



I > FORMER NSERC PRESIDENT ON BOARD
 'NEWLY CREATED'.....2



I > EXECUTIVE DIRECTOR BROUGHT ON BOARD.....2



I > IQC'S NEW HOME GETS A DESIGNER.....3

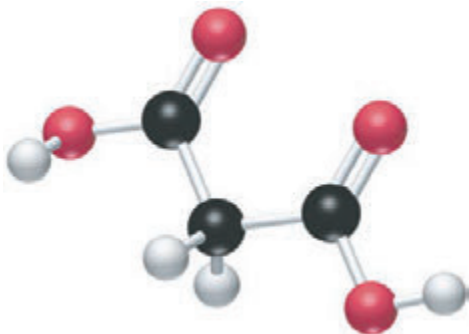


THE INSTITUTE FOR QUANTUM COMPUTING

NewBit

EXPERIMENTAL RESULTS GARNER INTERNATIONAL ATTENTION

IQC RESEARCHERS ADDRESS KEY EXPERIMENTAL CHALLENGE IN QUANTUM INFORMATION PROCESSING



Researchers from the University of Waterloo's Institute for Quantum Computing (IQC), in a paper published in Nature, have taken a major step forward in finding out how to make quantum information processing devices more powerful than today's computers.

Their work is presented in the Nov. 24 issue of the prestigious international journal. The paper, titled "A Spin-Based Heat Engine: Experimental Implementation of Heat-Bath Algorithmic Cooling," was written by IQC members Jonathan Baugh, Osama Moussa, Colm Ryan, Ashwin Nayak and Raymond Laflamme.

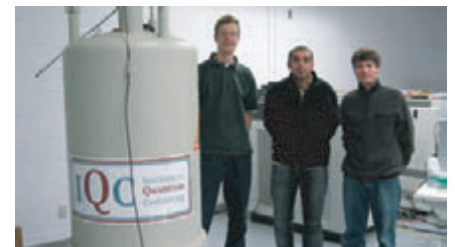
The paper discusses challenges of quantum computing implementations which seek to utilize quantum mechanical laws (laws that govern microscopic objects like atoms and molecules) to make information processing devices fundamentally more powerful than today's computers.

"An important ingredient in the physical implementation of these devices is the ability to initialize the quantum carriers of information (qubits) and to keep them 'cool,'" said IQC Director Raymond Laflamme, who is also a Long-Term Researcher at the Perimeter Institute for Theoretical Physics and a Physics professor at UW.

The work published in Nature describes the implementation of a powerful form of cooling, called heat-bath algorithmic cooling, in a solid-state nuclear spin system. It is a high-precision demonstration of this technique in a promising quantum information processing system.

Reviewers noted that the paper is a significant contribution to the field of quantum computation. According to one reviewer: "This manuscript reports on one

of the key experimental challenges in quantum information processing." A second reviewer said: "The experiment reported on in the paper is a carefully designed and meticulously executed piece of work. The result is a tour de force that marries experiment to theory in an elegant and convincing demonstration of the effect."



IQC Researchers (Left to Right) Colm Ryan, Osama Moussa and Jonathan Baugh

Dr. Jonathan Baugh is an IQC postdoctoral fellow researching solid-state NMR implementations for quantum computing. Osama Moussa and Colm Ryan are Ph.D. candidates in the Physics Department at University of Waterloo. Ashwin Nayak is an assistant professor in the Combinatorics and Optimization Department as well as an associate member of the Perimeter Institute.

The paper can be found in Nature 438, 470-473 (24 Nov 2005) or online at <http://www.nature.com/nature>.



RAPID GROWTH CONTINUES

NEWLY CREATED SENIOR ADVISOR POSITION BRINGS KEY LINKAGES TO INDUSTRY, GOVERNMENT

We are pleased to announce that Dr. Tom Brzustowski has been appointed to the newly created position of Senior Advisor, for an initial period of three years.

Dr. Brzustowski will "fulfill a special role in advancing the Institute," says a UW press release from provost Amit Chakma, "by establishing linkages with industry and governments as well as national and international research organizations and individuals."

An engineer, Brzustowski graduated with a B.A.Sc. in Engineering Physics from the University of Toronto in 1958, and a Ph.D. in Aeronautical Engineering from Princeton in 1963. He was a professor in the Department of Mechanical Engineering at the University of Waterloo from 1962 to 1987, teaching and carrying out research in thermodynamics and combustion. He served as Chair of Mechanical Engineering from 1967 to

1970 and as Vice-President, Academic of the University from 1975 to 1987. After that he served as deputy minister in



Dr. Tom Brzustowski (right) with UW Chancellor Mike Lazaridis at the NSERC Synergy Gala 2004

the Government of Ontario from 1987 to 1995, first in the Ministry of Colleges and Universities, and later in the Premier's Council. He was appointed President of NSERC in October 1995, and reappointed in 2000.

INDUSTRY CANADA ASSOCIATE DEPUTY MINISTER TO INAUGURATE "EXECUTIVE DIRECTOR" POSITION

IQC is pleased to announce the appointment of Dr. David Fransen as Executive Director. David most recently served as Industry Canada's Assistant Deputy Minister, Policy Sector and joined IQC in early January for an initial term of two years under the federal government's Executive Interchange Program.



Dr. Fransen speaks at the International Telecommunication Union Plenipotentiary Conference,

As the Executive Director, David will have strategic and management responsibilities for IQC.

David has also been appointed Associate Vice-President (Strategic Relations) of the University of Waterloo, where he will provide "critical leadership in establishing strategic relations and partnerships with key industry sectors and firms, research institutes, and community, provincial, national and international economic development leaders."

David received both his Bachelor of Arts and his Master of Arts degrees in History at the University of Waterloo, and he received his Ph.D. in 1984 at the University of Toronto. Since then, David has served in various capacities with several federal departments including the Department of National Defence, the Privy Council Office, Health Canada, and Industry Canada.



Welcome

The Institute is proud to have welcomed four new members over the fall term:

- ▶ Professor Joseph Emerson was appointed assistant professor in the UW Department of Applied Math and a member of IQC in early August. His research includes quantum control and noise estimation.
- ▶ Professor Debbie Leung joins IQC from the California Institute of Technology. She is the Canada Research Chair in Quantum Communication, where her research enhances computer security and provides more efficient quantum communication techniques.
- ▶ Before joining IQC, Dr. Scott Aaronson was a PhD student at UC Berkeley and then a postdoc at the Institute for Advanced Study in Princeton. His research deals with the limitations of quantum computers, and other topics at the intersection of computational complexity and physics.
- ▶ IQC also welcomed graduate students Sarvagya Upadhyay from Banaras Hindu University, Adam Hubbard from the University of Washington, as well as Jamie Sikora, Matthew McKague and Zhizhong Yan from the University of Waterloo.

We are also excited to welcome twelve new researchers starting in January 2006:

- ▶ Professor Frank Wilhelm joins IQC from the Department Physik and Center for Nanoscience, Ludwig-Maximilians-Universität. His previous research has involved quantum information with superconducting circuits. We also welcome Dr. Wilhelm's group, including Dr. Austin Fowler and researchers Patrick Rebentrost and Ioana Serban.
- ▶ Professor Norbert Lütkenhaus comes from the Institute of Optics, Information and Photonics at Friedrich-Alexander University. His team will include researchers Matthias Heid, Tobias Moroder, Hauke Hauseler, Volkher Scholz and Geir Ove Myhr.
- ▶ Dr. Christophe Couteau will join Professor Gregor Weihs' Photon Entanglement Group.
- ▶ Behnood Ghamsari will join the Integrated Quantum Optoelectronic group of Professor A. Hamed Majedi.





\$70 MILLION NEW HOME

NEW HOME FOR IQC ONE *BIT* CLOSER

The University of Waterloo has awarded the commission to design a new \$70-million facility for quantum computing and nanotechnology to Kuwabara Payne McKenna Blumberg Architects (KPMB). The firm will also engage the specialized services and expertise of HDR, multi-disciplinary specialized consultants in nanotechnology laboratories, quantum computing and clean room facilities. The combination of expertise will ensure creative design solutions for all elements of the program.

KPMB was selected from over 20 firms to design the new state-of-the-art building. The new 225,000-square-foot (20,250-square-metre) facility will be strategically sited to facilitate interaction between the disciplines of Engineering, Science and Mathematics.

The project will proceed under the direction of Marianne McKenna, principal-in-charge, and Mitchell Hall, design architect. McKenna and Hall have previously collaborated on the internationally acclaimed Jackson-Triggs Winery at Niagara-on-the-Lake and the McGill University and Genome Quebec Innovation Centre.

"The university is pleased to engage KPMB and looks forward to the realization of our dream to create a centre that will be the finest expression of design anywhere and will house what will emerge as the finest cluster of quantum computing and nanotechnology researchers, teachers and students in the world," said David Johnston, UW president.

"As universities compete for the best students, faculty and scholars, it is critical to create a facility that complements the high-quality academic program of the University of Waterloo and offers a state-of-the-art facility for both teaching and research in quantum computing and nanotechnology," KPMB's McKenna said.

"We are excited by the challenges of the project -- the specific demands of the site, the constraints of the campus, interior planning considerations, and the integration of highly technical systems. Our strategy will be to resolve these with inventiveness, skill and imagination."

Hall added: "We envisage an architectural response that expresses the revolutionary nature of nanotechnology and quantum research within the context of the University of Waterloo's research program."



KPMB Projects: Fields Institute at the University of Toronto (top left), McGill University & Genome Quebec Innovation Centre (bottom), James Stewart Centre for Mathematics at McMaster (far right)

At the same time, we will study how the new building can continue the existing network of courtyards which distinguish the campus and how linkages can be created to adjacent Faculties both above and below ground."

The facility has been given a huge kick-start through a \$50-million donation to UW from Mike and Ophelia Lazaridis. Lazaridis is the founder and Co-CEO of Research In Motion (RIM), and UW's Chancellor.

KPMB, one of Canada's leading architectural practices, has received more than 70 awards for design excellence and is the recipient of nine Governor General's Awards, Canada's highest architectural honour. The practice was founded in 1987 by Bruce Kuwabara, Thomas Payne, Marianne McKenna and Shirley Blumberg. In 2005, KPMB was named Firm of the Year by the Royal Architectural Institute of Canada.

KPMB's projects include the Kitchener City Hall and the Grand Valley Institution, both recipients of Governor General's Awards. Currently the firm is responsible for creating new architecture for some of Canada's major cultural institutions, including the Royal Conservatory of Music, the National Ballet School, the Gardiner Museum of Ceramic Art, the Canadian Museum of Nature, and the Toronto International Film Festival.

Recent laboratory and science projects include: the James Stewart Centre for Mathematics at McMaster University, which received the prestigious 2005 American Institute of Architects (AIA) Award of Honour, the Faculty of Engineering and Computer Sciences at Concordia University, the Centennial HP Science and Technology Centre for Centennial College, and the McGill University and Genome Quebec Innovation Centre in Montreal.

The new building for Quantum Computing and Nanotechnology presents a unique opportunity for KPMB to build on previous innovations in laboratory and educational facility design.

The practice brings extensive experience and the capacity to mitigate the pragmatic requirements for science facilities with distinctive architectural expressions that create supportive and inspiring platforms for research and innovation.

Attracting faculty and students of the highest caliber to quantum computing and nanotechnology engineering at UW will give tremendous support to creativity and research output in this field, while also enhancing the capacity of the local Waterloo Region, provincial and Canadian economies through infusion of talent, new discoveries and potential commercial



POTENTIAL ON THE RISE



Visitors

IQC IS HONOURED TO HAVE HOSTED THESE DISTINGUISHED GUESTS OVER THE SUMMER AND FALL OF 2005:

Jae-Seung Lee - Kent University
 Britton Plourde - University of Syracuse
 Hideo Mabuchi - Caltech
 Ignacio Cirac - Max Planck I.Q.
 Iordanis Kerendis - MIT
 Arvid Bessen - Columbia University
 Martin Roettler - NEC Laboratories
 Mark Hillery - Hunter College
 Mika Hirvensalo - University of Turku
 YeonJin Chung - Los Alamos N.L.
 Ben Reinhardt - UC Berkeley
 Sir Keith O'Nions - Oxford
 William Irvine - UC Santa Barbara
 Konrad Banaszek - St. John's College
 Edward Farhi - MIT
 Terry Rudolph - Imperial College
 Vincent Danos - University of Paris II
 Dmitry Gavinsky - University of Calgary
 Richard MacKenzie - U. de Montréal
 Philippe Grangier - Lab. Charles Fabry
 Tanja Reize - University of Munich
 Dan Brown - Oxford University
 Sagarmoy Dutta - IIT Kanpur
 Robert Spalek - CWI Amsterdam
 Peter Richter - Rutgers
 Alastair Kay - Cambridge University
 Jens Eisert - Imperial College
 Henry Haselgrove - U. of Queensland
 Mark Dowling - U. of Queensland
 Ross McGregor - TRRA
 Fernando Cucchietti - Los Alamos N.L.
 Man-Duen Choi - University of Toronto
 Xiongfeng Ma - University of Toronto
 Pranab Sen - NEC Laboratories
 LianAo Wu - University of Toronto
 Charlie Bennett - IBM
 Michael DesChamps - U. de France
 Masaoto Koashi - Osaka University
 Henri Angelino - N.I.I. Tokyo
 Rusins Freivalds - University of Latvia
 Lawrence Ioannou - Cambridge University

CANADIAN RESEARCH CHAIR OF QUANTUM COMMUNICATION SETS UP SHOP

Professor Debbie Leung joined the University of Waterloo in mid August, 2005. She is appointed in the Department of Combinatorics and Optimization and at the Institute for Quantum Computing.

She is still settling in her office in MC 4036, and has various locations, such as the C&O departmental lounge, the student lab in MC 5136A, various rooms at BFG and the Perimeter Institute.

Her research interest is just as delocalized, as can be seen from her recent submissions to the arXiv. In the past few months, she has been working on measurement-based QC, fault-tolerance (with Aliferis), noisy quantum communication (with Childs and Lo), randomized techniques in quantum information (with G. Smith), and quantum cryptography (with Horodecki, Lo and Oppenheim). This manifests the impossibility of commitment to a particular area, and her willingness to be distracted by anyone's problem and to work with a wide range of people.

To facilitate further distractions, Debbie submitted a proposal to CFI and was approved to construct a "Quantum Communication Research Hub" in MC, to serve offices 5161, 5162, and 5077. The

hub will serve multiple purposes and it will be equipped with simple webcam, speaker phone, internet connections, and data projection facilities that will allow external parties to join discussions held on campus. There will be computers and a library, so that research and discussion can continue nonstop (until the researchers' batteries run out). There will also be a simple digital camera to record discussions. Since her arrival, Debbie has been finalizing this project, with construction starting November 16th.

Debbie has also been taking a crash course on teaching and how to motivate students and graders alike.

Away from work, she has found a place to live, been visiting a dozen bureaus, and has been busy learning how to survive in the coming winter.

Despite (and through) several accidental misfortunes, Debbie has fully experienced the kindness of people around her (at IQC, C&O, UW, PI, her neighborhood, and the Kitchener-Waterloo area) that was much underestimated before her arrival.

DONATION PAVES WAY FOR GRADUATE RESEARCH

The Institute for Quantum Computing has received support from the Bell Family Fund to sponsor research scholarships for graduate students who show outstanding promise for research excellence in Quantum Information Science.

The scholarships will be awarded on the basis of merit to students pursuing their graduate studies under the direction of a full or associate member of the Institute for Quantum Computing.

Recipients for Winter 2006:
Christopher Erven
Adam Hubbard

NMR Q.I.P. PIONEER TO WORK CLOSELY WITH IQC

Professor David Cory, Nuclear Engineering at MIT, is joining the IQC as an adjunct Professor in Chemistry. David has collaborated with IQC faculty since its inception and this appointment leads to a more formal relationship.

Professor Cory's interest and specialization is to advance the state of the art in magnetic resonance methods and applications. The approach might be termed magnetic resonance engineering: the individual projects he tackles are problems focused with a significant engineering component up front, and hopefully a large payoff when they succeed. The engineering developments permit close ties to industry, and many of the advances have been commercialized. Many projects Professor Cory has worked on include emulation of quantum computers by mixed ensembles of spins, development of coherent control methods for quantum information processing and their demonstration via nuclear magnetic resonance.



CALIBRE OF OUR TEAM

CANADIAN INSTITUTE FOR ADVANCED RESEARCH DISTINGUISHES IQC DIRECTOR

The director of the Institute for Quantum Computing at the University of Waterloo has a new distinction to add to his lengthy curriculum vitae.

Professor Raymond Laflamme has been named the Ivey Foundation Fellow of the Canadian Institute for Advanced Research (CIAR). In supporting his research, the Ivey Foundation (formerly The Richard Ivey Foundation) has become one of the founding supporters of CIAR's Quantum Information Processing (QIP) Program. Laflamme has been the director of the program since 2002.

Quantum Information Processing is a very young field that promises exponential increases in computing power, likely in the form of a quantum computer. The goal of the CIAR QIP Program is to harness the laws of quantum mechanics and turn them to our advantage to improve the acquisition, transmission, storage and processing of information.

The questions at the core of the investigation are: What is the origin of the power of quantum information? What can we do with quantum information? How do we build devices that can behave quantum mechanically so that we can take advantage of quantum mechanics?

"We are very excited about the intellectual challenges posed by the QIP Program," said Bruce Lourie, President of the Ivey Foundation. "We look forward to having Dr. Raymond Laflamme be the new Ivey Foundation Fellow at CIAR and to following his work closely."

"Quantum mechanics was discovered more than a hundred years ago, but it is only recently that we learned of its tremendous power to manipulate information."

"The CIAR QIP Program has allowed us to bring together an international team of mathematicians, computer scientists and physicists to harness its power and open the doors to a new world of unexpected discoveries, from fundamental concepts to new technological developments," Laflamme said.

The Ivey Foundation has supported a variety of CIAR Programs since 1986 (first Artificial Intelligence and Robotics, then Population Health, and after that Evolutionary Biology), helping to build and sustain the Institute's capacity for leading-edge discoveries in each of these fields.

"Once again, the Ivey Foundation is demonstrating its astute intellectual insight in choosing to support the emerging field of QIP," said Chaviva Hosok, President and CEO of CIAR. "Canada has great potential to lead the world in this area of research."

The Ivey Foundation is a private charitable foundation located in Toronto. It was incorporated on Dec. 31, 1947 by the late Richard G. Ivey, LL.D., Q.C. and his son, Richard M. Ivey, C.C., LL.D., Q.C. The foundation's mission is to improve and enrich the well-being of Canadians by focusing its energy and resources on selected issues of significance.

Laflamme is one of the world's leading researchers in the study of quantum devices. He co-founded the Institute for Quantum Computing at UW, where seven out of 18 CIAR QIP Program Members are based, and holds a Canada Research Chair in Quantum Information.

He completed his PhD in the Department of Applied Mathematics and Theoretical Physics (DAMTP) at Cambridge University, under the direction of esteemed physicist Stephen Hawking. He and a colleague are responsible for changing Hawking's mind on the reversal of the direction of time in a contracting universe.



IQC Director Raymond Laflamme

CIAR is a pan-Canadian and international research institute committed to identifying significant intellectual questions in the natural and human sciences and bringing together top researchers to collaborate closely on them.

The QIP Program is one of twelve leading-edge research initiatives currently being led by CIAR. There are more than 250 eminent researchers collaborating through CIAR, representing more than 80 different research institutions and universities in 13 countries.

IQC STUDENT AWARDED ALUMNI GOLD MEDAL FOR Ph.D. STUDIES

Congratulations to Dr. David Poulin, who was awarded the Alumni Gold Medal for outstanding academic performance on completion of a Ph.D. program at Waterloo. This medal was awarded at Fall Convocation in October.

"David was supervised by Dr. Raymond Laflamme who should also be commended for providing such superb guidance in the past years," reads a memo from Wing-Ki Liu, Associate Dean of Science Faculty Graduate Studies.

David received his degree in June, and is now a Postdoctoral Research Fellow at the School of Physical Sciences, University of Queensland, Australia. Professor Ray Laflamme supervised his thesis, "Emergence of a Classical World from Within Quantum Theory" -- a "beautiful" thesis, according to the external examiner.

Dr. Poulin's work was reported in physics journals and in the prominent magazines *New Scientist* and *Nature*. He has published 12 papers, including five in *Physical Review Letters*.



Staff

IQC is delighted to announce that Michael Ditty and Connie Slaughter have received UW staff recognition awards for their work in 2005. Only 250 are awarded each year and both individuals are very much deserving of the award.

IQC is very lucky to have these two dedicated staff members to support us.



THE IQC FAMILY

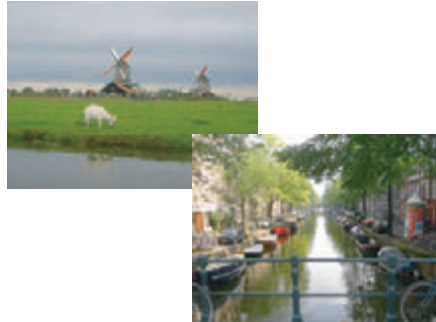
DEPUTY DIRECTOR



IQC is delighted to congratulate our Deputy Director, Michele Mosca on his recent marriage. Nelia Branco and Michele Mosca were married July 1st in Waterloo.

Nelia and Michele would like to thank the members of the IQC for the kind wishes and generous gifts they have received.

Professor Mosca is currently on a 6 month sabbatical leave. He visited the quantum computing group at the Centrum voor Wiskunde en Informatica (Center for



Mathematics and Computer Science) Amsterdam for 3 weeks in September, the Centre for Quantum Computation in Cambridge UK for 3 weeks in October, the Berkeley Quantum Information and Computation Center for 2 weeks in November, and will visit the Institut Henri Poincaré for 3 weeks in January to participate in their "Quantum Information, Computation and Complexity" programme.



Travel

VIENNA



Dr. Gregor Weihs traveled to Vienna, Austria to give a talk completing his "Habilitation" for Experimental Physics. Upon completion, Dr. Weihs was awarded a "Dozent," a type of degree required to officially supervise students.

JAPAN



Dr. Scott Aaronson traveled to Japan to speak at the ERATO Conference on Quantum Information Science (EQIS) 2005 in Tokyo. While visiting, Dr. Aaronson was treated to a three-day excursion to Kyoto, where Hirotsada Kobayashi and Harumichi Nishimura gave a guided tour of famous Buddhist temples, while talking about quantum complexity classes such as QMA/qpoly.

LOUISIANA



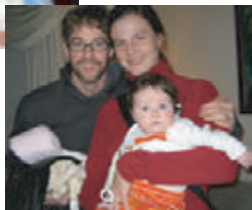
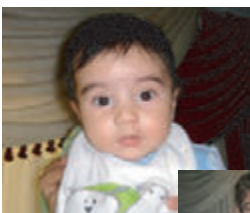
Casey Myers visited the Quantum Sciences & Technologies Group, Baton Rouge, Louisiana State University. As part of his visit, Casey began a collaboration with Jonathan P. Dowling and his group on applications of linear optics quantum computing.

ITALY



Martin Laforest attended the Enrico Fermi International School of Physics course on "Quantum Computers, Algorithms and Chaos," a 10 day summer school bringing together 100 graduate students in the field of quantum computing from around the world. Of the 100 attendees, 15 were selected to present their research results. Martin presented a talk entitled: "Is time reversal an answer to the mystery of entanglement?" Martin received a scholarship from the president of the Italian Physical Society to attend this summer school.

IQC'S YOUNGEST MEMBERS



Farhan Majedi (Left)
Rolf, Karen and Madeleine (Right)

Congratulations to IQC members Hamed Majedi and Rolf Horn who have both recently welcomed new IQC family members.

Hamed and wife Sheva had a son, Farhan, and Rolf and fiancée Karen Gordon had a daughter, Madeleine.

We also extend congratulations to former IQC member Martin Roeteller and his wife Simone Holderbach who recently welcomed Ella Marie to the family.





IQC THANKS ITS PARTNERS FOR THEIR CONTINUING SUPPORT OF OUR VISION



MIKE LAZARIDIS

- AND -

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