

Something to CHIRP ABOUT

EXCITING RESEARCH FROM KEVIN RESCH'S LAB



03 CHANGES TO THE IQC BOARD OF DIRECTORS 06 SCIENCE HIGHLIGHTS 11 IQC OUTREACH



UNIVERSITY OF
WATERLOO

IQC Institute for
Quantum
Computing



UNIVERSITY OF
WATERLOO



Institute for
Quantum
Computing

NEWBIT | **ISSUE 25** | WINTER 2015

CANADA | NEWBIT | ISS
WINTER 2015 | INSTITUT
INSTITUTE FOR QUANT

IN

WINTER 2015 | INSTITUTE FOR QUANTUM COMPUTING, UNIVERSITY OF WATERLOO, ONTARIO, CANADA | NEWBIT | ISSUE
JTING, UNIVERSITY OF WATERLOO, ONTARIO, CANADA | NEWBIT | ISSUE 25 | WINTER 2

this issue

COLLABORATION LEADS TO NEW DEVELOPMENTS pg 04

From experiments to theory, we take
a look at **KEVIN RESCH**'s lab.

ENTANGLED PHOTON TRIPLETS pg 06

IQC researchers collaborate to
successfully generate entangled
photon triplets for the first time.

MEET CAROLYN EARNEST pg 14

Student gives back to the community and
inspires youth interested in science.

ON THE COVER

PhD students **MIKE MAZUREK** and
KENT FISHER discuss a modification
to a chirped-pulse interferometer.

Cover Photo by: IQC

WINTER 2015

publisher
**IQC COMMUNICATIONS &
STRATEGIC INITIATIVES**

IQC.UWATERLOO.CA

Institute for Quantum Computing
200 University Avenue West
Waterloo, Ontario, Canada N2L 3G1
iqc.uwaterloo.ca

Phone: 1 - 519 - 888 - 4021
Fax: 1 - 519 - 888 - 7610
E-mail: iqc@uwaterloo.ca

FROM THE EDITOR

We welcome the most students to the university campus
each September marking the start of a new school year.
At IQC we celebrate this with a large gathering to welcome
everyone to our community. We also welcomed new
members to the Board of Directors and a new chair (see
Changes to the IQC Board of Directors on the next page).

We also hired a new Research Assistant Professor.
EDUARDO MARTIN-MARTINEZ is no stranger to the institute
– he was a postdoctoral fellow here for over two years.
He is one of the few researchers in Canada studying
Relativistic Quantum Information, and he was awarded the
John Charles Polyani Prize in November (see *IQC researcher
wins COU Polyani Prize* on page 16).

The fall term was also packed full of conferences and
talks that we hosted, co-hosted and attended. From
quantum cryptography to quantum materials, topics
including quantum mechanics in biology to the quantum
internet, visitors from around the world and IQC members
had several opportunities to learn.

Those opportunities to learn continue to inspire our
researchers and lead to collaboration. This leads to new
research findings, new processes and new measurement
schemes. Check out the feature article: *Collaboration leads
to new developments* on page 4 about the research in Kevin
Resch's lab, and *Scientific Highlights* so you can learn more
about quantum information science and technology.

JODI SZIMANSKI, Senior Communications Manager



New IQC Board of Directors chair,
MIKE LAZARIDIS.

Changes to the IQC Board of Directors

In November, the Institute for Quantum Computing (IQC) Board of Directors reconvened with a new chair and two new directors.

MIKE LAZARIDIS, a member of the IQC Board of Directors since its inception in 2005, takes on the chair role. His pioneering vision and generous personal investment was instrumental in establishing IQC.

MARK PECEN, CEO of Approach Infinity, Inc., joined the board in May. He most recently co-authored a white paper on quantum-safe cryptography and security that was presented at the European Telecommunications Standards Institute (ETSI) workshop in Ottawa co-hosted by IQC last October.

Our most recent addition to the board **PETER E. BROWN**, is a senior practice partner with Deloitte Canada. Brown is a frequent speaker on topics of entrepreneurship and what makes best-managed companies unique – he has written two books on the subject.

IQC welcomes our new directors to the board, congratulates the new chair and thanks outgoing and founding chair **TOM BRZUSTOWSKI** for his dedication and commitment in making IQC what it is today. He remains on the board and continues to aid IQC members. ■

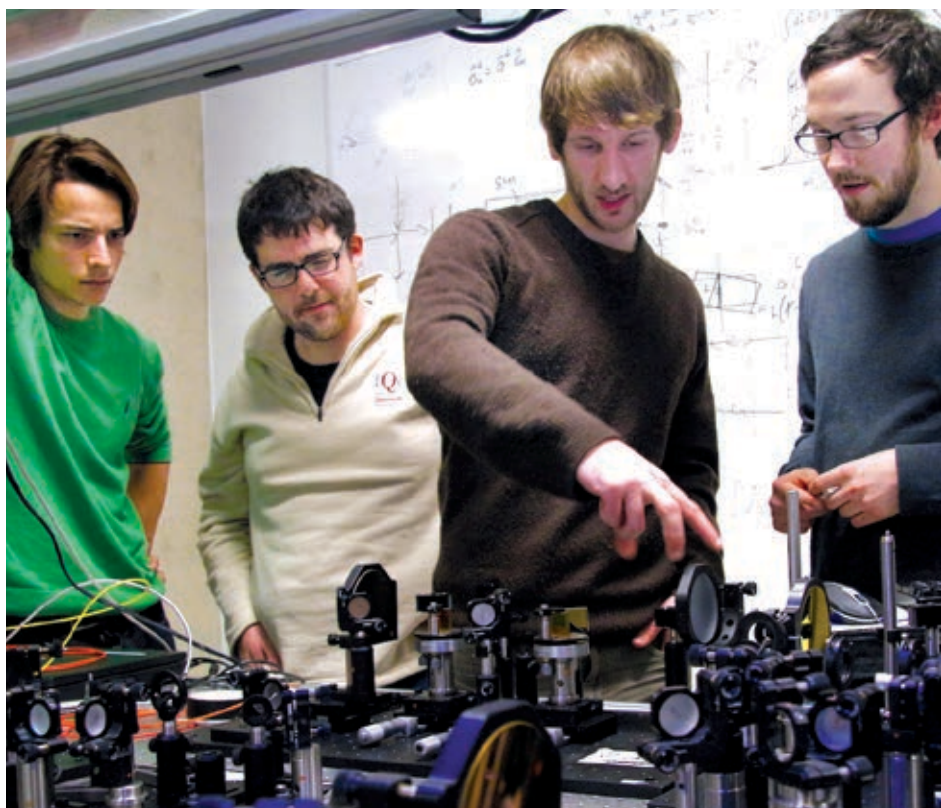
Collaboration leads to new developments

In the experimental quantum optics lab of **KEVIN RESCH**, Canada Research Chair in Optical Quantum Technologies, one of the questions the group asks themselves is: How can the quantum mechanical aspects of light be used to improve technologies?

It's a question Resch's group works on together with other research groups at IQC, at the Perimeter Institute for Theoretical Physics (PI) and beyond. Those collaborations have led to numerous discoveries and papers.

Resch's group has worked together to develop a new kind of interferometric technique called chirped-pulse interferometry. The new technique is immune to unbalanced dispersion and keeps the signal sharp and high contrast. A high contrast sharp signal is difficult when a broadband optical pulse comprised of a wide range of colours is sent through a material. The interferometer signal degrades because the different colours travel through the material and different speeds cause the pulse to become stretched or "chirped".

The team continues to investigate this new technique by imaging biological samples. They hope to show that it performs as well as current techniques with the additional benefit of dispersion cancellation. Chirped-pulse interferometry is ideal for measuring

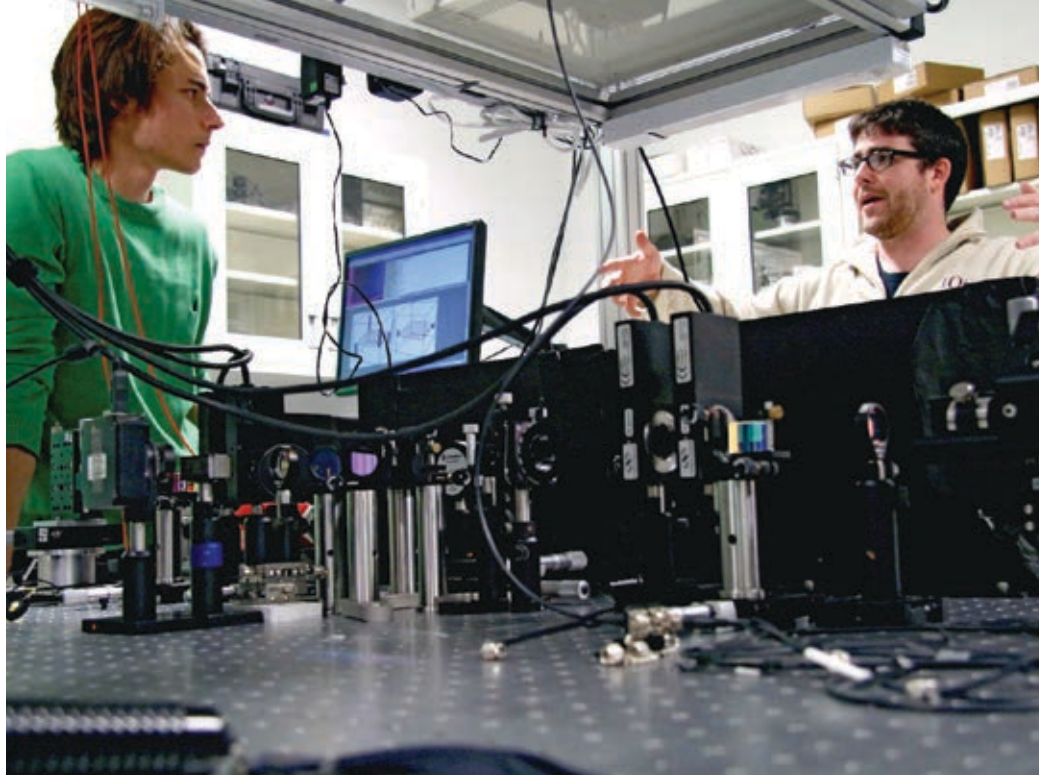


optical thickness where there's dispersion such as optical coherence tomography, an imaging technique using interferometry to measure tissue samples or eye samples.

Beyond the work within Resch's own research group, his team collaborates often with **THOMAS JENNEWAIN**'s research group. A recent source development project with Jennewain's group involved creating entangled photons in a new way. The teams took

a pair of photons and split the photons again. These successful findings allow the teams to start building further experiments – and they'll do it together.

Resch's collaborations don't only involve other experimentalists. **ROB SPEKKENS**, a faculty member at PI and adjunct faculty member with the Department of Physics at the University of Waterloo, focuses on the theoretical study of quantum foundations. Spekkens, along with PhD



MacLean and Donohue discuss a possible modification to the chirped-pulse experiment. ⤴



⤵ Master's student **JEAN-PHILIPPE MACLEAN** and PhD students **JOHN DONOHUE** and **KENT FISHER** look on while **MIKE MAZUREK** shows a pulse stretcher used for a chirped-pulse interferometry experiment.

student **KATJA RIED** and fellow theorist **DOMINIK JANZING**, considered the situation of an observer who is probing two variables and finds them to be correlated. The observer doesn't know whether this is because they are the input and output of a quantum process, that is, cause-effect related, or because they are the two halves of an entangled quantum state, and therefore correlated by a common cause. They realized that certain patterns of correlations are distinctive to each scenario.

Together, Spekkens and Resch tested this idea in Resch's lab. Through that collaboration, they developed a new class of tomography called causal tomography. Tomography

is a way of making a set of measurements in the lab to determine a state or process, or the causal relation between quantum states measured at different times. Using causal tomography, the researchers could show both states and process tomographies as two special cases, and that it can also handle more general kinds of transformations.

Resch's collaborations also go beyond Waterloo Region. A recent paper, *Storage and Retrieval of THz-Bandwidth Single Photons Using a Room-Temperature Diamond Quantum Memory*, was written with **BEN SUSSMAN**'s group at the National Research Council. This work involved a novel way to manipulate properties of light and store it in a controllable way using diamond materials. The team used the vibrations of the diamond lattice to store quantum information.

Resch's group's collaborations help them to study the quantum mechanical aspects of light. That work has led to new methods for preparing quantum states, new measurement schemes and new interferometry techniques. Unique perspectives and ideas through the research they do with other groups has led to new ways of controlling quantum states of light. That research could lead to applications ranging from communications to imaging, and into areas we haven't yet imagined. ■

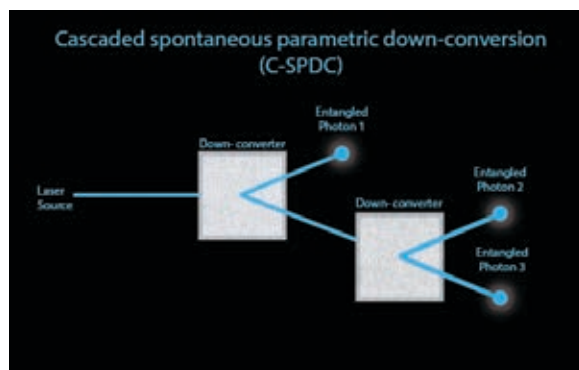


SCIENCE HIGHLIGHTS

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.

» Useful entangled photon triplets directly generated for the first time

NATURE PHOTONICS 8, 801-807 (2014)



The creation of three entangled photons.

Researchers from the Institute for Quantum Computing (IQC), in partnership with the National Institute of Standards and Technology (NIST) in Boulder, Colorado, have successfully generated entangled photon triplets for the first time in a technologically useful state. The three polarization-entangled photons are created directly by splitting a single initial laser photon, without the need to post-select successful entangled states. Unlike previous techniques that needed to measure, and hence destroy, the photons to create entanglement, this method allows for the immediate use of the entangled triplets for other applications.

Measuring the polarization entanglement between the three photons was made possible by NIST's ultra-efficient single-photon detectors. This entanglement will be useful for quantum communication protocols like quantum secret sharing and heralded entangled photon pairs. Additionally, advances in optical quantum computing and fundamental tests of quantum mechanics are now possible thanks to the new directly-produced entangled triplets.

The research by former IQC PhD student **DENY HAMEL**, former postdoctoral fellow (**LYNDEN**) **KRISTER SHALM**, and professors **THOMAS JENNEWAIN** and **KEVIN RESCH**, in collaboration with researchers from NIST and Stockholm University was published in the paper *Direct generation of three-photon polarization entanglement* in *Nature Photonics* in September.

WEB <http://bit.ly/directgen3photon> ■

» The role of quantum correlations

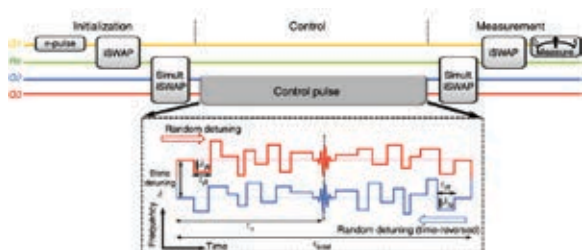
PHYS. REV. A 90, 042314 (2014)

Considering quantum information processing, quantum foundations, and the physics of strongly correlated systems, quantum correlations play a central role in many situations from communication tasks to measurement-based quantum computing to quantum cryptography, allowing one to go beyond what is classically possible. It is also the nonclassicality of quantum correlations – such as nonlocality, steering, entanglement or discord – that challenges the understanding of quantum mechanics. Research Assistant Professor **MARCO PIANI**, on leave at the University of Strathclyde, alumni **LIN CHEN** and **OLEG GITTSOVICH**, with **KAVAN MODI** (Monash University) investigated the quantum correlations required globally to explain what observations can be made locally about a multipartite quantum system. In their paper, *Role of correlations in the two-body marginal problem*, published as Editors' Suggestion in *Physical Review* in October, they shared their findings that strictly classical bipartite correlations may still require global entanglement and that unentangled reductions may require global genuine multipartite entanglement rather than simple entanglement.

WEB <http://bit.ly/2bodymarginalproblem> ■

EMULATING QUANTUM PHENOMENA

NATURE COMMUNICATIONS 5: 5184 (2014)



- Pulse sequence used to emulate weak localization, decomposed into three steps: initialization, control, measurement.

Research advances in the field of quantum computing use quantum interference as a fundamental resource for computation and control. Recently, faculty member **MATTEO MARIANTONI** collaborated in an effort together with the University of California, Santa Barbara; Zhejiang University; and HRL Laboratories to use a multiple-element superconducting quantum circuit to manipulate a single microwave photon, confirming that the basic effects of weak localization can be emulated. *Nature Communications* published their paper *Emulating weak localization using a solid-state quantum circuit* in October.

The experiment showed the potential for using superconducting quantum circuits as emulators for complex quantum phenomena. This demonstrated control could be extended to emulation using a large-scale circuit, in principle, which could offer insight into other aspects of weak localization and further exploration of fluctuation amplitudes.

WEB <http://bit.ly/WeakLocalization> ■

CONFERENCES & WORKSHOPS

Building connections around the world

IQC, together with the Canadian Institute for Advanced Research (CIFAR), hosted a four-day meeting with prominent scientists from China to exchange ideas in quantum information science at the Mike & Ophelia Lazaridis Quantum-Nano Centre in November. Delegates attended from the National Laboratory of Beijing Computational Science Research Centre (CSRC), the Interdisciplinary Information Sciences (IIS) at Tsinghua University (also based in Beijing) and the University of Science and Technology of China (USTC) located in Hefei, Anhui.

According to **PEKKA SINVERO**, Senior VP Research at CIFAR: "There are many talented researchers in China eager to collaborate with top researchers here in Canada. Collaboration is a win-win proposition for all." ■



- Delegates from China and Canada attended a collaborative meeting in Waterloo hosted by IQC and CIFAR.

SCIENCE HIGHLIGHTS

» CRYPTOGRAPHY IN A QUANTUM ERA

The Post-Quantum Cryptography (PQCrypto) Summer School brought 85 students to IQC on September 29 for a two-day workshop focusing on cryptography in a quantum era.

Following the summer school, more than 125 cryptographers from around the world gathered at IQC for the 6th international conference on post-quantum cryptography, PQCrypto 2014.

ALFRED MENEZES, department chair for Combinatorics & Optimization at the University of Waterloo and member of the Centre for Applied Cryptographic Research, and **MICHELE MOSCA**, IQC Deputy Director, Academic, chaired the conference.



« PQCrypto Summer School students



« PQCrypto 2014 conference attendees

Attendees sparked conversation about the need for standardizing quantum-resistant cryptography with the very cryptographers who design it, created a hub for emerging new partnerships and opened opportunities for research collaboration across institutions.

WEB View presentations from the PQCrypto Summer School:
<https://bit.ly/PQCryptoSchool>

View presentations from PQCrypto 2014:
<https://bit.ly/PQCryptoConference> ■

IQC partners with ETSI to deliver cryptography workshop

IQC partnered with the European Telecommunications Standards Institute (ETSI) to present the 2nd annual ETSI Quantum-Safe Crypto workshop in Ottawa from October 6-7. Industry, government and academia met to discuss the standardization and deployment of the next-generation cryptographic infrastructure — specifically, one that will be secure against emerging quantum computing technologies.

CORINNE CHARETTE, Chief Information Officer of the Government of Canada, was among the invited speakers.

IQC board member and CEO of Approach Infinity Inc., **MARK PECEN**, presented the ETSI Quantum-Safe whitepaper. This IQC-led effort involved over 20 researchers as well as industry and government leaders from around the world and describes the impact that quantum computation will have socially, technically and economically on information security. It provides an introduction to the challenges of making the global information and communications technology infrastructure safe against large-scale quantum computers and includes discussions on the quantum-safe alternatives.

WEB Read the ETSI Quantum-Safe whitepaper:
<http://bit.ly/ETSIwhitepaper> ■



Inspiring the next generation of quantum cryptographers



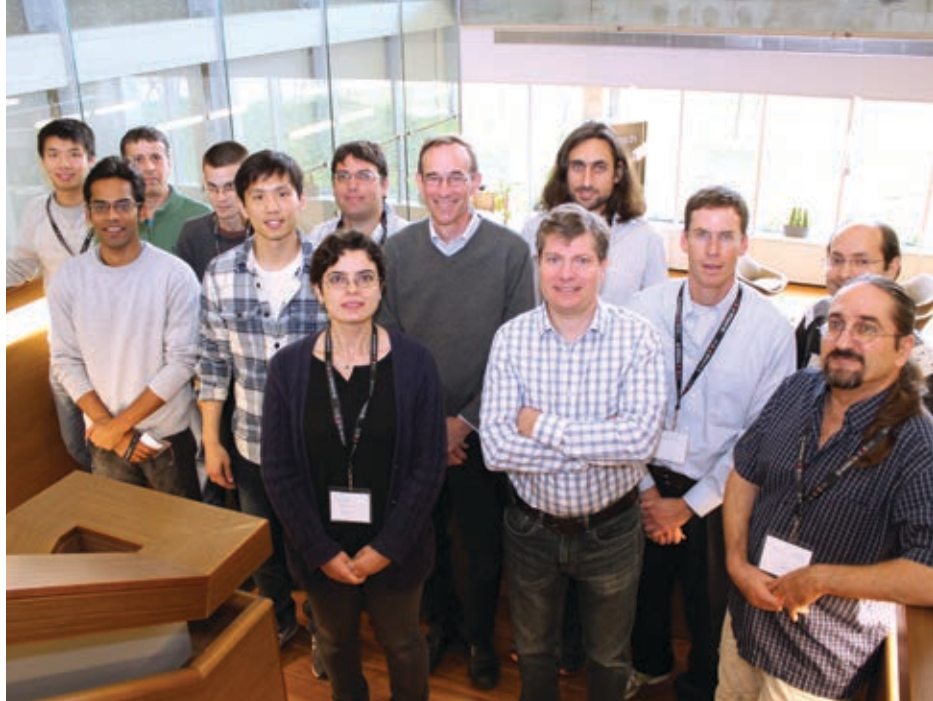
Forty-two high school students traveled to Waterloo from across Canada, the United States, South Africa, Latvia and Romania to participate in the Quantum Cryptography School for Young Students (QCSYS) August 11-15. Led by Senior Manager, Scientific Outreach **MARTIN LAFOREST**, students explored physics and mathematics of quantum mechanics, cryptography and how they merge into one of the most exciting topics in contemporary science – quantum cryptography. Students also enjoyed bowling, laser tag, a sports night and even a campfire! ■



TECHNION VISITS IQC

A delegation from the Technion-Israel Institute of Technology toured IQC on September 18. This is the first visit to IQC by Technion since signing a co-operation agreement during a joint conference at Technion in March 2014, led by Waterloo President and Vice-Chancellor **FERIDUN HAMDULLAHPUR**. The partnership between IQC and Technion aims to facilitate technology transfer, connect faculty and students with industrial partners, and increase international opportunities for undergraduate, graduate and postdoctoral student research exchanges.

Postdoctoral fellow **AHARON BRODUTCH**, who participated in the Technion visit, said, "The environment was very relaxed and friendly and we were able to exchange ideas and build collaborations. Rather than a long series of talks, we concentrated on discussions and questions." ■



⤴ Delegates from Technion with several of their IQC hosts.



Quantum Innovators gathers promising young researchers

Fifteen promising young researchers in the fields of quantum physics and engineering came together for the 3rd Quantum Innovators workshop, hosted at IQC October 6-8, to share their research and foster new connections. Invitees heard from **TERRY McMAHON** (Dean, Faculty of Science, University of Waterloo) and **PEARL SULLIVAN** (Dean, Faculty of Engineering, University of Waterloo) about research excellence at Waterloo. Several postdoctoral fellows also spoke including **TROY BORNEMAN**, **AHARON BRODUTCH**, **ROBABEH RAHIMI DARABAD**, **CHRIS HAAPAMAKI**, **ROLF HORN**, **TOENO VAN DER SAR** and **ANDREAS FOGNINI** (TU Delft Netherlands). ■



Quantum secrets of biology

The Quantum Frontier Distinguished Lecture series continued with **K. BIRGITTA WHALEY** (University of California, Berkeley and Lawrence Berkeley National Laboratory) in September. Whaley's lecture *What role does Quantum Mechanics play in Biology?* described how the development of quantum mechanics in the early years of the twentieth century transformed both physics and chemistry, providing a new understanding of the microscopic behaviour of atoms and molecules. The development of novel probes of living cells and the possible role of quantum mechanics in biological phenomena, such as photosynthesis, are being driven by advances in both quantum sciences and nanotechnology.

WEB Watch K. Birgitta Whaley's lecture on the IQC YouTube channel: <https://bit.ly/BirgittaWhaley> ■

Careers outside of academia

Alumnus **NATHAN WIEBE** shared his experience pursuing an industry career at Microsoft Research with a group of graduate students and postdoctoral fellows on October 14. Wiebe, an associate researcher in the Quantum Architectures and Computation (QuArC) group at Microsoft Research, answered questions and encouraged students to explore research opportunities in both academia and industry. Wiebe's talk was part of the IQC Graduate Student Association Quantum Industry lecture series.

WEB Hear about Nathan Wiebe's career in industry research on IQC's YouTube channel: <https://bit.ly/NathanWiebe> ■



THE WEIRDNESS OF WAVE PARTICLE DUALITY

ALAIN ASPECT, Augustin Fresnel Professor at Institut d'Optique, Professor at École Polytechnique, and a CNRS Distinguished Scientist (Director of Research), concluded the 2014 Quantum Frontiers Distinguished Lecture series on October 23. Aspect was recognized for his many contributions to quantum science with an honorary degree from Waterloo's Faculty of Science.

Aspect performed a series of experiments in 1982 decisively demonstrating that one of the most remarkable predictions of quantum mechanics – quantum entanglement – was true. This completely changed our understanding of the universe.

In his lecture titled *From Einstein to Wheeler: wave particle duality for a photon*, Aspect presented experiments he and his team realized with a true single photon source demonstrating that photons behave both like a wave and a particle. Such single photon sources are now an important resource in the domain of quantum information.

WEB Watch Alain Aspect's lecture on the IQC YouTube channel: <https://bit.ly/AlainAspect> ■

Changing the climate of the academic culture

FemPhys presented a talk *Strategies for Improving the Representation of Women in STEM* at the Institute for Quantum Computing on November 26. The speaker, **CARLA FEHR**, is the Wolfe Chair in Scientific and Technological Literacy in the philosophy department at the University of Waterloo. Her research focuses on ways that diversity promotes innovation and excellence in science and technology. The talk weighed the pros and cons of various strategies to make the academic culture more inclusive.

WEB Watch the video of Fehr's presentation on the IQC YouTube channel: <https://bit.ly/CarlaFehr> ■

Exploring new frontiers

World-renowned theoretical physicist **PETER ZOLLER** (University of Innsbruck) delivered a talk on *New frontiers of quantum simulation with atoms and ions* for students and faculty December 1. Zoller discussed quantum simulation of lattice gauge theories both from a condensed matter and a high-energy physics point of view. He also addressed system quantum simulation, quantum dynamics and realization with quantum optical systems. Zoller, a pioneer in quantum computing and communication research, is known for bridging quantum optics and solid state physics. ■

» Breakthroughs in the quantum world



Faculty member **JOSEPH EMERSON** gave a keynote address at the Canadian Network for Advancement of Research, Industry and Education (CANARIE) National Summit 2014 on September 18. Emerson talked about the quantum world, sharing the latest breakthroughs and the challenges ahead in the quest to build technologies based on quantum properties. The CANARIE National Summit brings together leaders from academia, industry and government to explore opportunities for Canada to seize a leadership position in the global knowledge economy. ■

KEEPING UP WITH **MARTIN**

MARTIN LAFOREST, Senior Manager, Scientific Outreach gives talks and workshops to curious minds including students, educators and community members.

Engaging the community

Laforest gave two public lectures:

» **Quantum Information: The Future of Technology**

October 29 for 150 members of Third Age Learning in Guelph

» **The Quantum Revolution**

November 26 at the Kitchener Public Library as part of the IDEAS & ISSUES lecture series.



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:

- » **40 graduate students and young professionals** attending the 5th International Union of Pure and Applied Physics (IUPAP) International Conference on Women in Physics, held at Wilfrid Laurier University August 5-8, 2014
- » **94 high school students** from the Ontario Science Centre Science School, The Study Academy, as well as Uxbridge and Woodlands secondary schools
- » **65 female high school students** in the Centre for Education in Mathematics and Computing (CEMC) Programming Challenge for Girls
- » **90 students** from Louise Arbour Secondary School participating in a computer science and quantum computing day, offered in partnership with CEMC
- » **125 K-12 science educators** at the Peel District Science & Tech Inquiry Symposium. ■

» Jennewein shares his vision: THE QUANTUM INTERNET



Faculty member **THOMAS JENNEW EIN** presented two lectures at the International Space University as part of the Space Study Program in Montreal. Jennewein spoke about the quantum cryptography satellite project and his experimental research in ultra-long distance quantum communications. He shared his long-term vision that the research advances in this field will eventually lead to the realization of a global quantum internet that uses satellites in space to extend quantum transmission to a global scale.

Jennewein also spoke at the National Research Council (NRC) uOttawa Schawlow-Townes Symposium on Photonics on October 30. The symposium highlights research and discoveries made by the photonics experts from Canada and the world who are continually pushing the limits in this area.

WEB Watch Thomas Jennewein's talk at the International Space University: <https://bit.ly/JenneweinISU> ■

BUILDING A QUANTUM CRYPTOGRAPHY COMMUNITY

Students and researchers working on all aspects of quantum cryptography gathered in Paris, France for QCrypt 2014 September 1-4. The 4th international conference on quantum cryptography supports the building of a research community in quantum cryptography through sharing recent research results. Faculty member **NORBERT LÜTKENHAUS** chaired the program committee. Lütkenhaus also presented his research findings in cryptography, in addition to Research Assistant Professor **VADIM MAKAROV** and postdoctoral fellow **AHARON BRODUTCH**. ■

SHARING IDEAS ON QUANTUM OPTIMIZATION

Deputy Director, Academic, **MICHELE MOSCA**, and Ophelia Lazaridis University Research Chair **TOM COLEMAN**, gave opening remarks at the Quantum Optimization workshop that took place October 27-29 in Toronto. The workshop provided a forum for scientific presentations and discussion of issues related to quantum optimization. Faculty members **RICHARD CLEVE** and **ASHWIN NAYAK**, and alumni **STACEY JEFFERY** and **ROBIN KOTHARI** were also invited to speak at the workshop. ■

» High school students design a QKD system

PhD student **SARAH KAISER** engaged 17 high school students from the Waterloo Unlimited enrichment program with a 90-minute cryptography workshop on November 13. Starting with a lecture on classical cryptography, Kaiser guided the students through the building of an entire quantum key distribution (QKD) system. Waterloo Unlimited is a collection of transdisciplinary enrichment opportunities for high school students in grades 10 through 12. ■

» Cory talks about superconductors and quantum processors



Canada Excellence Research Chair **DAVID CORY** and faculty member **GUOXING MIAO** were invited to Oxford Instruments' *Bringing the Nanoworld Together* workshop September 24-25 in Beijing, China. Scientists in the field of nanotechnology gathered at the Institute

of Semiconductors-Chinese Academy of Sciences (IOS-CAS) for the two-day workshop to discuss cutting-edge nanotechnology solutions for multiple applications. As a guest plenary speaker, Cory discussed superconductors and spin-based quantum processors. ■

Lütkenhaus shares research results at QCMC conference

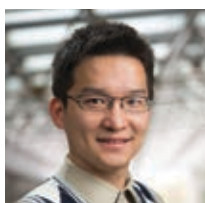


Faculty member **NORBERT LÜTKENHAUS** spoke at the 12th international conference on Quantum Communication, Measurement and Computing (QCMC) held November 2-6 in Hefei, Anhui, China. Lütkenhaus' talk, *Could Gaussian regenerative stations act as quantum repeaters?*, reviewed the research published in collaboration

with postdoctoral fellow **RYO NAMIKI**, former postdoctoral fellow **OLEG GITTSOVICH** and **SAIKAT GUHA** (Raytheon BBN Technologies).

WEB Read the article: <http://bit.ly/GaussianRegenStations> ■

Magnetic semiconductors control spin flows



Faculty member **GUOXING MIAO** was invited to speak at the International Conferences of Asian Union of Magnetics (IcAUMS) 2014 October 28-November 2 in Haikou City, China. Miao discussed how magnetic semiconductors can be used to actively and passively control spin flows, and to induce an

extremely large effective magnetic field. They are extremely powerful in manipulating low-dimensional electron systems (such as graphene, a topological insulator) and can potentially advance both digital spintronics and topological quantum information. Miao's talk, *Filtering Spins for Spintronics*, was based on a review article published in *Physical Chemistry Chemical Physics*. ■

WEB Read the article: <http://bit.ly/SpinManip> ■

» UPCOMING EVENTS

» Quantum Programming Languages and Circuits Workshop

Waterloo, Ontario
June 8-11, 2015

WEB <https://uwaterloo.ca/institute-for-quantum-computing/conferences/quantum-programming-languages-and-circuits-workshop>

» NanoMRI Conference

Waterloo, Ontario
July 27-31, 2015

WEB <http://uwaterloo.ca/nanomri/> ■

Undergraduate students trade insights about physics

KLAUDIA GOLOS, undergraduate research assistant (URA) and long-term visitor at IQC, and former URA **CHRISTIAN BARN** represented IQC and Waterloo at the 50th annual Canadian Undergraduate Physics Conference, hosted at Queen's University October 23-26. Barna presented a poster titled *Fine Point Mechanisms for Long Distance Free Space Quantum Key Distribution*. ■



Around the INSTITUTE



student

PROFILE: CAROLYN EARNEST

Embracing the spirit of experimentation



Science gets **CAROLYN EARNEST** really excited. Before high school, this was not the case – there was no joy, no experimentation, no curiosity; only scripts and robotic labs that never really worked. She went to an alternative high school where she studied fine arts and took part in FIRST, an afterschool robotics program. It was there she finally got the chance to experiment and have fun with science working as a science TA setting up and testing experiments.

This experience led to Earnest pursuing art and physics at Hampshire College in Massachusetts, an alternative undergraduate institution with narrative evaluations, project-based learning and independent plans of study. While finding the art classes stifling, Earnest was inspired by the physics classes and liked working in the machine shop. She quickly realized that she wanted to work in a lab.

Earnest went to work in a lab at the University of Massachusetts, Amherst after discovering a faculty member who was performing quantum information experiments. She ended up learning nanofabrication techniques while making a single electron transistor out of a combination of superconducting and non-superconducting metals.

She now uses those skills in the Lazaridis Quantum NanoFab facility making junctions and working with other fabricators to find a parametrized recipe for qubits for use in **MATTEO MARIANTONI's** superconducting lab. The group is working on a form of error correction called surface code. This method arranges qubits in a chain-link fence-like lattice. Through interaction with the lattice and lattice topological properties, researchers can detect any kind of error that might happen if the lattice is big enough.

Earnest also spends much of her time volunteering with Let's Talk Science, developing and teaching the curriculum on superconductors for Engineering Science Quest (ESQ), providing tours and demos for the Canadian Association for Girls in Science (CAGIS) and IQC, as well as judging at science fairs and working with Go ENG Girl. She wants to share her joy of science with others. "In my privileged state of being at IQC with an awesome job, in an awesome building, it's my duty and my pleasure to give back to the community," said Earnest. "I want to be the role model I never had as a child." ■

» TOURS/VISITS



» Expanding research partnerships

On September 22, IQC signed an agreement with the Korea Institute of Science and Technology (KIST) to expand research partnerships in the field of quantum information science. Ambassador Cho, Republic of Korea, toured IQC labs during a visit to Waterloo on November 21.

"This agreement brings two internationally recognized institutions together to advance quantum science," said **RAYMOND LAFLAMME**, executive director. "Our researchers will work to accelerate the development of quantum technologies for the benefit of both countries." Faculty member **KYUNG CHOI**, former senior scientist at KIST, will be among the main contributors to the research efforts in this agreement. ■

An honourable dinner

IQC and the Faculty of Science hosted a dinner for **ALAIN ASPECT** to congratulate him on his honorary doctorate from the Faculty of Science on October 23. The dinner included President & Vice-Chancellor **FERIDUN HAMDULLAHPUR**, Dean of Science **TERRY McMAHON**, Associate Dean of Science, Graduate Studies, **ROB HILL**, faculty member **KEVIN RESCH** and Senior Manager, Scientific Outreach **MARTIN LAFOREST**. Two special guests were also invited – **MIKE LAZARIDIS** and **AINSLIE WATT**, the wife of the late Professor Lynn Watt. Professor Watt had presented one of Aspect's papers in a class attended by Lazaridis and it's what got him hooked on quantum mechanics. While she was there, we presented Mrs. Watt with the room plaque that was made for the IQC meeting room named in Professor Watt's honour. ■

» MAKING GLOBAL CONNECTIONS

» A large delegation from France stopped in at IQC on November 6, including **CATHERINE COUTELLE**, **CLAUDE GREFF**, **MARIE-NOËLLE BATTISTEL**, **MICHÈLE BONNETON**, **JOËLLE HUILLIER** and **EMMANUELLE LAVIE** from the National Assembly, and Senate members **PIERRE-YVES COLLOMBAT**, **JEAN-MARC TODESCHINI**, **JACKIE PIERRE** and **DELPHINE BERT**. The group toured the NanoFab facility and several IQC labs as part of their visit.

» On November 13, members of the India ICT group working with IQC affiliate **URBASI SINHA** met with **THOMAS JENNEWEIN** for a lab tour and to learn more about the satellite project.

» Three members of the British Consulate, including **MICHELLE CUSACK**, **KEVIN McGURGAN** and **HENRY LONG**, were part of a visit organized by Waterloo International that included a tour of IQC October 23. ■



>> **IQC researcher wins COU Polanyi Prize**

EDUARDO MARTIN-MARTINEZ, research assistant professor, was awarded a \$20,000 John Charles Polanyi Prize at Massey College in Toronto. Martin-Martinez is one of the few researchers in Canada studying relativistic quantum information (RQI), combining quantum information theory and general relativity. "I see this great prize as recognition for the field of Relativistic Quantum Information," said Martin-Martinez, who also received a prestigious Banting Postdoctoral Fellowship in 2012. "I feel very fortunate to work in this hub in Waterloo where researchers are studying quantum information and theoretical physics at the Institute for Quantum Computing, the University of Waterloo and the Perimeter Institute."

The Polanyi Prizes are given in five categories: Physics, Chemistry, Physiology or Medicine, Literature and Economic Science. Martin-Martinez was given the only Physics prize for his work, which recognizes outstanding young researchers. He is the second Polanyi Prize winner from IQC (Anne Broadbent, 2010). ■



PhD student honoured with J. Alan George Student Leadership Award



PhD student **AIMEE GUNTHER** received the J. Alan George Student Leadership Award, which is presented to an entering female graduate student who is in their first year of graduate studies at Waterloo and who has already been awarded a Provost Doctoral Entrance Award for Women. ■

>> **ANNOUNCEMENTS**

CONGRATULATIONS TO OUR GRADUATES

- >> **MEGAN AGNEW**, MSc Physics (Quantum Information)
- >> **JASON BOISSELLE**, MMath Applied Mathematics (Quantum Information)
- >> **SHIMA BAB HADIASHAR**, MMath Combinatorics and Optimization (Quantum Information)
- >> **STACEY JEFFERY**, PhD Computer Science
- >> **ROBIN KOTHARI**, PhD Computer Science
- >> **STEPHANE LABRUYERE**, MSc Electrical and Computer Engineering (Quantum Information)
- >> **ANSIS ROSMANIS**, PhD Computer Science
- >> **AMIR JAFARI SALIM**, PhD Electrical and Computer Engineering (Quantum Information)
- >> **WILL STACEY**, MSc Physics (Quantum Information)
- >> **KYLE WILLOCK**, MSc Physics (Quantum Information) ■

» IN THE NEWS

SPOOKY ACTION IN THREES

Popular Science highlighted IQC's world-class research by researchers **DENY HAMEL, KEVIN RESCH, THOMAS JENNEWEIN**, and former postdoctoral fellow **(LYNDEN) KRISTER SHALM** who directly entangled three photons in the most technologically useful state for the first time. The story, *Spooky Action in Threes: Physicists Entangle Three Particles of Light*, described the team's experiment using superfast, super-efficient single-photon detectors developed by the National Institute of Standards and Technology (NIST). The photon triplets that were created were more stable than previous entanglements, meaning that the entangled photons are one step closer to practical use. The results were published in the paper *Direct generation of three-photon polarization entanglement in Nature Photonics* in September.

WEB <https://bit.ly/>

SpookyActioninThrees ■

Developing quantum-proofing systems

Quantum computing has the potential to crack the encryption codes that protect everything from email to online shopping and banking, even classified government documents, warns **ADAM HADHAZY** in his article *Preparing for the Quantum Storm* featured in *Discover* magazine. Since quantum computers use qubits to perform many operations simultaneously, they have the ability to "slash through today's encryption within minutes or seconds."

The need for quantum key distribution (QKD) secure networks and quantum encryption is prevalent. Preparing for these threats needs to happen now, according to **MICHELE MOSCA**, Deputy Director, Academic: "Planning and action need to start immediately to make our cryptography system robust against emerging quantum technology. If we do so, we can essentially avoid catastrophe." ■

COMMERCIALIZING QUANTUM TECHNOLOGIES

The Institute for Quantum Computing was highlighted in *The Record's 2014 Technology Spotlight*. Executive Director **RAYMOND LAFLAMME** shared IQC's world-class research in quantum information science and its future impact: "Behind IQC there is this vision that the work we do on quantum will have a fundamental impact. There are incredible opportunities for commercialization."

Spin off technologies are already being realized, such as Universal Quantum Devices (UQD), a company founded by faculty member **THOMAS JENNEWEIN**, Laflamme and former IQC Chief Operating Officer **STEVE MACDONALD**. UQD manufactures specialized quantum measurement devices for use in sophisticated optics labs. Postdoctoral fellow **ROLF HORN** developed a quantum light source device with the potential to spin off into another company. Looking ahead, the challenge becomes understanding the application of quantum technology and moving through the process of commercialization.

WEB Read the full *Technology Spotlight* article, *Imagining a quantum future*, online (pages 25 & 26): <https://bit.ly/TechSpotlight> ■



This fall, new graduate students were welcomed to the institute with the IQC GSA orientation event where they met their student mentors and enjoyed nachos. The annual bowling night, IQC's longest running event, was held at Frederick Lanes. The IQC GSA introduced two new events: the Quantum Queries Journal Club, which is a monthly discussion about a student-chosen topic related to quantum computing, and the international lunch potluck. The annual Halloween party was a hit, complete with a pumpkin-carving contest (shown left), a mummy-making contest and a costume contest. Recurring events such as the Quantum Industry Lecture Series and the monthly board games night continue to be held regularly.

Corey Rae McRae ■

Around THE INSTITUTE

>> **ARRIVALS**

(September-December)

Faculty

Eduardo Martin-Martinez

Staff

Hiba Amin
Erica Boland
Sara Clark
Janelle Santi

Students

Dusan Sarenac
Madelaine Liddy
Han Le
Honghao Fu
Maria Kieferova
Hamam Qassim
Hillary Dawkins
Thomas Alexander
Sumeet Khatri
Vinay Iyer
Rubayet Al Maruf
Ryan Barrage
Xingliang (David) Lou
Anqi Huang
Marian Berek
Meenu Kumari
Golam Bappi
Jeremy Flannery

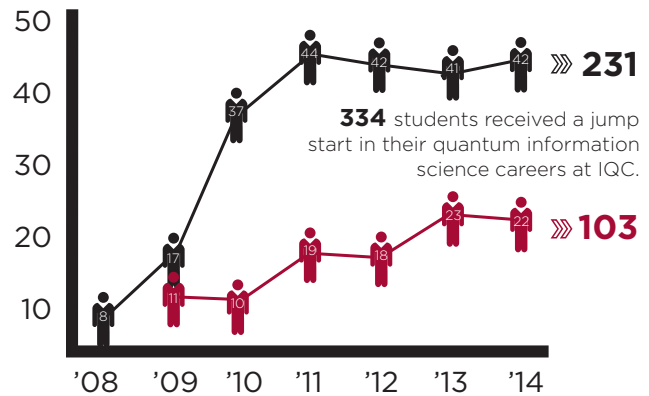
Postdocs

Chris Herdman
Guoming Wang
Guanru Feng
Jean-Francois Biasse
Toeno van der Sar
Patrick Coles
Jeongwan Jin
Chang Liu
Jean-Philippe Bourgoin
Sangil Kwon

Long-Term Visitors

Marta Palucka
Xiaodi Wu
Eyal Buks
Kai-Min Chung
Stacey Jeffery ■

QCSYS & **USEQIP** **ALUMNI**




Undergraduate Research Awards

>> 4 38 <<

28

Together the programs have attracted students from 28 different countries




5 IQC
USEQIP
 alumni have
become graduate
students at IQC



Quantum Key Distribution Summer School

August 17-21, 2015



APPLICATION DEADLINE:
JUNE 8, 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. In five days, QKD experts will cover topics including classical cryptography, security analysis and optical implementation of QKD and QKD in a cryptoworld.

- » Learn independent research techniques in quantum communication
- » Collaborate with renowned researchers
- » Present your poster at the QKD poster session

Apply now!

uwaterloo.ca/iqc/qkd

NanoMRI Conference

July 27-31, 2015

Hosted by the Institute for Quantum Computing

Join us at the NanoMRI Conference to discuss the varied approaches to imaging spins on the nanometer scale. We will explore applications to the physical and biological sciences as well as quantum information. ■

uwaterloo.ca/nanomri

Thanks to our sponsors



JANIS



Quantum Valley
INVESTMENTS



PERIMETER  INSTITUTE FOR THEORETICAL PHYSICS



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



UNIVERSITY OF
WATERLOO

IQC Institute for
Quantum
Computing



Ontario

Canada 