NEWSBIT

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

ISSUE 31 | WINTER 2017

No small feat

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UNIVERSITY OF WATERLOO | IQC Institute for Quantum Computing

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UNIVERSITY OF WATERLOO | IQC Institute for Quantum Computing

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Researchers at IQC's Laboratory for Ultracold Quantum Matter and Light keep their cool as they develop platforms for quantum applications.

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IQC researchers first to demonstrate an uplink to an airborne quantum satellite receiver prototype.

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Celebrating Canada 150 on a large, small scale.

ON THE COVER

Experimental station for cavity-coupled Rydberg polaritons

Cover Photo by: IQC

WINTER 2017

publisher
IQC COMMUNICATIONS & STRATEGIC INITIATIVES

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FROM THE EDITOR

Much of the content in this issue focuses on taking the science out of our labs and offices. At IQC, we've been doing this for some time through outreach initiatives and conferences, but it's especially true this year with the first travelling exhibition that made its debut at THEMUSEUM in Kitchener in October. It will continue its path across Canada throughout 2017.

Some of our researchers and staff will travel to the cities where *QUANTUM: The Exhibition* will land. This is in addition to the talks they give at conferences and courses at other institutions. In the fall, we had researchers present at the ETSI/IQC Workshop on Quantum-Safe Cryptography in Toronto and at the London Mathematical Society Research School at Queen's University Belfast.

An experiment by one of our research groups also went outside the lab during the fall term – and I mean literally outside. **THOMAS JENNEWEIN**'s team travelled to Smiths Falls, Ontario with a custom-built light source and receiver payload. This was the first demonstration of an uplink to an airborne quantum satellite receiver prototype for secure quantum communication, and you can learn more about it in one of this issue's feature articles.

As much as we like to go out and share IQC research, we think it's equally important to open our doors and welcome people to the Lazaridis Centre. That's one of the reasons why we participated in Doors Open Waterloo Region again in September. It gave us the opportunity to share what's happening here with nearly 1,000 people. And in addition to the usual school visits, we held our second weekend workshop for teachers, now named Schrödinger's Class. The workshop will help us to teach even more people about the wonderful world of quantum.

JODI SZIMANSKI, *Senior Communications Manager*

New **FACULTY** members

K. RAJIBUL ISLAM

Quantum Innovators (QI) 2015 workshop alumnus **K. RAJIBUL ISLAM** returns to IQC to lead the Laboratory for Quantum Information with Trapped Ions (QITI). His research interests include quantum computation, experimental quantum many-body physics and the use of holography and high resolution microscopy to manipulate many-body systems.

Before joining the Department of Physics and Astronomy, Islam was a postdoctoral researcher at the MIT-Harvard Center for Ultracold Atoms (CUA), where he studied entanglement in ultra-cold neutral bosonic atoms in optical potentials and optical potentials created in a high quality optical resonator.

CRYSTAL SENKO

While completing her postdoctoral research at the Center for Ultracold Atoms, **CRYSTAL SENKO** focused on the development of a photonic crystal waveguide for information transfer between atoms. During her fellowship she attended QI in 2015.

At IQC, and as a member of the Department of Physics and Astronomy, Senko explores how single atoms encoded with multiple levels of information, called qudits, can improve the efficiency of encoding information in quantum systems. Her work with trapped ions looks at the possibilities of building quantum systems, including spin chains with complicated behaviour that has yet to be demonstrated in a lab.

JON YARD

From the Station Q team at Microsoft Research, **JON YARD** joins IQC as Associate Professor in the Department of Combinatorics and Optimization in the Faculty of Mathematics and as an Associate Faculty member with the Perimeter Institute for Theoretical Physics (PI).

At IQC, Yard tackles complex mathematical problems in the areas of quantum information, quantum computing, algebraic number theory, quantum field theory and computational complexity theory. His research aims to understand the capabilities and limitations of devices for computing and distributing information. ■

Building

It may happen on a very small scale, but it's no small feat. Controlling individual atoms, photons and their interactions could lead to developments in simulating complex quantum systems. The Laboratory for Ultracold Quantum Matter and Light at the Institute for Quantum Computing (IQC) is working with atoms at extremely low temperatures to build a platform for quantum applications like sensors, metrology, computing and communication.

a quantum platform

Atom by atom, photon by photon

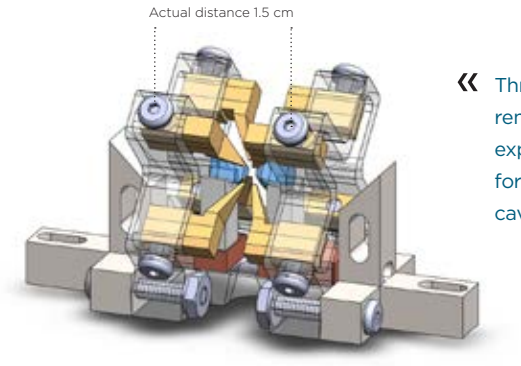
"Beginning with one atom and one photon, we can individually control the state of the atoms and make use of the interaction between atoms and photons to build, from the bottom up, a large-scale system where we can utilize artificial interactions that are completely synthesized from a vacuum," explained principal investigator and faculty member, **KYUNG SOO CHOI**.

Garnering the control of one atom and one photon, using an optical cavity for manipulation, can mediate very long-range or exotic interactions whose functional forms are designed for particular quantum simulations. Rydberg atoms are one of the key elements in Choi's lab because they are highly excited and, as a result, interact very strongly with each other. When the atom-photon interaction is strong enough, they become completely hybridized, like a molecule, called a Rydberg-dressed cavity polariton. The interactions between the atoms compete with the strong atom-light interaction, so it becomes a puzzle for the atoms and photons to arrange themselves in an order that creates extremely correlated quantum material consisting of cavity polaritons. Influencing the light, or the photon, influences the atom, setting the stage for tunable quantum simulation of topological quantum spin liquids, supersolidity, high-temperature superconductivity and exotic quantum magnetism. The ability to simulate these quantum systems provide unprecedented insight into condensed matter physics, potentially leading to advancements in building novel and robust quantum technologies.

Technical challenges

Since joining IQC in 2014, Choi has been focused on developing the technical infrastructure for his lab. The technical specifications required for his investigation of atom-light interactions at the quanta level do not yet exist, however that hasn't slowed down Choi's lab set-up. His team, including postdoctoral fellows **YING DONG**, **CHANG LIU**, **MAHMOOD SABOONI**, Master's students **HYERAN KONG**, **YOUN SEOK LEE**, **SOMENDU MAURYA**, **SAINATH MOTLAKUNTA**,

« Close-up microscopy image of the experimental station for Rydberg-dressed cavity polaritons



« Three-dimensional rendering of the experimental station for Rydberg-dressed cavity polaritons.

and undergraduate research assistants **JUNGJOON LEO KIM** and **CLAIRE WARNER**, is designing and building the custom infrastructure to perform experiments with ultracold Rydberg atoms in an optical cavity.

Competing technical requirements pose challenges when building experiments for Rydberg atoms. Rydberg atoms are so sensitive to electromagnetic fields that they can essentially act as quantum sensors with unprecedented sensitivity well beyond any classical device. The utilization of ultra-narrow Rydberg transition means that any type of electromagnetic interference could cause its quantum phase to change. It takes a tremendous amount of effort to reduce environmental noise that could interfere with the atomic state. Even the mere presence of a mirror in an optical cavity can cause interference.

Choi's team built a novel cavity system for Rydberg-dressed cavity polaritons that satisfies all technical requirements. "This is a world record optical finesse cavity system for Rydberg-dressed cavity polaritons," described Choi. Engineered for cutting-edge experiments with cavity-coupled Rydberg polaritons in quantum degenerate gases, the cavity system is impressive.

The cavity system uses superpolished titanium blade electrodes and a single-crystal sapphire cage to shield all external electromagnetic fields, including those from the mirrors themselves. The mirrors are placed a few hundred micrometers away from each other to localize a single photon, while three-dimensional blade electrodes enclose the optical mirrors to minimize their interference on the atom.

The optical mirrors in the system are so smooth that a single photon bounces more than 10^6 times inside of the resonator before getting lost. "One of the biggest challenges has been making these optical mirrors," explained Choi. "In order to maintain the requisite strong atom-light interaction, we had to develop a completely new, thin film material that improved the mirror reflectivity and reduced the optical loss by a factor of three, relative to what has been done in the past 30 years."

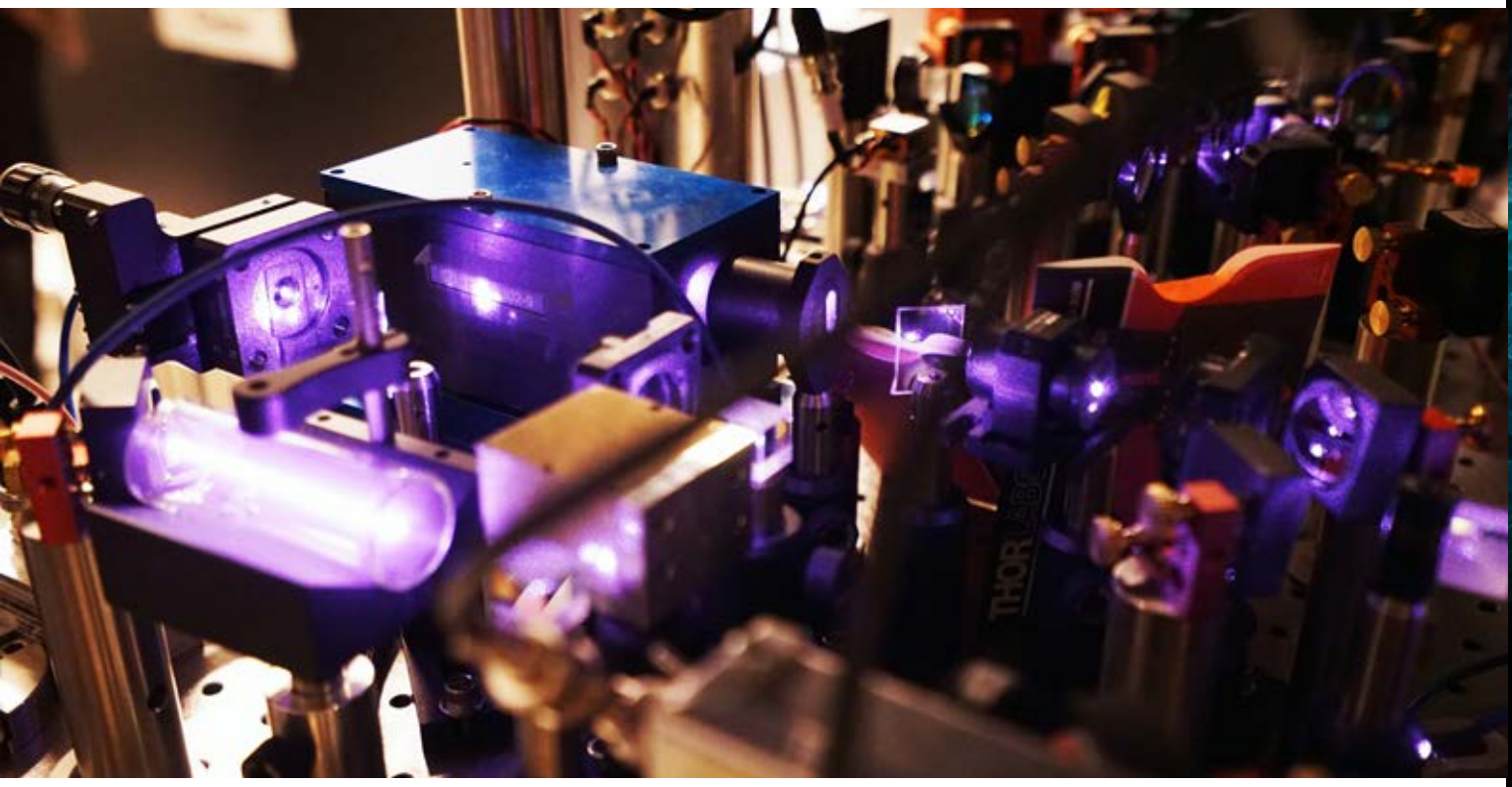
PUSHING QUANTUM SYSTEMS TO THE MAX

One major milestone that Choi and his team are trying to achieve is the realization of many-body states for light, opening up a new realm of research combining optical physics and quantum materials.

"It would be a breakthrough if photons, or more specifically polaritons, suddenly decide to interact with each other in the same way that electrons behave in a high-temperature superconductor," proposed Choi. "That's the kind of research we are doing here. We push quantum systems to extremal regimes heretofore not predicted."

Possible applications for novel quantum optical materials include:

- understanding high-temperature superconductivity
- discoveries of topological order
- supersolidity.



The ultrastable laser system with quality factor of 10^{15} in the Laboratory for Ultracold Quantum Matter and Light.

His team rose to the challenge and successfully created an ion-beam sputtered (IBS) thin film deposition method with proprietary materials that achieves a mirror reflectivity of 99.9996%. The mirrors are so smooth, the average surface roughness measures less than 0.25 Angstrom. One Angstrom is a unit of length used to describe atomic distances, equal to a tenth of a nanometer. The proprietary thin film material is a first – tailored specifically for ultra-low-loss mirrors, it has not yet been explored in optical cavities. With record optical finesse, the distance between two mirrors is stabilized to a length uncertainty below 1/1,000 of a single proton. Seismic activities including quakes generated by people walking down the corridor need to be isolated with passive dampers to protect the mechanical structure.

Precision matters

The use of ultra-narrow Rydberg-transition requires the excitation lasers to be extremely precise. Choi and his team use lasers stabilized to a cutting-edge optical clock to narrow the linewidths of the lasers to 1 part in 10^{15}. This level of precision is equivalent to throwing a ball towards Pluto and hitting a target the size of a dust mite. The optical clock is built out of an ultra-low expansion optical cavity in ultra-high vaccuum. The clock maintains the stability and phase coherence of the 20 lasers that are part of the experimental setup, making them fundamentally indistinguishable from each other.

The lasers control and monitor the state of the atom. The ultrastable laser system traps the atom in an extreme ultra-high vacuum (XHV) chamber. Once the atom is cooled as low as a few millionths of a degree above absolute zero and the motions of the atoms are manipulated to sub-micrometer resolution, the experiment can begin.

Big goals on a nano scale

"The science happening in the lab is very exciting. But to me, this is more about discovering these connections between people who are intensely passionate about the science, working days and nights, and trying to achieve this goal together. I am immensely fortunate to be working with my students and postdocs," said Choi, recognizing the efforts of his team.

While the team is still working on setting up the lab, Choi expects to see the first experimental observation of strongly coupled Rydberg polaritons later this year. They are also setting up a second lab across the hall. "Much of the infrastructure we have developed will be used in a second experiment that focuses on coupling ultracold atoms to nanophotonic crystal structures," said Choi. Here, his team plans on controlling ultracold atoms on the nanoscale to simulate quantum circuits and to study many-body physics. The scale remains small but the research goals are growing. ■

Taking quantum into space

"We are receiving photons!"

The source on the ground in Smiths Falls.

A team of researchers led by faculty member **THOMAS JENNEWEIN** at the University of Waterloo's Institute for Quantum Computing (IQC) successfully demonstrated quantum key distribution (QKD) between a transmitter on the ground and a receiver payload onboard an airplane. While researchers in Germany and China have previously conducted QKD experiments with quantum transmitters flown on an aircraft and a tethered low-altitude balloon, the team is the first to demonstrate a QKD uplink to an airborne quantum receiver.

The field experiment, a culmination of seven years of research, took place in Smiths Falls. A custom-built photon source, called Alice, randomly prepared photons in four different polarization states — horizontal, vertical, +45 degrees and -45 degrees — on the ground and sent them to the custom-built receiver payload aboard a National Research Council of Canada aircraft.

The receiver payload, Bob, detected the photons that weren't lost in the beam spread, analyzed the polarizations and recorded the time. Alice and Bob then compared their data to determine which photons made it and their polarization states to construct a secret key.

"When [the team on board the aircraft] radioed down: 'We are receiving photons!', that was one of the biggest moments," said Jennewein. The successful transmission of the secure quantum key is another step towards establishing a secure quantum communications network, laying the possible framework for the quantum internet — a global exchange of quantum information.

The paper, *Airborne demonstration of a quantum key distribution receiver payload*, is available on the arXiv.

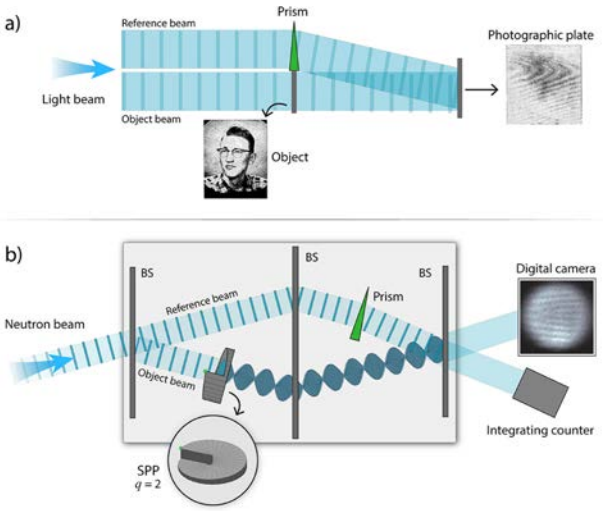
> **"WE ARE NOT ONLY SHOWCASING CANADIAN SCIENCE AND TECHNOLOGY DEVELOPMENT, PUTTING US ON THE WORLD STAGE IN THIS FIELD, BUT WE ARE SHOWING OTHER COUNTRIES THAT THEY CAN COME TO CANADA FOR THESE KINDS OF RESOURCES AND EMPLOY CANADIAN COMPANIES TO HELP WITH THE IMPLEMENTATION OF DIFFERENT TECHNOLOGIES."**
>
> Christopher Pugh, IQC PhD student

NEWS: The demonstration made the front page of *The Globe and Mail* on December 20 in an article entitled "Canadians solve key puzzle for future of encryption."

WEB **bit.ly/solving-encryption-puzzle**

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.



Creating holograms with neutron beams

Optics Express 24, 20, 22528-22535 (2016)

A team of researchers including Canada Excellence Research Chair in Quantum Information Processing **DAVID CORY**, research assistant professor **DMITRY PUSHIN** and PhD student **DUSAN SARENAC** used neutron beams to create holograms of macroscopic objects for the first time. The results, published in *Optics Express*, also revealed details about their interiors in ways that ordinary laser light-based visual holograms cannot.

At the Neutron Interferometry and Optics Facility (NIOF) at the National Institute of Standards and Technology (NIST), a neutron entered a single-crystal silicon Mach-Zehnder neutron interferometer. An initial beamsplitter separated the neutron into two paths. The researchers used a spiral phase plate to generate the object beam and a prism to provide the reference beam, which were then reflected at a central beam splitter. A final beamsplitter coherently combined the two beams. One was sent to an imaging detector, the other to an integrating counter that served as an intensity monitor. Given that there was only ever one neutron in the neutron interferometer at a time, the hologram was built up from an incoherent superposition of many events.

WEB **bit.ly/holography-neutron-interferometer**

ON REDDIT **bit.ly/neutron-holography-on-reddit** ■

NEW 3-D WIRING TECHNIQUE

Phys Rev App 6, 4 (2016)

MATTEO MARIANTONI led an international team of researchers in the development of a new extensible wiring technique. The novel technique is capable of controlling superconducting qubits. This is a significant step towards the realization of a scalable quantum computer.

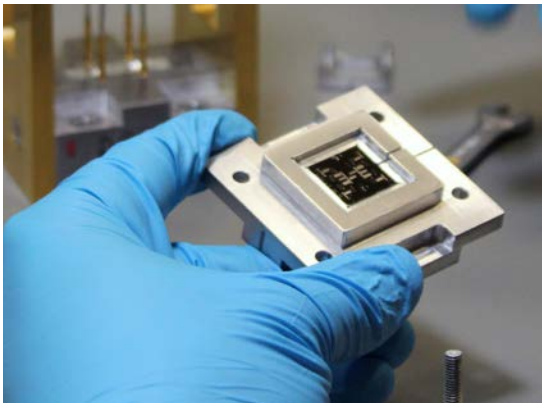
Until recently, the complex infrastructure of accessing qubits inside a cryostat through a network of cables to room-temperature electronics has been a barrier to scaling the quantum computing architecture. This new quantum socket uses three-dimensional wires based on spring-loaded pins to address individual qubits. The architecture is potentially extendable to thousands of qubits.

IQC and Waterloo researchers who contributed to the paper include **JÉRÉMY BÉJANIN**, **THOMAS McCONKEY**, **JOHN RINEHART**, **CAROLYN EARNEST**, **COREY RAE McRAE**, **DARYOUSH SHIRI**, **JAMES BATEMAN** and **YOUSEF ROHANIZADEGAN**. The paper was published in *Physical Review Applied*, October 18.

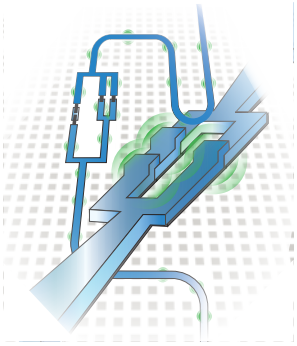
WEB **bit.ly/quantum-socket**

NEWS: The prestigious journal *Nature* featured the work of Mariantoni's team in the Research Highlights. It noted that the structure can interconnect as many as 100 qubits, with the potential to be scaled up to 100,000 in the future.

WEB **bit.ly/qubits-wired-up** ■



SCIENCE HIGHLIGHTS



STRONGEST COUPLING BETWEEN LIGHT AND MATTER

Nature Physics 13, 39-43 (2017)

IQC researchers recorded an interaction between light and matter 10 times larger than previously seen. The paper, *Ultrastrong coupling of a single artificial atom to an electromagnetic continuum in the nonperturbative regime*, published in *Nature Physics* in October reports measurements of a range of frequencies broader than the qubit frequency itself.

The researchers controlled the quantum state of a superconducting circuit by using microwave pulses to send photons into the circuit and applying a small magnetic field through a coil inside the dilution refrigerator. By measuring the photon transmission, the researchers could define the resonance of the qubit, indicated by the reflection of the photons off the qubit.

This ultrastrong coupling between photons and qubits may lead to the exploration of new physics related to biological processes, exotic materials such as high-temperature superconductors, and even relativistic physics. IQC researchers contributing to this work include postdoctoral fellow **POL FORN-DIAZ**, PhD students **JEAN-LUC ORGIAZZI** and **MUHAMMET ALI YURTALAN**, undergraduate research assistant **RON BELYANSKY**, and faculty members **ADRIAN LUPASCU** and **CHRISTOPHER WILSON**.

WEB **bit.ly/ultrastrong-coupling** ■

CONFERENCES

Future-proof security, now

The European Telecommunication Standards Institute (ETSI), in collaboration with IQC, held the 4th ETSI/IQC Workshop on Quantum-Safe Cryptography in Toronto from September 19-21. Workshop organizers aimed to increase awareness about the threat quantum computing poses to traditional cryptography methods among science and industry communities, emphasizing that the time to develop quantum cryptography and post-quantum cryptography solutions is now.

IQC faculty members **NORBERT LÜTKENHAUS** and **MICHELE MOSCA**, as well as IQC board member and COO of ISARA Corporation **MARK PECEN** participated in the workshop. ■

Cutting edge of quantum

Twenty-six postdoctoral experimentalists and theorists of experiments in quantum physics and engineering gathered to explore the frontier of their field at the Quantum Innovators Workshop held at IQC October 23-26. IQC faculty member and 2014 Quantum Innovators alumnus **NA YOUNG KIM** was among the many speakers from academia and industry who presented. ■

TALKS & TOURS

EMERGING INNOVATION

RAYMOND LAFLAMME presented as part of the *Emerging Innovators: The Job of Growing New Businesses in Canada* panel at the Public Policy Forum on October 18. Focused on how Canada can create a culture of innovation, Laflamme spoke about the importance of forming ecosystems to bring all the pieces together – from discovery to innovation to commercialization – just as we have in the Quantum Valley in Waterloo. **JANET BANNISTER**, general partner of Real Ventures moderated the panel that also included the CEO of Orpyx and recipient of the Governor General's Innovation Award **BREANNE EVERETT**, President & CEO of Evok Innovations **MARTY REED** and CEO of the MaRS Discovery District **ILSE TREURNICHT**.

WEB **bit.ly/panel-2-emerging-innovators** ■

QUANTUM VISION

Atomic, molecular and optical physicist **CHARLES W. CLARK** from the National Institute of Standards and Technology (NIST) gave a public lecture at IQC November 15.

In the talk, Clark described the vast expanses of electromagnetic spectrum beyond the "small island" of colours that humans perceive, and how that spectrum changes the visual worlds of many animals. Of particular interest was ultraviolet light, which is seen by many non-human animals. It is a realm fundamentally ruled by quantum physics, and the scene of a discovery that laid the foundation of the quantum theory of matter. ■

Distance education

Professor **VERN PAULSEN** of IQC and the Department of Pure Mathematics at the University of Waterloo taught a course at the London Mathematical Society Research School, Queen's University Belfast. The course, *Non-commutative order in quantum games*, was part of an effort to introduce PhD students and young researchers to both the methods and problems of combinatorics and operators in quantum information theory. ■

QUANTUM & CYBERSECURITY

At the Canadian Association for Security and Intelligence Studies Symposium on September 23, not only did **RAYMOND LAFLAMME** present a talk entitled *Cybersecurity in a Quantum World*, but **GRETA BOSSENMAIER**, Chief, Communications Security Establishment, recognized the work of IQC in the John Tait Memorial Lecture. Her talk, *Perspective on the Cyber Challenge*, discussed the opportunity of quantum computing, but also how it will render the current methods of encryption totally ineffective. After explaining that quantum computing could be realized in the next 10 years she said: "Waterloo's Institute for Quantum Computing has been doing some incredible work in that area [quantum and cybersecurity], so stay tuned." ■

Doors Open 2016

Nearly 1,000 visitors flooded into IQC September 17 as part of Doors Open Waterloo Region. Guests witnessed the unveiling of IQC's GUINNESS WORLD RECORDS™ record title for Smallest National Flag. The flag measured 1.178 micrometres in length and is invisible without the aid of an electron microscope. The flag will travel across Canada in 2017 with *QUANTUM: The Exhibition*.

Tour guides showed visitors around the Mike & Ophelia Lazaridis Quantum-Nano Centre. Guests asked researchers about their work in quantum information science and tested their skill at Quantum Cats.

WEB **bit.ly/smallest-national-flag**

NEWS: The Discovery Channel show *Daily Planet* described the GUINNESS WORLD RECORDS™ setting flag as a part of a big step forward for Canadian technology. The show aired on September 20. ■

Doors Open guests show their patriotic pride while waiting for a guided building tour.

The smallest national flag on display.

QUANTUM: THE EXHIBITION

celebrates Canada's leadership in quantum science

IQC Executive Director **RAYMOND LAFLAMME** gave a private tour to the Honourable **KIRSTY DUNCAN**, Minister of Science; the Honourable **BARDISH CHAGGER**, Leader of the Government in the House of Commons and Minister of Small Business and Tourism; and MP **RAJ SAINI** (Kitchener-Centre).

"THIS IS YOUR OPPORTUNITY TO PEEK INTO THE QUANTUM WORLD, AND SEE HOW CANADA IS PROVIDING GLOBAL LEADERSHIP IN QUANTUM RESEARCH AND TECHNOLOGY. THIS IS YOUR OPPORTUNITY TO SEE INTO THE FUTURE."

FERIDUN HAMDULLAHPUR,
President and Vice-Chancellor,
University of Waterloo

How do you take a complex topic like quantum mechanics, a concept that redefines our understanding of nature, and make it accessible to everyone? The answer: you build an interactive, 4,000 square foot exhibition about it. After one year of planning and consulting with IQC researchers, *QUANTUM: The Exhibition* was ready for its national debut.

Visitors are welcomed by Prime Minister **JUSTIN TRUDEAU** via video. He weighed in on the impact of quantum technologies.

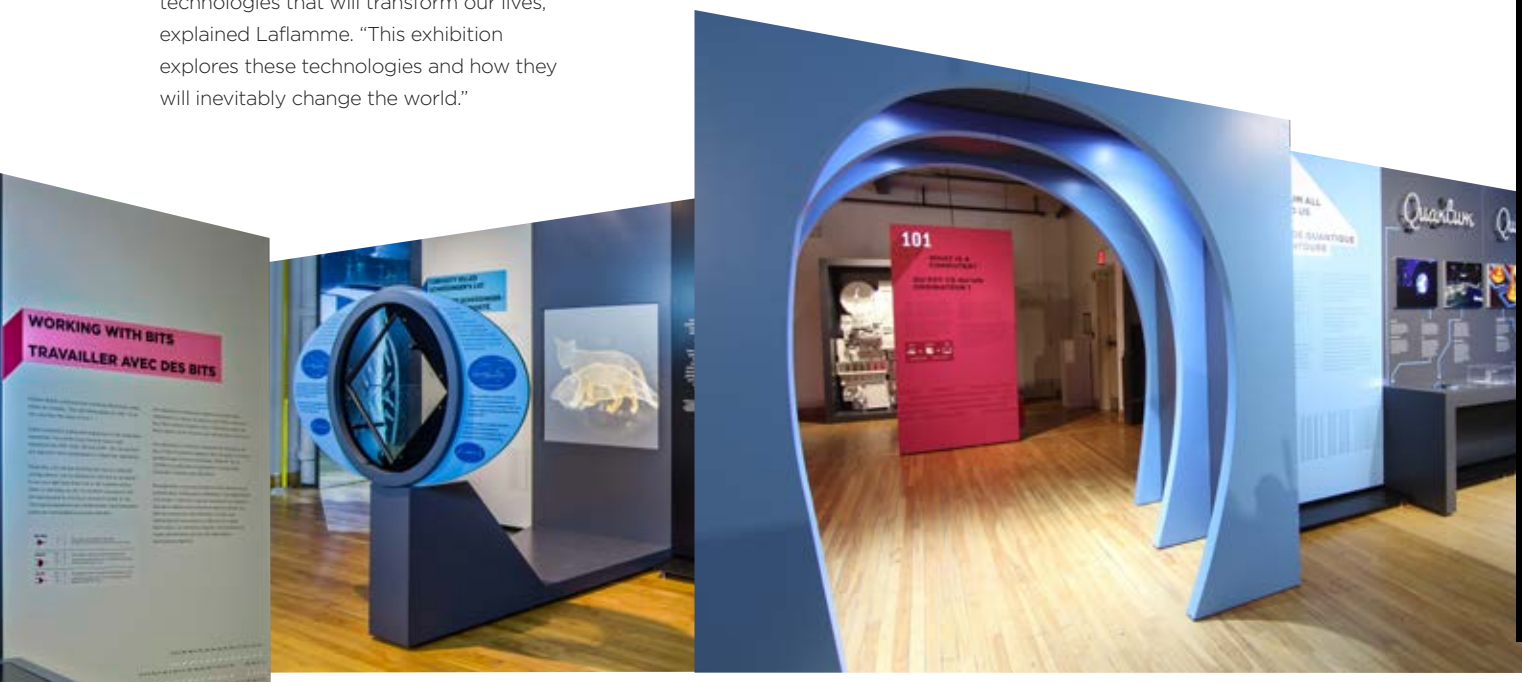
Special guests gathered at the October 13 launch of *QUANTUM: The Exhibition*. Pictured left to right is University of Waterloo President and Vice-Chancellor **FERIDUN HAMDULLAHPUR**, the Honourable **BARDISH CHAGGER**, IQC Senior Outreach Manager **MARTIN LAFOREST**, IQC Executive Director **RAYMOND LAFLAMME**, Mayor of Waterloo **DAVE JAWORSKY**, the Honourable **KIRSTY DUNCAN**, MP **RAJ SAINI**, MPP **DAIENE VERNILE**, Councillors **ANGELA VIETH** and **JEFF HENRY,** IQC Director, Communications and Strategic Initiatives **TOBI DAY-HAMILTON** and MP **HAROLD ALBRECHT**.

QUANTUM: The Exhibition premiered downtown Kitchener at THEMUSEUM on October 13. Special guests not only had the opportunity to see the exhibition before anyone else, but they saw a video message from world-renowned theoretical physicist **STEPHEN HAWKING** deliver a surprise video message for his former student, **RAYMOND LAFLAMME**, congratulating him on his advocacy to share quantum science with the world.

"In many ways, Canadian researchers are leading the development of new quantum technologies that will transform our lives," explained Laflamme. "This exhibition explores these technologies and how they will inevitably change the world."

The opening kicked off a series of events tied to the exhibition including the Girl Guides Sleepover, QUANTUM Unleashed!, STEM week, Quantum Education Days, The Quantum Dialogues and the Qubit Club. Over 15,000 people learned more about quantum information science and technology, its impact on our lives and Canada's leadership in the field.

"We often hear from people that quantum science is intimidating," said **TOBI DAY-HAMILTON**, Director, Communications and Strategic Initiatives. "From the beginning, our goal in developing *QUANTUM* was to engage people of all ages in a fun and unique way. A lot of amazing quantum research takes place right in our own backyard and we want to share this great work with our fellow Canadians." ■



IQC OUTREACH

TEACHING TEACHERS QUANTUM

At Schrödinger's Class, class was not as it seemed. The 24 high school teachers became students for three days in November so that they could return to class to teach quantum mechanics. The teachers attended lectures and engaged in hands-on activities focused on integrating quantum technology into the current teaching curriculum. They didn't just leave with knowledge so that they could discuss cutting-edge advances in the field, but lesson plans and ready-to-go activities too. One teacher enjoyed revisiting "'classical' experiments as viewed through the quantum mechanics/probabilistic lens and the quantum computing simulations (such as the quantum coin flip game) were fundamental in helping me further understand ideas in quantum mechanics." ■

Physics Lab Days

Towards the end of the fall and winter terms, the IQC Outreach team partners with the Faculty of Science to bring high school students to learn more about the study of science at the University of Waterloo. Over the course of two weeks in December, IQC labs were filled with over 430 grade 11 and 12 students for Physics Lab Days. Through workshops and tours led by IQC Scientific Outreach Officer **ELECTRA ELEFTHERIADOU** and Senior Manager, Scientific Outreach **MARTIN LAFOREST**, students learned more about the research at IQC. Perhaps we'll see many of these students return to Waterloo for their undergraduate studies. ■

LEARNING LIGHT

The United Nations' HeForShe campaign recognizes the need to remove social and cultural barriers that prevent women and girls from achieving their potential. The University of Waterloo HeForShe IMPACT 10x10x10 program brought 60 female grade seven and eight students to PhysiXX: Girls Matter to campus on December 3. To engage young women and encourage their interest in STEM, Scientific Outreach Officer **ELECTRA ELEFTHERIADOU** and postdoctoral fellow **FILIPPO MIATTO**, taught the students about the fascinating properties of light. They even took part in an experiment to measure the width of their own hair with lasers to recreate the famous Young double-slit experiment. ■

CONFERENCES

COLLECTIVE QUANTUM CRYPTOGRAPHY

Several IQC members and alumni presented their results at QCrypt 2016 at the Carnegie Institution for Science September 12-16. The sixth International Conference on Quantum Cryptography gave researchers the opportunity to share the previous year's best results and to support the building of a research community in quantum cryptography. Former postdoctoral fellows **SCOTT AARONSON** and **ANNE BROADBENT** shared recent findings, as did **KRISTER SHALM** about the loophole-free Bell tests he conducted with several IQC members.

Faculty members **THOMAS JENNEWEIN** and **MICHELE MOSCA** also traveled to Washington, DC to present at the conference as invited speakers. Mosca delivered two talks - one a public lecture as part of the conference's outreach and the second an industry session. ■

Talking theory

Berlin hosted the 11th Conference on the Theory of Quantum Computation, Communication and Cryptography (TQC) September 27-29. The TQC conference series focuses on theoretical aspects of quantum computation, quantum communication, and quantum cryptography. The objective of the conference is to bring together researchers so that they can interact with each other and share problems and recent discoveries, one of which was a talk by **JOHN WATROUS** called *Operational meaning of quantum measures of recovery*. Several IQC members presented posters at the conference including Master's student **OLIVIA DI MATTEO**, alumnus **JUAN MIGUEL ARRAZOLA**, and faculty members **NORBERT LÜTKENHAUS** and **MICHELE MOSCA** presented posters at the conference. ■

Publishing policy

Many IQC students get involved in activities in their field beyond the institute. PhD student **AIMEE GUNTHER** is no exception. A member of the Canadian Association of Physicists (CAP), Gunther wrote two articles for the CAP publication *Physics in Canada* last year.

The first Science Policy Update gave Canadian scientists best practices to ensure their research receives the government and public support that it deserves. The second update discussed the Government of Canada's independent review of national fundamental science funding mechanisms by a panel of experts and the CAP response to it. While the response generally lauded the NSERC Discovery Grant Model, CAP also made some recommendations to make the funding system more streamlined and flexible.

WEB **bit.ly/sci-policy-update-1 and bit.ly/sci-policy-update-2** ■

UPCOMING CONFERENCES

WIPC 2017
6th Annual Women in Physics Conference

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

WEB **uwaterloo.ca/wipc-2017**

Workshop on Operator Systems in Quantum Information

August 14-17, 2017
University of Guelph, Guelph, Ontario

WEB **fields.utoronto.ca/activities/17-18/operator-systems-quantum** ■

Around the INSTITUTE

postdoctoral fellow PROFILE: **PATRICK COLES**

From movie magic to quantum communication

A long and winding road led theoretical researcher **PATRICK COLES** to IQC, and it all began with the magic of movies. "My ninth grade biology class took a field trip to see Jurassic Park...That's one of the things that got me interested in science," said Coles.

While earning his Master's in Biochemistry as a Churchill Scholar at University of Cambridge, a biography of Richard Feynman planted the idea of becoming a theoretical physicist in his mind.

Coles focused on physics-oriented courses while earning his PhD in Chemical Engineering at the University of California, Berkeley. When he returned home to Pittsburgh as a postdoctoral fellow under **ROBERT GRIFFITHS** at Carnegie-Mellon, he became a theoretical physicist like Feynman. He continued his research under **STEPHANIE WEHNER** at Singapore's Centre for Quantum Technologies, before reaching out to IQC faculty member **NORBERT LÜTKENHAUS**.

"I chose IQC because it's one of the best places in the world for quantum cryptography. In Norbert's group, we do very practical theory, and yet at the same time, we are also developing elegant tools that are applicable to many situations," said Coles.

The most recent of those tools is a MATLAB-based software that enables researchers to evaluate the performance of any conceivable Quantum Key Distribution (QKD) protocol. Coles and his team were able to develop a quick and reliable numeric way to calculate the key rate for any given QKD protocol. They tested their method on protocols with known key rates to confirm its validity, and then began investigating unstudied protocols. A year after they submitted their findings to *Nature Communications*, they completed the software that is now freely available on Lütkenhaus' research group website.

Coles has already put the software to use calculating key rates for IQC experimentalists, as well applying it to open theoretical problems with his own group. In the future, he hopes their research will be extended to operate on finite-key scenarios, as it is currently used for asymptotic key rates. He and his group are now working on improving the speed and reliability of the key rate discovery method. ■

TOURS/VISITS

GRADUATES

Congratulations to our Fall 2016 graduates:

- **HONGHAO FU**
  MMath Computer Science (Quantum Information)
- **DAVID LAYDEN**
  MMath Applied Mathematics (Quantum Information)
- **ALEX PARENT**
  MSc Physics (Quantum Information)
- **KENT FISHER**
  PhD Physics
- **NICHOLAS FUNAI**
  MSc Physics
- **TOMAS JOCHYM-O'CONNOR**
  PhD Physics
- **SARAH KAISER**
  PhD Physics (Quantum Information)
- **XIAN MA**
  PhD Physics (Quantum Information)
- **KATJA RIED**
  PhD Physics (Quantum Information)
- **YUVAL SANDERS**
  PhD Physics (Quantum Information)
- **ZACHARY WEBB**
  PhD Physics (Quantum Information)

CANADA LEADS BY EXAMPLE IN QUANTUM RESEARCH

Canada, a leading country in quantum information science and technology research, has become a prime source of insight for international partners investing in quantum technologies. Fall visits to IQC from two European delegations came on the heels of the European Union's spring announcement of the EU Flagship in Quantum Technologies, an initiative dedicated to advancing quantum research in Europe.

The University of Waterloo welcomed President of Croatia **KOLINDA GRABAR-KITAROVIĆ** on November 21. Joined by Mayor of Kitchener **BERRY VRBANOVIC**, **MARTIN LAFOREST** led the Croatian delegation through IQC to showcase the research happening in the labs. The University of Waterloo was one stop on her tour of the Waterloo Region innovation ecosystem.

On December 1, a second delegation of officials from the European Union visited IQC as part of a world tour of quantum centres. As the delegation plans the EU Flagship in Quantum Technologies, they met with IQC faculty to learn about the research happening in the Quantum Valley.

Around
THE INSTITUTE

AWARDS AND FELLOWSHIPS

Tackling quantum challenges

The Honourable **KIRSTY DUNCAN**, Minister of Science, was on hand at the University of Waterloo on September 6 to announce the recipients of the second competition of the Canada First Research Excellence Fund (CFREF). CFREF will contribute $76.3 million to the Transformative Quantum Technologies (TQT) initiative of more than $140 million.

Led by IQC Canada Excellence Research Chair **DAVID CORY**, the TQT program will focus on three grand challenges in quantum research: to develop a universal quantum processor, quantum sensors and long-distance quantum communications. Researchers will work to push the frontier of our understanding of quantum processes, develop robust quantum devices, and connect academic research with industry applications in a variety of fields.

"Quantum mechanics enable devices that are otherwise impossible in the classical world, and these revolutionary devices will transform the way we interact with and learn about the world," said Cory, also a professor of chemistry in the Faculty of Science at Waterloo. "Transformative Quantum Technologies aims to develop new quantum technologies and to connect quantum devices to applications spanning the fields of medicine, health, navigation, environment, materials and others."

One of the projects combines quantum technologies and pathology to develop new ways to diagnose and characterize cancer. These new diagnosis technologies have the potential to detect cancer and its precursors at an earlier stage by improving conventional screen, lowering costs and improving diagnostic accuracy.

NEWS: University of Waterloo President FERIDUN HAMDULLAHPUR told CBC that the huge investment via the Canada First Research Excellence Fund demonstrates that "this current government values fundamental research."

WEB **bit.ly/TQT-announcement**

A lifetime of achievement

Wolf Blass Wines and Startup Canada partnered to present **MIKE LAZARIDIS** with the Adam Chowaniec Lifetime Achievement Award for Ontario on September 28. The award is given to individuals who have made a long-term impact and enduring legacy in advancing an environment and culture for entrepreneurial growth and success in Canada.

In addition to founding the technology company Research in Motion (RIM), Lazaridis has been instrumental in establishing Waterloo, Ontario as Canada's Quantum Valley with his founding and financial support of the Perimeter Institute for Theoretical Physics, IQC and Quantum Valley Investments (QVI). ■

EXPLORING THE ABSTRACT

JOEL WALLMAN, postdoctoral fellow at IQC, along with **MATTHEW PUSEY** from the Perimeter Institute for Theoretical Physics and **LLUIS MASANES** from University College London received a 2016 Physics of the Observer mini-grant from the Foundation Questions Institute (FQXi) valued at more than $60,000 for their research on observers and observation in quantum theory.

The mini-grant will fund a workshop to bring together theoretical researchers for a short period of time, an approach that allows the investigation of abstract questions often considered higher risk in the research field. ■

MIKE AND OPHELIA LAZARIDIS FELLOWSHIPS

NICHOLAS FUNAI
MORGAN MASTROVICH
EMMA BERGERON
YONGCHAO TANG
NAYELI AZUCENA RODRIGUEZ BRIONES
LI LIU
HAMMAM QASSIM
MARIA KIEFEROVA ■

Around
THE INSTITUTE

NEW CANADA RESEARCH CHAIR

IQC affiliate **PIERRE-NICHOLAS ROY**, professor in the Department of Chemistry at the University of Waterloo, was awarded a Canada Research Chair in Quantum Molecular Dynamics December 2, 2016. The award, valued at $1.4 million over seven years, will allow Roy and his research group to "better understand how molecules that make up matter and solids and liquids and everything, move around," said Roy. ■

IQC ENTRANCE AWARDS

NICHOLAS MANOR
GUILLAUME VERDON-AKZAM
SIMON DALEY ■

Promising young researcher awarded prestigious scholarship

Former Quantum Cryptography School for Young Students (QCSYS) student **STEPHANIE GAGLIONE** was named a 2017 Rhodes Scholar last term, giving her a prestigious scholarship to the University of Oxford. Her research began in high school studying the effects of insulin on a protein in cholesterol at the Toronto Hospital for Sick Children. Since then, she has researched drug delivery to cells in the immune system at MIT and the challenges to vaccination and immunization programs in middle-income countries with the World Health Organization in Geneva. Gaglione was one of 11 Canadian students selected for the Rhodes Scholarship, which is awarded on the basis of "intellect, character, leadership and commitment to service." ■

New Courses & Workshops

QIC 710 Quantum Information Processing

QIC 890 Qubits with Semiconductors and Spins

QIC 890 Functional Analysis Methods for Quantum Information Technologies

QIC 890 Theory of Quantum Communication

QIC 890 Solid-state Photonic Devices ■

THESIS DEFENCE

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

ZACHARY WEBB, PhD
RAZIEH ANNABESTANI, PhD
JOHN DONOHUE, PhD
GREG HOLLOWAY, PhD
MATTHEW GRAYDON, PhD ■

FROM THE IQC GSA

The IQC Graduate Student Association (GSA) organized an Escape Room night November 29. The event allowed new graduate students to team up with current IQC members and work with them in order to escape their predicament! Thankfully, everyone had fun and managed to make their way out. The teams then regrouped for food and refreshments, giving everyone an additional opportunity to socialize.

Written by Jérémy Béjanin ■

ARRIVALS

Faculty

Jon Yard
Rajibul Islam
Crystal Senko

Staff

Devika Khosla
Yufei Ge
Lino Eugene
Shravan Mishra
Blanka Peterka

Postdoctoral fellows

Razieh Annabestani
Hilary Carteret
Hyun Ho Kim
Hao Qin
Peter Tysowski

Visitors

Andreas Fognini
Youn Seok Lee
Haining Pan
Atmn Patel
Hugo Woerdeman

Students

Julia Amoros Binefa
Stefanie Beale
Simon Daley
Emma Bergeron
Nicholas Funai
Laura Henderson
Taylor Hornby
Jaron Huq
Ian DSouza
Jun An Lin
Morgan Mastrovich
Mats Powlowski
Denis Melanson
Sainath Motlakunta
Nachiket Sherlekar
Nicholas Manor
Tarun Patel
Sai Sreesh Venuturumilli
David Schmid
Somendu Maurya
Huichen Sun
Ramy Tannous
Theerapat Tansuwannont
Archana Tiwari
Cameron Vickers
Shazhou (Joey) Zhong
Mike Nelson ■

QUANTUM: THE EXHIBITION

Traveling

12,732 km

across Canada in 2017

About

1400

visitors per day in Vancouver

Over **4,000**

square feet of displays

traveling in **2** tractor trailers

Equations

Contributions by

24 IQC researchers AND **1** Prime Minister

INNOVATION150 CREATE • CONNECT • CELEBRATE

CANADA 150

QUANTUM: THE EXHIBITION

#SPIN

TELUS Spark, Calgary
June 26 - August 7

INNOVATION150

CANADA 150

Canada

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

Women in Physics Canada

WIPC conference 2017

July 26-28

Come build strong bonds with young women in physics

University of Waterloo, Waterloo, Ontario

For more information, please visit:

uwaterloo.ca/wipc-2017

PANELS INCLUDE:

- Work/Life balance
- 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

Hosted by:

UNIVERSITY OF WATERLOO
FACULTY OF SCIENCE
Department of Physics & Astronomy

IQC Institute for Quantum Computing

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

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