Institute for
Quantum Information Science
at the University of Calgary

QUANTUM FRONTIERS

ANNUAL REPORT 2010-2011

vision

To be a world leader in research, teaching, and outreach in pure and applied quantum information science and technology.

mission statement

To conduct world-leading experimental and theoretical research in quantum information;

to provide deep and diverse education and training for senior undergraduate and graduate students;

and to conduct vigorous outreach and service to the public, the University, industry, and the quantum information science community.

key facts

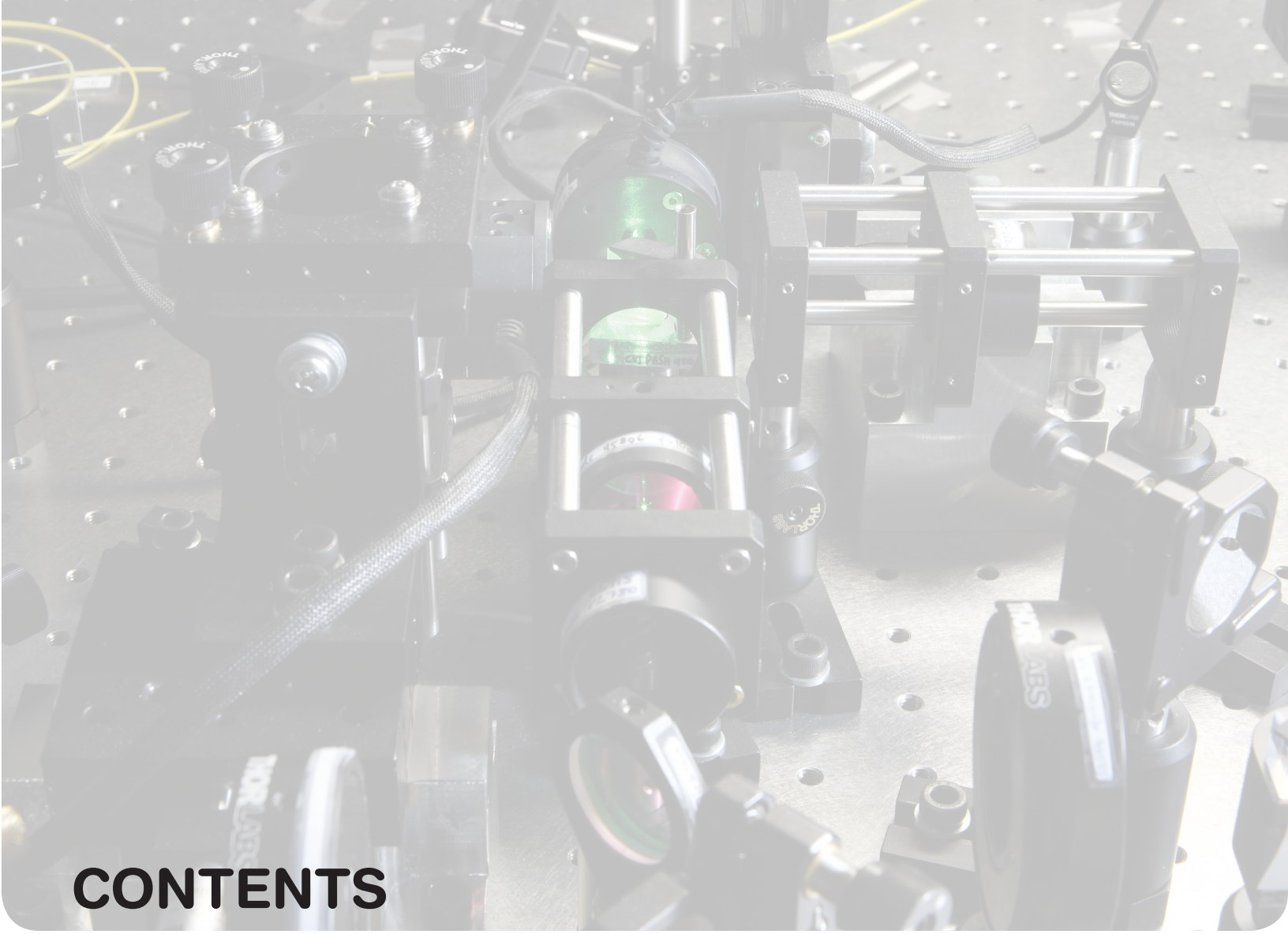
10 postdoctoral associates/fellows, 41 graduate students, and 8 undergraduate students.

36 visiting researchers during the year including 3 long-term visiting professors and 6 long-term visiting students.

47 publications in refereed journals and conference proceedings with 4 published in Physical Review Letters, 1 published in Nature, and 1 published in Proceedings of the National Academy of Sciences.

34 invited talks at national and international conferences/workshops including 1 plenary talk.

$2.8 million cash income in 2010/2011.



CONTENTS

Director's Report

THE INSTITUTE FOR QUANTUM INFORMATION SCIENCE (IQIS) AT THE UNIVERSITY OF CALGARY HAS ENJOYED ANOTHER YEAR OF STRONG PERFORMANCE. THE NUMBER OF FULL FACULTY MEMBERS AND AFFILIATES HAS INCREASED AS WELL AS STUDENT NUMBERS. THE LABORATORIES OF TWO OF THE THREE EXPERIMENTAL GROUPS ARE NOW MATURE AND PRODUCTIVE, AND THE THIRD EXPERIMENTAL GROUP WAS ESTABLISHED IN JANUARY 2011 WITH WORK ON CREATING THE LABORATORY STILL UNDERWAY. COLLABORATIONS AND MEMBERSHIP IN NATIONAL AND INTERNATIONAL NETWORKS HAVE INCREASED. IQIS IS A MAJOR PLAYER IN THE GROWING QUANTUM INFORMATION EFFORT WORLDWIDE.

On a strategic level, Paul Barclay's commencement as a faculty member in IQIS, with a 50% secondment to the National Institute for Nanotechnology (NINT) based in Edmonton, enables bridge-building between Calgary's prowess in quantum science and technology and Alberta's focus and investment in nanotechnology. As nanotechnology reaches smaller scales, the implications of quantum physics will becoming increasingly pronounced, and Calgary's quantum information team will play a vital role in pushing nanotechnology to its ultimate limits.

The field of quantum information science is quite diverse, and IQIS has balanced the competing needs of breadth and depth. The Institute features leading research efforts in computer science, mathematics and both theoretical and experimental physics. At the same time, the Institute has achieved a leading role in the quantum optics side of quantum information research. Experimental work on quantum memory, both in atoms and in solid state, is second to none. As an example Wolfgang Tittel and his group recently demonstrated storage and on-demand release of entangled quantum information in solid state with this work reported in Nature in 2011.

BARRY SANDERS

IQIS continues its leadership role in Canadian quantum information science. I lead the newly established Pacific Institute for Mathematical Sciences Collaborative Research Group on the Mathematics of Quantum Information, which ties together mathematical quantum information researchers at the Universities of British Columbia, Calgary, and Washington and Simon Fraser University. I also am leader of a second network focusing on the mathematics of quantum information: the long-standing Quantum Information Processing Project within the National Centres of Excellent for the Mathematics of Information Technology and Complex Systems (MITACS). This MITACS project includes members from the Universities of British Columbia, Calgary, Sherbrooke, and Waterloo. The focus of our project is on quantum algorithms.

Wolfgang Tittel and I are members of the newly established binational research network called "Frequency". This strategic project jointly supported by France's Agence Nationale de la Recherche (ANR) and Canada's NSERC aims to bring quantum cryptography closer to practical applications in industry and for defence. This consortium involves Canadian researchers at the Universities of Calgary, Montréal, and Waterloo. IQIS is also a member of the European-Canadian network as part of the Program for North American Mobility in Higher Education Collaborative. The specific program to which IQIS belongs provides student training opportunities in quantum information processing through student exchanges and international faculty visits.

IQIS was the host of the annual Canadian Student Conference on Quantum Information Science. This conference is special in that only students and postdoctoral researchers can participate thereby providing a less intimidating environment for early-stage graduate students to share their results with other and to build friendships and links that serve them well throughout their academic career. The conference has strong participation from the international community as well as participation from the main quantum information research groups in Canada.

Although quantum information research at the University of Calgary is strong, IQIS cannot afford to be complacent. Quantum information science is a rapidly growing area of research in Canada and worldwide. Huge groups and investments have been made elsewhere in Canada (especially Waterloo), the United States, Great Britain, Germany, Switzerland, Australia, Singapore, China, and Russia, to name a few. Although IQIS was

established early, governments and universities elsewhere have seized upon the excitement and potential of quantum information and quickly developed enviable capabilities.

Despite this growing competition, IQIS remains a strong player in the field, but further investment is needed to ensure that Calgary is a world leader in select areas of quantum information research. Most importantly IQIS has critical mass in both theoretical and experimental physics but lacks critical mass in mathematics and computer science and is still to establish a foothold in engineering. As quantum information science is a highly interdisciplinary endeavour, critical mass in these core disciplines is needed to ensure sufficient strength to support leading initiatives.

IQIS enables an interdisciplinary seminar and colloquium program, brings its members together in research activities and social events, and ensures that the world knows about and continues to be impressed by the range and quality of its activities.

IQIS continues to be a highly effective, low-cost organizational unit that fosters a culture of outstanding research and development. IQIS enables an interdisciplinary seminar and colloquium program, brings its members together in research activities and social events, and ensures that the world knows about and continues to be impressed by the range and quality of its activities. None of this would be possible without the outstanding administrative team lead by IQIS Administrator Nancy Jing Lu. This team guarantees that our visitors are looked after properly, incoming students and postdocs transition well into Calgary's quantum information experience, alumni keep in touch, and data are complete for performance metrics and reports. An effective organization requires an effective administration, which is the case with IQIS.

Barry Sanders
Director, IQIS

A Message from the Chair

I AM VERY PLEASED TO HAVE ASSUMED THE CHAIR OF IQIS IN JULY 2010 BECAUSE IT IS AN EXCITING AND DYNAMIC GROUP WITH AN AGGRESSIVE AND NOVEL RESEARCH AGENDA. UNDER THE STRONG AND CAPABLE LEADERSHIP OF DR. BARRY SANDERS, IQIS HAS DEVELOPED INTO ONE OF THE WORLD LEADERS IN QUANTUM INFORMATION SCIENCE. THE MULTI–DISCIPLINARY APPROACH TAKEN BY IQIS DRAWS TOGETHER EXPERTISE FROM PHYSICS, MATHEMATICS, AND COMPUTER SCIENCE AFFORDS THE INSTITUTE A UNIQUE AND IMPORTANT NICHE IN THE GENERAL AREA OF QUANTUM SCIENCE.

The IQIS Board met for its annual meeting in July 2010 to set direction and to identify possible opportunities to bring additional industrial, governmental and academic stakeholders into the agenda. Dr. Sanders team has sought new opportunities and worked to position IQIS within the changing operational structures at AET as *i*CORE has evolved into the Alberta Innovates corporations. These efforts have been critical in ensuring that IQIS's valuable research agenda continues into the future.

KEN BARKER

The University has also gone through substantial leadership changes with the consequent changes in approach associated with any such significant administrative transition. IQIS has ensured that quantum's value to the University and its importance has remained at the forefront throughout this process. This will position IQIS to take the next step in its evolution by expanding partnerships both within the University and beyond to industrial stakeholders.

I look forward with great anticipation to its accomplishments in the next year!

Ken Barker
Chair of the Board of Directors, IQIS

Highlights of 2010

A. Research Achievements

OF THE MANY RESEARCH ACHIEVEMENTS IN IQIS DURING THE PAST YEAR, WE HIGHLIGHT THREE. THESE THREE ACHIEVEMENTS HIGHLIGHT BOTH THE EXPERIMENTAL AND THE THEORETICAL NATURE OF QUANTUM INFORMATION SCIENCE. AS WELL THESE HIGHLIGHTS UNDERSCORE THE INTERDISCIPLINARITY THAT EXISTS NOT ONLY AMONGST QUANTUM INFORMATION RESEARCHERS BUT ALSO BEYOND TO WHAT IS SOMETIMES CALLED QUANTUM INFORMATION-INSPIRED RESEARCH, IN THIS CASE TO QUANTUM CHEMISTRY.

Gilad Gour discovered a simple factorization law for multipartite entanglement evolution of a composite quantum system with one subsystem undergoing an arbitrary physical process. In this Physical Review Letters publication, Gour introduced the "entanglement resilience factor", which uniquely determines the multipartite entanglement decay rate. Well known bipartite entanglement evolution emerges as a special case, and this theory also readily reveals whether a permuted version of a given entangled state can be obtained by local operations.

Barry Sanders and his student Nathan Babcock collaborated with Dennis Salahub's group in Chemistry on the metabolic process of electron transfer between proteins. The key result, published in the Proceedings of the National Academy of Sciences, demonstrated that residues on the surfaces of the proteins dynamically organize water bridges to enhance the electron transfer rate, with this process supporting efficient metabolism. The collaboration subsequently yielded an important modification to transition-state theory for calculating electron transfer rates within the semiclassical formalism, with this work published in the Journal of the American Chemical Society.

On the experimental side, long-distance quantum communication took a major leap forward with the demonstration by Wolfgang Tittel's group of entangled light storage and release using solid-state systems. Specifically they demonstrated broadband-waveguide quantum memory for entangled photons with a thulium-doped lithium niobate waveguide in conjunction with a photon-echo quantum memory protocol. This result was published in Nature.

WOLFGANG TITTEL
PHOTO COURTESY OF THE UNIVERSITY OF CALGARY

B. Awards

INTERNATIONAL AWARDS

CARLSBERG FOUNDATION POSTDOCTORAL GRANT (DENMARK)
Daniel Oblak

INTERNATIONAL QUANTUM COMMUNICATION AWARD
Alex Lvovsky

KING SAUD UNIVERSITY AWARD (SAUDI ARABIA)
Khulud Almutairi

PAAET AWARD (KUWAIT)
Hessa Alotaibi

THE MEXICAN NATIONAL COUNCIL FOR SCIENCE AND TECHNOLOGY AWARD (MEXICO)
Itzel Lucio Martinez

NATIONAL AWARDS

NSERC ALEXANDER GRAHAM BELL CANADA GRADUATE SCHOLARSHIP
Nathan Babcock
Philip Chan
Connor Kupchak
Ryan Thomas

NSERC POSTGRADUATE SCHOLARSHIP
Ben Lavoie
Andrew MacRae
Michael Underwood

NSERC POSTDOCTORAL FELLOWSHIP
Michael Lamont

NSERC USRA PROGRAM
Adam Green
Simon Verret

PIMS POSTDOCTORAL FELLOWSHIP
Ben Fortescue

PROVINCIAL AWARDS

ALBERTA INNOVATES GRADUATE STUDENTS SCHOLARSHIP
Nathan Babcock
Adam D'Souza
Alexander Hentschel
Jeongwan Jin
Connor Kupchak
Ben Lavoie
Andrew MacRae
Joshua Slater
Ryan Thomas
Michael Underwood

BILL BRIDGER AWARD
Ryan Thomas

RALPH STEINHAUER AWARD OF DISTINCTION
Ryan Thomas

UNIVERSITY OF CALGARY AWARDS

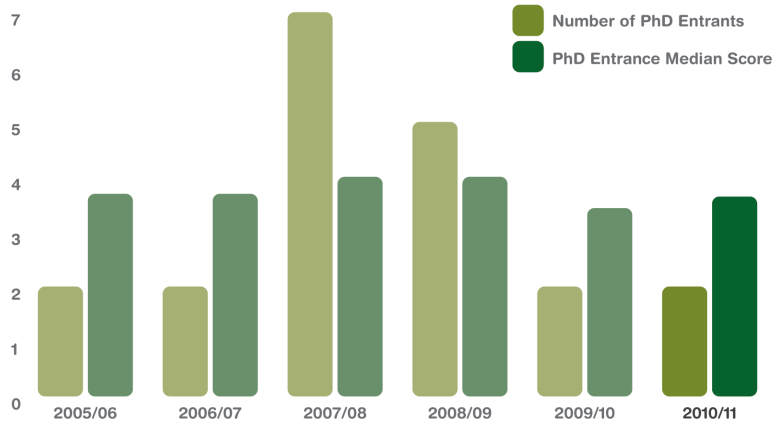
DEPARTMENT OF PHYSICS & ASTRONOMY AWARD
Andrew MacRae

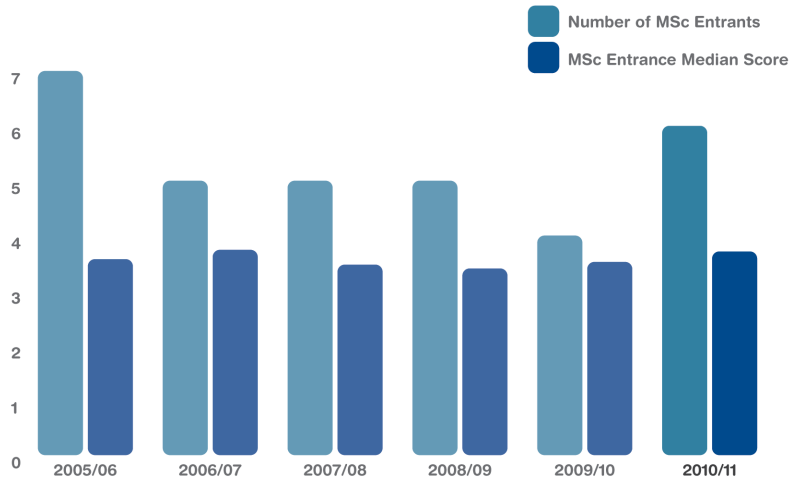
DEPARTMENT OF PHYSICS & ASTRONOMY TUITION SCHOLARSHIP
Adam D'Souza

QUEEN ELIZABETH II GRADUATE SCHOLARSHIP
Chris Healey
Zahra Shaterzadeh Yazdi
Neil Sinclair

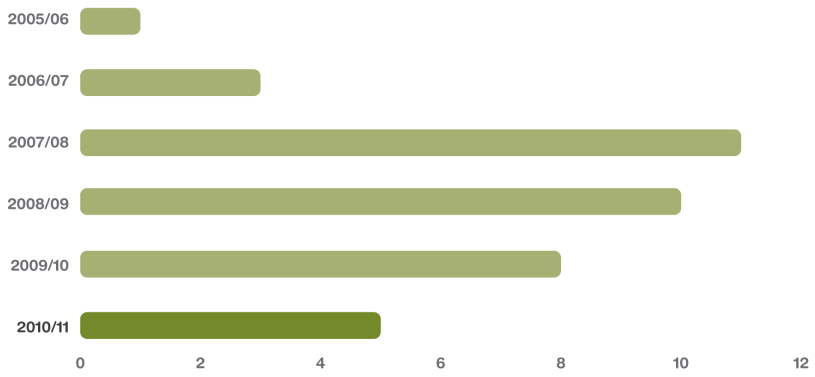
C. Key Performance Indicators

GRADUATE STUDENTS ENROLMENTS AND QUALITY OF ENTRANTS

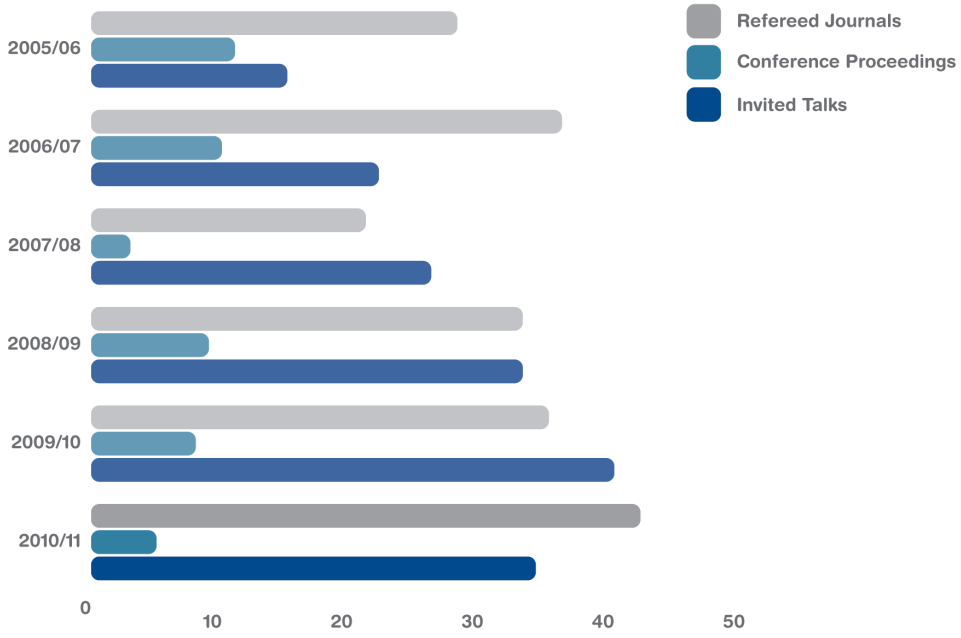




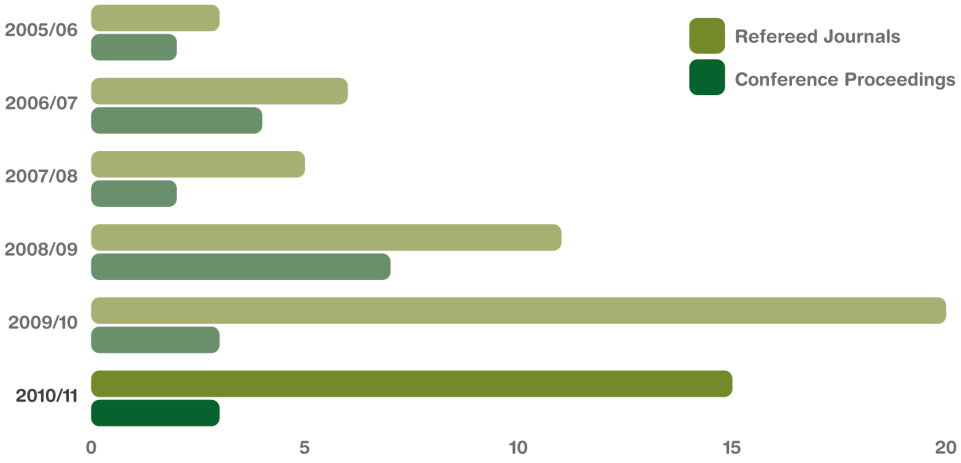
UNDERGRADUATE PROJECTS



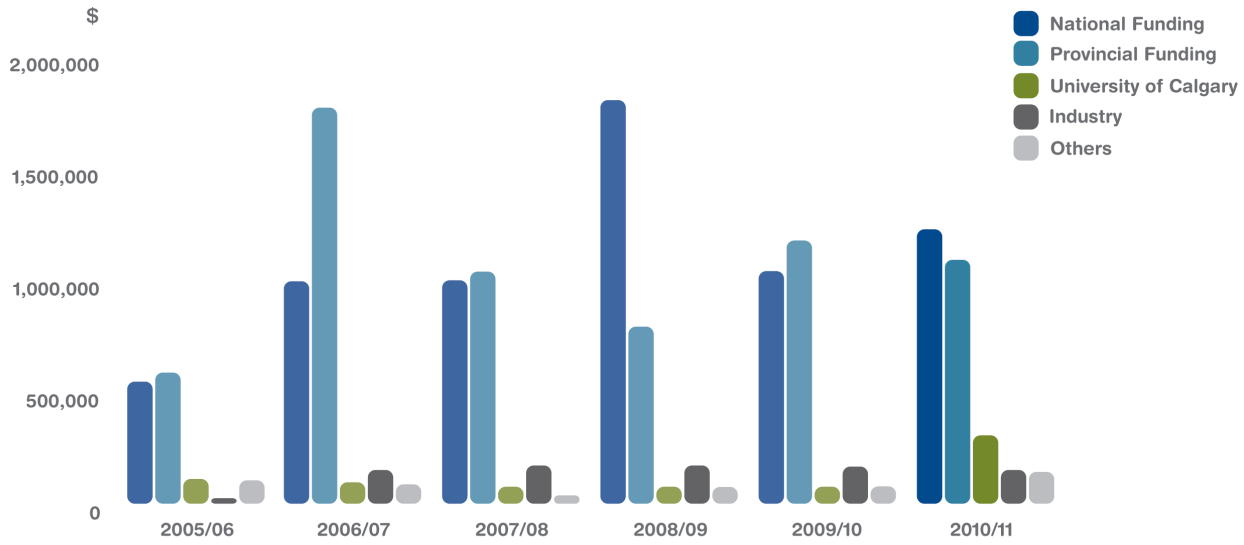
PUBLICATIONS AND PRESENTATIONS



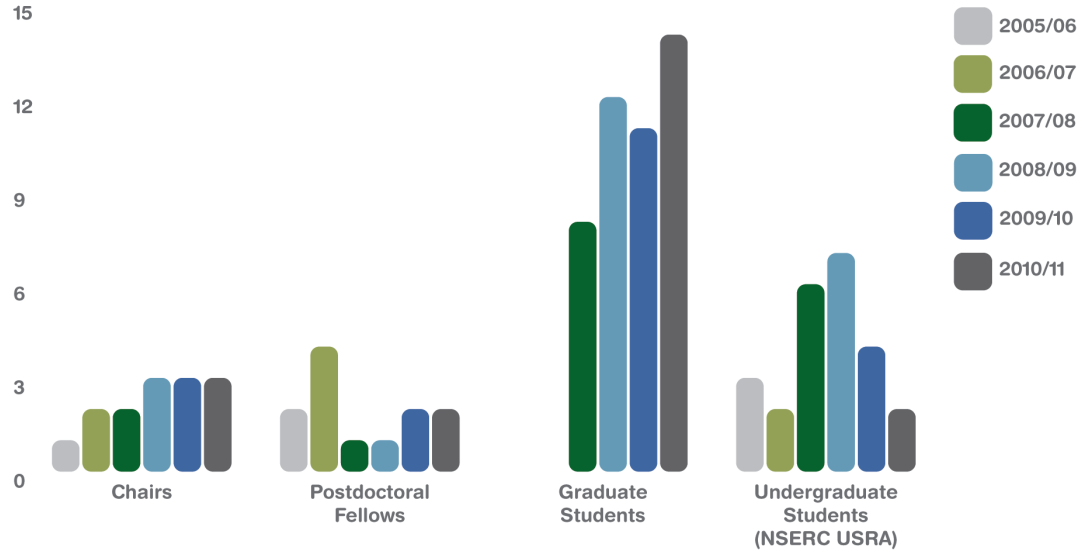
STUDENT PUBLICATIONS



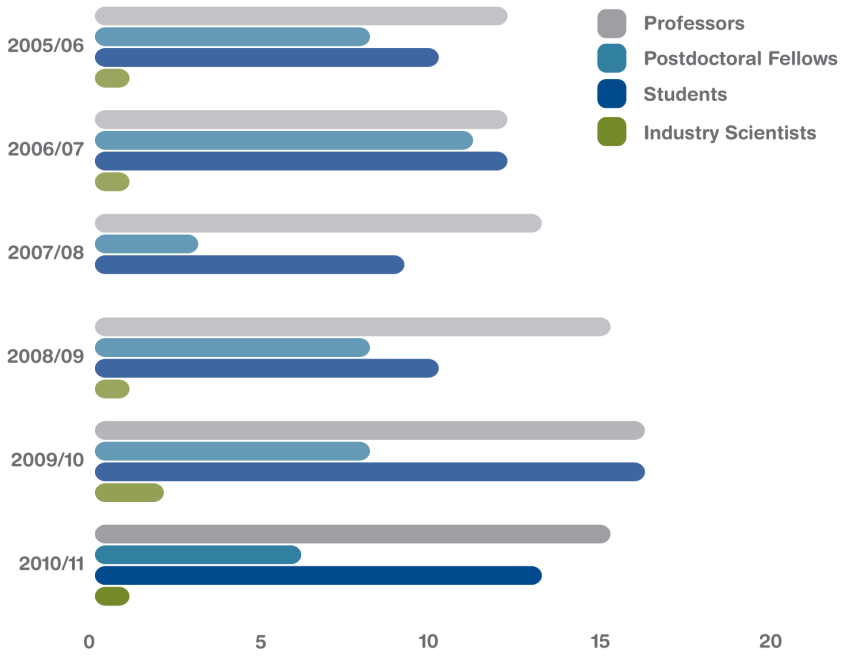
REVENUE (UNAUDITED)



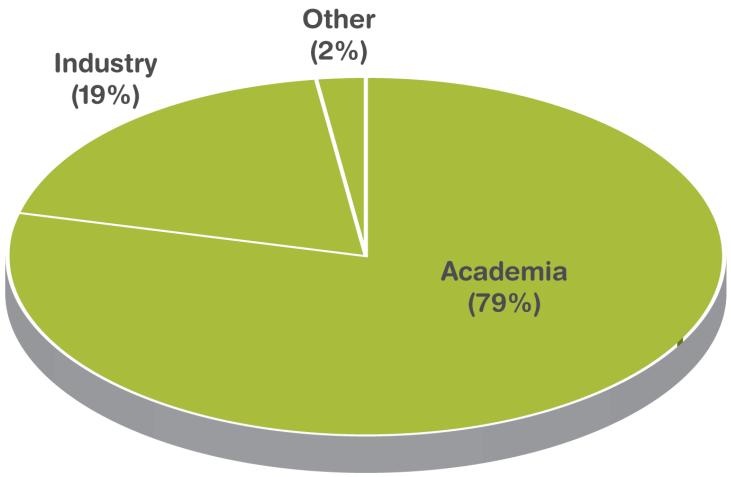
EXTERNAL AWARDS



VISITORS



GRADUATES IN THE WORKFORCE



Research Groups

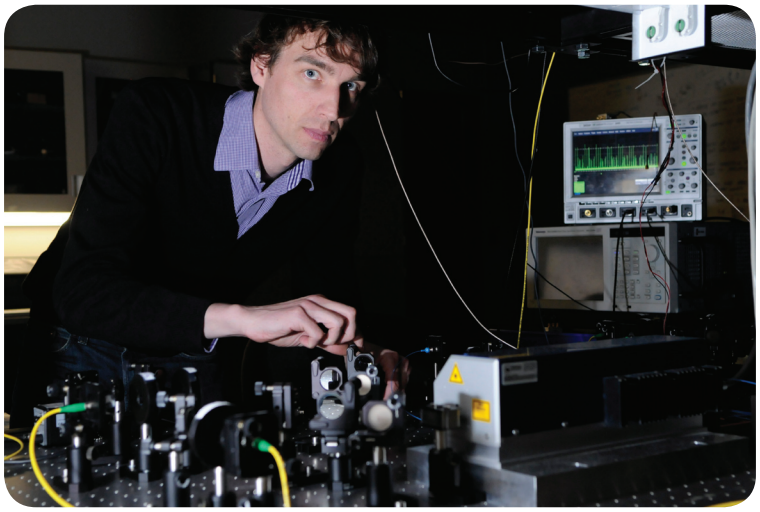
NANOSCALE OPTICS

DR. PAUL BARCLAY
(joined January 2011)

Our research studies interactions between light and nanoscale systems such as single atoms, electron spins and nanomechanical structures. Using nanofabrication methods to engineer the optical properties of these systems, it is possible to dramatically enhance light-matter coupling, opening the door to experiments that use light to delicately measure and transmit information describing the dynamics of nanoscale quantum systems.

Our current focus involves coupling single quantum emitters, or "artificial atoms" to optical nanocavities. These quantum emitters are formed by impurities in materials such as diamond, whose quantum state is useful for storing information and sensitively probing magnetic fields. This research has applications in quantum information processing, developing low power optical devices, and creating sensitive and compact environmental sensors.

We are fortunate to have labs at both the University of Calgary and the NRC National Institute for Nanotechnology (NINT) located in Edmonton, providing access to advanced nanofabrication tools and close contact with leading quantum optics and nanotechnology researchers.

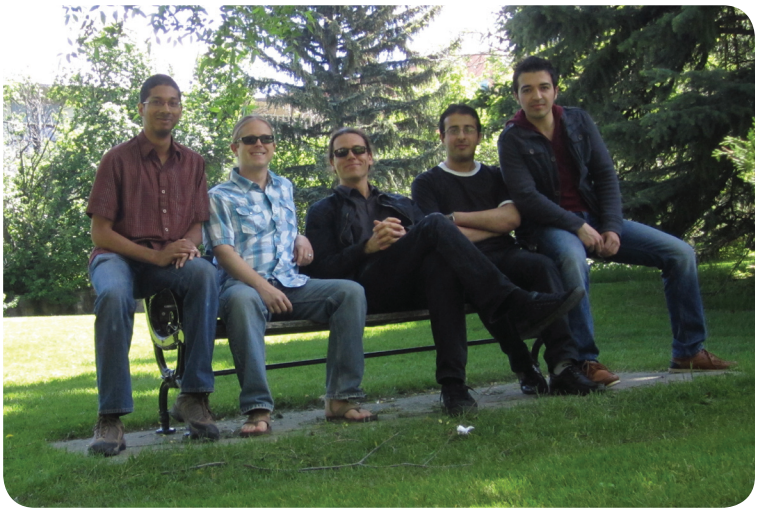


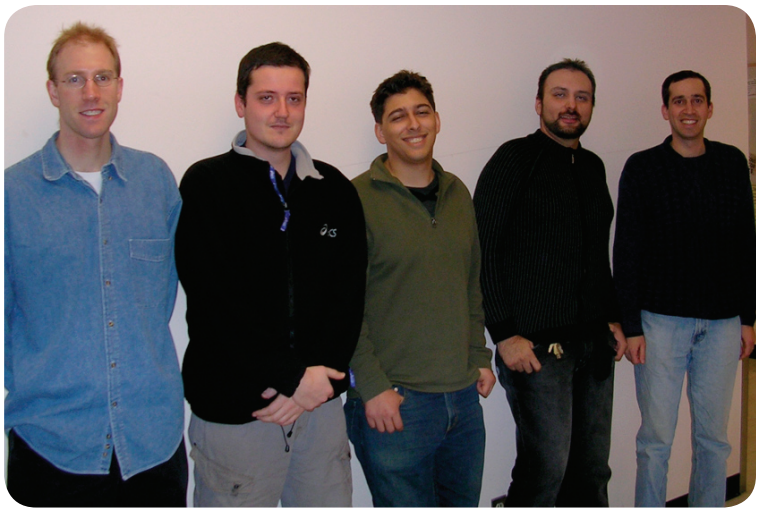
PAUL BARCLAY
PHOTO COURTESY OF THE UNIVERSITY OF CALGARY

PRACTICAL APPROACHES TO QUANTUM COMPUTATION

DR. DAVID FEDER

Quantum computers have the potential to solve numerous problems more efficiently than the best-known classical computers, but so far only very small, proof-of-principle quantum computers have been built. The research of our group is focused mainly on understanding how the intrinsic properties of physical systems, such as ultracold atomic gases or spin lattices, can be employed to construct larger devices able to perform quantum computation. In the process, we are exploring alternative models for the implementation of quantum logic, such as one-way quantum computation, quantum walks, and topological quantum computation.

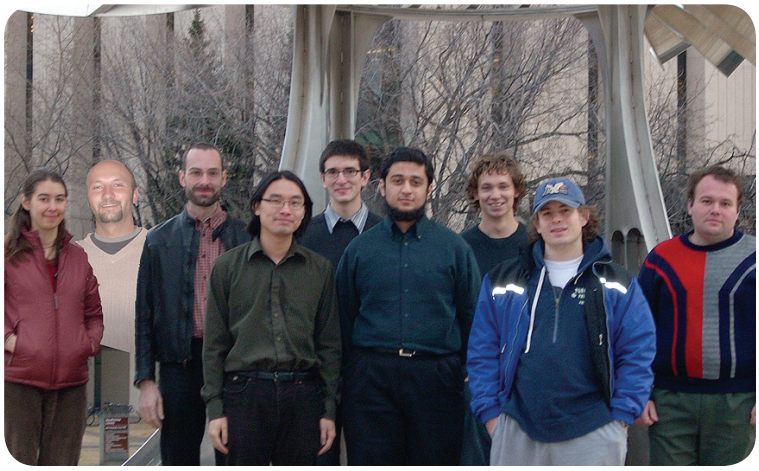




QUANTUM INFORMATION THEORY

DR. GILAD GOUR

Quantum information science is an interdisciplinary research endeavour that brings together computer scientists, mathematicians, physicists, chemists, and engineers to develop revolutionary information processing and communication technologies which are infeasible without exploiting the principles of quantum mechanics. The Quantum Information Group in the Department of Mathematics and Statistics conducts research on the mathematics of quantum information. Theoretical research in quantum information relies on sophisticated mathematical methods, such as algebraic geometry, matrix analysis, group theory, and C*-algebras. The goal of our group is to use the knowledge in these fields to solve core problems in quantum information science.



QUANTUM COMPUTING

DR. PETER HØYER

The Quantum Computing Research Group within the Department of Computer Science conducts research in computational aspects of quantum mechanical systems. Quantum computers are in particular interesting because they offer a possibility to achieve computations that cannot be easily achieved on traditional computers. We utilize the potential powers of quantum systems to develop quantum algorithms, quantum communication protocols, and quantum computer simulations of quantum mechanical systems. We conduct work on characterizing these powers and the limitations by studying quantum complexity theory, non-locality, entanglement, and quantum information theory. We organized and hosted the Third and Sixth Canadian Summer School on Quantum Information Processing.

QUANTUM INFORMATION TECHNOLOGY WITH LIGHT AND EXPERIMENTAL QUANTUM OPTICS

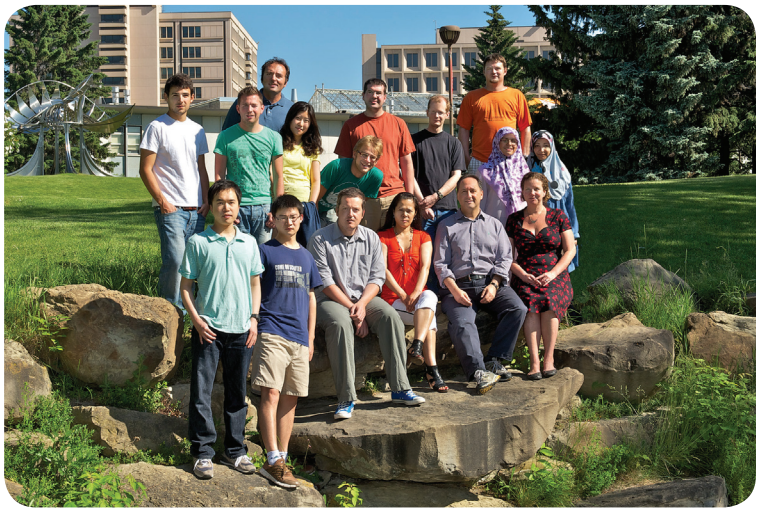
DR. ALEX LVOVSKY

Photons are excellent carriers of quantum information. One can build an entire quantum information processor by means of single-photon sources, detectors, and simple linear optical elements such as mirrors and beam splitters. Our group concentrates on implementing light for the purposes of quantum information technology – that is, learning to synthesize, control, characterize, and store arbitrary quantum states of the electromagnetic field.

QUANTUM INFORMATION SCIENCE

DR. BARRY SANDERS

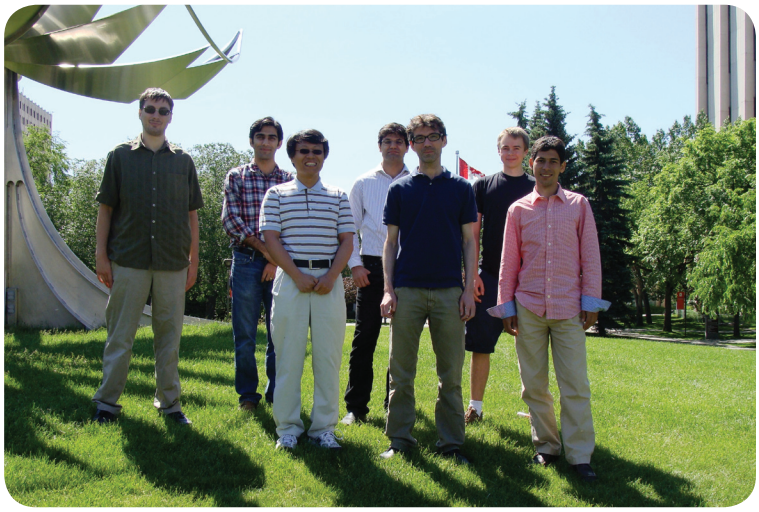
Our aim is to develop quantum information technologies that have transformative applications and will be feasible within a decade. The research program is divided into five strands: (i) long-distance secure communication, (ii) simulations of complex systems, (iii) implementations of quantum information tasks, (iv) empirical characterization of quantum states and processes, and (v) determining and quantifying all resources for quantum information processing.



THEORETICAL QUANTUM OPTICS

DR. CHRISTOPH SIMON

The interaction of light and matter at the quantum level played a major role in the development of quantum physics. Its detailed study in the field of quantum optics has led to the development of important applications such as the laser, and to the first experimental demonstrations of the most striking features of quantum physics, such as entanglement and quantum non-locality. However, quantum optics is not ready to rest on its laurels. There are two key future challenges. On the one hand, we strive to develop genuine applications of these fundamental quantum features. Our group is particularly interested in the development of quantum repeaters, which will be essential for future long-distance quantum communication. This motivates us to study potential implementations of quantum memories and of quantum gates between individual photons in various systems. On the other hand, quantum optical systems are ideally positioned to explore the quantum-classical transition, allowing us to deepen our understanding of how the classical macroscopic world arises out of microscopic quantum behaviour. This motivates us to study the quantum amplification of photons to macroscopic levels, as well as quantum opto-mechanical systems.



QUANTUM CRYPTOGRAPHY AND COMMUNICATION

DR. WOLFGANG TITTEL

Photons and atoms are key constituents for long distance quantum communication and quantum networks. Our group's effort focuses on building photon-based quantum cryptography systems through optical fibres, and targets the development of a quantum repeater to extend quantum cryptography past its current distance limit. This includes developing novel techniques for rendering photonic quantum communication primitives such as quantum teleportation practical, plus hitherto unrealized means for efficient and reversible transfer of quantum information between photons and atoms for temporal storage.

Management and Membership

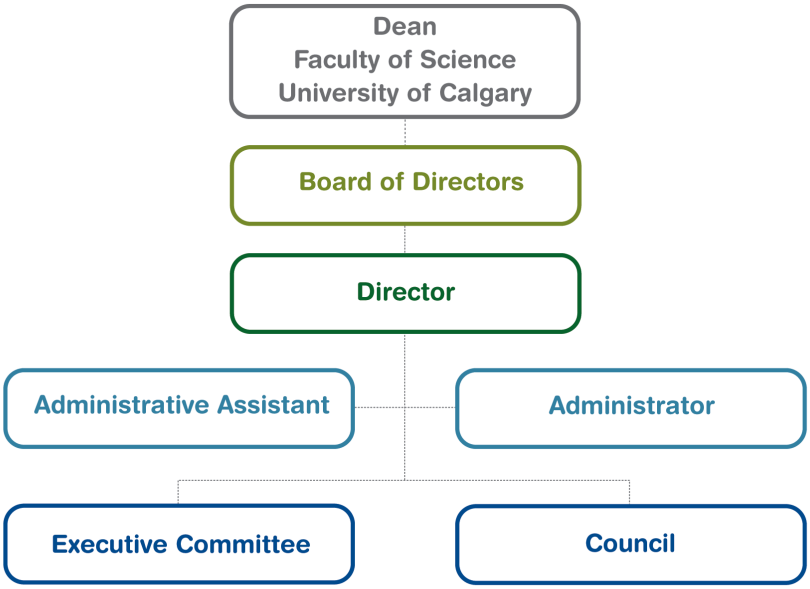
A. Institute Structure

The Institute is managed on a day-to-day level by the Institute Director and the Institute Administrator. The Director and his research group are additionally supported by an administrative assistant. The Director reports to the Board of Directors and is ex officio a member of this Board. The Board reports to the Dean of Faculty of Science who chairs the Board.

The Director and the Administrator of the Institute work on day-to-day matters of the Institute. The Institute Executive comprises the Director, Deputy Director, Administrator, and two faculty members other than the Director and Deputy Director. The Executive meets monthly to discuss and make decisions on executive matters. The Executive receives advice and guidance from the IQIS Council, which comprises all full and affiliate faculty members of the Institute.

All of the Institute's research, teaching, service, and outreach activities are conducted by faculty members and their research groups.

IQIS ORGANIZATIONAL CHART



B. IQIS Governance

BOARD OF DIRECTORS

KEN BARKER
Dean, Faculty of Science, University of Calgary

PAUL BRUMER
Professor, Department of Arts and Science, University of Toronto

JIM HASLETT
Professor, Department of Electrical and Computer Engineering, University of Calgary

SIR PETER KNIGHT
Principal, The Kavli Royal Society International Centre

GREG LUOMA
President, LuomaTech Inc.

BARRY SANDERS
Director, Institute for Quantum Information Science, University of Calgary

BRIAN UNGER
Professor, Department of Computer Science, University of Calgary

ANDREW VALLERAND
Centre for Security Science, Defence R&D Canada

EXECUTIVE COMMITTEE

GILAD GOUR
Assistant Professor, Department of Mathematics and Statistics, University of Calgary

PETER HØYER
Associate Professor, Department of Computer Science, University of Calgary

ALEX LVOVSKY
Professor, Department of Physics and Astronomy, University of Calgary

BARRY SANDERS
Director, Institute for Quantum Information Science, University of Calgary

COUNCIL

PAUL BARCLAY
Assistant Professor, Department of Physics and Astronomy, University of Calgary

DAVID FEDER
Associate Professor, Department of Physics and Astronomy, University of Calgary

GILAD GOUR
Assistant Professor, Department of Mathematics and Statistics, University of Calgary

DAVID HOBILL
Associate Professor, Department of Physics and Astronomy, University of Calgary

PETER HØYER
Associate Professor, Department of Computer Science, University of Calgary

ALEX LVOVSKY
Professor, Department of Physics and Astronomy, University of Calgary

DENNIS SALAHUB
Professor, Institute for Biocomplexity and Informatics, University of Calgary

BARRY SANDERS
Director, Institute for Quantum Information Science, University of Calgary

RENATE SCHEIDLER
Professor, Department of Mathematics and Statistics, University of Calgary

CHRISTOPH SIMON
Associate Professor, Department of Physics and Astronomy, University of Calgary

ROBERT THOMPSON
Associate Professor, Department of Physics and Astronomy, University of Calgary

WOLFGANG TITTEL
Associate Professor, Department of Physics and Astronomy, University of Calgary

RICHARD ZACH
Professor, Department of Philosophy, University of Calgary

C. Students

UNDERGRADUATE STUDENTS

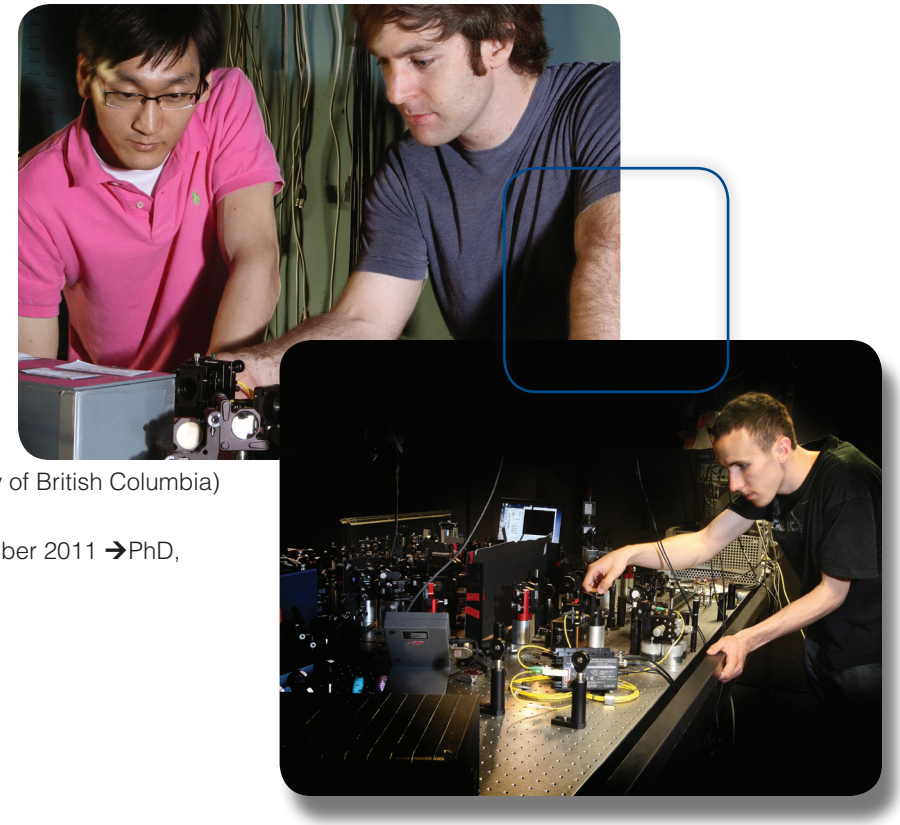
Chris Dascollas (PHYS 598)
Monika Deviat (PHYS 598)
Adam Green (PHYS 598 & NSERC USRA)
Aimee Heinrichs (PHYS 598)
Matthew Mitchell (research assistant)
Randy Squires (research assistant)
Peter VanderMeulen (PHYS 599)
Simon Verret (NSERC USRA)

GRADUATE STUDENTS (PHD PROGRAM)

Mark Adcock
Hessa Alotaibi
Nathan Babcock
Philip Chan
Jérémie Choquette
Adam D'Souza
Catalin Dohotaru
Roohollah Ghobadi
Alexander Hentschel
Khabat Heshami
Jeongwan Jin
Connor Kupchak
Ben Lavoie
Andrew MacRae
Itzel Lucio Martinez
Jibran Rashid
Erhan Saglamyurek
Zahra Shaterzadeh Yazdi
Neil Sinclair
Michael Skotiniotis
Joshua Slater
Borzumehr Toloui Semnani
Michael Underwood
Nathan Wiebe (completed March 2011 →Postdoc, University of Waterloo)

GRADUATE STUDENTS (MSC PROGRAM)

Khulud Almutairi
Neda Aminshariati
Erick Barrios
Kevin Van De Bogart
Ran Hee Choi
Chris Healey
Mahdi Ebrahimi Kahou
Hamidreza Kaviani
Ranjeet Kumar
Pantita Palittapongarnpim
Mark Przepiora
Sadegh Raeisi
Saleh Rahimi Keshari (completed December 2011 →PhD, University of British Columbia)
Allison Rubenok
Yuval Sanders (completed December 2011 →PhD, University of Waterloo)
Terence Stuart
Ryan Thomas



D. Postdoctoral Fellows

Ben Fortescue
Bing He (completed January 2011 ➔Postdoc, University of California, Merced)
Jaewoo Joo (completed May 2010 ➔Postdoc, University of Leeds)
Jeong San Kim
Michael Lamont
Patrick Ming-yin Leung
Xianfan Mo
Daniel Oblak
Artur Scherer (completed September 2010 ➔Research Scientist, Telcordia)
Jianming Wen

E. Administration and Support

Hyejeong Hwang (resigned March 2011)
Vladimir Kiselyov
Catherine Kosior (part-time)
Nancy Jing Lu
Jibran Rashid (part-time)
Lucia Wang

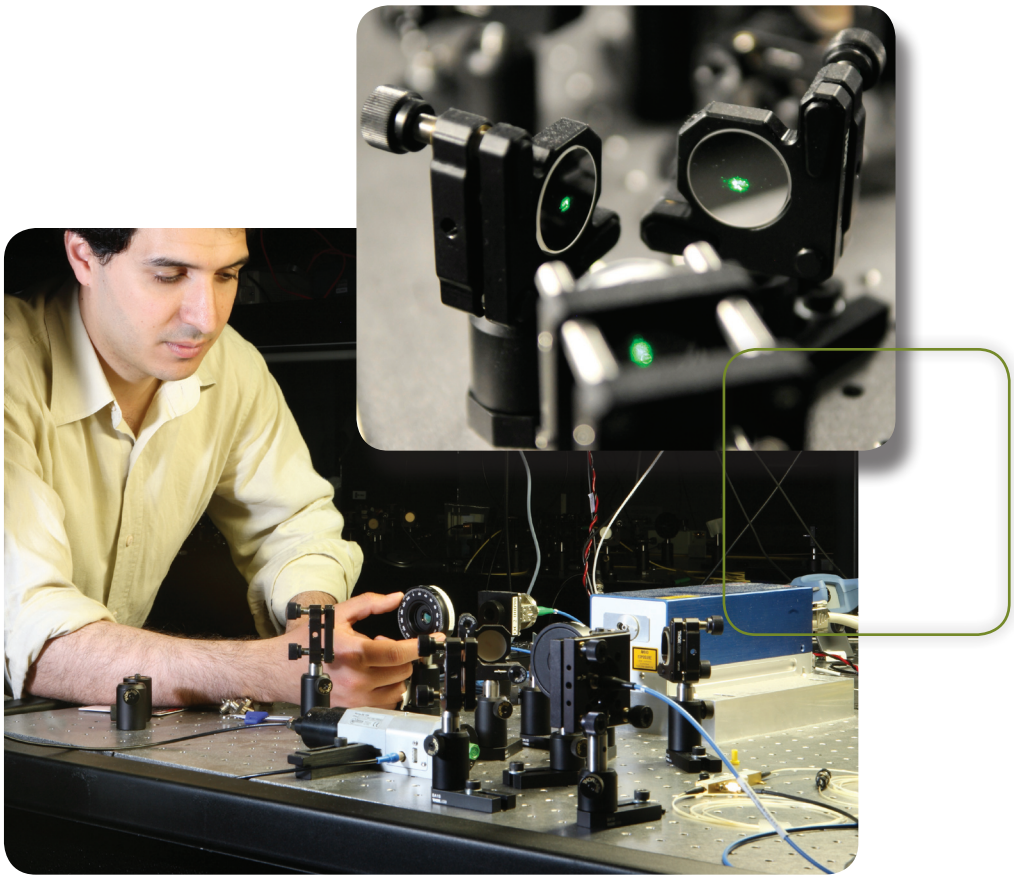


PHOTO COURTESY OF THE UNIVERSITY OF CALGARY

Publications and Presentations

REFEREED JOURNALS

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INVITED CONFERENCE PRESENTATIONS

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3 May 2010, L. Livadaru, P. Xue, Z. Shaterzadeh-Yazdi, G. A. DiLabio, J. Mutus, J. L. Pitters, B. C. Sanders and R. A. Wolkow, "Dangling-bond charge qubit", 2nd Nanoelectronics Meeting, QuantumWorks 2010, Sherbrooke, Canada, 3 May 2010 – 3 May 2010.

11 May 2010, W. Tittel, C. La Mela, M. George, R. Ricken, E. Saglamyurek, N. Sinclair and W. Solher, "Memoire quantique intégrée", 78 congrès de l'Association francophone pour la savoir, Montréal, Canada, 10 May 2010 – 14 May 2010.

25 May 2010, E. Bimbard, N. Jain, A. MacRae and A. I. Lvovsky, "Quantum technology of light at the two-photon level", 5th Workshop ad Memoriam of Carlo Novero: Advances in Foundations of Quantum Mechanics and Quantum Information with Atoms and Photons, Turin, Italy, 23 May 2010 – 29 May 2010.

26 May 2010, J. Joo and D. L. Feder, "The theory of local complementation is useful for building concatenated error-correction codes", MITACS/ CORS 2010, Edmonton, Canada, 25 May 2010 – 28 May 2010.

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26 May 2010, N. Wiebe, D. W. Berry, P. Høyer and B. C. Sanders, "Higher order decompositions of ordered operator exponentials", MITACS/ CORS 2010, Edmonton, Canada, 25 May 2010 – 28 May 2010.

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31 May 2010, A. I. Lvovsky, "Characterizing quantum optical "black boxes"", XIII International Conference on Quantum Optics and Quantum Information (ICQOQI'2010), Kiev, Ukraine, 28 May 2010 – 1 Jun 2010.

7 Jun 2010, C. Simon, "Quantum memories and quantum information processing with photons and atomic ensembles", Canadian Association of Physicists Congress 2010 (CAP Congress 2010), Toronto, Canada, 7 Jun 2010 – 11 Jun 2010.

8 Jun 2010, P. Høyer and J. Rashid, "Protocols for nonlocality distillation", INTRIQ biannual meeting, Saint-Sauveur, Canada, 7 Jun 2010 - 8 Jun 2010.

14 Jun 2010, B. C. Sanders, "Quantum cryptography for information-theoretic security", NATO Advanced Study Institute: Technological Innovations in Detection and Sensing of Chem.-Bio-Radiological-Nuclear and Ecological Terrorism, Vila Verde Hotel & Tourist Complex, Chisinau, Moldova, 7 Jun 2010 – 17 Jun 2010.

15 Jun 2010, I. Lucio Martinez, X. F. Mo, P. Chan, C. Healey, S. Hosier and W. Tittel, "Increasing the secret key rate in quantum key distribution", Theory and Realisation of Practical Quantum Key Distribution 2010, Waterloo, Canada, 14 Jun 2010 – 17 Jun 2010.

19 Jun 2010, B. C. Sanders, "Surface residues dynamically organize water bridges to enhance electron transfer between proteins", Quantum Effects in Biological Systems (QuEBS 2010), Harvard University, Cambridge, United States of America, 17 Jun 2010 – 20 Jun 2010.

24 Jun 2010, R. L. Cone and W. Tittel, "Storage of quantum information using rare-earth-ion doped crystals (tutorial)", 17th International Conference on Dynamical Processes in Excited States of Solids (DPC '10), Argonne, United States of America, 20 Jun 2010 – 25 Jun 2010.

5 Jul 2010, I. Lucio Martinez, X. F. Mo, P. Chan, C. Healey, S. Hosier and W. Tittel, "Towards high-rate real-world quantum key distribution with quantum frames", 19th International Laser Physics Workshop 2010 (LPHYS 2010), Foz do Iguaçu, Brazil, 5 Jul 2010 – 9 Jul 2010.

5 Jul 2010, E. Saglamyurek, N. Sinclair, J. Jin, J. A. Slater, F. Bussières, W. Tittel, M. George, R. Ricken and W. Sohler, "Integrated quantum memory for quantum communication", 19th International Laser Physics Workshop 2010 (LPHYS 2010), Foz do Iguaçu, Brazil, 5 Jul 2010 – 9 Jul 2010.

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19 Jul 2010, B. Fortescue, A. Keet, D. Markham and B. C. Sanders, "Threshold quantum secret sharing using graph states of prime-dimensional systems", Canadian Applied and Industrial Mathematics Society Annual Meeting 2010 (CAIMS 2010), St. John's, Canada, 18 Jul 2010 – 20 Jul 2010.

19 Jul 2010, M. Lobino, D. Korystov, C. Kupchak, E. Figueroa, R. Kumar, E. Barrios, S. Rahimi-Keshari, A. Scherer, B. C. Sanders and A. I. Lvovsky, "Quantum-optical process tomography using coherent states", 10th International Conference on Quantum Communication, Measurement and Computation (QCMC2010), Brisbane, Australia, 19 Jul 2010 – 23 Jul 2010.

23 Jul 2010, B. C. Sanders, L. Livadaru, P. Xue, Z. Shaterzadeh-Yazdi, G. A. DiLabio, J. Mutus, J. L. Pitters and R. A. Wolkow, "Dangling-bond charge qubit on a silicon surface", 10th International Conference on Quantum Communication, Measurement and Computation (QCMC2010), Brisbane, Australia, 19 Jul 2010 – 23 Jul 2010.

5 Aug 2010, M. Lobino, C. Kupchak, R. Kumar, E. Barrios, A. J. Hendricks, E. Figueroa and A. I. Lvovsky, "Coherent-state quantum process tomography", SPIE Optics and Photonics 2010, San Diego, United States of America, 1 Aug 2010 – 5 Aug 2010.

20 Aug 2010, W. Tittel, "Quantum cryptography and communication", 2010 Research and Commercialization Summit Alberta Innovates Technology Futures, Banff, Canada, 19 Aug 2010 – 21 Aug 2010.

23 Aug 2010, B. C. Sanders, "Machine learning for precise quantum measurement", 5th Asia Pacific Conference in Quantum Information Science (APCQIS 2010), Taiyuan, People's Republic of China, 21 Aug 2010 – 24 Aug 2010.

24 Aug 2010, J. S. Kim and B. C. Sanders, "Monogamy of entanglement using Rényi and Tsallis", KIAS Workshop on Quantum Information Science, Seoul, Republic of Korea, 23 Aug 2010 – 25 Aug 2010.

24 Aug 2010, A. I. Lvovsky and D. W. Berry, "Limitations on linear-optical processing of single photon efficiency", Workshop on Quantum Decoherence & Thermodynamics Control, Safed, Israel, 22 Aug 2010 – 27 Aug 2010.

26 Aug 2010, B. He, "Multi-mode effects in photonic logic gate", First Canadian Prairie Theoretical Physics Network (CPTPN) Meeting, Lethbridge, Canada, 25 Aug 2010.

26 Aug 2010, C. Simon, "Micro-macro entanglement based on cloning by stimulated emission", Workshop on Quantum Decoherence & Thermodynamics Control, Safed, Israel, 22 Aug 2010 – 27 Aug 2010.

20 Oct 2010, E. Saglamyurek, N. Sinclair, J. Jin, J. A. Slater, D. Oblak, F. Bussières, W. Tittel, M. George, R. Ricken and W. Sohler, "Integrated quantum memory for sub-nanosecond non-classical light", Updating Quantum Cryptography and Communication (UQCC 2010), Tokyo, Japan, 18 Oct 2010 – 20 Oct 2010.

19 Nov 2010, B. Fortescue, A. Keet, D. Markham, G. Gour and B. C. Sanders, "New directions in quantum secret sharing", Canadian Institute for Advanced Research (CIFAR) Quantum Information Processing Program Meeting, Toronto, Canada, 19 Nov 2010 - 21 Nov 2010.

26 Jan 2011, B. C. Sanders, "Large nonlinearities with few photons", Advances in Photonics of Quantum Computing, Memory, and Communication IV, San Francisco, United States of America, 22 Jan 2011 – 27 Jan 2011.

29 Jan 2011, B. C. Sanders, "Large nonlinearities with few photons", Quantum Optics and New Materials (IV), Beijing, People's Republic of China, 27 Jan 2011 – 30 Jan 2011.

7 Mar 2011, W. Tittel, "Quantum cryptography and communication", Ottawa, Canada, NSERC Council meeting.

24 Mar 2011, B. C. Sanders, "Autler-Townes splitting vs. electromagnetically induced transparency: objective criterion to discern between them in any experiment", International Conference on Quantum Optics and Quantum Computing (ICQOQC-11), Noida, India, 24 Mar 2011 – 26 Mar 2011.

Linkage

A. Collaboration

IQIS and its members have strong linkage with various external organizations and research networks. The IQIS Director is leader of two Canadian research networks on the mathematics of quantum information, one network being with the Network Centres of Excellence for the Mathematics of Information Technology and Complex Systems (MITACS) and the other network being a Collaborative Research Group within the Pacific Institute for Mathematical Sciences (PIMS).

Some IQIS Faculty are members of the Canadian Institute for Advanced Research (CIFAR) Quantum Information Processing Program. IQIS is also strongly involved in the Canadian Innovation Platform 'QuantumWorks'.

IQIS has a strong research effort in quantum communication and cryptography. IQIS is linked to General Dynamics Canada via the Industrial Research Chair in Quantum Communication and Cryptography. IQIS is also part of the France-Canada strategic network "Frequency", which is a binational initiative in quantum cryptography. In 2011, IQIS has established linkage with Canada's National Institute for Nanotechnology (NINT) in Edmonton through the appointment of Paul Barclay at the University of Calgary and his 50% secondment to NINT.

With respect to training, IQIS is one of the two Canadian partners in the joint Canada and European Union training program in quantum information under the auspices of the EU-Canada Programme for Cooperation in Higher Education, Training and Youth. The Canadian portion of this funding originates from Human Resources and Social Development Canada.

INTERNATIONAL INSTITUTIONS

China Southeast University, People's Republic of China
Chonnam National University, Republic of Korea
CNRS – Télécom ParisTech, France
École Normale Supérieure, France
ETH Zürich, Switzerland
Harvard University, United States of America
Indian Institute of Technology, Powai, India
Kazan Physical-Technical Institute of the Russian Academy of Science, Russia Federation
Kyung Hee University, Republic of Korea
Max Planck Institute for the Science of Light, Erlangen, Federal Republic of Germany
National University of Defence Technology, People's Republic of China
Paris-Sud 11 University, France
Sharif University of Technology, Iran
Technion - Israel Institute of Technology, Israel
The Institute for Photonic Sciences, Barcelona, Spain
University of Bristol, United Kingdom
University of California at San Diego, United States of America
University of California at Santa Barbara, United States of America
University of Copenhagen, Denmark
University of Geneva, Switzerland
University of Illinois at Chicago, United States of America
University of Jazan, Kingdom of Saudi Arabia
University of Leiden, The Netherlands
University of Paderborn, Federal Republic of Germany
University of Southern California, United States of America
University of Twente, The Netherlands

CANADIAN INSTITUTIONS

National Institute for Nanotechnology
Perimeter Institute for Theoretical Physics
Polytechnique Montréal
Southern Alberta Institute of Technology
St. Francis Xavier University
University of Alberta
University of Montréal
Université de Sherbrooke
University of Toronto
University of Waterloo
Wilfrid Laurier University

UNIVERSITY OF CALGARY

Advanced Technology Information Processing Systems Laboratory
Department of Electrical and Computer Engineering
Institute for Biocomplexity and Informatics
Institute for Security, Privacy and Information Assurance
Institute for Sustainable Energy, Environment and Economy

INDUSTRY

General Dynamics Canada

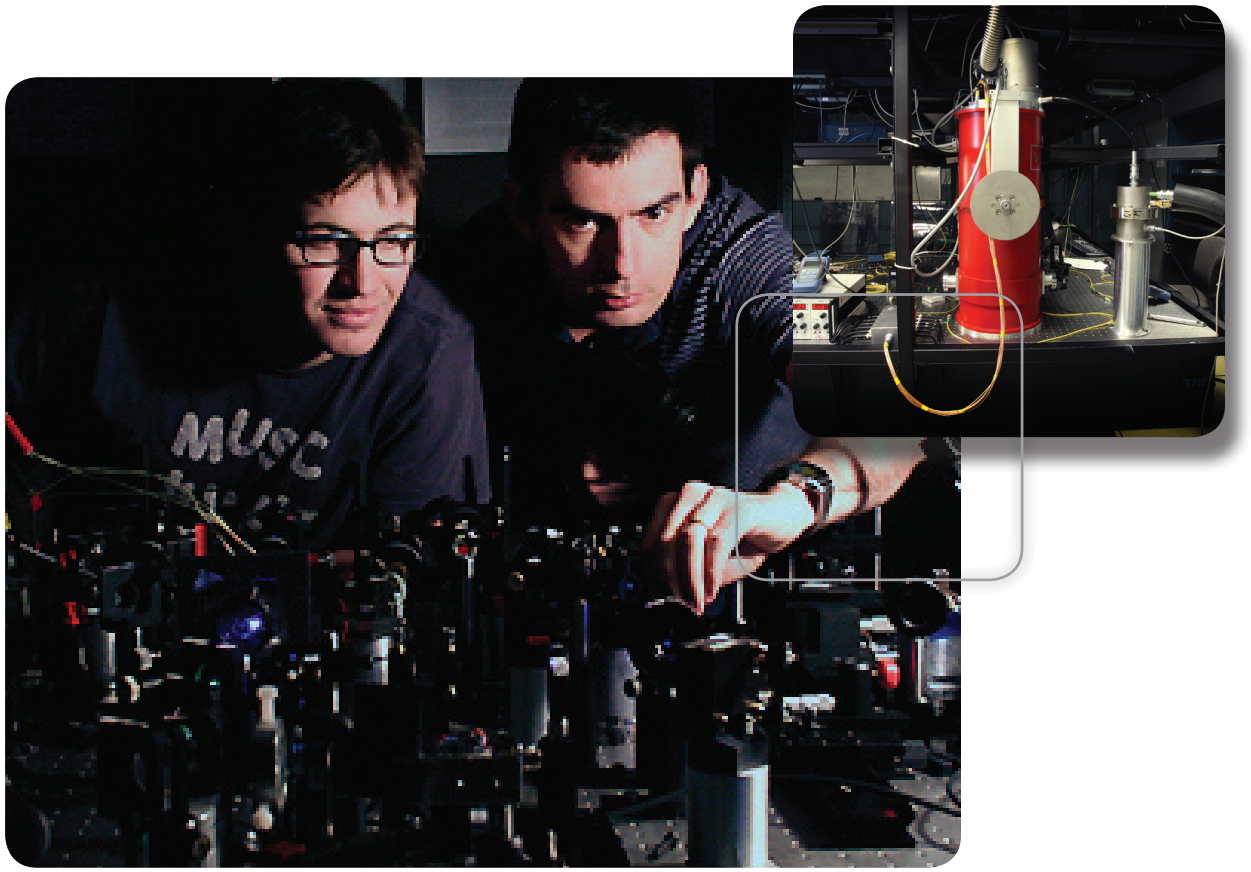
B. Visitors

VISITOR	INSTITUTION
Russell Barbour	University of Oregon
Paul Barclay	Hewlett-Packard Labs
Sean Barrett	Imperial College London
Jacob Bekenstein	The Hebrew University of Jerusalem
Dominic Berry	University of Waterloo
Robert W. Boyd	University of Ottawa
Francesco Buscemi	University of Nagoya
Mark Byrd	Southern Illinois University
Giulio Chiribella	Perimeter Institute for Theoretical Physics
Roger Colbeck	Perimeter Institute for Theoretical Physics
Sean Collins	QuantumWorks
Zijian Diao	Ohio University Eastern Campus
Shmuel Friedland	University of Illinois at Chicago
Michael Förtsch	University of Erlangen-Nürnberg
Sharon Hammes-Schiffer	Pennsylvania State University
Yang Han	National University of Defense Technology of China
Jose Hipolito Garcia	Tecnológico de Monterrey
Elanor Huntington	University of New South Wales at the Australian Defence Force Academy
Nathaniel Johnston	University of Guelph
Ali Kamli	University of Jazan
David Kribs	University of Guelph
Antia Lamas-Linares	The National University of Singapore
Netanel Lindner	California Institute of Technology
Neil Lovett	University of Leeds
Iman Marvian	Perimeter Institute for Theoretical Physics
Sergey Moiseev	Kazan Physical-Technical Institute of the Russian Academy of Science
Samira Nazifkar	Ferdowsi University
Christian Nölleke	Max Plank Institute of Quantum Optics
Jobez Pierre	École Normale Supérieure
Matthew Pysher	University of Virginia
Arnaud Rispe	École Normale Supérieure
Alireza Shabani	Princeton University
Rob Spekkens	Perimeter Institute for Theoretical Physics
Nolan Wallach	University of California at San Diego
Yunjiang Wang	Xi Dian University
Peng Xue	China Southeast University

Teaching, Training and Education

A. Quantum Information Graduate Courses

COURSE NAME	INSTRUCTOR	DESCRIPTION
AMAT 601.19 Introduction to Quantum Information	Gilad Gour	Introduction to quantum information theory emphasizing the topics of quantum compression, quantum communication, entanglement, channels, coding, nonlocality, distinguishability, steering, and resources.These topics require basic knowledge of linear algebra.
PHYS 615 Advanced Quantum Mechanics I	Christoph Simon	Basic formalism of the theory and its interpretation, symmetry generators. Scattering theory. Bound states. Charged particles in electric and magnetic fields. Approximation methods



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Services and Outreach

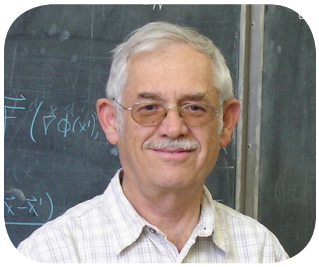
A. Conferences

MEMBER(S)	COMMITTEE	CONFERENCE/WORKSHOP/ AWARD	LOCATION	CONFERENCE DATES
N. Aminshariati	Chair	Seventh Annual Canadian Quantum Information Students' Conference 2010	Calgary, Canada	12 – 16 July 2010
A. I. Lvovsky	Deputy Chair	Annual International Laser Physics Workshop (LPHYS'12)	Calgary, Canada	23 – 27 July 2012
B. C. Sanders	Co-Chair	2012 Canadian Association of Physicists Congress	Calgary, Canada	10 – 14 June 2012
B. C. Sanders	Chair	Annual International Laser Physics Workshop (LPHYS'12)	Calgary, Canada	23 – 27 July 2012

B. Professional Services

NAME	ROLE	JOURNAL/SOCIETY/INSTITUTION
A. I. Lvovsky	Associate Editor	Optics Express
A. I. Lvovsky	Member, Steering Committee	Russian Quantum Institute
B. C. Sanders	Chair, Division of Atomic and Molecular Physics and Photon Interactions	Canadian Association of Physicists
B. C. Sanders	Co-Chair, Division of Atomic, Molecular, and Optical Physics	Canadian Association of Physicists
B. C. Sanders	Reviewer, Atomic Q Uantum Technologies (AQUTE) Integrated Project, Information Society and Media, FET – Proactive	European Commission
B. C. Sanders	Reviewer, Qubit Applications (QAP) Integrated Project, Information Society and Media, FET – Proactive	European Commission
B. C. Sanders	Member	International Council for Quantum Electronics
B. C. Sanders	Member, Physics Evaluation Group (1505)	National Sciences and Engineering Research Council of Canada
B. C. Sanders	Project Leader, Quantum Information Processing	Networks of Centres of Excellence for Mathematics of Information Technology and Complex Systems
B. C. Sanders	Regional Editor of North America	New Journal of Physics
B. C. Sanders	Editor	Optics Communications
B. C. Sanders	Principal Coordinator, Collaborative Research Group for Mathematics of Quantum Information	Pacific Institute for the Mathematical Sciences
B. C. Sanders	Member, Scientific Review Panel	Pacific Institute for the Mathematical Sciences
B. C. Sanders	Member, Editorial Board	Physical Review A

C. IQIS Public Lecture



JACOB BEKENSTEIN

The first IQIS Public Lecture was held on 2 June 2010. Professor Jacob Bekenstein gave a general talk titled "The Limits of Information and Black Holes". Professor Bekenstein was John Wheeler's doctoral student at Princeton University and is now Polak Professor of Theoretical Physics at the Hebrew University. He is a member of the Israel Academy of Sciences and Humanities and a recipient of the Israel Prize. He discovered the theory of black hole thermodynamics, which resulted in the famous Bekenstein-Hawking theory of black-hole radiation. About 168 people participated in the event. The event was sponsored by *i*CORE.

D. Media Coverage

SOURCE	TITLE OF ARTICLE	LOCATION	DATE
Science Blog	Developing mathematics for more secure on-line communication: Barry Sanders	online	6 Apr 2010
Research in Action Online	Molecular 'breakwater' that helps electron transfer: Nathan Babcock, Dennis Salahub, Barry Sanders	online	1 Jun 2010
Rocky Ridge Community Newsletter	IQIS annual public lecture: The limits of information and black holes: Professor Jacob Bekenstein	P23	1 Jun 2010
U Magazine	All about black holes: Professor Jacob Bekenstein	P8	1 Jun 2010
University of Calgary Events	IQIS annual public lecture: The limits of information and black holes: Professor Jacob Bekenstein	online	2 Jun 2010
Wired Science	How to see quantum entanglement: Christoph Simon	online	2 Jun 2010
Calgary Herald	Brain game, a quest to find Calgary's smartest person: Barry Sanders, Adrian Keet, Alexander Hentschel	online	13 Jun 2010
Eureka Alert	Raising the bar for biomolecular modeling: Nathan Babcock, Dennis Salahub, Barry Sanders	online	14 Jun 2010
e! Science News	Raising the bar for biomolecular modeling: Nathan Babcock, Dennis Salahub	online	14 Jun 2010
Genetic Engineering & Biotechnology News	Raising the bar for biomolecular modeling: Nathan Babcock, Dennis Salahub, Barry Sanders	online	14 Jun 2010
Physorg.com	Raising the bar for biomolecular modeling: Nathan Babcock, Dennis Salahub	online	14 Jun 2010
News Guide	University of Calgary scientists discover 'breakwater' to help control electron transfer: Nathan Babcock, Dennis Salahub, Barry Sanders	online	15 Jun 2010
FARS News Agency	'Breakwater' to help control electron transfer: Nathan Babcock, Dennis Salahub	online	16 Jun 2010
Science Daily	Biomolecular modeling: scientists discover 'breakwater' to help control electron transfer: Dennis Salahub, Nathan Babcock, Barry Sanders	online	16 Jun 2010
UToday	Outstanding research programs spurred on with major funding: Alexander Lvovsky	online	24 Jun 2010

SOURCE	TITLE OF ARTICLE	LOCATION	DATE
Research in Action Online	U of C receives 8 discovery accelerator grants: Alexander Lvovsky	online	1 Jul 2010
CBC News	Quantum networks closer with Alberta discovery: Wolfgang Tittel		12 Jan 2011
Global TV	Quantum networks closer with Alberta discovery: Wolfgang Tittel		12 Jan 2011
NewScientist	Ethereal quantum state stored in solid crystal: Wolfgang Tittel	online	12 Jan 2011
Physicsworld.com	Quantum communications boosted by solid memory devices: Wolfang Tittel	online	12 Jan 2011
UToday	Quantum quirk contained: Wolfgang Tittel	online	13 Jan 2011
Wissenschaft	Physiker bauen photonenknast: Wolfgang Tittel	online	13 Jan 2011
Nature Phys.	Highlights: entanglement stored: Wolfgang Tittel		1 Feb 2011
NHEvents.com	Doing science with Iran: Barry Sanders	online	22 Feb 2011
MIT News	The quantum singularity: Barry Sanders	online	2 Mar 2011
Physicsworld.com	Quantum probe beats Heisenberg limit: Barry Sanders	online	24 Mar 2011

E. Outreach Lectures

12 Jul 2010, C. Simon, "Some well intentioned career advice" (invited), Canadian Quantum Information Students' Conference (CQISC 2010), Calgary, Canada, 12 Jul 2010 – 16 Jul 2010.

17 Jul 2010, N. S. Babcock, "Quantum physics at MoNo" (invited), Motion Notion, Drayton Valley, Canada, 15 Jul 2010 – 19 Jul 2010.

12 Nov 2010, B. C. Sanders, "Quantum computing: how it could transform our world" (invited), Telus World of Science Einstein & Darwin Exhibit Genius Speaker Series, Calgary, Canada, 12 Nov 2010.

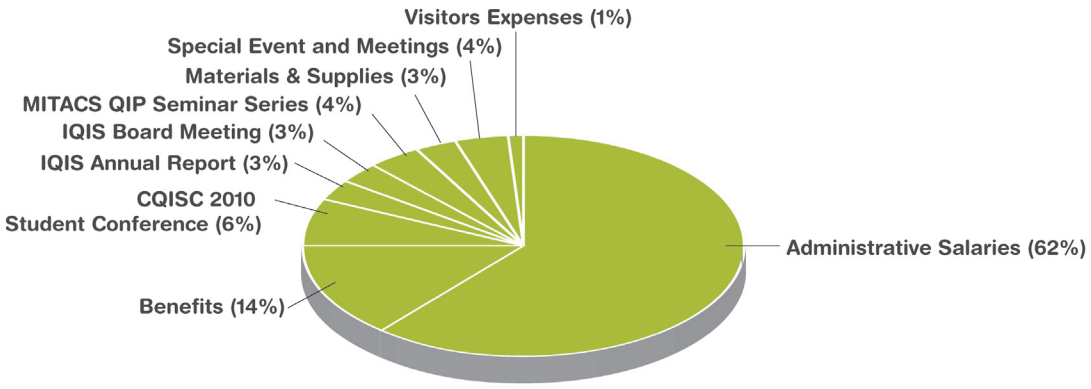
22 Feb 2011, B. C. Sanders, "Doing science with Iran" (invited), Saint Anselm College, New Hampshire Institute of Politics.

22 Feb 2011, B. C. Sanders, "Whither quantum computing", Saint Anselm College, New Hampshire Institute of Politics.

Finances

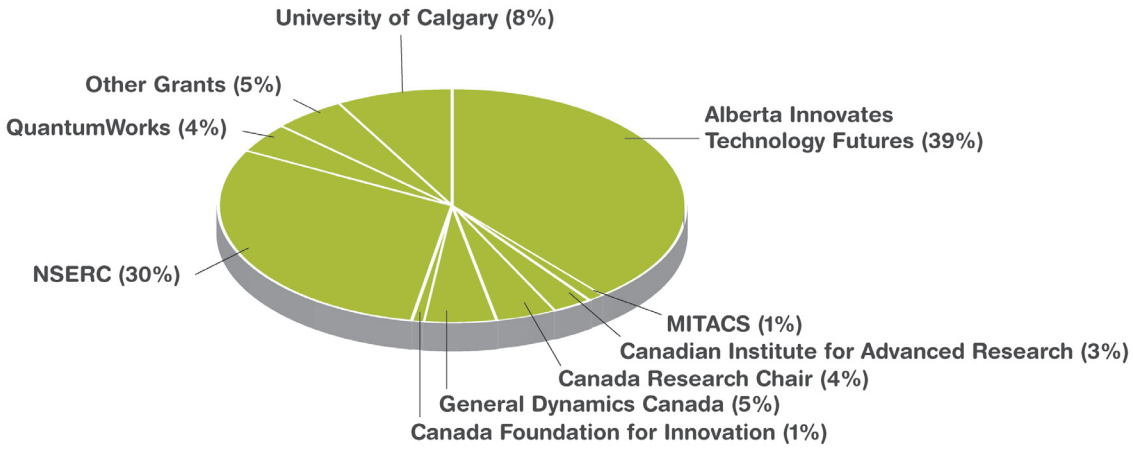
A. Operating Account (unaudited)

TOTAL EXPENDITURES: $102 (IN THOUSANDS)

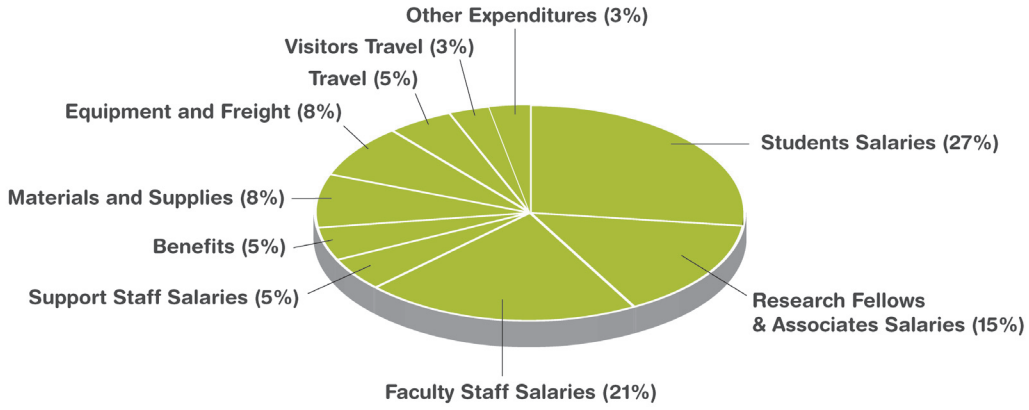


B. Research Grants (unaudited)

TOTAL REVENUE: $2,824 (IN THOUSANDS)



TOTAL EXPENDITURES: $2,692 (IN THOUSANDS)



Plans and Requirements for Next Year

The Institute for Quantum Information Science has been renewed for another year, until June 2012. During the coming year, the Faculty of Science will conduct a review of the Institute with external assessors. This will be the first review of Faculty of Science Institutes and Centres, and the Institute aims to pass with flying colours. The Institute has been diligent with producing informative annual reports and detailed assessments of administrative, research and training matters so the review should not be too onerous on Institute operations.

A key challenge for the Institute is the cessation of central University funding. IQIS has grown into an internationally renowned centre for interdisciplinary quantum information research, and the excellence of IQIS has been built through nurturing a collaborative, high-performing quantum information team. Various initiatives are underway to explore how quantum information can flourish over the next few years. Active discussions are underway with University of Calgary chemists under the umbrella of the Faculty of Science emerging priority of "Quantum Science and Technology". Strong collaborations exist between the information security and quantum information groups as the two group meet at the topic of quantum cryptography, which aims to provide communication that is secure against any computational attack.

WOLFGANG TITTEL

PHOTO BY DAVID MOLL COURTESY OF THE UNIVERSITY OF CALGARY

Another major initiative that is underway concerns the overlap of quantum and nano researchers in Alberta. A "quantum-nano workshop" is planned in Red Deer on 6 July 2011. The goal is to bring together researchers from the Universities of Alberta and Calgary and from the National Institute for Nanotechnology (NINT) who are interested in quantum and nano science and technology. The purpose of the workshop is to seek common interests between these researchers, foster potential collaboration, identify industrial and commercial opportunities and learn about opportunities in Alberta to support cutting-edge research and development in this area.

IQIS has identified several key research objectives for the 2011-2012 reporting year. Wolfgang Tittel's quantum communication and cryptography group is striving to create a high-rate commercial-grade quantum-communication system. To make strides in this direction, his group will integrate four detectors into the system, develop a protocol for quantum private database queries, and demonstrate quantum frame-determined optical switching between different receiver nodes. This latter initiative will pave the way to go beyond peer-to-peer links and towards quantum communication in multi-user networks.

Alex Lvovsky and his group are improving their coherent-state quantum process tomography method to be highly efficient. This tomography technique affords a way of empirically testing an actual experimental process without making undue assumptions. One specific experimental objective in the coming year is to implement quantum process tomography on photon-added and photon-subtracted processes as well as on gradient-echo quantum optical memory. They also plan to implement high-efficiency storage of nonclassical optical states using gradient-echo memory. In another direction, entanglement is one of the most important resources for quantum information processing, and the Lvovsky laboratory will undertake entanglement distillation of the continuous-variable Einstein-Podolsky-Rosen state. Lvovsky's group is also embarking on research of tapered nanofibers and plan to observe the interaction between cold trapped atoms and the nanofiber's evanescent optical field arising from a propagating field within.

The newest experimental group in IQIS and NINT is Paul Barclay's, which commenced January 2011. A major objective is to get the laboratories at the University of Calgary and NINT running in the coming year. Specifically the group will develop nanofabrication capabilities necessary to fabricate optical waveguides and microcavities with quality factors comparable or better than the current state of the art. They will also set up a closed-cycle cryostat system compatible with scanning

confocal microscopy and fiber- taper spectroscopy. As a theoretical tool, they will develop finite-element simulation tools capable of modeling the mechanical and optical properties of nanoscale structures that can be cooled to their ground state of motion. Experimental objectives include demonstrating new types of nano-photonics devices coupled to “atom-like” impurities in diamond with an initial target of creating hybrid gallium phosphide and diamond photonic crystal nanocavities. The group collaborates with NINT researchers to use optomechanical devices to probe the properties of nanomagnetic and superconducting systems.

David Feder’s group is studying universal resources for a measurement-based approach to quantum computation. They are seeking a new class of universal-resource quantum states that are strikingly similar to ground states of certain strongly correlated spin systems. The group is also investigating multiple-walker quantum walks where the walkers are interacting bosons. They expect to quantify the trade-off between graph size and number of walkers for practical implementations of quantum algorithms. They are also studying fermions and expect to answer whether a ground state of pairwise-interacting fermions could serve as a universal resource for quantum computation.

Christoph Simon’s group is studying photon-photon interactions and specifically will investigate the implementing photon-number quantum non-demolition measurements in solid-state atomic ensembles, atomic gases, Rydberg polaritons and Bose-Einstein condensates. The group will also closely investigate acoustically-controlled quantum optical memory as well as controlled-dipole quantum memory. A third group objective concerns how to couple a single NV center to a mechanical oscillator through an intermediary nano-photonic cavity.

Barry Sanders and his group have three overarching objectives for the coming year. One is to develop a scheme that will fully characterize the tunneling and decoherence rates of charged qubits formed from dangling bond pairs on a silicon surface. This research is collaborative with *i*CORE Chair Wolkow’s group at NINT. In collaboration with Alexandre Blais at the University of Sherbrooke and with Andreas Wallraff’s group at ETH Zürich, the plan is to complete theory and experiment on microwave interaction and transmission for multiple mutually interacting flux qubits connected to an open transmission line. In another direction, quantum simulations are one of the hottest topics in quantum information because it could soon be possible to create quantum information processors that will simulate quantum dynamics beyond the capability of foreseeable non-quantum computers. The group will develop highly efficient oracle-less algorithms for simulating quantum Hamiltonian dynamics for many-body systems.

In Mathematics and Statistics, Gour’s group aims to address one of the most fundamental questions in quantum information, namely the amount of information that can be transmitted reliably through a quantum channel. The group will also focus on other problems including whether there exists exotic bipartite mixed states with negative partial transpose and from which it is impossible to distill ebits (i.e. Bell states), optimal strategies to share a quantum secret with a hybrid of quantum and classical shares, optimal ways to share entanglement in quantum networks, and necessary and sufficient conditions for local manipulation of multipartite pure states.

In Computer Science, Peter Høyer’s group will continue research into quantum algorithms and complexity.

IQIS has a challenging but promising year ahead. Changes are afoot as the Institute seeks to establish a strong future perhaps in close collaboration or partnership with related research areas. Meanwhile the research objectives are promising and place IQIS researchers amongst the world leaders in quantum information science.

Appendices

A. Charter

Charter of the Institute for Quantum Information Science at the University of Calgary

Name

1. The name of the organization shall be the Institute for Quantum Information Science at the University of Calgary (hereinafter referred to as "Institute").

Supervising Officer

2. Under the University's policy on Institutes and Centres (ss. 3.4 & 4.6), each institute reports to an appropriate "supervising officer" within the University's administrative structure. The supervising officer of the Institute shall be the Dean of the Faculty of Science.

Approval and Review Bodies

3. The bodies responsible for approving, reviewing, and renewing the Institute under the policy on Institutes and Centres (s. 3.5) are the Dean of the Faculty of Science and the Research Development and Policy Committee (RDPC).

Term of the Institute

4. Under the limited-term provision of the University's policy on Institutes and Centres (s. 4.4), the Institute is established for a seven and half years term ending 30 June 2012. The Institute is eligible for renewal (s. 4.4) upon favourable external review (s. 4.3).

Goals

5. The goals of the Institute shall be:
   a) to establish and maintain leading quantum information science in the areas of quantum algorithms and processing, implications of quantum information on information security and communication complexity, development of physical implementations of quantum information tasks and protocols, and critically evaluate proposals and experimental results in the field;

   b) to educate and train persons with expertise at the frontiers of the allied disciplines of quantum information science;

   c) to bring together top researchers in the world in order to further the development of the field of quantum information science through a focused, multi-disciplinary effort;

   d) to identify promising research areas that will lead to valuable intellectual property and to conduct research in these areas;

   e) to collaborate in complementary research activities in the areas of computer science, engineering, mathematics and experimental and theoretical physics and chemistry.

Targets and Measures of Success

6. At the establishment and/or renewal of an institute, the University's policy on Institutes and Centres (ss. 4.1 & 4.3) requires the setting of targets against which to measure success in adding value.

Schedule of Review

7. Under the terms of the University's Institutes and Centres Policy (ss. 4.1-4.3) and Procedures (ss. 2.4-2.6), the Institute undertakes to be reviewed upon the following schedule during its term:

- at the discretion of the Dean of the Faculty of Science, an internal review after two years of the Institute's limited term;
- as required by the policy on Institutes and Centres, an external review during the final 18 months of the Institute's term.

In addition, the Institute shall submit an annual report on its activities to the Dean of the Faculty of Science.

Institute Board of Directors

8. a) The governing body of the Institute shall be referred to as the "Board of Directors" (hereinafter "Board").

b) Membership of the Board shall comprise:

i. The Institute's "supervising officer" (or designate), who shall Chair the Board and appoint a Vice Chair from among other board members;

ii. At least 4 "members at large," drawn from or nominated by
- companies whose primary operations are synergistic with quantum information science;
- agencies that provide funding for quantum information science research in Alberta; and
- leading members of the quantum information science academic community.

At least one (1) "member at large" shall be appointed from each of these three categories.

c) The President of the University of Calgary shall appoint "members at large" on the advice of the supervising officer. Terms of appointment, commencing on April 1, shall normally be for three years. This length of appointment may be varied to ensure an appropriate staggering of terms. Members of the Board shall be eligible for re-appointment for consecutive terms of office.

d) The Board shall be responsible for the overall success and governance of the Institute. More particularly, its responsibilities include:

i. approving and/or amending this Charter under the provisions of clause 10 below;

ii. ensuring that relevant University policies are respected (see section 9 below);

iii. appointing a Director for the Institute;
iv. approving the Institute's budget and strategic plans;
v. determining membership categories and requirements for the Institute;
vi. determining the procedures and requirements of general meetings of institute members (with at least one such meeting required annually);
vii. helping to create opportunities for the Institute;
viii. facilitating the periodic reviews and external assessments of the Institute, as required by the University's policy on Institutes and Centres (s. 4.3).

e) The Board shall appoint a Secretary of the Board for a three-year term. The Board can revoke such appointment at any time. The Secretary is not a Board Member and is not eligible to vote.

f) The Board shall meet not less than once in each calendar year, prior to the annual general meeting of Institute members. Special Meetings of the Board shall be convened by the Chair of the Board or upon the written request of at least two (2) members of the Board addressed to the Chair.
i. At least thirty days notice of any meeting shall be given in writing to each member of the Board. Such notice shall specify the time, place and agenda of the meeting;
ii. At any meeting of the Board 50 percent of members, present physically or via teleconference, shall constitute a quorum.

g) The cost for Board members of attending Board meetings (annual and special) will be incurred by the Institute.

Director

9. a) The Director reports to the Board and to the University through the Dean of the Faculty of Science (who, directly or through a designate, chairs the Board).

b) The Director exercises a general superintendence over the operational affairs of the Institute in accordance with the goals of the Institute, and within Board-approved budgets and strategic plans.

c) The duties of the Director shall include, but not be limited to, the following:
i. preparing an annual budget and strategic plan for consideration and approval by the Board;
ii. preparing periodic financial updates for consideration by the Board;
iii. ensuring that all Institute policies and procedures adopted by the Board are made widely known among Institute members and stakeholders, including the broader University of Calgary community;
iv. preparing an annual report on the Institute's affairs, which shall include reporting on measures of success;
v. making any additional submissions or reports, as appropriate or requested, to the Board or the University of Calgary on any matter affecting the Institute;

vi. facilitating the periodic reviews and external assessments of the Institute required by the University's policy on Institutes and Centres (s. 4.3).

Policies and Procedures

10. The Institute will operate in accordance with all applicable University of Calgary policies and procedures.

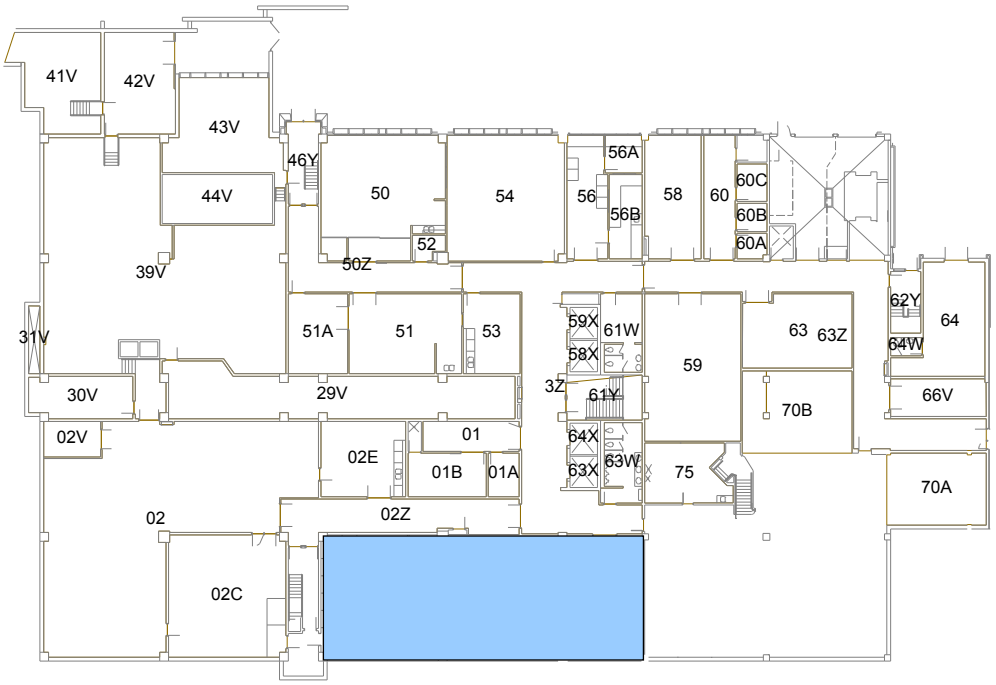
Amendments

11. Amendments to this Charter shall require approval by the supervising officer and two-thirds of the Board. (The supervising officer may refer proposed amendments to RDPC for its advice.)

B. Floor Plans for Existing Use of Space

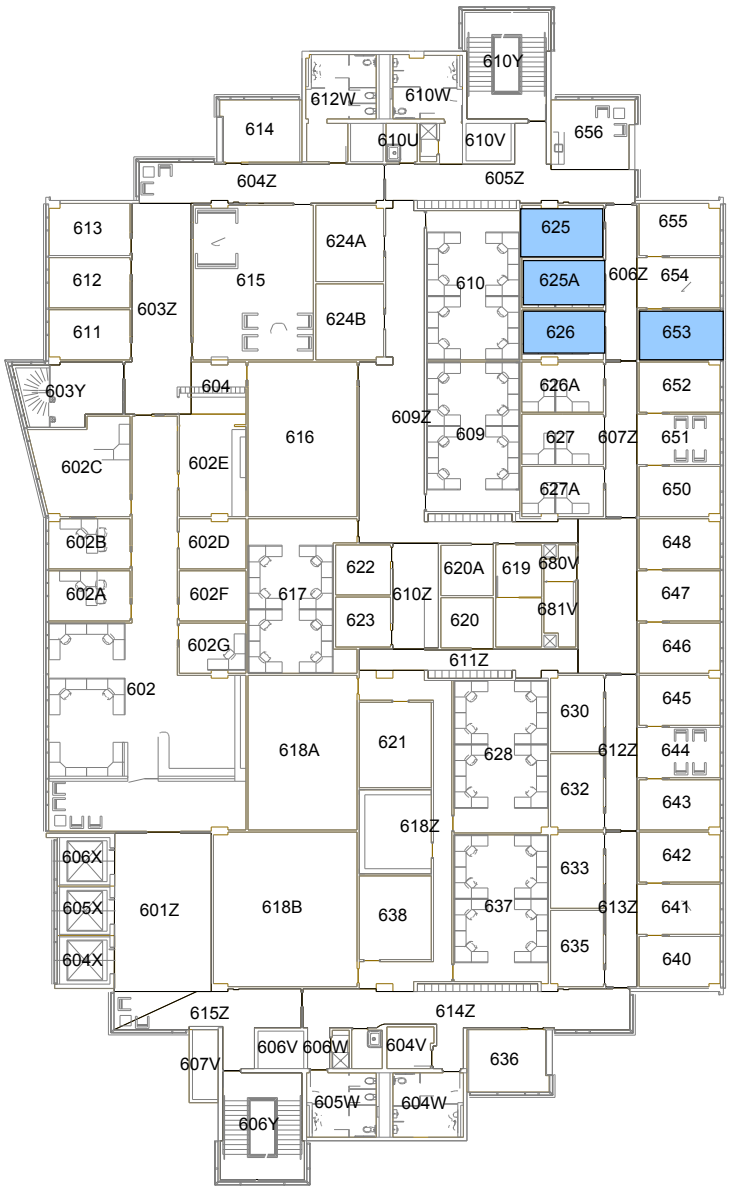
Earth Science Basement

IQIS



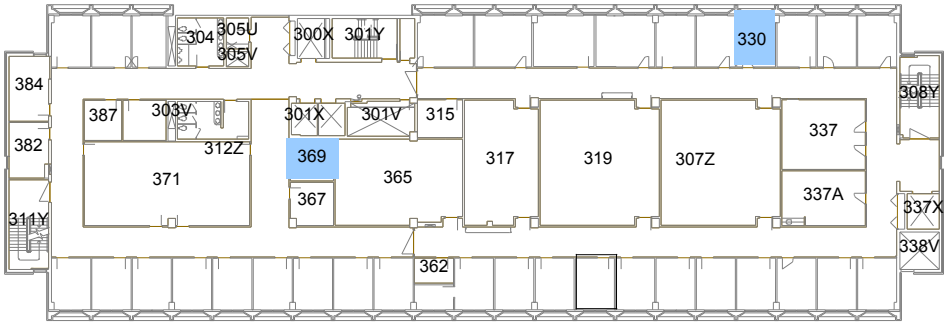
ICT Sixth Floor

IQIS



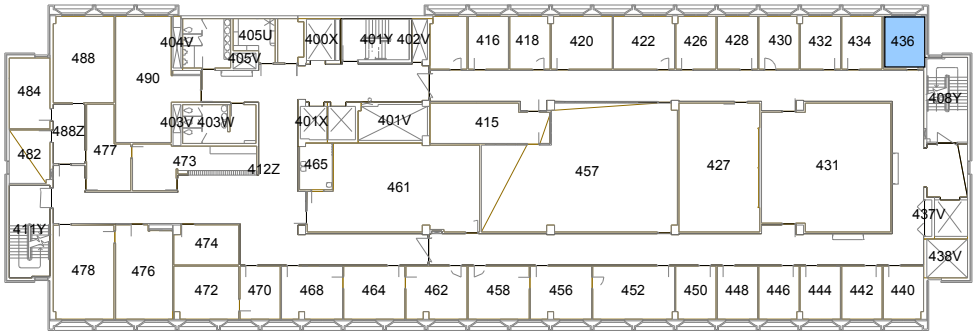
Mathematics Third Floor

IQIS



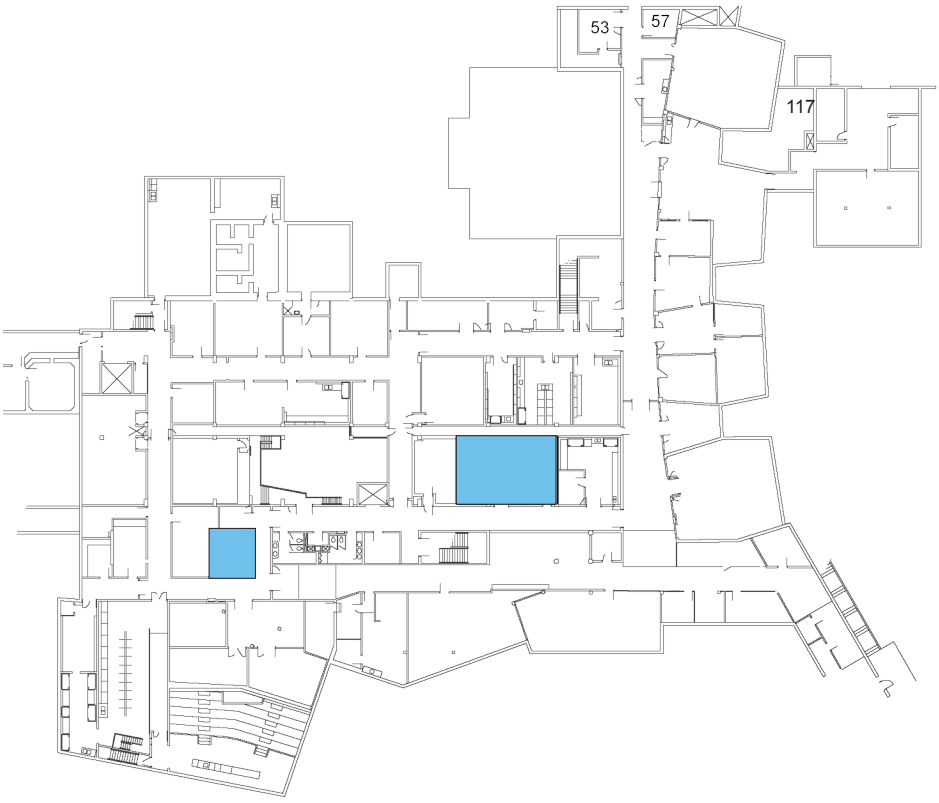
Mathematics Fourth Floor

IQIS



Science B Basement

IQIS



Science B Main Floor

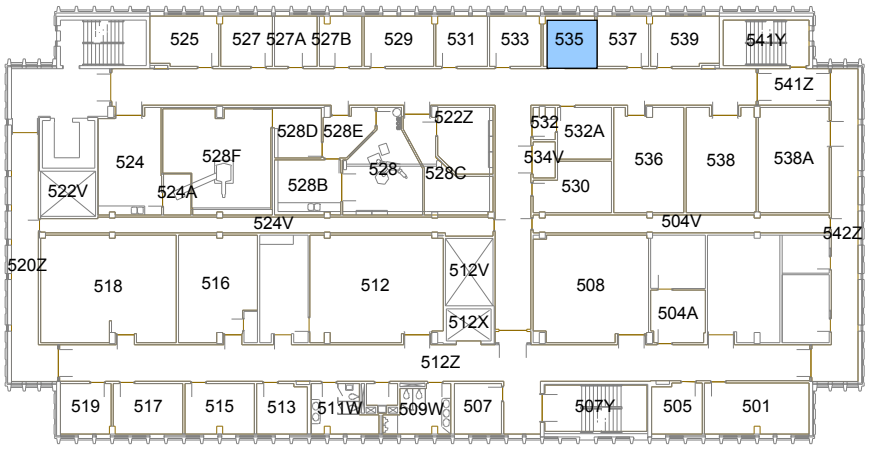
IQIS

Science B Third Floor

IQIS

Science B Fifth Floor

IQIS



IQIS adds value to the University of Calgary in the following ways:

Fosters a multidisciplinary research team through financial, administrative, and computer support

Builds a quantum information research community by providing visitor, seminar, and colloquium programs

Assists new faculty members with a rapid transition to becoming productive researchers with a strong research group and necessary equipment

Publishes reports and web pages that ensure recognition of the Institute and its researchers as leaders in quantum information

Supports recruiting efforts to bring the best faculty members, postdoctoral researchers, and graduate students to the University

Sponsors and provides logistical support for leading international conferences to be held in or near Calgary

Partners with other quantum information institutes within national and international research and training networks

Enhances the University's reputation by conducting and disseminating outstanding research results

Provides benefit to the community by generating new knowledge in a strategic area

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