USEQIP students gained a well-rounded introduction to quantum information science and technology.

More than 75 percent of the 25 USEQIP students accepted an Undergraduate Research Award (URA) to conduct quantum research with an IQC faculty member for the rest of the summer.

IQC OUTREACH





High school students jump into quantum cryptography

IQC hosted 22 female and 21 male secondary students from all over the world for the eight-day Quantum Cryptography School for Young Students (QCSYS) enrichment program, August 5-12. The group of outstanding students jumped into the world of quantum cryptography through a blend of lectures, hands-on experiments and group work. More than 30 IQC members volunteered their time to teach and mentor the QCSYS group. Physics teacher **RICK DEBENEDETTI** from Streetsville Secondary School, Mississauga, also volunteered his time to guide the QCSYS students through activities.

CONFERENCES



MacLean invited to the 66th Lindau Nobel Laureate Meeting

PhD student JEAN-PHILIPPE MacLEAN was among 400 successful applicants invited to attend the 66th Lindau Nobel Laureate Meeting in Lindau, Germany, from June 26 to July 1. The meeting, held every five years, brings together young scientists and Nobel prize winners dedicated to three natural science disciplines: physiology or medicine, physics and chemistry. The 2016 meeting focused on physics and encouraged attendees to educate, inspire and connect with each other. Nobel Laureates in attendance included Canadian ARTHUR McDONALD (2015), SERGE HAROCHE (2012), **STEVEN CHU** (1997), **HIROSHI AMANO** (2014), KLAUS von KLITZING (1985), STEFAN HALL (2014) and GEORGE SMOOT (2006).

12

A NEW ERA IN TECHNOLOGY

IQC's Board Chair and Quantum Valley Investments co-founder **MIKE LAZARIDIS** presented a keynote lecture at Quantum Europe 2016, in Amsterdam. Lazaridis described the growing Quantum Valley in Waterloo Region and the public-private partnership that is driving the Second Quantum Revolution in Canada.

The two-day conference, May 17-18, marked the launch of a large-scale research initiative by European partners, including a one billion Euro investment for the development of quantum technologies. "Building on the strong support for the Quantum Manifesto, we aim to launch an ambitious, large-scale Flagship initiative to unlock the full potential of quantum technologies, accelerate its development and bring commercial products to the consumer marketplace," said EU Commissioner for Digital Economy and Society **GÜNTHER OETTINGER.**



IQC researchers present at APS DAMOP16

Master's student **THOMAS ALEXANDER**, PhD students **HOLGER HAAS**, **RAHUL DESHPANDE**, faculty member and Canada Excellence Research Chair in Quantum Information Processing **DAVID CORY**, in collaboration with **PATRYK GUMANN** from IBM Research presented at the 47th regular meeting of the American Physical Society (APS) Division of Atomic, Molecular and Optical Physics. The week-long meeting, May 23-27, took place in Providence, Rhode Island.

The abstract, Optical hyperpolarization and inductive readout of 31P donor nuclei in natural abundance single crystal 29Si, describes an experiment where the researchers hyperpolarized phosphorus nuclei in a single crystal of silicon. By doing so, order was created in the naturally randomized spin of silicon atoms in a crystal, which may lead to the study of spin transport.



SCIENTISTS TALK ABOUT QIST IN SINGAPORE

The Centre for Quantum Technologies (CQT) and the National University of Singapore organized the 2016 International Conference on Quantum Communication, Measurement and Computing (QCMC). Among the attendees was postdoctoral fellow **PATRICK COLES**, who gave a talk on *Unstructured quantum key distribution*. The conference brings together scientists and engineers working in the interdisciplinary field of quantum information science and technology.



UPCOMING CONFERENCES

>> Women in Physics Canada (WIPC) 2017

> July 26-28, 2017 University of Waterloo, Waterloo, Ontario

uwaterloo.ca/wipc-2017 =

Around the INSTITUTE

Student BROFILE: DARIUSZ LASECKI Exploring quantum information theory, from QCSYS to URA

Quantum information science and technology intrigues **DARIUSZ LASECKI**. He developed a passion for mathematics, physics and computer science growing up in Poland. But it was on a tour of IQC in 2012 with the Perimeter Institute for Theoretical Physics' International Summer School for Young Physicists that he got hooked on quantum.



In 2013, Lasecki returned to IQC to attend the Quantum Cryptography School for Young Students (QCSYS). The highlight was seeing the state-of-the-art experimental labs. "I am generally focused on theoretical aspects," noted Lasecki, "but it was neat to see how theory is implemented in a lab setting; this really broadened my research perspective."

Lasecki spent this past summer at IQC researching with faculty member **DEBBIE LEUNG** as a recipient of an Undergraduate Research Award (URA). Lasecki's theoretical research looked at methods of communication between two parties using quantum data. Specifically, he was working on quantum communication channels and their assisted capacities, trying to determine the upper bounds on the capacity of the quantum depolarizing channel. "The quantum depolarizing channel is not yet well understood, however in the future, it may allow us to find out what are the fundamental limits for quantum information transmission."

Before starting his research as part of the URA program, Lasecki attended the 2016 Undergraduate School on Experimental Quantum Information Processing (USEQIP). This experience enhanced his understanding of theory by deepening his knowledge of experimental techniques, such as using optical devices to implement the BB84 quantum key distribution scheme. "I remembered learning about the BB84 protocol at QCSYS, so that helped me to grasp this concept and implement it in the lab," said Lasecki.

Lasecki is one of the first students to study at both QCSYS and USEQIP, and to receive an undergraduate research award. "I have a much better understanding of how scientific research is conducted," said Lasecki, reflecting on his time at IQC. "Exploring different areas of research is useful before entering graduate school. It turns out that for me, this is what I love and what I would like to spend my future researching."



USEQIP STUDENTS TAKE ON IBM'S QUANTUM EXPERIENCE

The first time that the IBM Quantum Experience was used as an educational tool in the classroom was on June 7 at IQC. **SARAH SHELDON**, research staff member at the IBM T.J. Watson Research Center, introduced USEQIP students to IBM's new quantum processor. Formerly an IQC PhD student, Sheldon assisted the students in using the platform, worked through examples and described the inner workings of IBM's quantum processor. USEQIP students had the unique opportunity to use the IBM Quantum Experience to test algorithms they were learning in class.





US Ambassador to Canada tours IQC

On May 4, the United States Ambassador to Canada, **BRUCE HEYMAN**, toured IQC with faculty member **DAVID CORY** to learn more about quantum information science and technology research.

FROM THE IQC GSA

When the summer sun comes out, the barbecues fire up, and IQC took full advantage. Students, staff, and faculty came out to the RAC patio every two weeks for burgers and sun, keeping a three-year old tradition alive. IQC also took a trip out to Canada's Wonderland in June, with grad students eager to get out of the lab and onto a roller coaster. By the end of August, with the sun finally becoming tiresome, IQC grad students hid out in an air-conditioned laser tag labyrinth; no advantage was to be seen for the laser physicists. Fall brings a new group of students and a new IQC GSA, and the promise of much more to come.



Written by John Donohue

Around THE INSTITUTE

PROMOTING JOINT RESEARCH WITH INTERNATIONAL PARTNERS

In May, the University of Waterloo signed a Memorandum of Understanding with the Beijing Computational Science Research Center (CSRC) to facilitate joint research and exchange of postdoctoral fellows. Shared postdoctoral fellows spend their first year at CSRC and a second year at IQC. The goal of the MOU is to promote possibilities for cooperation in education and research between the two institutions.



COLLABORATION ON THE COURSE

Twenty-two IQC members enjoyed a day out on the green at IQC's Annual Golf Tournament July 12 at Foxwood Country Club. Placing first overall was the Mis-communicators, including team members JOHN DONOHUE, CHRIS PUGH and MATT SCHUMACHER. Prizes were also awarded for closest to the pin (TOMAS JOCHYM-O'CONNOR), closest to the keg (MARTIN LAFOREST), putting competition (THOMAS McCONKEY), closest to a house (MATTHEW SCOTT) and weirdest shot (THOMAS ALEXANDER).

Female researchers attend media training workshop

On June 8, eight female IQC members participated in an interactive Media Training Workshop. The workshop aimed to equip women with the tools to contribute their expertise to the public discourse through compelling, short-form written commentary for newspaper op-ed pages and online sites. Faculty members **NA YOUNG KIM**, **DEBBIE LEUNG**, postdoctoral fellows **ELECTRA ELEFTHERIADOU**, **KATANYA KUNTZ**, **GUANRU FENG**, graduate students **AIMEE GUNTHER**, **PAULINA CORONA** and undergraduate student **KAYLA HARDIE** attended the workshop, held at the University of Waterloo.

Quantum Shorts 2016: A festival for quantum-inspired films

IQC is proud to partner once again with the Centre for Quantum Technologies (CQT) and the National University of Singapore for the 2016 Quantum Shorts short-film contest. Alternating between flash fiction and short-film, Quantum Shorts encourages the submission of creative pieces inspired by quantum science. This year's contest put out the call for short films of five minutes or less.

Check out the shortlist and cast your online vote for the People's Choice Prize between February 15 – March 21, 2017 at **www.shorts2016.quantumlah.org.**



GRADUATES Congratulations to our Spring 2016 graduates:

- POOMPONG CHAIWONGKHOT, MSc Physics (Quantum Information)
- ZHIWEI GAO, MASc Electrical and Computer Engineering
- ANIRUDH KRISHNA, MSc Physics (Quantum Information)
- DAVID LUONG, MSc Physics (Quantum Information)
- ANNIE (JIHYUN) PARK, MSc Physics (Quantum Information)
- JOHN SCHANCK, MMath Combinatorics and Optimization

- FEIRUO SHEN, MSc Physics (Quantum Information)
- SUMIT SIJHER, MMath Applied Mathematics (Quantum Information)
- SEAN WALKER, MSc Chemistry (Quantum Information)
- JUAN MIGUEL ARRAZOLA, PhD Physics (Quantum Information)
- EVAN MEYER-SCOTT, PhD Physics (Quantum Information)

IN THE NEWS



Cory weighs in on quantum computing advancement

IBM announced the development of a fivequbit quantum processor where users can run algorithms and experiments on the processor, accessing it via the cloud platform called the IBM Quantum Experience. IQC faculty member and Canada Excellence Research Chair in Quantum Information Processing, **DAVID CORY**, tested the online interface. Cory told *Fortune* that the machine impressed him. "It is very robust and easy to use," he said. "I think it gives something real for people to play with. That brings quantum computing a bit closer to everyone."

WEB http://bit.ly/IBM-quantumexperience =

WATERLOO REGION HOME TO INNOVATION HUB

Journalist **DAVID CRANE** described **MIKE LAZARIDIS**, IQC board chair and co-founder of Quantum Valley Investments, as the leader of the most visionary innovation hub in an article in *The Hill Times* published June 1. The Quantum Valley was recognized as one of three innovation hubs where government, academia and industry are working together to support the next generation of Canadian innovators. Lazaridis' vision to build the Quantum Valley in Waterloo Region started with the founding of the Perimeter Institute for Theoretical Physics in 2000, followed by IQC in 2002, and most recently Quantum Valley Investments.

WEB http://bit.ly/nurturing-next-blackberry =

Around THE INSTITUTE



Building the workforce for a quantum-safe world

According to IQC faculty member and director of CryptoWorks21, **MICHELE MOSCA**: "In order to be cyber-safe, our information and communication infrastructure will need to be quantumsafe. We need to prepare the next generation workforce to design, implement, deploy and standardize these next-generation tools that will be secure in a world with quantum technologies." The NSERC CREATE training program CryptoWorks21 for graduate students and postdoctoral fellows is building the workforce for the cryptographic infrastructure of the 21st century.

CryptoWorks21 courses offered in the spring term develop both professional and technical skills. The specialized technical skills program, *Topics in* *Quantum-Safe Cryptography*, delivers an unprecedented breadth of necessary technical and scientific knowledge, including network security, cryptography, post-quantum cryptography, quantum cryptography, implementation of quantum communication and quantum computing for cryptographers.



Our quantum world features new EBL equipment

An IQC blog post about the new electron beam lithography (EBL) tool installed in the Quantum NanoFab in early 2016 made waves through the scientific equipment manufacturing field. Nanofabrication Process Engineer **NATHAN NELSON-FITZPATRICK** wrote a post for *Our quantum world* about the JEOL JBX-6300FS EBL system, one of only three 100kV EBL systems in academic fabrication facilities in Canada. The ultimate precision and potential of the new tool outlined in the post was shared across many JEOL channels, including Facebook, Twitter, LinkedIn and even their website.

http://bit.ly/EB-litho-tool-blog-post

THESIS DEFENCE

Congratulations to those who successfully defended their thesis in the spring term:

KENT FISHER, PhD TOMAS JOCHYM-O'CONNOR, PhD SARAH KAISER, PhD KATJA REID, PhD XIAN MA, PhD



PHYS 777 Sir Anthony Leggett Lectures

QIC 890/891 Selected Advanced Topics in Quantum Information

QIC 890 Quantum Error Correction and Fault Tolerance

QIC 890 Introduction to Noise Processes

QIC 890

Entanglement and Nonlocality



OVER \$2.1 MILLION IN NSERC AWARDS FOR IQC MEMBERS

Faculty, associates and affiliates of IQC collected 10 awards from the Natural Sciences and Engineering Research Council of Canada (NSERC) on June 23. **KEVIN RESCH**, Deputy Director, Academic and the Canada Research Chair in Optical Quantum Technologies was awarded an NSERC Research Tools and Instruments (RTI) grant for close to \$150,000.

IQC award recipients also include:

- >> RAYMOND LAFLAMME
- >> DEBBIE LEUNG
- >> VERN PAULSEN
- >> MICHAEL REIMER
- IQC Associates ACHIM KEMPF (Department of Applied Mathematics), JAMES MARTIN (Department of Physics and Astronomy), ZBIGNIEW WASILEWSKI (Department of Electrical and Computer Engineering)
- IQC Affiliates AGATA BRANCZYK (Department of Physics and Astronomy), PIERRE-NICHOLAS ROY (Department of Chemistry)



Memorial scholarship awarded for research excellence and service

The Canadian Association of Physicists Foundation (CAPF) and the Optical Society of America Foundation (OSAF) awarded PhD student **CHRIS PUGH** the 2016 Boris P. Stoicheff Memorial Graduate Scholarship. Pugh received the award for his research and novel technological developments related to long-distance transmission of entangled photons and foundational tests of three-photon entanglement, as well as for his contributions to both the physics and broader communities. He also engaged industry in his research and has contributed to physics outreach in schools.

CSA GRANT FUNDS STUDENT PARTICIPATION IN INTERNATIONAL PROJECT



Faculty member **THOMAS JENNEWEIN** received a \$182,000 grant from the Canadian Space Agency (CSA) to train and develop IQC graduate students through participation in an international space satellite project. IQC students will develop a payload to demonstrate technologies for quantum communications networks that will be launched aboard a CubeSat mission led by an international academic partner.

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PhD STUDENT AWARDED POSTER PRIZE AT PHOTONICS NORTH

PhD student **MOHD ZEESHAN** received third place for his poster *Tunable quantum light sources* at Photonics North 2016, held at the Québec City Convention Centre May 24-26. Researchers, government representatives and industry professionals met to discuss the new capabilities, knowledge and products evolving from developments in optics and photonics.

Research by IQC postdoctoral fellow recognized for excellence



ZHE LIU, postdoctoral fellow, received the 2016 FNR Outstanding PhD Thesis award. Liu's thesis, *Lightweight Public-Key Cryptography for Wireless Sensor Nodes*, describes

the design and implementation of three public-key cryptosystems and the underlying mathematical operations for resource-constrained sensor nodes, such as those used to detect traffic conditions in self-driving cars or to monitor vital body functions in patients. The FNR Awards recognize outstanding researchers and science communicators for excellence in research and science communication.



Fellowship promotes women returning to career in research

Postdoctoral fellow **HILARY CARTERET** received the M. Hildred Blewett Fellowship, awarded by the American Physical Society (APS) to enable women to return to physics research careers following a career interruption. The award was established through a generous bequest from the late accelerator physicist M. Hildred Blewett to help women overcome obstacles to careers in research. Carteret's theoretical research in quantum information theory focuses on applications for condensed matter physics.

Recognizing community outreach and engagement

Congratulations to JEAN-PHILIPPE MacLEAN and DARRYL HOVING, recipients of the 2016 IQC David Johnston Award for Scientific Outreach. This award was created in honour of His Excellency DAVID JOHNSTON, Canada's Governor General, for his passion, leadership and enthusiasm for continuous learning, innovation and achievement. Johnston was president of the University of Waterloo from 1999 to 2010. The award recognizes students who have shown an outstanding commitment to scientific outreach and community engagement.



Lazaridis named to Government of Canada review panel

The Government of Canada announced on June 13 that an independent panel of distinguished research leaders and innovators will seek input from the research community and Canadians on how to optimize support for fundamental science in Canada. **MIKE LAZARIDIS**, co-founder of Quantum Valley Investments, will participate in the panel that will also examine international best practices for funding science.

WEB http://bit.ly/review-fundamental-science



FISHER RECEIVES IQC ACHIEVEMENT AWARD

IQC recognized PhD student **KENT FISHER** with the IQC Achievement Award for exceptional achievement in research at the graduate level in quantum information. Fisher made significant contributions to research on diamond quantum photonics, done in collaboration with his supervisor **KEVIN RESCH**, fellow PhD student **JEAN-PHILIPPE MacLEAN**, and **BENJAMIN SUSSMAN** and his group at the University of Ottawa.

IQC recognized for excellence in publications

In June, IQC received two 2016 Awards for Publication Excellence (APEX) including:

AWARD OF EXCELLENCE in NEWSLETTERS: PRINT for NewBit

GRAND AWARD in **DESIGN & ILLUSTRATION: INFOGRAPHICS** for the *IQC highlights* brochure



Around THE INSTITUTE

>>> ARRIVALS

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PANELS INCLUDE:

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- Careers outside academia
- How to minimize the gender gap

WORKSHOPS INCLUDE:

- How to choose a supervisor and build a good working relationship
- Implicit bias
- Mental health



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







