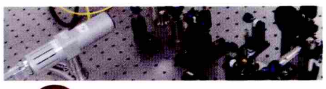



IQC Institute for Quantum Computing
UNIVERSITY OF WATERLOO


ISSUE 13
WINTER
2010

THE INSTITUTE FOR QUANTUM COMPUTING

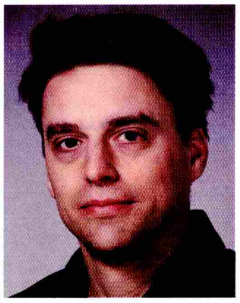
NewBit

IQC FACULTY DISCOVERS QIP = PSPACE

IQC faculty member John Watrous achieved a major breakthrough this past July in collaboration with researchers from Perimeter Institute and The David R. Cheriton School for Computer Science.

Watrous and his collaborators resolved a decade-old problem in the theory of quantum computing by proving the equivalence of two collections of computational problems called QIP and PSPACE.

To understand the importance of their result, it is helpful to first summarize some historical developments that pre-date quantum computing:



PSPACE ("polynomial space") is the collection of all computational problems that can be solved by a computer whose memory usage scales according to some fixed power of the instance size. IP ("interactive proof") designates the class of all computational problems whose solutions can be "verified" through an interaction with a "prover" agent that answers a series of challenge questions, in time bounded by a fixed power of the instance size.

A celebrated result of 20 years ago asserts that IP and PSPACE are in fact two descriptions of the same entity (any problem in PSPACE is in IP and vice versa).

Watrous was among the first researchers to investigate the quantum analogues of these concepts, namely QSPACE and QIP.

Although Watrous uncovered several properties of QSPACE and QIP, their true relationship remained a mystery until July. That's when Watrous — in collaboration with Sarvagya Upadhyay (SCS), Zhengeng Ji (PI) and Rahul Jain (formerly of IQC and SCS) — demonstrated that QIP is equivalent to PSPACE.

Explained Watrous: "We want to understand the impact of quantum information on the way we classify the inherent difficulty of computational problems. In the case of interactive proof systems, we now have an answer: quantum information doesn't actually have any effect at all on the class of problems they define."

IQC OPEN HOUSE

On Oct. 17, IQC opened its doors to the public for its third annual Open House, inviting visitors to tour labs and chat with researchers.

More than 80 people attended the panel discussion, which saw six world-leading experts engage in a wide-ranging discussion about the field of quantum computing.

The panel discussion was, in a sense, a live version of the documentary *The Quantum Tamers*, which premiered that night as part of Perimeter Institute's Quantum to Cosmos festival, since all the panelists were featured in the film.

IQC's Joseph Emerson moderated the lively discussion between Dorit Aharonov, Gerard Milburn, Barbara Terhal, Andrew White, Stuart Wolf and Anton Zeilinger.

Following the discussion, audience members were free to tour eight IQC laboratories, where faculty and student volunteers offered demonstrations and answered questions.

Many thanks to the dozens of IQC members who volunteered their time to make the Open House a success.

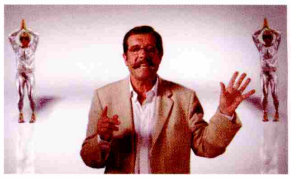
HIGHEST HONOURS

Visitors

IQC is honoured to have hosted these distinguished guests during the summer term:

- Mark Rudner – Harvard University
- Erik Lucero - University of California, Santa Barbara
- Christian Weedbrook - University of Queensland
- Prof. Hosano - WIN
- British Consulate
- Nicolas Menicucci – Perimeter Institute
- Greg Chaitin – IBM
- Don Aldridge – IBM Canada Research and Life Science
- Nancy Lu, University of Calgary
- Jerry Chow – Yale University
- Tin-An Wang – Taipei Economic and Cultural Office
- Howard Wiseman – Griffith University
- Anton Zeilinger – University of Vienna
- Peter Shor – MIT
- Dorit Aharonov – Hebrew University
- Andrew White – University of Queensland
- Gerard Milburn – University of Queensland
- Umesh V. Vazirani – University of California at Berkeley
- Barbara Terhal – University of Virginia
- Stuart Wolf - University of Virginia
- Fei Yan – MIT
- Douglas Stebila – Queensland University
- Brandon Armstrong – Univeresity of California, Santa Barbara
- Roman Barankov – Boston University
- Jonathan Hodges – MIT
- Dima Pushin – MIT
- Kevin Krsulich – MIT

QUANTUM TAMERS WINS INTERNATIONAL FILM AWARDS



The Quantum Tamers: Revealing our Weird and Wired Future won top prize at the Pariscience Film Festival on Oct. 11. The documentary was awarded the "Prix Audace" (or Audacity Prize) in a ceremony at the Muséum national d'Histoire naturelle in Paris. The prize recognizes "a film showing originality in its subject matter and treatment."

The Quantum Tamers was produced by the Perimeter Institute for Theoretical Physics. Raymond Laflamme, director of the Institute for Quantum Computing, served as senior scientific advisor for the film, and IQC faculty member Joseph Emerson was a scientific advisor and co-writer.

Frank Taylor, co-executive producer of *The Quantum Tamers*, was on hand to accept the award. The documentary has also recently won a "Best of Show Award" in the television category at the 2009 Accolade TV Awards in California. Roughly 40 films from North America, Europe and Australia were in competition for seven prizes. The top prize went to *The Music Instinct: Science and Song*, an American production from director Elena Mannes.

DR. GREGORY CHAITIN AT IQC

Renowned American computer scientist and mathematical philosopher Dr. Gregory Chaitin delivered a lunch-hour lecture at IQC on Sept. 23 during a week-long visit to Ontario that also included stops at Perimeter Institute and the University of Western Ontario.

Chaitin, an Emeritus researcher at IBM's Thomas J. Watson Research Center, has made significant contributions to algorithmic information theory, including defining his own incompleteness theorem in response to Gödel's incompleteness theorems.

He also writes on the topics of metaphysics and the philosophy of mathematics.

"I consider myself to be a computer programmer who does mathematics as a hobby, a computer programming professional and amateur mathematician," Chaitin wrote in 2007. "I do not consider myself a philosopher. I have been forced to face some philosophical issues because of the kind of mathematics I do."

During his visit to IQC, Chaitin presented a talk titled: "Algorithmic information as a fundamental concept in physics, mathematics & biology."

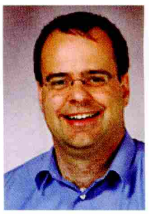
DR. FRANK WILHELM SHARES IN US GOVERNMENT GRANT

The Quantum Device Theory group led by IQC faculty member Dr. Frank Wilhelm was awarded in September a multi-institution grant to fund research into advanced materials for superconducting qubits.

The grant, funded by the Intelligence Advanced Research Projects Activity (IARPA), an initiative of the United States government, will benefit experimental groups at Syracuse University, IBM and University of California-Irvine, in addition to the IQC group.

The project is a collaborative effort between materials scientists and physicists to investigate how to produce solid materials that are as free from imperfections as possible.

Dr. Wilhelm will receive $100,000 USD per year for up to five years to support his work modeling Josephson junctions – a key component of integrated circuits for quantum computing.



Josephson junctions are composed of two layers of superconducting material separated by a thin layer of an insulator. Dr. Wilhelm's group works to create very detailed models of imperfections and noise in Imperfections in solid materials are a limiting factor for progress in advancing hardware for quantum computation. By eliminating imperfections, researchers can increase the coherence time of computations.

"Quantum information is very sensitive to noise, and I am glad that we can work with top materials scientists to solve this problem," Dr. Wilhelm said.

SO LONG AND WELCOME

WELCOMING THE BEST & BRIGHTEST

Seth Merkel
Postdoctoral Researcher

Seth completed his Ph.D. at the University of New Mexico (2009) under the advisement of Ivan Deutsch. His Ph.D. thesis work was on quantum control of d-dimensional quantum systems with application to alkali atomic spins.

Bei Zeng
Postdoctoral Researcher

Bei Zeng received the B.Sc. degree in physics and mathematics and M.Sc. degree in physics from Tsinghua University, Beijing, China, in 2002 and 2004, respectively. She received the Ph.D. degree in physics from Massachusetts Institute of Technology (MIT), Cambridge, Massachusetts, USA, in 2009.

Lawrence Ioannou
Postdoctoral Researcher

Lawrence completed his Ph.D. at the Department of Applied Mathematics and Theoretical Physics (DAMTP) at the University of Cambridge (2005); his thesis was on the computational complexity of the quantum separability problem. He then won a three-year EPSRC research grant to investigate quantum-public-key cryptography, also at Cambridge, while he was a Research Fellow at Clare Hall. At IQC, he continues to work on quantum cryptography.

Jasmine Graham
Communications Specialist

A graduate of The University of Western Ontario and Humber College's Public Relations program, Jasmine joined IQC in November to specialize in web-based outreach and social media. Jasmine is a competitive rower, a rowing coach and an accomplished double-bassist with the Steeltown Symphony and Dundas Valley Orchestra.

NEW STUDENTS

Graduate Students:
Varun Narasimhachar
Cheng Shen
Nicholas LeCompte
Thomas McConkey
Amir Eftekharian
Milad Khoshnegar
MirMojtaba Gharibi
Stacey Jeffery

Undergraduate Research Project Student:
Max Julian

Colin Hunter
Communications Specialist

Prior to joining IQC, Colin was a reporter at the Waterloo Region Record for seven years, during which time he won the National Newspaper Award and Canadian Science Writers' Association Award. He joined IQC in November with a focus on science writing and outreach.

Suzette Pearson
Executive Assistant

Prior to joining IQC in November, Suzette worked in related capacities at a number of firms including Pricewaterhousecoopers LLP, RSM Richter Inc and the Canadian Arthritis Network. Suzette will assist in many administrative duties, especially for Raymond Laflamme. In her spare time she plays ultimate frisbee and hunts moose.

Laurie Kitchen
Financial Analyst

Laurie joined the staff at IQC in October in a part-time capacity to assist with finances. Laurie worked at a number of organizations prior to IQC, including a 17-year career as a director of Financial Management Consulting at Sun Life Financial / Clarica.

Brian Goodard
Senior Fabrication Equipment Technologist/Lab Instructor

Brian joined IQC in August with a wealth of experience as a technologist at a number of electronics companies in Ottawa, including a decade as a service engineer at Canon Canada, Inc.

Departures

We bid farewell to members who are leaving us for now, and wish them the best of luck in their future endeavours.

- Xiodi Wu
- Hauke Haeseler
- Normand Beaudry
- Thiru Sivakumaran
- Matt Volpini
- Tzu-Chieh Wei
- Simone Severini
- Mohsen Razavi
- Alex De Souza
- Claire Biddiscombe
- Devon Biggerstaff
- Bharti Desai
- Lana Sheridan
- Mohammad Derakhshani

Rosanne Li
Coop Student

IQC both welcomed back Rosanne (she did an earlier co-op placement last winter) and bade farewell to Rosanne this past fall term. A student of economics and speech communication at UW, Rosanne helped rebuild, streamline and update the IQC Wiki page. Thanks for all your hard work Rosanne!

UPCOMING EVENTS

Future Events

TEDxWaterloo
Feb 25, 2010

A local incarnation of the highly popular online lecture series featuring a talk by Raymond Laflamme.

Visit www.tedxwaterloo.com for more info.

Cross Border Workshop on Laser Science
June 3rd to 5th, 2010

A summit of researchers from Ontario, Michigan and New York State. Several high-profile researchers will give talks about laser science and student attendees will be given the opportunity to give short presentations as well. The workshop will also include a poster session to facilitate interaction between students and researchers.

QCSYS
July 26 to 30, 2010

The Quantum Cryptography School for Young Students is an exciting week-long program offered to Canadian students in grades 10-12. Students are given a first-hand look into quantum cryptography. Not only will students be exposed to cutting-edge topics like quantum physics and cryptography, they will also have the opportunity to meet some of the most renowned researchers the field has to offer.

In addition, students will get a tour of quantum computing and quantum cryptography experiments. The program requires that applicants have taken (or are currently taking) Grade 11 mathematics. Grade 11 physics is recommended for QCSYS.

Grad Program Gets UW Approval

The University of Waterloo recently approved a proposed graduate program in quantum information that promises to give students an unprecedented breadth of study in the field.

The collaborative program — created with consultation and approval from six academic units, three faculties and the university Senate — will expose students to a wide range of advanced research projects and courses on the foundations and implementations of quantum information processing.Though the program is pending approval from the Ontario Council on Graduate Studies (OCGS), applications are now being accepted for the Fall 2010 term.

The graduate program is unique in North America, possibly the world, because of its scope and breadth, encompassing both experimental and theoretical aspects of quantum information. Students will be required to take two key courses: Quantum Information Processing, and Implementation of Quantum Information Processing. Students will be based in their home program and earn a Quantum Information qualification to their degrees; for instance, Master of Mathematics in Computer Science (Quantum Information), or Doctor of Philosophy of Science in Chemistry (Quantum Information).

Faculty from IQC will be instructors for the new courses, including: Debbie Leung (Theory of Quantum Communication), Norbert Lütkenhaus (Applied Quantum Cryptography), and Frank Wilhelm (Implementation of Quantum Information Processing). Students enrolled in the quantum information graduate program will be eligible for the Mike and Ophelia Lazaridis Fellowship scholarship.

Quantum Information Processing with Solid State Systems Workshop
May 17 to 19, 2010

A three-day lecture series on solid-state QIP. The workshop will focus on high-fidelity single and two-qubit gates, new designs and superconducting qubits, decoherence sources and error estimations, generating and measuring entanglement, encoded spin qubits (singlet-triplet vs. singlet-spin) and hybrid systems.

The workshop will also include a poster session, which will provide the opportunity for IQC members with a more mathematical or quantum-optical background to share their work with the invited participants.

Faculty Retreat
March 6, 2010

Faculty will meet for a retreat on Saturday March 6th, away from day-to-day distractions, in order to discuss the medium and long-term objectives, goals and strategies of IQC.

USEQIP
May 24 to June 4, 2010

Undergraduate school on Experimental Quantum Information Processing (USEQIP) is a two-week program on the theory and experimental study of quantum information processors.

The program is targeted toward students just completing their third year as an introduction to the field of quantum information processing. The two-week program consists of lectures introducting quantum information theory and experimental approaches to quantum devices, followed by hands-on exploration of QIP using the experimental facilities of IQC.

For questions, comments or general feedback regarding IQC, contact:
iqc@iqc.ca

IQC IN ACTION

QUANTUM TO COSMOS FESTIVAL RECAP

IQC researchers joined scientists from around the globe in October for Perimeter Institute's Quantum to Cosmos festival, a 10-day celebration of science in Waterloo.

The festival, which marked the 10th anniversary of Perimeter Institute, featured dozens of lectures, panel discussions, interactive exhibits and a week of live broadcasts of TVO's *The Agenda with Steve Paikin*.

Raymond Laflamme appeared on *The Agenda* for a program entitled "Wired 24/7," and later joined PI director Neil Turok and COSMOS Magazine editor Wilson Da Silva for the "Q2C Wrap-Up" panel discussion.

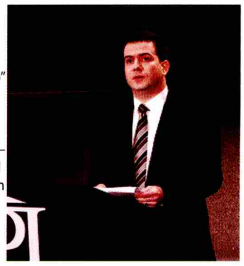


Photo Credit Ian Adare

Michele Mosca moderated a discussion called "Harnessing Quantum Physics," during which a panel of renowned experts — including Peter Shor, Avi Widgerson, Dorit Aharonov and Daniel Gottesman and Ignacio Cirac — explored the future of quantum computing.

Anne Broadbent, a postdoctoral fellow at IQC, participated in one of the festival's "Science in the Pub" sessions — informal chats with scientists hosted at The Huether Hotel in downtown Waterloo.

The Quantum To Cosmos festival was a resounding success scientific outreach, thanks in no small part to the outstanding contributions of IQC representatives.

STEVE MACLEAN VISITS IQC

IQC was honoured to host astronaut Steve MacLean, who toured our laboratories on Dec. 4. MacLean, who is president of the Canadian Space Agency, visited IQC as part of a tour of universities and other academic institutions. Given that he has a PhD in physics with a specialty in laser optics, MacLean came to IQC armed with questions and curiosity about the work being done at the institute.

MacLean, an Ottawa native, became the second Canadian in history to perform a spacewalk when he served as a Mission Specialist on STS-115, which launched on Sept. 9, 2006. On that mission, he also became the first Canadian to operate the robotic arm Canadarm2. Around the time of that mission, Steve MacLean Public School in Ottawa was named in his honour.

Thanks to everyone who participated in giving a tour to this distinguished guest.

IQC HOLIDAY CELEBRATION

During a fierce December storm, IQC members and their loved ones gathered within the cozy confines of the Waterloo Inn for IQC's Seasonal Gathering on December 10th.

Roughly 40 children of the IQC family enjoyed a visit from Santa Claus (who looked a bit like Lorna Kropf's husband, Larry), while their parents dined from a bountiful buffet. In his pre-dinner remarks, Raymond Laflamme acknowledged the generous gifts IQC received in 2009, including a donation of $25 million from "IQC's own Santa Claus," Mike Lazaridis, and $50 million from Industry Canada.

Raymond thanked the researchers, students and staff of IQC for making 2009 another stellar year, and made a toast to further successes in 2010.

After-dinner entertainment was provided by local magician Scott Hammell, who bantered easily with the children seated in front of the stage while he juggled, performed magic tricks and escaped from a straightjacket.

Thank you to everyone who attended the gathering, and here's to a great 2010.

Visitors

- Robin MacNab – Trade Commisioner, Ontario Region, Foreign Affairs and International Trade
- Robert Ulmer – Ontario Representative for Japan
  Waichi Sekiguchi – Nikkei Inc. Japan
- Ramy Nassar – RIM
- Renjie Butalid – TedX Waterloo
- Giuseppe Prettico – ICFO Barcelona
- Otfried Guhne – Institut fur Quantenoptik und Quanteninformation
- Ray Filteau – Carnegie Mellon University
- Jessica Zhang – Carnegie Mellon University
- Dmitry Gavinsky – NEC Laboratories America
- Jerome Bourassa – Universite de Sherbrooke
- Anya Tafliovich – University of Toronto
- Steve MacLean – Canadian Space Agency
- Alex Russell – University of Connecticut
- Frederic Grosshans – Laboratoire de photonique quantique et moléculaire (LPQM)
- William Wooters – Williams College LTV at PI
- Chris Payette – McGill University
- Paul Nation – Dartmouth College
- Chris Laumann – Princeton University
- Olena Huzar
- Sergei Alilujko
- Adi Shamir – Weizmann Institute of Science, Israel
- Adan Cabello – Universidad de Sevilla
- Katja Nowack – Delft University of Technology
- Sarah Sheldon – MIT
- Mohamed Abutaleb – MIT
- Daniel Kumar – MIT
- Myroslaw Tataryn

UNDER CONSTRUCTION

Speakers

Sept. 14 -- Erik Lucero, "High-fidelity gates in Josephson phase qubits."

Sept. 21 -- Nicolas Menicucci, "Entangling Power of an Expanding Universe."

Sept. 24 -- Greg Chaitin, "Algorithmic information as a fundamental concept in physics, mathematics and biology."

Sept. 28 -- Jerry Chow, "Quantum Algorithms and Entanglement Metrology with Superconducting Qubits."

Oct. 5 -- Howard Wiseman, "Rapid Cooling and Read-out by Continuous Measurement and Control."

Oct. 19 -- John Watrous, "QIP = PSPACE."

Oct. 26 -- Adan Cabello, "Quantum contextuality: Experiments and applications."

Nov. 2 -- Katja Nowack, "Coherence and control of single electron spins in quantum dots."

Nov. 9 -- Bei Zeng, "Graph Concatenation for Quantum Codes."

Nov. 16 -- Seth Merkel, "State Transfer in Atomic Spin Systems."

Nov. 23 -- Jonathan Baugh, "Electron spin qubits: nanowire devices and robust control."

Nov. 26 -- Otfried Guhne, "The compatibility loophole in Kochen-Specker experiments."

Nov. 30 -- Anya Tafliovich, "On writing correct quantum programs."

Dec. 12 -- William Wootters, "The Entanglement Cost of a Nonlocal Measurement."

QNC BUILDING UPDATE

Construction is approximately one-third complete on IQC's future home, The Mike and Ophelia Lazaridis Quantum-Nano Centre. Slated for completion in 2011, the building will be a state-of-the-art facility housing both IQC and the Waterloo Institute for Nanotechnology.

You can watch the construction process as it happens on a live webcam at http://uwaterloo.ca/qnc. Above in an artist's rendition of the QNC building and to the right are some screenshots from the webcam site taken in late December.

NEW LAB SPACE AT IQC

A new IQC laboratory focussed on superconducting quantum devices is in the works under the guidance of faculty member Adrian Lupascu.

Completion of the lab now hinges on the arrival of two main pieces of equipment, expected to be delivered within in late January.

The first, a dilution refrigerator, will create extremely low temperatures of roughly 20 mK, which is essential for observing quantum behaviour in the lab's devices. The second is a thin film evaporator, which is crucial in the fabrication of qubit devices and will be installed in IQC's clean room.

Once the lab is complete, experimental activity will explore two key subjects: quantum computing with superconducting qubits, and the interaction between artificial atoms and "light" at microwave frequencies.

Experiments should begin in early 2010, with the help of PhD student Jean-Luc Orgiazzi, master's students Chunqing Deng and Jason Soo Hoo, and postdoctoral affiliate Jay Gambetta.

Looking toward the future, Lupascu hopes to expand research activities to hybrid quantum systems, and sensitive measurements using superconducting devices.

LIFE AT IQC

IQC Photo Gallery

Optics Lab

A visit from Santa. M. Hossein & M. Javad

Maddox Gambetta

Scott Hammell entertains at the IQC holiday party

Trick-or-treating at IQC

Quantum Dance

IQC Open House, October 17

Bill Coish and Maddox Gambetta at the Toronto Zoo

Students working in the Quantum Optics Lab at IQC

Send us your photos for the next IQC newsletter to iqc@iqc.ca

IQC THANKS ITS PARTNERS FOR THEIR CONTINUING SUPPORT OF OUR VISION

MIKE & OPHELIA LAZARIDIS

- AND -

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Canadian Institute for Advanced Research
Centre for Applied Cryptographic Research
The City of Waterloo
Communications Securities Establishment Canada
Government of Canada
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Industry Canada
Institute for Computer Research
Mathematics of Information Technology and Complex Systems
Natural Sciences and Engineering Research Council of Canada
Ontario Centres of Excellence
Ontario Ministry of Research and Innovation
Ontario Innovation Trust
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