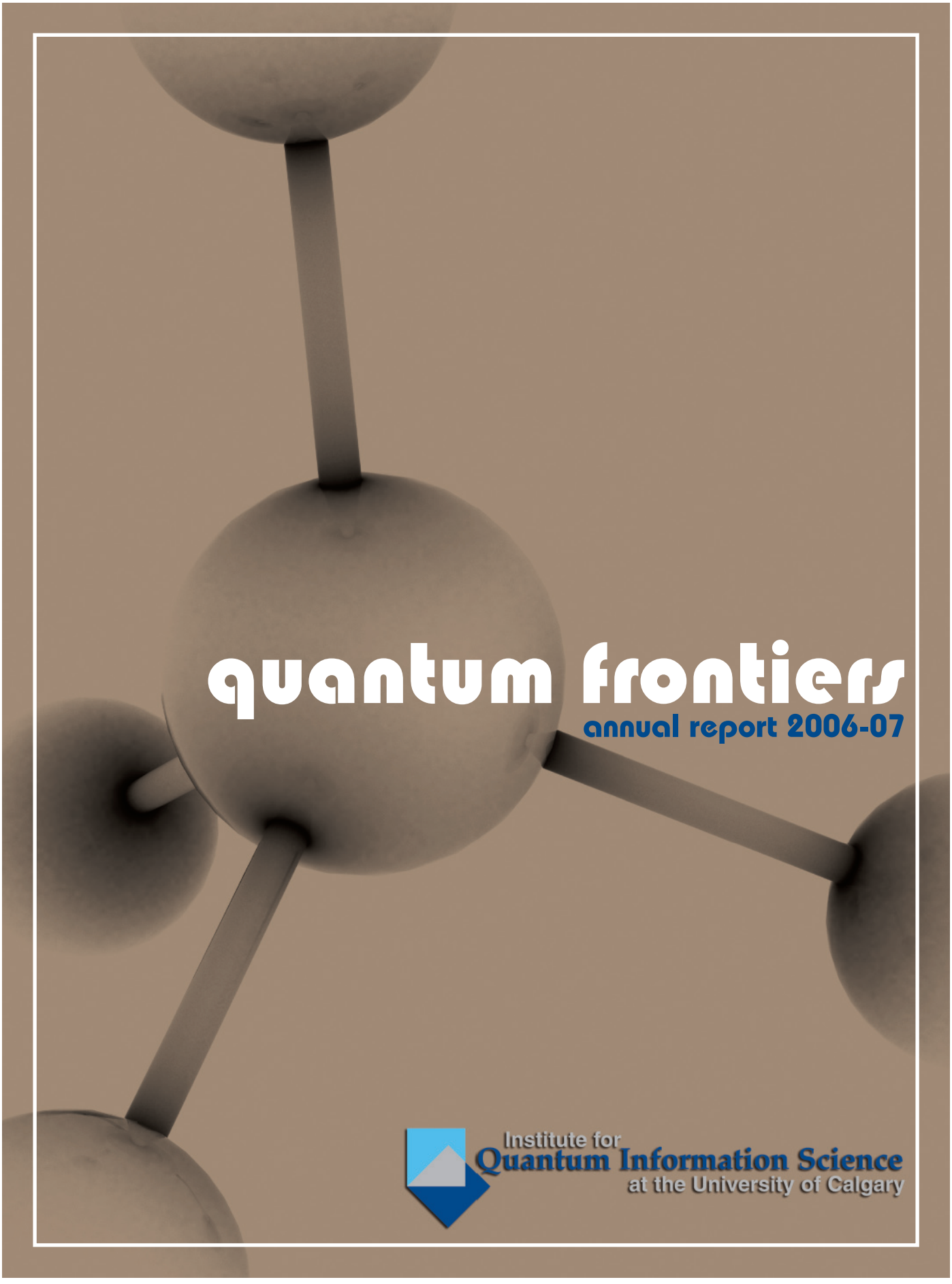

quantum frontiers

annual report 2006-07

Institute for
Quantum Information Science
at the University of Calgary

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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.

1. director's report

The Institute for Quantum Information Science (IQIS) was established in October 2005 as a University of Calgary Institute. The Institute conducts leading experimental and theoretical research in select areas of quantum information, provides education and training to undergraduate and graduate students and to postdoctoral fellows, and engages in outreach and service to the local and professional communities. Although the Institute is quite young, with all current six faculty members and one adjunct faculty member appointed between 2002 and 2006, the Institute has grown quickly and has numerous achievements that are highlighted in the pages to come.

This report is for the financial year commencing 1 April 2006 and ending 31 March 2007 (FY 2006-07). Thus all inputs including grant funding and incoming students, and all outputs including publications and degree completions, are reported for this period. This task is made feasible by the IQIS database system. As this is the first IQIS Annual Report, and a comparison with the past is valuable, this report also includes a summary for FY 2005-06.

The content of this report comprises organizational and financial overviews and summaries for IQIS, summaries of achievements and objectives provided by each research group, a summary of national, international, and industry linkage, data for IQIS inputs and outputs, a summary of performance indicators and targets contained in the IQIS charter accompanied by an analysis of performance relative to these targets, and a section on outcomes resulting from IQIS activities.

IQIS is involved with quantum information research activities worldwide. The field of quantum information science has an excellent future: it takes a long-term view towards solving information technology problems that appear to be intractable or at least unlikely without exploiting quantum properties. Examples include making certain intractable computational problems efficiently solvable and providing unconditional communication security in contrast to existing computationally secure public cryptography. IQIS is especially renowned within this field for contributions to algorithms, complexity, resources, quantum optical implementations, and practical quantum cryptography.

Members of the Institute are partners with national and international institutes and research networks, including the Australian National Centre of Excellence for Quantum Computer Technology, the Canadian Natural Sciences and Engineering Research Council (NSERC) Innovation Platform QuantumWorks, the Canadian Network of Centres of Excellence for Mathematics for Information Technology and Complex Systems (MITACS), the Canadian Institute for Advanced Research (CIFAR), and formerly with two European research networks under the fifth framework. In addition to formal links, personnel exchanges, including students, postdoctoral fellows, and faculty, continue with many universities.

In addition to research excellence, IQIS also focuses on both undergraduate and graduate education during the period of the report. IQIS hosted 5 summer student scholars, and 5 undergraduates enrolled in formal course projects in quantum information. The number and the quality of graduate students both continue to increase steeply: the graduate students enrolled in the quantum information program in the Department of Physics & Astronomy has dramatically enhanced

this Department's graduate education standing in Canada, and the quantum information students constituted 31% of the Department's total enrolment. Graduate students are provided with an excellent set of graduate courses in quantum information with more in preparation: existing graduate courses are advanced quantum mechanics, quantum optics, implementations of quantum information, and quantum computing; courses under development are the mathematics of quantum information and quantum cryptography. Through these courses, which are also open to undergraduate students, and the expertise of IQIS faculty, IQIS offers an excellent environment for learning quantum information science.

IQIS places a high value on outreach to the professional community and to the public. IQIS is represented on editorial boards of top journals and on program committees of the most important quantum information conferences. In 2006 IQIS was host for both the Third Annual Canadian Quantum Information Students' Conference and the Sixth Canadian Summer School on Quantum Information Processing. Furthermore, the University of Calgary will host the 2007 joint conference of the American Physical Society Division of Atomic, Molecular, and Optical Physics and the Canadian Association of Physicists Division of Atomic and Molecular Physics and Photon Interactions, and will host the QuantumWorks Annual Meeting in September 2007, the prestigious international biennial Quantum Communication, Measurement and Computation Conference in 2008 and the 2008 International Conference on Information Theoretic Security (ICITS 2008).

The Institute also has embarked on an outreach program based on animating existing and proposed quantum information implementations, including quantum teleportation, quantum cryptography, and quantum computing. These animations are used in lectures and teaching at the University of Calgary and beyond and have also been produced for other parties. As quantum information concepts and implementations can be difficult to convey to a non-expert, significant effort has been directed to development of quantum information animations so that animations are based on effective, clear, and can be produced at minimal cost.

We are proud of the Institute and its achievements, and are discussing its future, both formally through the IQIS Council and informally through casual discussions and e-mail. The Institute now has the breadth in both experimental and theoretical research to make it a worldwide destination of choice for students, postdoctoral fellows, and visiting faculty members. However there are important challenges and opportunities ahead. Two of the most important challenges for the Institute are the need for more operational funding and the need for space. The Institute operates as efficiently as possible but cannot operate on its current budget and is thus subsidized by research grants. The growth of the Institute has put enormous pressure on limited space, especially in the Department of Physics & Astronomy, which has led to crowded conditions for IQIS researchers. On the bright side, the provincial strategy for nanotechnology promises opportunities for quantum information provided that a faculty member can be recruited into a research field in the nexus of quantum information and nanotechnology, for example in quantum nanophotonics or quantum nanoscience. Pursuing these opportunities and defeating the challenges should keep the Institute busy for the coming year.

2. overview of the institute

HISTORICAL BACKGROUND

1990 – 2002

The University of Calgary Department of Computer Science was one of the first computer science departments worldwide that had research activity in quantum computing. Richard Cleve was appointed Assistant Professor in the Department in 1990 and subsequently wrote his seminal work on quantum communication complexity. Whereas work by Peter Shor and others showed exponential speed-up for certain computational problems over known algorithms, Richard proved an absolute exponential speed-up for quantum communication over any classical protocol whatsoever in the absence of randomness.

Richard was joined by John Watrous, who was appointed Assistant Professor in 1999 and became a Tier II Canada Research Chair in Quantum Computing in 2002. Like Richard, John was also recognized as a leader in quantum computing for his ground breaking contributions to quantum walks and quantum interactive proofs.

Richard and John were joined by Peter Høyer in 2001 as an Alberta Ingenuity Fund postdoctoral fellow. With Peter's appointment the team grew to three exceptionally strong quantum computing researchers and placed Calgary as one of the world's top places for quantum computing. Peter was appointed Assistant Professor in the Department of Computer Science in July 2003.

2002 - 2005

Although quantum computing was strong in computer science, there was recognition that Calgary's activities would be further strengthened by the appointment of physicists. David Feder joined the Department of Physics & Astronomy in 2002. Soon after, with the support of an Alberta Informatics Circle of Research Excellence (iCORE) Chair and Professor Establishment Grant, Barry Sanders became iCORE Professor of Quantum Information Science in the Department of Physics & Astronomy on 1 July 2003. Karl-Peter Marzlin joined Barry's group as a Senior Scientist and was appointed Adjunct Professor with the Department of Physics & Astronomy in January 2004. With these three appointments, the University of Calgary had a strong team of theoretical physicists in quantum information.

The next stage of development was in experimental physics. Alex Lvovsky was appointed Associate Professor in 2004 and, on 1 April 2005, was awarded a Tier II Canada Research Chair in Experimental Quantum Information Science.

Soon after Alex's appointment, discussions commenced with the company General Dynamics Canada, which has laboratories in Calgary, to create an Industrial Research Chair in Quantum Cryptography. This direction for applied quantum information research received enthusiastic support as a key component of the University's nascent thrust into the broad spectrum of information security.

In order to coalesce the diverse quantum information activities at the University of Calgary into a synergistic effort and also to create unified goals and present a monolithic face to the outside community, an Institute for Quantum Information was proposed in 2003. Provisional status was granted in 2004, and full status conferred in October 2005. The establishment of the Institute was instrumental in gaining worldwide awareness and recognition of the dynamic growth and quality of quantum information science at the University of Calgary.

2005 TO THE PRESENT

Between 2005 and 2006, two of the quantum computing professors in the Department of Computer Science resigned. Effective 1 July 2005, Richard Cleve resigned his University Professorship at the University, and John Watrous resigned

his Tier II Canada Research Chair in Quantum Computing on 3 June 2006. Richard and John both left their positions in Calgary to join the fast-growing Institute for Quantum Computing at the University of Waterloo. Neither of these two positions were replaced, but Gilad Gour was appointed to an assistant professorship in the Department of Mathematics & Statistics effective 1 July 2006. Gilad's appointment enabled the multi disciplinary field of quantum information science to be practised in three Departments within the Faculty of Science.

At the same time as Gilad's appointment in 2006, Wolfgang Tittel was appointed as an Associate Professor in the Department of Physics & Astronomy and was awarded an Industrial Research Chair by both iCORE and NSERC, supported by an award from General Dynamics Canada. Wolfgang's appointment gave IQIS another superb experimental research group and also a formidable link to a company renowned for its security research and development, including information security.

IQIS was formally launched as a University Institute in a full day event on 21 January 2005 that included top speakers from the field of quantum information science and was kicked off by a talk from renowned sociologist Steve Woolgar. Over one hundred people from campus and beyond attended the event.

WHAT IS QUANTUM INFORMATION SCIENCE?

Quantum information science is the study of information, communication, and computation using devices that are governed by the principles of quantum physics. Whereas information technology is based on binary representations of information and boolean logic, quantum information exists as superpositions of different informational states, which can be processed by quantum gates that preserve their quantum properties.

Quantum information science is an exciting field because of potential revolutionary advances over any other form of information technology. Quantum computing converts some hard computational problems into easy-to-solve problems, with the notable success of factorization of numbers whose hardness is the basis of public key cryptosystems. Other successful protocols include the discovery that a quantum search of a database is provably faster than any classical search algorithm, and quantum cryptography can provide information theoretic security via public-channel communication in contrast to all existing public key cryptosystems, which are only computationally secure. Also quantum communication enables dense packing of information into quantum states thereby enabling more information to be sent down channels than allowed classically.

In addition to the enticing prospects of quantum information science, experimental advances are proceeding remarkably quickly. Quantum cryptography is now a commercial enterprise, and numerous technologies are candidates for quantum computer realizations. Quantum error correction provides a strategy for managing errors that arise in quantum information processing, and quantum memory has been demonstrated.

These exciting theoretical and experimental advances have catapulted quantum information science to becoming one of the most exciting interdisciplinary scientific fields, one that brings together computer scientists, mathematicians, electrical engineers, physicists, chemists, and material scientists.

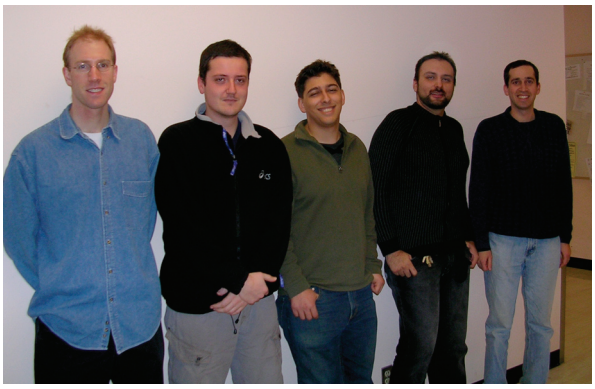
QUANTUM INFORMATION RESEARCH GROUPS

ULTRACOLD ATOMS AND CONDENSED MATTER THEORY

Dr. David Feder

Ultracold atomic gases enable the creation of completely new states of matter that only exist at temperatures extremely close to absolute zero. These systems can be strongly decoupled from their environment and are therefore well-suited for the exploration of novel phenomena in quantum matter and the construction of quantum information devices. We are studying the superfluid behaviour and strong correlation properties of ultracold atoms, particularly those subjected to rapid rotation and to optical lattice potentials (crystals formed by laser interference). The resulting states are expected to be useful for the implementation of quantum algorithms. In particular, we are interested in quantum computation based on measurements only (the so-called one-way model and its extensions), on quantum walks, and on braiding of particles with fractional statistics (topological quantum computation with anyons).

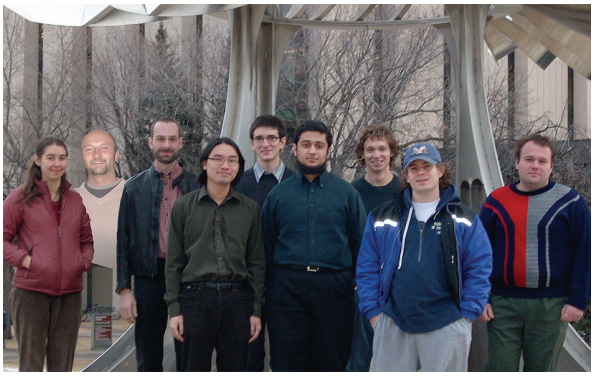
QUANTUM INFORMATION RESEARCH GROUP IN MATHEMATICS & STATISTICS



Dr. Gilad Gour

Quantum resources, like entanglement, are the key ingredients of quantum information processing tasks. They are needed in many cases where quantum networks contain certain kinds of limitations or imperfections. For example, situations in which different parties in the network are not familiar with the exact orientation of each other (i.e. they are lacking a shared reference frame) induce limitations called super-selection rules. With such restrictions new quantum resources are needed. Our group objectives are to study the fascinating resource theories that emanate from such constraints. The study of quantum information in the presence of super-selection rules, for example, not only lead to new, interesting physics and the discovery of new resources, but also have applications in related fields, such as quantum cryptography, quantum optics, and quantum communication.

QUANTUM COMPUTING RESEARCH GROUP IN COMPUTER SCIENCE



Dr. Peter Høyer

The Quantum Computing Research Group within the Department of Computer Science conducts research in computational aspects of quantum mechanical systems. We study systems based on quantum mechanical principles. Our research areas include quantum algorithmics, quantum complexity theory, quantum communication complexity, quantum information theory, and quantum computer simulations of quantum mechanical systems. Our work is collaborative. Together with researchers at other groups and institutions in North America and Europe, we explore the possibilities and limitations of quantum computing. We organized and hosted the Third and Sixth Canadian Summer School on Quantum Information Processing (Equips). Our work is internationally and nationally funded, we offer courses on quantum computing, and we provide a rich and flexible environment.

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.

THEORETICAL QUANTUM OPTICS AND NONLINEAR OPTICS

Dr. Peter Marzlin

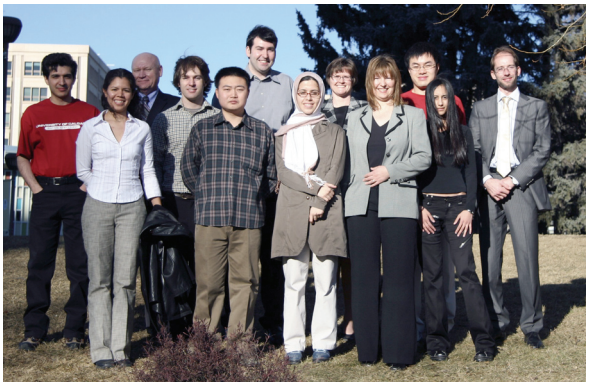
Atom-light interaction touches most fundamental aspects of quantum mechanics; many-particle effects in dense atomic gases, the nature of quantum states of light, and even relativity are relevant to understand it. Despite this conceptual depth it is also very close to experiments. We investigate novel effects in this interaction for use in quantum information processing; stopping of light or strong interaction between two photons may be used to realize a quantum memory or controlled quantum gates, respectively. We study the use of electromagnetically induced transparency, atom-atom correlations, and dielectric media for this goal and are also considering problems in relativistic quantum information theory.

QUANTUM INFORMATION SCIENCE

Dr. Barry Sanders

Quantum information science is revolutionizing the principles of information, communication, and computation. Our efforts are focused on studies of quantum information resources (such as entanglement and measurements), tasks (such as quantum teleportation, cryptography, and fingerprinting), and implementations (such as photon-based realizations), and our goal is to make quantum information work in the real world.

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 the building of 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.

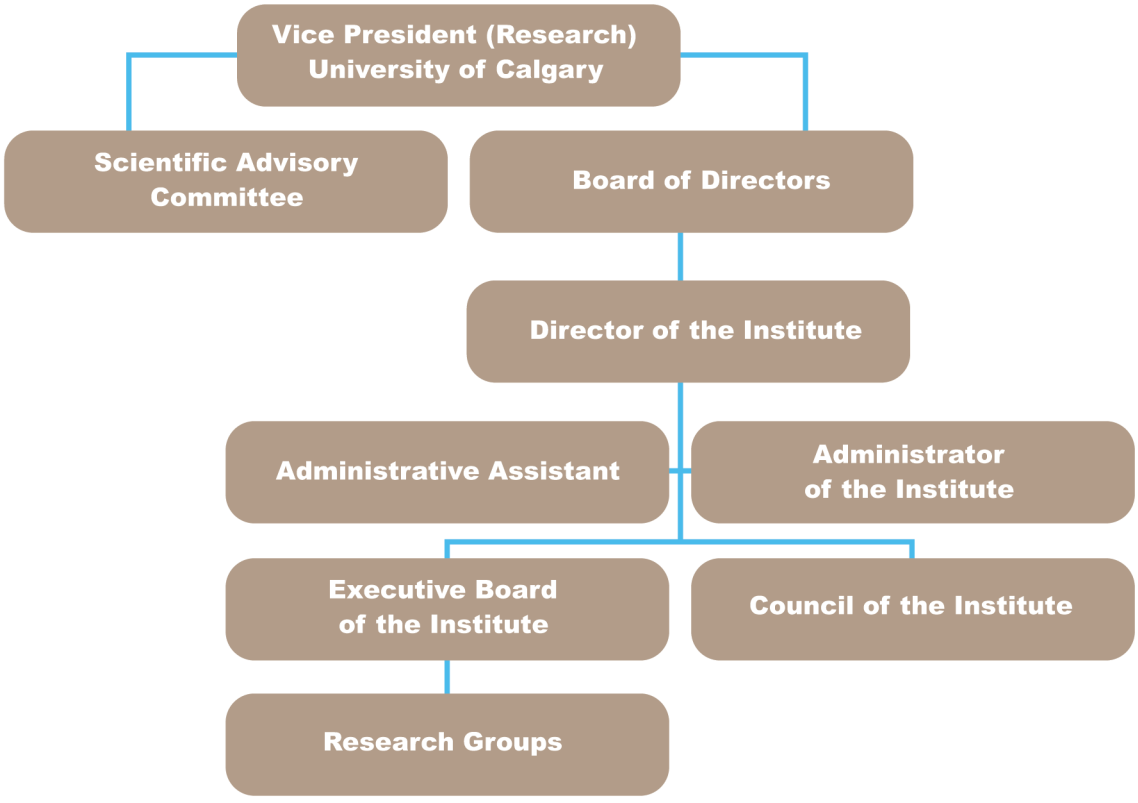
3. management

STRUCTURE

The organizational structure of the Institute is depicted in the organizational chart. 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 receives advice from a Scientific Advisory Committee, which is not yet established, and reports to the University of Calgary Vice- President (Research). The Vice-President (Research) may be Chair of the Board or appoint a separate Chair.

The Director and the Administrator of the Institute work on day-to- day matters of the Institute. The Institute Executive comprises the Director (Barry Sanders), Deputy Director (Peter Høyer), Administrator (Nancy Jing Lu), and two faculty members (Alex Lvovsky and Gilad Gour). 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.



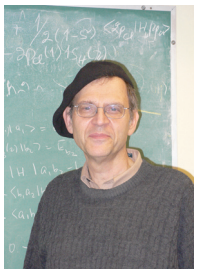
ORGANIZATIONAL CHART – INSTITUTE FOR QUANTUM INFORMATION SCIENCE

BOARD OF DIRECTORS

CHAIR

Dr. Rose Goldstein
Vice-President (Research), University of Calgary

Dr. Goldstein is Vice-President, Research of the University of Calgary. She obtained her BSc and MD degrees from McGill University and has done residency and fellowship training at the University of Toronto, University of Ottawa, and the University of Texas at Houston. As a clinician scientist, Dr. Goldstein has held a series of research grants and has served on editorial boards and scientific review panels in her area of research. She has also received grants to support her work in medical education, including exploration of gender and health topics in the training of medical students.



MEMBER

Dr. Paul Brumer
Department of Chemistry, Faculty of Arts and Science, University of Toronto

Dr. Brumer joined the University of Toronto in 1975 after completing his BSc at Brooklyn College and his PhD at Harvard University and was appointed a University Professor in 1995. Dr. Brumer has been at the forefront of two major areas in chemical physics: using nonlinear mechanics to understand molecular dynamics, and controlling chemical reactions with lasers. Dr. Brumer's work has been recognized in numerous ways. He has been an A.P. Sloan Foundation Fellow and is a Fellow of the Royal Society of Canada, the Chemical Institute of Canada and the American Physical Society. He has received two Canada Council Killam Research Fellowships and is one of the youngest recipients of the CIC Palladium Medal, the highest award of the Chemical Institute of Canada. He was the recipient of the prestigious 2000 Killam Memorial Prize in Physical Sciences and is currently the Roel Buck Chair in Chemical Physics.

MEMBER

Dr. Greg Luoma
Chief Technology Officer, General Dynamics Canada

Dr. Luoma has over 26 years of experience conducting, managing and directing diverse defence R&D programs including large multiyear programs with Canadian and international governments, industries and universities. He has internationally recognized expertise in a number of areas of defence science, particularly Chemical/Biological Defence and advanced materials.

Following his completion of BSc, MSc and PhD degrees at the University of British Columbia in 1976, 1978 and 1980, Dr. Luoma began his career at the Defence Research Establishment Pacific in Victoria in 1980 with responsibility for Dockyard analytical chemistry support to the Canadian Navy while conducting research into advanced materials used in military platforms. In 1992, he left Victoria to take on the role of Head of the Chemical and Biological Defence Section at the Defence Research Establishment Suffield (now DRDC Suffield) where he directed the research efforts of 40 scientists and technicians in developing new defensive technologies against weapons of mass destruction.

Dr. Luoma joined General Dynamics (GD) Canada in 1998 to lead efforts to commercialize biodetection technology transferred to GD Canada from DRDC Suffield under a Technology Demonstration program. In 2001 Dr. Luoma took on additional responsibilities as Director of R&D to develop a common process for internal R&D project selection and management across all business areas of GD Canada. In 2004 he was named Chief Technology Officer for GD Canada with responsibility for developing and leading the company technology strategy as well as retaining executive oversight for all R&D within GD Canada.

MEMBER

Professor Sir Peter Knight
Principal, Faculty of Natural Sciences , Imperial College London

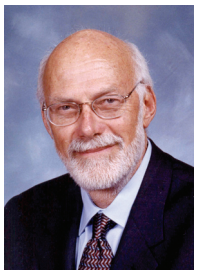
Professor Sir Peter Knight is Principal of the Faculty of Natural Sciences at Imperial College, London U.K., and is past Head of Imperial's Department of Physics. He is a past President of the Optical Society of America and a past Chair of the European Physical Society's Quantum Electronics and Optics Division, and has been Chief Scientific Advisor to the UK National Physical Laboratory. Professor Sir Peter Knight is renowned for research in quantum optics, strong field physics and quantum information and is widely recognized for both his research and communication abilities and achievements, including having been a Parsons Memorial Lecturer in 1991 and Wood Memorial Lecturer in 1996, winner of the Thomas Young Medal and Prize in 1999 and joint winner of the Einstein Medal and Prize for Laser Science of the Society of Optical and Quantum Electronics and Eastman Kodak in 1996.

MEMBER

Dr. J. Sandy Murphree
Dean, Faculty of Science, University of Calgary

Dr. J.S. (Sandy) Murphree came to the University of Calgary in 1975 as a Postdoctoral Fellow. He served as a Research Associate, and Adjunct Associate Professor before being appointed as an Associate Professor in 1988. In 1991 Dr. Murphree was promoted to Professor, and in 1995 he became Head of the Department of Physics and Astronomy. Dr. Murphree stepped down as Department Head on June 30, 2000, and resumed regular duties in the department on July 2, 2001. He was appointed Associate Dean (Research and Academic Affairs) on July 1, 2003, with the title changing to Vice-Dean a year later. He became Acting Dean on July 1, 2005, and in March of 2006 he accepted the position of Dean of Science.

Dr. Murphree is an experimental space physicist whose research efforts deal with the physics of the earth's magnetosphere and in particular the processes resulting in the aurora. Primary datasets are those obtained from several satellite borne low-light level imagers of the auroral distribution.



MEMBER

Dr. Brian Unger
Department of Computer Science, University of Calgary

Dr. Unger is currently the Executive Director of the Grid Research Centre (grid.ucalgary.ca) and a Special Advisor for iReach ("informatics for rural empowerment and community health"), a research project supported by the International Development Research Centre of Canada (IDRC), and by the Cambodian Ministry of Commerce (ireach.org.kh). He was the founding president and CEO of iCORE (the "informatics circle of research excellence") from 1999 through 2004, (www.icore.ca), a not-for-profit corporation aimed at recruiting exceptional ICT researchers to Alberta universities. In its first five years iCORE invested $43 million in 17 research chairs and professorships that now support over 500 faculty, graduate students and research staff. Dr Unger was the founding president of Cybera Inc. (formerly the Netera Alliance) (www.cybera.ca), a consortium that builds cyberinfrastructure to support research in Alberta, and was the founding board chair of C3.ca Inc. (www.c3.ca), a national consortium aimed at building Canada's infrastructure in high performance computation. He is a Co-Principal Investigator of WestGrid (www.westgrid.ca), 2002-2008, which raised $48 million to provide research infrastructure for Western Canada universities; and was the founding president and CEO of a for-profit startup company, Jade Simulations, that developed and marketed parallel simulation software products from 1988 through 1993.

Dr. Unger was named a Canada Pioneer of Computing at the IBM CASCON conference, Toronto, October, 2005, and received the IWAY Public Leadership award for outstanding contributions to Canada's information society in 2004, and the 1993 ASTech award for "Innovation in Alberta Technology" for research in parallel simulation and distributed computation.

DIRECTOR

Dr. Barry C. Sanders
iCORE Professor of Quantum Information Science

Dr Barry Sanders is iCORE Professor of Quantum Information Science and Director of the Institute for Quantum Information Science at the University of Calgary. He is especially well known for seminal contributions to theories of quantum-limited measurement, highly nonclassical light, practical quantum cryptography, and optical implementations of quantum information tasks. His current research interests include quantum resources and also optical and atomic implementations of quantum information tasks and protocols.

Dr. Sanders is a Fellow of the Institute of Physics (U.K.), the Optical Society of America, the Australian Institute of Physics, and the American Physical Society, a past President of the Australian Optical Society, current Secretary-Treasurer of the American Physical Society Topical Group on Quantum Information, Concepts, and Computation, a member of the American Institute of Physics Education Advisory Committee, and an editorial board member for both Physical Review A and the New Journal of Physics. In addition, Dr. Sanders serves on numerous conference committees for the American Physical Society, the International Society for Optical Engineering (SPIE), the Optical Society of America, and various quantum information conferences and is Chair of the Photons, Atoms, and Qubits conference to be held in London in 2007.

4. performance and analysis

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5 May 2005, B. C. Sanders, "Quantum fingerprinting: theory and experiment" (colloquium), Los Alamos National Laboratory, Quantum Institute.

2 May 2005, A. J. Scott, J. Walgate and B. C. Sanders, "Classical and quantum fingerprinting strategies", T16, NATO Advanced Study Institute: Quantum Computation and Quantum Information, Chania, Crete, Greece, 2 May 2005 - 13 May 2005.

2 May 2005, A. I. Lvovsky, "The continuous-variable approach in discrete-variable quantum optics" (invited), 9th International Conference on Squeezed States and Uncertainty, Besançon, France, 2 May 2005 - 6 May 2005.

1 May 2005, B. C. Sanders, "Quantum fingerprinting: theory and experiment" (colloquium), Masaryk University, Department of Theoretical Physics.

6 Apr 2005, B. C. Sanders, "Elements of quantum information science" (colloquium), University of Victoria, Department of Physics and Astronomy.

PRESENTATIONS FOR 2006/07

(presenter is underlined)

29 Mar 2007, P. S. Turner, "Hidden degrees of freedom and distinguishability" (seminar), University of Bristol, Department of Mathematics.

29 Mar 2007, D. W. Berry, G. Ahokas, R. Cleve and B. C. Sanders, "Efficient quantum algorithm for simulating Hamiltonian evolution" (colloquium), Louisiana State University, Department of Physics and Astronomy.

22 Mar 2007, G. Gour, "Entanglement in quantum information" (seminar), University of Calgary, Department of Mathematics and Statistics.

13 Mar 2007, B. C. Sanders, "Quantum computing and quantum complexity" (seminar), University of Calgary, Complexity Group of Department of Physics and Astronomy.

8 Mar 2007, B. C. Sanders, Z. Shaterzadeh Yazdi and P. S. Turner, "The su(1,1) symmetry of tripartite entangled Gaussian states", W33.00003, 2007 APS March Meeting (APS 2007), Denver, United States of America, 5 Mar 2007 - 9 Mar 2007. (http://meetings.aps.org/link/BAPS.2007.MAR.W33.3).

8 Mar 2007, W. Tittel, M. U. Staudt, S. R. Hastings-Simon, M. Afzelius, V. Scarani and N. Gisin, "Investigations of an optical memory based on stimulated photon echoes", V33:000002, 2007 APS March Meeting (APS 2007), Denver, United States of America, 5 Mar 2007 - 9 Mar 2007. (http://meetings.aps.org/link/BAPS.2007.MAR.V33.2).

7 Mar 2007, T. Friesen and D. L. Feder, "One-way quantum computing in optical lattices with many atom measurements", J32.00013 , 2007 APS March Meeting (APS 2007), Denver, United States of America, 5 Mar 2007 - 9 Mar 2007. (http://meetings.aps.org/link/BAPS.2007.MAR.J32.13).

7 Mar 2007, M. U. Staudt, S. R. Hastings-Simon, B. Lauritzen, M. Afzelius, H. De Riedmatten, N. Sangouard, C. Simon, W. Tittel and N. Gisin, "Coherence investigations of Erbium doped in waveguide structures for a quantum memory", S32:00007, 2007 APS March Meeting (APS 2007), Denver, United States of America, 5 Mar 2007 - 9 Mar 2007. (http://meetings.aps.org/link/BAPS.2007.MAR.S32.7).

7 Mar 2007, S. R. Hastings-Simon, M. U. Staudt, B. Lauritzen, M. Afzelius, H. De Riedmatten, N. Sangouard, C. Simon, W. Tittel and N. Gisin, "Three level systems for quantum memories in Erbium doped materials", S32: 00010, 2007 APS March Meeting (APS 2007), Denver, United States of America, 5 Mar 2007 - 9 Mar 2007. (http://meetings.aps.org/link/BAPS.2007.MAR.S32.10).

7 Mar 2007, D. L. Feder, "Quantum search algorithm with many bosons in optical lattices", U33.00015 , 2007 APS March Meeting (APS 2007), Denver, United States of America, 5 Mar 2007 - 9 Mar 2007. (http://meetings.aps.org/link/BAPS.2007.MAR.U33.15).

6 Mar 2007, R. Stock, N. S. Babcock and B. C. Sanders, "Entangling operations and rapid measurement of clock-state qubits in Yb or Sr for quantum information processing", J32.00006 , 2007 APS March Meeting (APS 2007), Denver, United States of America, 5 Mar 2007 - 9 Mar 2007. (http://meetings.aps.org/link/BAPS.2007.MAR.J32.6).

6 Mar 2007, M. Garrett and D. L. Feder, "Perfect GHZ states from imperfect cluster states in optical lattices", K1.00170, 2007 APS March Meeting (APS 2007), Denver, United States of America, 5 Mar 2007 - 9 Mar 2007. (http://meetings.aps.org/link/BAPS.2007.MAR.K1.170).

5 Mar 2007, A. Morris and D. L. Feder, "Using custom potentials to access quantum Hall states in rotating Bose gases", A32.00002 , 2007 APS March Meeting (APS 2007), Denver, United States of America, 5 Mar 2007 - 9 Mar 2007. (http://meetings.aps.org/link/BAPS.2007.MAR.A32.2).

18 Feb 2007, G. Gour, "Quantum resource theories and super selection rules", Southwest Quantum Information and Technology Ninth Annual Meeting (SQuInT 2007), California Institute of Technology, Pasadena, United States of America, 16 Feb 2007 - 18 Feb 2007.

18 Feb 2007, N. S. Babcock, R. Stock and B. C. Sanders, "Rapid control and measurement of clock-state qubits in Yb and Sr ", Southwest Quantum Information and Technology Ninth Annual Meeting (SQuInT 2007), California Institute of Technology, Pasadena, United States of America, 16 Feb 2007 - 18 Feb 2007.

17 Feb 2007, P. Høyer, T. Lee and R. Špalek, "Strengthening the quantum adversary method with negative weights", Southwest Quantum Information and Technology Ninth Annual Meeting (SQuInT 2007), California Institute of Technology, Pasadena, United States of America, 16 Feb 2007 - 18 Feb 2007.

16 Feb 2007, B. C. Sanders, "Efficient algorithm for simulating Hamiltonian evolution" (seminar), National Institute of Standards and Technology.

15 Feb 2007, B. C. Sanders, "Efficient quantum algorithm for simulating Hamiltonian evolution" (seminar), University of Maryland, Laboratory for Physical Sciences.

31 Jan 2007, P. Xue, "Quantum information processing using atoms and cavity QED" (colloquium), Université de Sherbrooke , Département de Physique.

24 Jan 2007, B. C. Sanders, "Efficient quantum algorithm for simulating Hamiltonian evolution" (seminar), Pacific Institute for Theoretical Physics.

4 Jan 2007, B. C. Sanders, "Harmonic oscillatorology for quantum informationalists" (invited), CIAR Quantum Information Processing Meeting, Toronto, Canada, 4 Jan 2007 - 5 Jan 2007.

20 Dec 2006, G. Ahokas, D. W. Berry, R. Cleve and B. C. Sanders, "Efficient algorithms for simulating general dynamics on a quantum computer" (invited), APCTP-TPI Joint Meeting, University of Alberta, Edmonton, Canada, 19 Dec 2006 - 23 Dec 2006.

15 Dec 2006, A. I. Lvovsky, "Raman adiabatic transfer of optical states in multilevel atoms" (seminar), University of Queensland.

12 Dec 2006, A. I. Lvovsky, "Electromagnetically-induced transparency in multilevel atoms" (seminar), Australian National University.

5 Dec 2006, A. I. Lvovsky, "Quantum optical technology at the single-photon level and beyond" (keynote), Australian Institute of Physics 17th National Congress, Brisbane, Australia, 3 Dec 2006 - 8 Dec 2006.

3 Dec 2006, S. D. Bartlett, T. Rudolph, B. C. Sanders and P. S. Turner, "Quantum and semiclassical approaches to quantum reference frame degradation" (poster), P1-48, The 8th International Conference on Quantum Communication, Measurement and Computing (QCMC 2006), Tsukuba International Congress Center, Tsukuba, Japan., 28 Nov 2006 - 3 Dec 2006.

1 Dec 2006, B. C. Sanders, "Optical quantum information processing" (invited), The 8th International Conference on Quantum Communication, Measurement and Computing (QCMC 2006), Tsukuba International Congress Center, Tsukuba, Japan., 28 Nov 2006 - 3 Dec 2006.

30 Nov 2006, A. I. Lvovsky, J. Appel, E. Figueroa, G. Guenter, F. Vewinger and K.-P. Marzlin, "Electromagnetically-induced transparency in systems with multiple excited levels" (invited), The 8th International Conference on Quantum Communication, Measurement and Computing (QCMC 2006), Tsukuba International Congress Center, Tsukuba, Japan., 28 Nov 2006 - 3 Dec 2006.

27 Nov 2006, S. D. Bartlett, T. Rudolph, B. C. Sanders and P. S. Turner, "Quantal and semiclassical approaches to quantum reference frame degradation", Tokyo Workshop on Information and Locality (TWIL), University of Tokyo, Tokyo, Japan, 26 Nov 2006 - 27 Nov 2006.

27 Nov 2006, B. C. Sanders, "Secret sharing and concealing a bit in GHZ states" (invited), Tokyo Workshop on Information and Locality (TWIL), University of Tokyo, Tokyo, Japan, 26 Nov 2006 - 27 Nov 2006.

23 Nov 2006, B. C. Sanders, "Optical quantum information science" (colloquium), University of Waterloo, Department of Physics and Astronomy.

16 Nov 2006, W. Tittel, "Quantum cryptography, entanglement and teleportation: experiments with photons" (colloquium), University of Waterloo, Department of Physics and Astronomy.

16 Nov 2006, A. I. Lvovsky, "Photons and quantum IT" (seminar), University of Calgary , Engineering Student Society.

15 Nov 2006, B. C. Sanders, "Rolling quantum dice" (dinner speech), The Big Rock University, Calgary, Canada.

10 Nov 2006, B. C. Sanders, "On the road to optical quantum information" (colloquium), Université de Sherbrooke , département de physique .

9 Nov 2006, B. C. Sanders, "Implementing quantum information" (invited), Université de Montréal, Centre de recherches mathématiques. (Launch of the Transdisciplinary Institute for Quantum Information - INTRIQ).

8 Nov 2006, B. C. Sanders, "On the road to optical quantum information" (colloquium), Miami University, Department of Physics. (Arfken Scholar Lecture).

28 Oct 2006, J. Appel, "Frequency conversion and routing of quantum information carried by light", CIAR Quantum Information Processing (CIAR QIP), Hotel Sacacomie, St-Alexis-des-Monts, Canada, 26 Oct 2006 - 28 Oct 2006.

27 Oct 2006, G. Gour, "Hiding entanglement in classical bits", CIAR Quantum Information Processing (CIAR QIP), Hotel Sacacomie, St-Alexis-des-Monts, Canada, 26 Oct 2006 - 28 Oct 2006.

26 Oct 2006, P. Høyer, "The complexity of graph states", CIAR Quantum Information Processing (CIAR QIP), Hotel Sacacomie, St-Alexis-des-Monts, Canada, 26 Oct 2006 - 28 Oct 2006.

13 Oct 2006, B. C. Sanders, "Optical quantum information science" (colloquium), University of Calgary, Department of Physics and Astronomy.

8 Oct 2006, A. I. Lvovsky, "Adiabatic transfer of quantum optical information in atomic vapor" (poster), Frontiers in Optics 2006 (OSA Annual Meeting), Rochester, United States of America, 8 Oct 2006 - 12 Oct 2006.

4 Oct 2006, B. C. Sanders, "Applied QKD" (invited), Quantum Cryptography and Computing Workshop, Fields Institute, Toronto, Canada, 2 Oct 2006 - 6 Oct 2006.

29 Sep 2006, N. S. Babcock, R. Stock, M. G. Raizen and B. C. Sanders, "Rapid control and measurement of clock-state qubits in Yb and Sr" (seminar), Institute for Quantum Computing, University of Waterloo.

27 Sep 2006, B. C. Sanders, "Quantum building blocks: making quantumworks work" (invited), First QuantumWorks Annual General Meeting (QuantumWorks 2006), Waterloo Inn, Waterloo, Canada, 27 Sep 2006 - 27 Sep 2006.

18 Sep 2006, W. Tittel, M. Afzelius, N. Gisin, S. R. Hastings-Simon and M. U. Staudt, "Towards quantum memory" (invited), Optical Science and Engineering Conference, Bozeman, United States of America, 18 Sep 2006 - 19 Sep 2006.

15 Sep 2006, W. Tittel, "Quantum cryptography, entanglement and teleportation: experiments with photons" (colloquium), Montana State Univesity, Department of Physics.

8 Sep 2006, W. Tittel, "QC2 lab: the quantum cryptography and communication laboratory" (seminar), University of Calgary. PHYS.020 Research Day.

5 Sep 2006, J. Appel, "Raman adiabatic transfer of optical states", The Third Annual Canadian Quantum Information Students' Conference (CQISC 2006), University of Calgary, Canada, 14 Aug 2006 - 18 Aug 2006.

5 Sep 2006, B. C. Sanders, "Optical quantum information science" (colloquium), Institute of Physics, Chinese Academy of Science, Key Laboratory of Optical Physics.

1 Sep 2006, B. C. Sanders, D. W. Berry, G. Ahokas and R. Cleve, "Efficient quantum algorithms for simulating sparse Hamiltonians" (invited), Asian Conference on Quantum Information Science 2006 (AQIS 2006), Beijing, China, 1 Sep 2006 - 4 Sep 2006.

26 Aug 2006, Z.-B. Wang, K.-P. Marzlin and B. C. Sanders, "Large cross-phasemodulation between slow co-propagating week pulses in ^{87}Rb", International Conference on Quantum Foundation and Technology: Frontier and Future (ICQFT2006), Hangzhou, China, 25 Aug 2006 - 31 Aug 2006.

26 Aug 2006, N. S. Babcock, R. Stock and B. C. Sanders, "Rapid control and measurement of clock-state qubits in Yb and Sr" (invited), International Conference on Quantum Foundation and Technology: Frontier and Future (ICQFT2006), Hangzhou, China, 25 Aug 2006 - 31 Aug 2006.

23 Aug 2006, S. D. Bartlett, T. Rudolph, B. C. Sanders and P. S. Turner, "Quantal and semi-classical approaches to the degradation of quantum reference frames" (seminar), University of Toronto, Fields Institute.

18 Aug 2006, E. Figueroa, "Characterization of atomic coherence decay for storage of light", The Third Annual Canadian Quantum Information Students' Conference (CQISC 2006), University of Calgary, Canada, 14 Aug 2006 - 18 Aug 2006.

18 Aug 2006, Z.-B. Wang, "Large cross phase modulation with DEIT system", The Third Annual Canadian Quantum Information Students' Conference (CQISC 2006), University of Calgary, Canada, 14 Aug 2006 - 18 Aug 2006.

16 Aug 2006, M. Garrett, "Stochastic one-way quantum computing with ultracold atoms in optical lattices", The Third Annual Canadian Quantum Information Students' Conference (CQISC 2006), University of Calgary, Canada, 14 Aug 2006 - 18 Aug 2006.

14 Aug 2006, E. Figueroa, A. Vishwanath, J. Appel, A. I. Lvovsky and G. Günter, "Characterization of atomic coherence decay for storage of light experiments" (poster), 6305-43, SPIE Optics & Photonics 2006 (SPIE OP 2006), San Diego, United States of America, 13 Aug 2006 - 17 Aug 2006.

14 Aug 2006, M. Durocher, "Distinguishability of states using LOCC" (contributed), The Third Annual Canadian Quantum Information Students' Conference (CQISC 2006), University of Calgary, Canada, 14 Aug 2006 - 18 Aug 2006.

14 Aug 2006, Z. Shaterzadeh Yazdi, "Tripartite continuous variable entangled states", The Third Annual Canadian Quantum Information Students' Conference (CQISC 2006), University of Calgary, Canada, 14 Aug 2006 - 18 Aug 2006.

13 Aug 2006, B. C. Sanders, Z.-B. Wang and K.-P. Marzlin, "Large cross-phase modulation between slow co-propagating weak pulse in rubidium" (invited), 6305-18, SPIE Optics & Photonics 2006 (SPIE OP 2006), San Diego, United States of America, 13 Aug 2006 - 17 Aug 2006.

11 Aug 2006, D. L. Feder, "Graphs in quantum information theory", 6th Canadian Summer School on Quantum Information Processing (CSSQI 2006), University of Calgary, Canada, 7 Aug 2006 - 11 Aug 2006.

11 Aug 2006, J. Watrous, "Distinguishing quantum states and operations", 6th Canadian Summer School on Quantum Information Processing (CSSQI 2006), University of Calgary, Canada, 7 Aug 2006 - 11 Aug 2006.

10 Aug 2006, J. Watrous, "Quantum proofs", Sixth Canadian Summer School on Quantum Information Processing, Calgary, Canada, 7 Aug 2006 - 11 Aug 2006.

10 Aug 2006, W. Tittel, "Practical quantum cryptography and communication", 6th Canadian Summer School on Quantum Information Processing (CSSQI 2006), University of Calgary, Canada, 7 Aug 2006 - 11 Aug 2006.

9 Aug 2006, P. Høyer, "Grover's algorithm", Sixth Canadian Summer School on Quantum Information Processing, Calgary, Canada, 7 Aug 2006 - 11 Aug 2006.

8 Aug 2006, H. A. Carteret, "Noiseless quantum circuits for measuring entanglement", Conference on Quantum Information and Quantum Control II, Fields Institute, Toronto, Canada, 8 Aug 2006 - 11 Aug 2006.

7 Aug 2006, P. Høyer, "Quantum algorithms", 6th Canadian Summer School on Quantum Information Processing (CSSQI 2006), University of Calgary, Canada, 7 Aug 2006 - 11 Aug 2006.

4 Aug 2006, B. C. Sanders, "Decoherence, errors, and correction in quantum information processing" (invited), Regroupement Québécois des Étudiants sur les Matériaux de Pointe (RQEMP), Hotel Cheribourg, Magog, Canada, 2 Aug 2006 - 4 Aug 2006.

30 Jul 2006, A. T. Rezakhani, "Topological entanglement and quantum computation" (invited), Spin, Charge and Topology in Low Dimesions, Banff, Canada, 29 Jul 2006 - 3 Aug 2006.

25 Jul 2006, Z. Shaterzadeh Yazdi, P. S. Turner and B. C. Sanders, "A three boson su(1,1) realisation for linear optical quantum information" (seminar), University of Toronto, Department of Physics.

25 Jul 2006, J. Appel, F. Vewinger, E. Figueroa, G. Günter, K.-P. Marzlin and A. I. Lvovsky, "Adiabatic transfer of quantum optical information by means of electromagnetically-induced transparency" (invited), Fifteenth Annual Laser Physics Workshop, Lausanne, Switzerland, 24 Jul 2006 - 28 Jul 2006.

24 Jul 2006, A. I. Lvovsky, "Photons and quantum information" (seminar), Technische Universität Kaiserslautern.

18 Jul 2006, R. Stock and I. H. Deutsch, "Quantum logic in optical lattices via trap-induced resonances in controlled collisions of Cesium atoms" (poster, contributed), 20th International Conference on Atomic Physics (ICAP 2006), Innsbruck, Austria., 16 Jul 2006 - 21 Jul 2006.

18 Jul 2006, W. Tittel, M. Afzelius, N. Gisin, S. R. Hastings-Simon and M. U. Staudt, "Investigation of an Erbium doped optical fiber for quantum state storage", TuB2.5, IEEE/LEOS Summer Topical Meeting on Quantum Communication in Telecom Networks, Quebec City, Canada, 17 Jul 2006 - 19 Jul 2006.

17 Jul 2006, R. Stock, N. S. Babcock, A. M. Dudarev, M. G. Raizen and B. C. Sanders, "Rapid control and measurement of clock-state qubits in Yb and Sr for quantum information processing" (poster, contributed), 20th International Conference on Atomic Physics (ICAP 2006), Innsbruck, Austria., 16 Jul 2006 - 21 Jul 2006.

3 Jul 2006, R. Stock, "Generalizing pseudopotentials beyond s-wave interactions – or how to sort out the pseudopotential mess" (seminar), Istituto Nazionale per la Fisica della Materia, Trento, Italy.

1 Jul 2006, B. C. Sanders, "Efficient quantum algorithm for simulating Hamiltonian evolution" (invited), International Workshop on Quantum Informatics and Quantum Devices, Nathiagali, Pakistan, 26 Jun 2006 - 1 Jul 2006.

29 Jun 2006, K.-P. Marzlin, "Quantum information with photons and atoms" (seminar), Quantum Optics Seminar, University of Stanford.

27 Jun 2006, B. C. Sanders, "Rapid control and measurement of clock-state qubits in Yb and Sr" (invited), International Workshop on Quantum Informatics and Quantum Devices, Nathiagali, Pakistan, 26 Jun 2006 - 1 Jul 2006.

22 Jun 2006, B. C. Sanders, D. W. Berry, G. Ahokas and R. Cleve, "Efficient algorithms for simulating general dynamics on a quantum computer" (seminar), University of Innsbruck, Center for Quantum Optics and Quantum Information.

16 Jun 2006, J. Briet and D. L. Feder, "Entangled pure state classification with stabilizers" (poster), CIAMS-MITACS 2006 Joint Annual Conference, Toronto, Canada, 16 Jun 2006 - 20 Jun 2006.

12 Jun 2006, Z.-B. Wang, K.-P. Marzlin and B. C. Sanders, "Large cross-phase modulation between slow co-propagating weak pulses in ^{87}Rb" (poster), MO-A2-9, *Physics in Canada* 62(3):p. 54, 2006 Canadian Association of Physicists Congress (CAPC 2006), St. Catharines, Canada, 11 Jun 2006 - 14 Jun 2006.

12 Jun 2006, B. C. Sanders, E. Waks, E. Diamanti and Y. Yamamoto "Highly nonclassical photon statistics in parametric down conversion", MO-P1-2, *Physics in Canada* 62(3):p. 64, 2006 Canadian Association of Physicists Congress (CAPC 2006), St. Catharines, Canada, 11 Jun 2006 - 14 Jun 2006.

12 Jun 2006, E. Figueroa, J. Appel, G. Guenter, K.-P. Marzlin and A. I. Lvovsky, "Raman adiabatic transfer of optical states", MO-P1-3, *Physics in Canada* 62(3):p. 64, 2006 Canadian Association of Physicists Congress (CAPC 2006), St. Catharines, Canada, 11 Jun 2006 - 14 Jun 2006.

9 Jun 2006, H. A. Carteret, "Physically accessible non-completely positive maps" (invited), Theory Canada 2, Montreal, Canada, 7 Jun 2006 - 10 Jun 2006.

9 Jun 2006, K.-P. Marzlin, "Decoherence-free subspaces: necessity of Dicke limit" (invited), Theory Canada 2, Montreal, Canada, 7 Jun 2006 - 10 Jun 2006.

6 Jun 2006, S. D. Bartlett, T. Rudolph, B. C. Sanders and P. S. Turner, "Quantal and semi-classical approaches to the degradation of quantum reference frames" (seminar), Griffith University, School of Biomolecular and Physical Sciences.

26 May 2006, S. D. Bartlett, T. Rudolph, B. C. Sanders and P. S. Turner, "Quantal and semi-classical approaches to the degradation of quantum reference frames" (seminar), Macquarie University, Department of Physics.

24 May 2006, N. S. Babcock, R. Stock, B. C. Sanders, A. M. Dudarev and M. G. Raizen, "Rapid control and measurement of qubits in atomic Yb and Sr" (poster), iCORE Summit 2006 (iCORE 2006), Banff, Canada, 23 May 2006 - 25 May 2006.

24 May 2006, G. Howard, "Quantum cryptography: an overview" (poster), iCORE Summit 2006 (iCORE 2006), Banff, Canada, 23 May 2006 - 25 May 2006.

23 May 2006, B. C. Sanders, "Efficient quantum algorithm for simulating Hamiltonian evolution" (invited), Quoxic Workshop, Imperial College, London, United Kingdom, 23 May 2006 - 23 May 2006.

21 May 2006, J. Appel, "Routing of optical states by atomic media" (invited), Continuous Variable Quantum Information Workshop, Copenhagen, Denmark, 19 May 2006 - 22 May 2006.

20 May 2006, K.-P. Marzlin, R. Karasik, B. C. Sanders and B. K. Whaley, "Decoherence-free subspaces and spontaneous emission cancellation: necessity of Dicke limit" (contributed), Z5 6, *Bulletin of the American Physical Society* 51(3):p. 167, 2006 37th Meeting of the Division of Atomic, Molecular and Optical Physics (DAMOP06), Knoxville, United States of America, 16 May 2006 - 20 May 2006.

20 May 2006, K.-P. Marzlin, Z.-B. Wang and B. C. Sanders, "Large cross-phase modulation between slow co-propagating weak pulses in ^{87}Rb" (invited), G2.00006 , 8th Annual Meeting of the APS Northwest Section, University of Puget Sound, Tacoma, United States of America, 19 May 2006 - 20 May 2006.

19 May 2006, I. Reichenbach, A Silberfarb, R. Stock and I. H. Deutsch, "A quasi-hermitian pseudo potential for higher partial-wave scattering", V5 6, *Bulletin of the American Physical Society* 51(3):p. 133, 2006 37th Meeting of the Division of Atomic, Molecular and Optical Physics (DAMOP06), Knoxville, United States of America, 16 May 2006 - 20 May 2006.

18 May 2006, Z.-B. Wang, K.-P. Marzlin and B. C. Sanders, "Large cross-phase modulation between slow co-propagating weak pulses in ^{87}Rb" (contributed), N4 8, *Bulletin of the American Physical Society* 51(3):p. 81, 2006 37th Meeting of the Division of Atomic, Molecular and Optical Physics (DAMOP06), Knoxville, United States of America, 16 May 2006 - 20 May 2006.

17 May 2006, B. C. Sanders, N. S. Babcock, A. M. Dudarev, M. G. Raizen and R. Stock, "Rapid control and measurement of clock-state qubits in Yb and Sr" (contributed), C5 1, *Bulletin of the American Physical Society* 51(3):p. 21, 2006 37th Meeting of the Division of Atomic, Molecular and Optical Physics (DAMOP06), Knoxville, United States of America, 16 May 2006 - 20 May 2006.

8 May 2006, K.-P. Marzlin, "Quantum information with atoms and photons" (seminar), University of Toronto, Department of Physics.

8 May 2006, R. Karasik, K.-P. Marzlin, B. C. Sanders and B. K. Whaley, "Decoherence-free subspaces: necessity of Dicke limit" (poster), Gordon Research Conference on Quantum Information Science, Lucca, Italy, 7 May 2006 - 12 May 2006.

7 May 2006, J. Appel, E. Figueroa, F. Vewinger, G. Günter, K.-P. Marzlin and A. I. Lvovsky, "Quantum information science" (poster), Gordon Research Conference on Quantum Information Science, Lucca, Italy, 7 May 2006 - 12 May 2006.

2 May 2006, J. Appel and A. I. Lvovsky, "Routing of optical states by atomic media" (invited), Third International Workshop ad Memoriam of Carlo Novero: Advances in Foundations of Quantum Mechanics and Quantum Information with Atom and Photons, Turin, Italy, 2 May 2006 - 5 May 2006.

1 May 2006, R. Stock, "Quantum control of atomic collisions for quantum information processing" (seminar), University of Toronto, Department of Physics.

20 Apr 2006, A. I. Lvovsky, "Quantum technology and information security" (invited), Future of Information Security: Southern Alberta Intellectual Property Network Conference, Calgary, Canada, 20 Apr 2006 - 20 Apr 2006.

COLLABORATIONS FOR 2005/06

INSTITUTION	LOCATION
Australian National University	Canberra, Australia
Centre National de la Recherche Scientifique, Grenoble	Grenoble, France
Centrum voor Wiskunde en Informatica Amsterdam, The Netherlands	Amsterdam, The Netherlands
Commonwealth Science and Industrial Research Organisation, Sydney	Sydney, Australia
Imperial College, London	London, United Kingdom
Jagiellonian University	Krakow, Poland
Lincoln Laboratory, Massachusetts Institute of Technology	Lexington, United States of America
Macquarie University	Sydney, Australia
Masaryk University	Brno, Czech Republic
Nicolaus Copernicus University	Torun, Poland
Queen's University, Belfast	Belfast, United Kingdom
Stanford University	Palo Alto, United States of America
Tel Aviv University	Tel Aviv, Israel
The University of Queensland	Brisbane, Australia
University of California at Berkeley	Berkeley, United States of America
University of California at Los Angeles	Los Angeles, United States of America
University of California at San Diego	San Diego, United States of America
University of New Mexico	Albuquerque, United States of America
Université de Montréal	Montréal, Canada
University of Oregon	Eugene, United States of America
Université Paris-Sud	Paris, France
University of Sydney	Sydney, Australia
University of Toronto	Toronto, Canada
University of Waterloo	Waterloo, Canada
Warsaw University	Warsaw, Poland
Wilfrid Laurier University	Waterloo, Canada

COLLABORATIONS FOR 2006/07

INSTITUTION	LOCATION
Advanced Technology Information Processing Systems (ATIPS) Laboratory	Calgary, Canada
Centre for Information Security and Cryptography (CISaC)	Calgary, Canada
Commonwealth Science and Industrial Research Organization, Sydney	Sydney, Australia
Fujian Normal University	Fuzhou, China
Imperial College, London	London, United Kingdom
Institute of Physics, Bhubaneswar	Bhubaneswar, India
Institute for Scientific Interchange	Torino, Italy
Macquarie University	Sydney, Australia
Masaryk University	Brno, Czech Republic
Nicolaus Copernicus University	Torun, Poland

INSTITUTION	LOCATION
Perimeter Institute	Waterloo, Canada
Sharif University of Technology	Tehran, Iran
Stanford University	Palo Alto, United States of America
University of Cambridge	Cambridge, United Kingdom
University of California at Berkeley	Berkeley, United States of America
University of California at San Diego	San Diego, United States of America
University of Isfahan	Isfahan, Iran
Université de Montréal	Montréal, Canada
University of New Mexico	Albuquerque, United States of America
University of Science and Technology of China	Hefei, China
University of Southern California	Los Angeles, United States of America
University of Sydney	Sydney, Australia
University of Vienna	Vienna, Austria
University of Waterloo	Waterloo, Canada
University of Western Australia	Perth, Australia
Warsaw University	Warsaw, Poland
Wilfrid Laurier University	Waterloo, Canada

MAP OVERLAY OF COLLABORATION WITH IQIS

VISITORS FOR 2005/06

NAME	DATES OF VISIT	HOME INSTITUTION
Philipp Schneeweiß	24 Aug 2004 – 30 Apr 2005	University of Dresden, Dresden, Germany
Safa Jami	2 Feb 2005 – 27 Nov 2005	Ferdowsi University of Mashhad, Mashhad, Iran
Ashish Jha	2 May 2005 - 27 Jul 2005	Atal Bihari Vajpayee - Indian Institute of Information Technology & Management, Gwalior, India
Norbert Lütkenhaus	6 Jun 2005 - 10 Jun 2005	Universität Erlangen-Nürnberg, Enlangen, Germany
Raisa Karasik	7 Jun 2005 – 15 Aug 2005	University of California, Berkeley, United States of America
Andrew White	14 Jun 2005 - 17 Jun 2005	University of Queensland, Brisbane, Australia
Dianmin Tong	16 Jun 2005 - 15 Aug 2005	National University of Singapore, Singapore
Alexei Trifonov	3 Jul 2005 – 7 Jul 2005	MagiQ Technologies Inc., Boston, United States of America
Wolfgang Tittel	10 Jul 2005 – 16 Jul 2005 7 Sep 2005 – 20 Sep 2005 11 Dec 2005 – 19 Dec 2005 30 Mar 2006 – 8 Apr 2006	Université de Genève, Genève, Switzerland
Travis Beals	25 Jul 2005 – 24 Aug 2005 9 Jan 2006 - 21 Apr 2006	University of California, Berkeley, United States of America
Peter Brooke	1 Aug 2005 – 29 Oct 2005	Macquarie University, Sydney, Australia
Dominic Berry	5 Aug 2005 – 25 Aug 2005	University of Queensland, Brisbane, Australia
Sibasish Ghosh	5 Aug 2005 – 15 Aug 2005	The University of York, York, United Kingdom
Robert Špalek	5 Aug 2005 – 25 Aug 2005	Centrum voor Wiskunde en Informatica, Amsterdam, The Netherlands
Hilary Carteret	7 Aug 2005 – 25 Aug 2005	Université de Montréal, Montréal, Canada
Karol Życzkowski	15 Aug 2005 – 17 Aug 2005	Jagiellonian University, Kraków, Poland
Chris Dawson	31 Aug 2005 – 6 Sep 2005	University of Queensland, Brisbane, Australia
Georg Günter	1 Sep 2005 – 30 May 2006	Universität Konstanz, Konstanz, Germany
Ady Mann	1 Sep 2005 – 30 Sep 2005	Technion – Israel Institute of Technology, Technion City, Israel
Shohini Ghose	26 Sep 2005 – 7 Oct 2005 31 Oct 2005 – 11 Nov 2005 23 Nov 2005 – 28 Nov 2005	Wilfrid Laurier University, Waterloo, Canada
Simon Perdrix	26 Sep2005 – 26 Oct 2005	Institut d'Informatique et Mathématiques Appliquées de Grenoble, Grenoble, France
Rob Spekkens	30 Oct 2005 – 6 Nov 2005	Perimeter Institute for Theoretical Physics, Waterloo,Canada
Gilad Gour	31 Oct 2005 – 6 Nov 2005	University California, San Diego, United States of America
Igor Shparlinski	3 Nov 2005 – 5 Nov 2005	Macquarie University, Sydney, Australia
Sophie Laplante	7 Nov 2005 – 10 Nov 2005	Laboratoire de Recherche en Informatique (LRI), Paris,France
Mark Tame	7 Nov 2005 – 16 Dec 2005	Queen's University Belfast, Belfast, United Kingdom
Jamil Daboul	21 Nov 2005 – 24 Nov 2005	Ben Gurion University, Beer-Sheva, Israel
André Allan Méthot	27 Nov 2005 – 2 Dec 2005	Université de Montréal, Montréal, Canada
Richard MacKenzie	29 Nov 2005 – 4 Dec 2005	Université de Montréal, Montréal, Canada
Nick Peters	11 Jan 2006 – 15 Jan 2006	University of Illinois, Urbana, United States of America
Aephraim Steinberg	23 Feb 2006	University of Toronto, Toronto, Canada

VISITORS FOR 2006/07

NAME	DATES OF VISIT	HOME INSTITUTION
Georg Günter	1 Sep 2005 – 15 Aug 2006	University of Konstanz, Konstanz, Germany
Shohini Ghose	10 Apr 2006 – 17 Apr 2006 21 Sep 2006 – 22 Sep 2006	Wilfrid Laurier University, Waterloo, Canada
Terry Rudolph	13 Apr 2006 – 21 Apr 2006	Imperial College, London, United Kingdom
Peter Knight	30 Apr 2006 – 3 May 2006	Imperial College, London, United Kingdom
Martin Oberst	1 May 2006 – 27 May 2006	Technische Universität Kaiserslautern, Kaiserslautern, Germany
Dominic Berry	7 May 2006 – 21 May 2006	The University of Queensland, Brisbane, Australia
Mayank Maheshwari	8 May 2006 – 17 Jul 2006	Institute of Technology, BHU, Varanasi, India
Daniel Terno	8 May 2006 – 13 May 2006	Perimeter Institute for Theoretical Physics, Walterloo, Canada
Aidan Roy	9 May 2006 – 12 May 2006	University of Waterloo, Waterloo, Canada
Anne Broadbent	14 May 2006 – 19 May 2006	Université de Montréal, Montréal , Canada
Anirban Pathak	4 Jun 2006 – 19 Jul 2006	Jaypee Institute of Information Technology, Uttar Pradesh, India
Emanuel Knill	6 Jun 2006 – 9 Jun 2006	National Institute of Standards and Technology, Gaithersburg, United States of America
Gilad Gour	12 Jun 2006 – 22 Jun 2006	University of California, San Diego, United States of America
Raisa Karasik	3 Jul 2006 – 24 Aug 2006 9 Sept 2006 – 14 Jan 2007	University of California at Berkeley, United States of America
Viv Kendon	25 Jul 2006 – 29 Jul 2006	University of Leeds, Leeds, United Kingdom
Robert Raussendorf	28 Jul 2006	Perimeter Institute for Theoretical Physics, Waterloo,Canada
Anirban Roy	2 Aug 2006 – 29 Oct 2006	The Abdus Salam International Centre for Theoretical Physics, Trieste, Italy
Anning Zhang	10 Aug 2006 – 12 Aug 2006 28 Sep 2006 – 30 Oct 2006	University of Toronto, Toronto, Canada
Howard Wiseman	16 Aug 2006 – 20 Aug 2006	Griffith University, Griffith, Australia
Elinor K. Irish	20 Aug 2006 – 25 Aug 2006	University of Rochester, Rochester, United States of America
Andrew Greentree	23 Aug 2006 – 24 Aug 2006	The University of Melbourne, Melbourne, Australia
Chris Vo	8 Sep 2006 – 12 Sep 2006	Stanford University, Palo Alto, United States of America
Austin Fowler	17 Sep 2006 – 30 Sep 2006	University of Waterloo, Waterloo, Canada
Dmitry Korystov	20 Sep 2006 – 23 Sep 2006	University of California at Santa Barbara, United States of America
Jonathan Dowling	3 Oct 2006 – 6 Oct 2006	Louisiana State University, Baton Rouge, United States of America
Shannon Mayer	4 Oct 2006 – 6 Oct 2006	The University of Portland, Portland, United States of America
Dmitri Maslov	9 Oct 2006 – 13 Oct 2006	University of Waterloo, Waterloo, Canada
Birgitta Whaley	17 Oct 2006 – 20 Oct 2006	University of California at Berkeley, United States of America
Troy Lee	29 Oct 2006 – 3 Nov 2006	Université de Paris-Sud, Orsay Cedex, France
Gus Gutoski	14 Nov 2006 – 19 Nov 2006	University of Waterloo, Waterloo, Canada
Félix Bussières	14 Nov 2006 – 25 Nov 2006 16 Jan 2007 – 14 Dec 2007	Université de Montréal, Montréal, Canada
Sun-Hyun Youn	15 Dec 2006 - 15 Dec 2007	Chonnam National University, Gwangju, Korea
Dmitry Gavinsky	10 Jan 2007 - 12 Jan 2007	University of Waterloo, Waterloo, Canada
Mirko Lobino	24 Jan 2007 - 30 Jan 2007	Politecnico di Milano, Milano, Italy
Stephen Bartlett	25 Jan 2007 - 8 Feb 2007	University of Sydney, Sydney, Australia
Martin Roetteler	16 Feb 2007	NEC Laboratories America, Inc., Princeton, United States of America

NAME	DATES OF VISIT	HOME INSTITUTION
Patrick Hayden	21 Feb 2007- 21 Feb 2007	McGill University, Montréal, Canada
Pavel Kolchin	27 Feb 2007 - 3 Mar 2007	Stanford University, Palo Alto, United States of America
Matthew D. Eisaman	22 Mar 2007 - 25 Mar 2007	National Institute of Standards and Technology, Gaithersburg, United States of America

TEACHING, TRAINING AND EDUCATION

UNDERGRADUATE PROJECTS AND SUPERVISION FOR 2005/06

NAME	NAME OF PROJECT	SUPERVISOR
Andrew Graham	Conversion of inequivalent graphs with assisted entanglement	D. Feder
Ethan Heming	1. Discrete quantum walks on two-dimensional lattices 2. Accelerating self-consistency of BCS equations with DIIS	D. Feder

UNDERGRADUATE PROJECTS AND SUPERVISION FOR 2006/07

NAME	NAME OF PROJECT	SUPERVISOR
Goeff Campbell	Exchange of quantum information between light and atomic ensembles	A. Lvovsky
Peter Gagliardi	QViz	B. C. Sanders
Chris Healey	Exchange of quantum information between light and atomic ensembles	A. Lvovsky
Dallas Hoffman	Quantum technology of light	A. Lvovsky
Yuval Sanders	Entangled rings	B. C. Sanders/H. Carteret

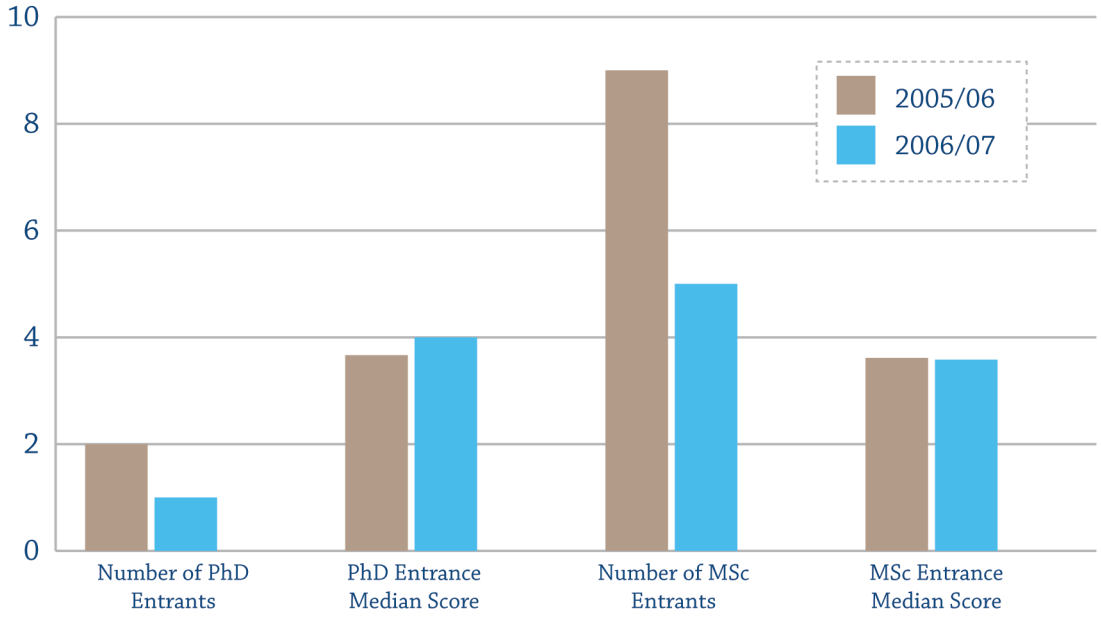
GRADUATE COURSES FOR 2005/06

COURSE NAME	INSTRUCTOR	DESCRIPTION
CPSC 619 Quantum Computation	J. Watrous	Quantum information, quantum algorithms including Shor's quantum factoring algorithm and Grover's quantum searching technique, quantum error correcting codes, quantum cryptography, nonlocality and quantum communication complexity, and quantum computational complexity.
PHYS 615 Advanced Quantum Mechanics I	R. Thompson	Basic formalism of theory and its interpretation, symmetry generators. Scattering theory. Bound states. Charged particles in electric and magnetic fields. Approximation methods.
PHYS 617 Advanced Quantum Mechanics II	D. Feder	Second quantized description of N-particle systems. Quantum theory of the electromagnetic field, coherent states. Relativistic quantum mechanics.
PHYS 677 Implementations of Quantum Information	B.C. Sanders	Principles of quantum information, physical realizations in various technologies: optics, atoms, ions, quantum dots, etc. Survey of major experimental implementations and future prospects.

GRADUATE COURSES FOR 2006/07

COURSE NAME	INSTRUCTOR	DESCRIPTION
PHYS 615 Advanced Quantum Mechanics I	R. Thompson	Basic formalism of theory and its interpretation, symmetry generators. Scattering theory. Bound states. Charged particles in electric and magnetic fields. Approximation methods.
PHYS 673 Non-Linear and Quantum Optics	K.-P. Marzlin	Quantum theory of light, atom-light interactions, incoherence processes, density matrix theory, linear and non-linear susceptibilities, electromagnetically-induced transparency. Nonlinear optical processes. Additional topics may include: atom optics, laser cooling, photonic crystals, cavity QED, quantum information and other applications.

GRADUATE STUDENTS: ENROLMENT AND QUALITY OF ENTRANTS



GRADUATE STUDENTS - NUMBERS OF INTEREST

One student was from England and received 1st class honours (no GPA), so GPA median score for 2005/06 was calculated based on 8 students' GPA.

SUMMER SCHOOLS AND STUDENT CONFERENCES

CONFERENCE NAME	PERIOD
The Sixth Canadian Summer School on Quantum Information	7 – 11 August 2006
Third Annual Canadian Quantum Information Students' Conference 2006	14 – 18 August 2006

SERVICES AND OUTREACH

CONFERENCE COMMITTEES FOR 2005/06

MEMBER(S)	COMMITTEE	CONFERENCE/ WORKSHOP/AWARD	LOCATION	CONFERENCE DATES
K.–P. Marzlin	Member, Organizing Committee	CLEO/EQEC Symposium on Quantum/Atom Optics in Periodic Media	Munich, Germany	12–17 Jun 2005
B. C. Sanders	Member, Program Committee	SPIE Conference on Quantum Communications and Imaging III	San Diego, United States of America	13 – 17 Aug 2005

CONFERENCE COMMITTEES FOR 2006/07

MEMBER(S)	COMMITTEE	CONFERENCE/ WORKSHOP/AWARD	LOCATION	CONFERENCE DATES
A. Lvovsky	Member, Organizing Committee	The American Physical Society Division of Atomic, Molecular, and Optical Physics Annual Meeting (DAMOP 07)	Calgary, Alberta	5 – 9 Jun 2007
K. –P. Marzlin	Member, Organizing Committee	The American Physical Society Division of Atomic, Molecular, and Optical Physics Annual Meeting (DAMOP 07)	Calgary, Alberta	5 – 9 Jun 2007
K. –P. Marzlin	Member, Organizing Committee	The Photons Atoms and Qubits Conference (PAQ 07)	London, United Kingdom	2 – 5 Sep 2007
A. T. Rezakhani	Member, Organizing Committee	The First International Conference on Quantum Information (IICQI)	Kish Island, Iran	7 – 10 Sep 2007
B. C. Sanders	Member, Advisory & Award Committees	Quantum Communication, Measurement and Computing (QCMC2006)	Tsukuba, Japan	28 Nov – 3 Dec 2006
B. C. Sanders	Member, QELS Subcommittee 02: Quantum Information	Conference on Lasers and Electro-Optics / Quantum Electronics and Laser Science Conference (CLEO/ QELS 2007)	Baltimore, United States of America	6 – 11 May 2007
B. C. Sanders	Program Committee	SPIE Symposium "Fluctuations and Noise"	Florence, Italy	20 – 24 May 2007
B. C. Sanders	Treasurer, Organizing Committee	The American Physical Society Division of Atomic, Molecular, and Optical Physics Annual Meeting (DAMOP 07)	Calgary, Canada	5 – 9 Jun 2007
B. C. Sanders	Member, Program Committee	The International Conference on Quantum Information (ICQI)	Rochester, United States of America	10 – 13 Jun 2007
B. C. Sanders	Member, Technical Program Sub-Committee	7th Pacific Rim Conference on Lasers and Electro-Optics (CLEO-PR 2007)	Seoul, Korea	26 – 31 Aug 2007
B. C. Sanders	Chair, Steering Committee	Photons, Atoms, and Qubits Conference(PAQ07)	London, United Kingdom	2 – 5 Sep 2007
B. C. Sanders	Member, Program Committee	Asian Conference on Quantum Information (AQIS 2007)	Kyoto, Japan	3 – 6 Sep 2007

MEMBER(S)	COMMITTEE	CONFERENCE/ WORKSHOP/AWARD	LOCATION	CONFERENCE DATES
B. C. Sanders	Co-Chair, Organizing Committee	The First International Conference on Quantum Information (IICQI)	Kish Island, Iran	7 – 10 Sep 2007
B. C. Sanders	Members, International Program Committee	2007 IEEE Congress on Evolutionary Computation (CEC 2007)	Singapore	25 – 28 Sep 2007

PROFESSIONAL SERVICES FOR 2005/06

NAME	ROLE	JOURNAL/SOCIETY
B. C. Sanders	Member, Advisory Board	American Physical Society Topical Group on Quantum Information Science
B. C. Sanders	Member, Editorial Board	*Physical Review A*
B. C. Sanders	Member, Editorial Board	*New Journal of Physics*
B. C. Sanders	Past President	Australian Optical Society
B. C. Sanders	Secretary-Treasurer	American Physical Society Topical Group on Quantum Information Science

PROFESSIONAL SERVICES FOR 2006/07

NAME	ROLE	JOURNAL/SOCIETY
H. Carteret	Member, Advisory Panel	*Journal of Physics A*
K.-P. Marzlin	Associate Editor	*Canadian Journal of Physics*
B. C. Sanders	Member, Editorial Board	*Physical Review A*
B. C. Sanders	Member, Editorial Board	*New Journal of Physics*
B. C. Sanders	Secretary-Treasurer	American Physical Society Topical Group on Quantum Information Science

APPEARANCES IN THE MEDIA FOR 2005/06

SOURCE	TITLE OF ARTICLE	LOCATION	DATE
TKO	"Online gambling" quantum computing	TKO Episode #3-67	27 April 2005
IQC	Quantum leap in Lazaridis gift		1 May 2005
On Campus	Extreme makeover: the quantum mechanics edition	p. 3	6 May 2005
On Campus	New Canada Research Chairs join U of C	p. 3	6 May 2005
Innovation Alberta	#167 The road to quantum computing		21 June 2005
Globe and Mail	Data encryption about to make quantum leap		22 Sep 2005
Report on Business Television (ROBTV)	Quantum cryptography		27 Sep 2005

APPEARANCES IN THE MEDIA FOR 2006/07

SOURCE	TITLE OF ARTICLE	LOCATION	DATE
On Campus	Highlight of the four-year budget and business plan		7 Apr 2006
Calgary Inc	Quantum progress, bit by bit: Alex Lvovsky, Barry Sanders	P 27	Jul/Aug 2006

SOURCE	TITLE OF ARTICLE	LOCATION	DATE
Innovation Canada	Quantum leap: A chance encounter between a computer-science professor and a physicist launches new field of quantum cryptography	Issue 24	Sep – Oct 2006
Netera Alliance	Points of interest: Maria Lantin	pp. 24-25	05/06 Annual Report
Netera Alliance	Points of interest: Barry Sanders	pp. 18-19	05/06 Annual Report
University of Waterloo Daily Bulletin	National quantum network launched	2nd item	26 Sep 2006
CTV	U of C developing cryptographic technology: Dr. Wolfgang Tittel		25 Jan 2007
Calgary Sun	Online security nets quantum reap at U of C: Dr. Wolfgang Tittel, Dr. Barry Sanders		26 Jan 2007
Fort McMurray Today	The Province: Swiss physicist coming to develop technology: Dr. Wolfgang Tittel	A2	26 Jan 2007
On Campus	Keeping secrets: Dr. Wolfgang Tittel, Josh Slater		26 Jan 2007
CTV, Sci-Tech	Cryptography could stop Web hackers: Dr. Wolfgang Tittel		26 Jan 2007
Calgary Herald	U of C researchers study quantum leap in security: Dr. Wolfgang Tittel, Dr. Barry Sanders		26 Jan 2007
Grande Prairie Daily Tribune	Swiss quantum physicist joins Calgary university to work on Internet security: Dr. Wolfgang Tittel, Dr. Barry Sanders		26 Jan 2007
CBC Homestretch with Jeff Collins	Regarding the upcoming announcement from D-Wave: Dr. Barry Sanders		9 Feb 2007

PRODUCTION FOR 2005/06

None.

PRODUCTION FOR 2006/07

Creator: B. C. Sanders (producer)
Title: **Solid state quantum computer in Silicon**
Description: 4 minute animated film

PUBLIC LECTURES FOR 2005/06

Speaker: A. Lvovsky
Title: **Quantum computing**
Date: 9 Feb 2006
Location: Calgary Council for Advanced Technology

PUBLIC LECTURES FOR 2006/07

Speaker: B. C. Sanders
Title: **Rolling quantum dice**
Date: 15 Nov 2006
Location: Big Rock Brewery

5. finances

INSTITUTE OPERATIONS

OPERATING ACCOUNT: REVENUE AND EXPENDITURE

Income Statement for the Period 2005/06 Ending 31 March 2006 and the Period 2006/07 Ending 31 March 2007

		2006-07	2005-06
REVENUE			
	University of Calgary Support	$75,000.00	$75,000.00
	Internal Rec - Board Declared (for Visualization)	0.00	20,000.00
		75,000.00	95,000.00
	Less expenditures carried from previous year	0.00	-55,371.04
	TOTAL REVENUE	**$75,000.00**	**$39,628.96**
EXPENDITURES			
	Administrative Salaries	64,211.03	74,708.60
	Benefits	10,066.72	25,407.15
	Equipment	4,254.52	11,699.15
	Office Supplies	2,846.93	2,385.73
	Software	600.00	0.00
	Travel and Other expense - Visitors	8,531.63	-2,727.06
	Postage, Phone, Fax and Courier	842.76	1,338.54
	Printing and Engraving Services	651.17	303.00
	Com Media Services	358.00	168.00
	Legal Fees	0.00	2,957.34
	Special Event and Meetings	3,125.73	246.07
	Other Expenditures	5,831.51	8,835.65
	TOTAL EXPENDITURES	**$101,320.00**	**$125,322.17**
NET OPERATING RESULTS		**-$26,320.00**	**-$85,693.21**

RESEARCH GRANTS: REVENUE AND EXPENDITURE

** Due to limited resources, the following statement may have some discrepancies, and it can be for reference only.*

Income Statement for the Period 2005/06 Ending 31 March 2006 and the Period 2006/07 Ending 31 March 2007

		2006-07	2005-06
REVENUE			
	Alberta Ingenuity Fund	$228,502.96	$124,600.00
	ASRIP	627,644.00	0.00
	Canada Foundation for Innovation	446,675.20	122,375.00
	Canadian Institute for Advanced Research	73,750.00	96,250.00
	Canada Research Chair	100,000.00	100,000.00
	France-Canada Research Foundation	0.00	10,000.00
	General Dynamics Canada	150,000.00	24,000.00
	iCORE	910,769.94	460,000.00
	MITACS	158,072.22	0.00
	NSERC	213,649.64	225,625.54
	Total Research Grants	2,909,063.96	1,162,850.54
	Contracts	53,633.38	82,013.78
	Interest	32,170.45	11,503.00
	University of Calgary Support	20,000.00	34,785.00
		105,803.83	128,301.78
	TOTAL REVENUE	**$3,014,867.79**	**$1,291,152.32**
EXPENDITURES			
	Student Salaries and Fees	263,823.49	339,072.65
	Research Fellows and Associates	350,275.84	586,065.88
	Administrative Salaries	28,121.18	2,607.00
	Faculty Salaries	327,939.21	269,311.08
	Benefits	198,610.09	80,884.00
	Total Salary and Benefits	1,168,769.81	1,277,940.61
	Office & Lab Administration	93,336.29	111,722.42
	Furniture & Equipment	453,524.45	175,804.96
	Consumables and Software	2,100.00	0.00
	Books and Journals	682.22	1,601.60
	Travel	95,140.87	108,186.26
	Visitors	58,570.82	72,656.68
	Contracted Services	49,536.67	4,889.49
	Other Expenditures	21,842.72	11,178.56
		774,734.04	486,039.97
	TOTAL EXPENDITURES	**$1,943,503.85**	**$1,763,980.58**
NET OPERATING RESULTS		**$1,071,363.94**	**-$472,828.26**

6. plans and requirements for next year

RESEARCH OBJECTIVES

ULTRACOLD ATOMS & CONDENSED MATTER THEORY

Dr. David Feder

Fault-tolerant quantum computation with atoms in optical lattices

Graduate students Michael Garrett and Timothy Friesen are collaborating with Travis Beals and Birgitta Whaley (University of California, Berkeley) on methods to implement fault-tolerant quantum computation using ultracold atoms in optical lattices. In particular, we are working on a scheme that combines features of cluster-state and circuit-model computation. The goal is to demonstrate that reasonable error thresholds can be obtained in these experimentally promising systems.

Ground states of spin Hamiltonians for one-way quantum computation

In the measurement-based model of quantum computation (MMQC), the algorithm is effected by sequential measurements on a highly entangled resource state. It is not currently clear, however, what kinds of states are universal resources for MMQC. Particularly useful would be ground states of simple spin Hamiltonians, with a sizeable gap to excitations. Adam D'Souza is exploring the possibility that the ground states of various standard two-body models are equivalent to known universal resource states by stochastic local operations and classical communication.

Rotating Bose gases as resources for topological quantum computation

It is widely believed that the so-called Pfaffian state of rotating Bose gases has excitations that obey non-Abelian fractional exchange statistics. In principle, the topological character of these could be used to implement intrinsically fault-tolerant quantum computation. However, very recent numerical work on similar states in Fermi gases indicates that the true ground states may not have as high an overlap with the Pfaffian states as is widely believed. Graduate student Alexis Morris will investigate this possibility by considering the topological entropy and the Chern number.

QUANTUM INFORMATION RESEARCH GROUP IN MATHEMATICS & STATISTICS

Dr. Gilad Gour

Our group project is concerned with the quantification and manipulation of quantum resources and with their applications. For every QIP task imaginable, we would like to quantify the success with which one could achieve this task given a set of restrictions and one or more copies of the quantum state in question. In order for the degree of success to be uniquely defined, one must perform an optimization over all protocols for achieving the task subject to the constraints. Clearly then, the degree of success must be non-increasing under the set of allowed operations, so that if we take a measure of the success with which one can achieve a distributed QIP task under the set of restricted operations, then any such measure must be a monotone under the set of allowed operations. In particular, it quantifies the capacity of the system to perform the task in question.

The objectives of our group are to (i) develop a quantitatively accurate theory for the degree of success of distributed QIP tasks, (ii) produce analytical methods to quantify existing known resources such as entanglement (iii) propose operational interpretations for the different measures of success (iv) find new resources to overcome the limitations that arise from superselection rules or other restrictions and quantify them, and (v) identify and promote the applications of these new resources, especially in the field of quantum cryptography.

Specific goals include: developing quantum resource theories that arise due to the absence of shared reference frames, such as the phase reference and the Cartesian frame; defining new quantities which are monotones (but not necessarily entanglement monotones) under restricted operations subject to SSR (e.g. frameness monotones), and comparing the theory of multipartite entanglement with the theory of bipartite entanglement subject to super-selection rules; identifying optimal strategies to distribute and manipulate resources, such as bipartite entanglement, in quantum communication networks; investigating methods to lock quantum resources (such as entanglement or frameness) in classical or quantum bits; investigating major open problems in quantum information, such as the additivity conjecture, and comparing them with analogous problems in other quantum resource theories; introducing quantities that quantify the distinguishability of probability distributions of quantum states and investigating possible applications to quantum cryptography.

QUANTUM COMPUTING RESEARCH GROUP IN COMPUTER SCIENCE

Dr. Peter Høyer

The group's current research includes quantum algorithmics, quantum complexity, quantum communication complexity, quantum information theory, and quantum computer simulations of quantum mechanical systems. We consider in addition quantum computations based on hamiltonians and other physically motivated models. We apply algorithmic and computational arguments to obtain results that could not easily be obtained by physical arguments by themselves. We study properties of multiparty entanglement and nonlocality, and we investigate fundamental properties of quantum systems used in proving quantum lower bounds.

QUANTUM INFORMATION TECHNOLOGY WITH LIGHT & EXPERIMENTAL QUANTUM OPTICS

Dr. Alex Lvovsky

Implement quantum memory for squeezed light

We will store a pulse of squeezed vacuum from our solid-state source in an EIT medium for a few microseconds, retrieve it and verify that the quantum state of the pulse is still squeezed. The retrieved state will be characterized by means of time-domain homodyne tomography, which will pave the way for the implementation of quantum memory for light. As a more distant goal, we plan to store and retrieve a quadrature entangled state.

Commence experiments on pulsed phase gates in atomic vapours

Quantum information processing with light is complicated by very weak optical nonlinearity of most materials. Based on a theoretical proposal of our IQIS theoretician colleagues, we plan to implement a giant optical nonlinearity in atomic rubidium vapour, which will enable construction of quantum computational gates for photons.

Commence construction of a magneto-optical trap for rubidium atoms

Most of our experiments so far were performed in warm atomic vapour. Although this medium has allowed us to do many interesting experiments, its potential for quantum information processing is limited by the Doppler broadening of atomic lines. In this project, we will cool a cloud of atoms down to a temperature of 100 microkelvins, which will enable a large variety of new experiments on interfacing quantum information between light and atoms.

THEORETICAL QUANTUM OPTICS & NONLINEAR OPTICS

Dr. Peter Marzlin

We will continue our efforts to design a feasible controlled quantum gate for photons by studying two different approaches. On one hand, we will investigate whether surface plasmons (SP) can help to increase nonlinear optical effects. SP are generated near a dielectric interface and can dramatically enhance the intensity of light. We are developing a full quantum theory of light that includes SP-induced noise, which may affect the fidelity of quantum gates based on SP. On the other hand, we will examine a novel way to implement a Rydberg gate. Here the large van der Waals interaction between Rydberg atoms is used to generate a large interaction between two photon pulses.

Furthermore, it has recently been questioned by Shapiro (MIT) whether optical nonlinearities are even in principle useful to construct controlled quantum gates. His arguments are based on a general model for optical pulse propagation in nonlinear media. We believe that this model does not address the special features of giant nonlinearities for slow light and will develop an ab-initio theory for pulse propagation in specific atomic media to refute or to overcome the detrimental effects predicted by Shapiro.

QUANTUM INFORMATION SCIENCE

Dr. Barry Sanders

We will develop numerical simulations to test the simple, efficient, practical approach to solve quantum key distribution's two major security weaknesses. First the team will simulate the security of networks under various topologies as the cost of bandwidth is expected to be topology-dependent. This simulation will take place on a network of existing linux-operated computers in the group. The goal is to collaborate with iCORE Chair Dr. Wolfgang Tittel's team to test these proposals in real world settings. Licensing arrangements with various companies are being explored.

In a separate project, we will explore the production of a giant optical nonlinearity from media other than gases. These latter media are important to enable fixed circuits with giant optical nonlinearities to be possible in the future. The researchers will also adapt models to accommodate pulses rather than just continuous wave sources. Experiments are being set up with Rubidium-87 gas as the medium to test part of the proposal, namely the existence of double electromagnetically-induced transparency.

The team will extend efficient quantum algorithms for simulating the evolution of a quantum state for time-dependent Hamiltonians. In particular we will study the simulation of adiabatic quantum evolution, which is at the heart of some quantum computer developments including work at D-Wave System's in Vancouver. The goal is to identify conditions for whether the time-dependent Hamiltonian can be efficiently simulated, to write the circuit-based algorithm for doing so for generic adiabatically evolving Hamiltonians, and to assess the resources consumed during this evolution.

Our goal with circuit quantum electrodynamics with superconducting charge qubits coupled to niobium resonators is to propose a feasible experiment that will observe, for the first time, a quantum walk, and will include controllable decoherence. The quantum walk is important as a primitive in quantum information, and its realization in the laboratory will connect the concept to experimental reality and ultimately lead to its practical use.

QUANTUM CRYPTOGRAPHY & COMMUNICATION

Dr. Wolfgang Tittel

Quantum Cryptography

During the next year, we will build a complete QC system based on polarization coding. It will also include classical post-processing. Furthermore, we will start work on quantum key distribution based on encoding of quantum information in superposition of faint laser pulses located in different "time-bins". The polarization-based system will comprise standard single photon detectors and run at a clock frequency of a few MHz. It will be a laboratory-type setup, implemented on the UofC-SAIT test-bed link, and will allow the demonstration of the principles of QC plus yield important information for future packaging and development of commercial grade technology.

Integration and Networks

We will continue theoretical studies for integrating QKD with Internet protocols, and into networks.

Quantum Relays and Repeaters

We will develop a realistic theoretical model that allows us to simulate the performance of various QKD schemes based on quantum repeater technology, and that will guide our activities in future.

SPACE

The Institute had 43 members on 31 March 2006, 55 members on 31 March 2007, and is projected to have 61 members on 31 March 2008. Of these members, the division between the Departments of Physics & Astronomy, Computer Science, and Mathematics & Statistics was 35:8:0 in 2006, 50:4:1 in 2007, and is projected to be 57:3:1 in 2008. The rapid growth of the Institute naturally puts pressure on the availability of space within the University, and particularly within the Faculty of Science.

Floor plans depicting the use of space are provided in Appendix C. Space limitations are particularly evident in the distribution of students and postdoctoral researchers in the Department of Physics & Astronomy.

INSTITUTE FUNDING

The University of Calgary provides annual funding of $75,000. The cost of operating the institute was $101,320 in 2006, and is projected to be $100,000 in 2007.

PERSONNEL

Institute personnel comprise the Administrator (1), group administrative assistants (1.5 supported by individual researcher funding), IT support (part-time), webmaster (part-time and supported by research funding). Our plan is to have an additional part-time administrative assistant in consideration of increasing demands. Our long-term plan is to have one more full-time Administrator position in the Institute.

7. appendices

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

15 June 2005

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 Vice-President (Research).

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 Vice-President (Research) 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 five-year term ending 31 December 2009**.** 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. These targets have been developed and will be used to measure success in achieving the above goals during the Institute's five-year term. They are outlined in Appendix 1.

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 Vice-President (Research), 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 Vice-President (Research).

Institute Board of Management

8. a) The governing body of the Institute shall be referred to as the "Board of Management" (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. Dean of Science;
   iii. At least 5 "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 Vice-President (Research) (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.)

Appendix 1

Targets and Measures of Success

Measures of Success:

a) Certified national testbed for quantum cryptography
b) Expertise and productive research
c) Demonstrate quantum memory for light
d) Demonstrate quantum optical state engineering at the multiphoton level
e) Establishment of fundamental relations among measures of quantum complexity
f) Theoretical power and limits of quantum models and protocals
g) Demonstrate few-qubit quantum fingerprinting
h) Efficient numerical simulation routines for quantum communication protocols accounting for realistic imperfections
i) Groundwork for applied research in QIS with expectation of valuable intellectual property
j) Self-funding QIS educational arm based on sophisticated visualization technology in collaboration with Banff New Media Institute
k) IQIS is a demonstrable QIS destination of choice for top students, postdocs, visitors, and prospective faculty

Specific Targets to Achieve by 2010:

Highly Qualified Personnel

- 30 graduate students with median entrance GPA > 3.75 or equivalent
- 2 external awards for students annually
- 8 postdocs including 4 with external fellowships
- 4 annual undergraduate student projects
- 5 summer students including at least 3 NSERC summer scholars
- 7 tenured or tenure-track faculty in QIS including 4 externally funded chairs (iCORE, IRC, CRC, ...)

Education and Training

- 3 graduate courses offered in QIS

- Annually: 4 students/postdocs visiting collaborating institute for at least 4 weeks
- Establishment of QViz as the premier source of sophisticated visualization presentations of QIS

Research Inputs
- At least $1,200,000 external funding for QIS research, stipends, scholarships, and fellowships per annum
- 8 distinguished visitors per annum
- 5 visitors at PhD level or higher per annum who stay at least 4 weeks

Research Outputs
- 30 papers in international refereed journals or refereed conference proceedings per annum including
- 8 in Physical Review Letters, or FOCS/STOC/STACS/ICALP/Complexity
- 1 in Science or Nature every second year commencing in the third year after the establishment of the Institute
- 30 invitations to give talks per annum including 3 keynote/plenary talks
- 15 student oral or poster presentations per annum at QIS conferences

Collaborations
- Demonstrable collaboration with at least 5 leading QIS groups
- Student exchanges with at least 2 leading QIS groups
- At least one corporate partnership with >$100k annual cash support
- Major experimental research project with leading international partner

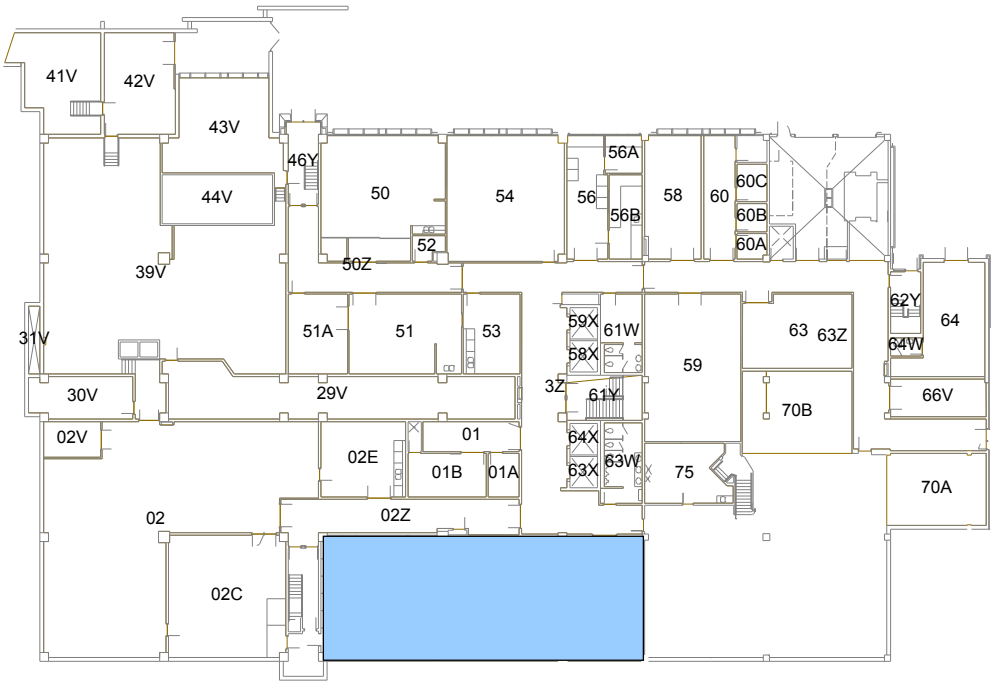
Citizenship
- Memberships of 8 conference/workshop program committees annually
- Chair or Co-Chair at least one conference biennially
- At least 2 editorial board members of QIS-related journals

Key result areas /performance indicators	*Target (by 2010)*	*Achievements (2006/07)*
Highly Qualified Personnel		
Number of students	30 graduate students	33
Median GPA	30 graduate students with median entrance GPA >3.75 or equivalent - MSc - PhD	 3.58 4
External Awards	2 external awards for students annually	3
Number of postdoctoral associates	8 postdoctoral associates	11
External Fellowships	8 postdoctoral associates including 4 with external fellowships	5
Undergraduate student projects	4 annual undergraduate student projects	5
Number of summer students	5 summer students	5
Number of summer scholars	5 summer students including at least 3 NSERC summer scholars	2
Number of tenured or tenure-track faculty in QIS	7 tenure-track faculty	7
External funding of faculty	4 externally funded chairs (iCORE, IRC, CRC)	3
Training and Education		
Number of graduate courses	3 graduate courses offered in QIS	3
Students/postdocs visiting collaborating institutes	4 students/postdocs annually visiting collaborating institutes for at least 4 weeks	2
QViz	Establish QViz as the premier source of sophisticated visualization presentations of QIS	On-going
Research Inputs		
Distinguished visitors per annum	8 distinguished visitors per annum	7
Number of visitors	5 visitors at PhD level or higher per annum who stay at least 4 weeks	6
Number of publications	30 papers in international refereed journals or refereed conference proceedings per annum including - 8 in Physical Review Letters, or FOCS/STOC/STACS/ICALP/Complexity - 1 in Science or Nature every second year commencing in the 3rd year after the establishment of the Institute	47 7 0
Invitations to address conferences	30 invitations to give talks per annum including 3 keynote/plenary talks	22
Number of student presentations	15 student oral or poster presentations per annum at QIS conferences	12
Collaborations		
Number of collaborations	Demonstrated collaboration with at least 5 leading QIS groups	11

Number of student exchanges	Student exchanges with at least 2 leading QIS groups	2
Corporate partnership	At least one corporate partnership with >$100k annual cash support	1
Major experimental research project	Major experimental research project with leading international partner	0
Citizenship		
Program committee membership	Membership of 8 conference/workshop program committees annually	14
Chair or Co-Chair	Chair or Co-Chair at least one conference biennially	2
Editorial board membership	At least 2 editorial board membership of QIS-related journals	3

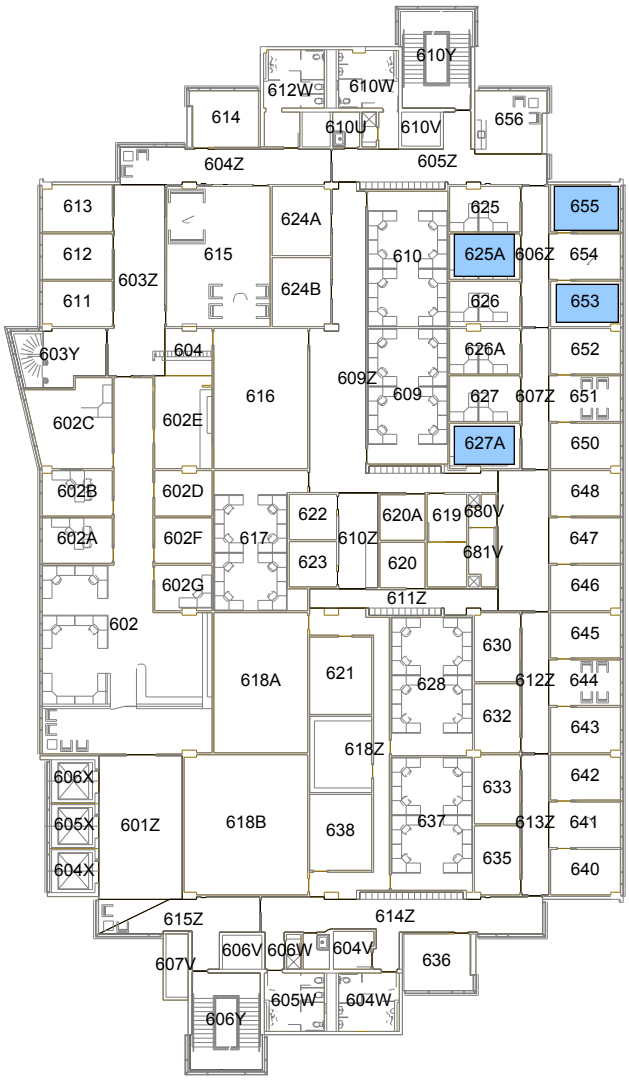
Earth Science Basement

IQIS



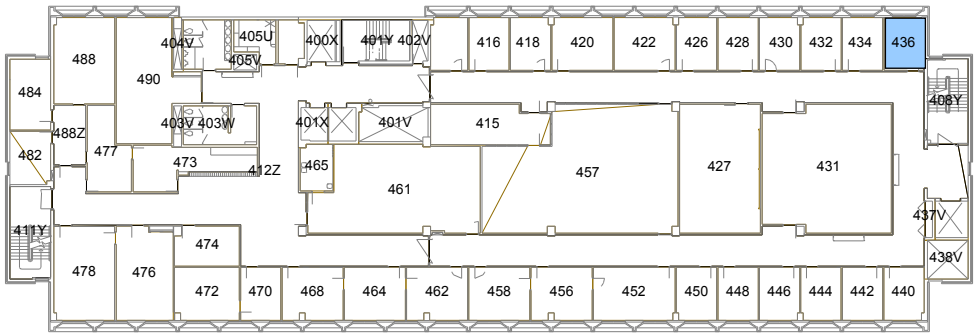
ICT Sixth Floor

IQIS



Mathematics Fourth Floor

IQIS



Science B Basement

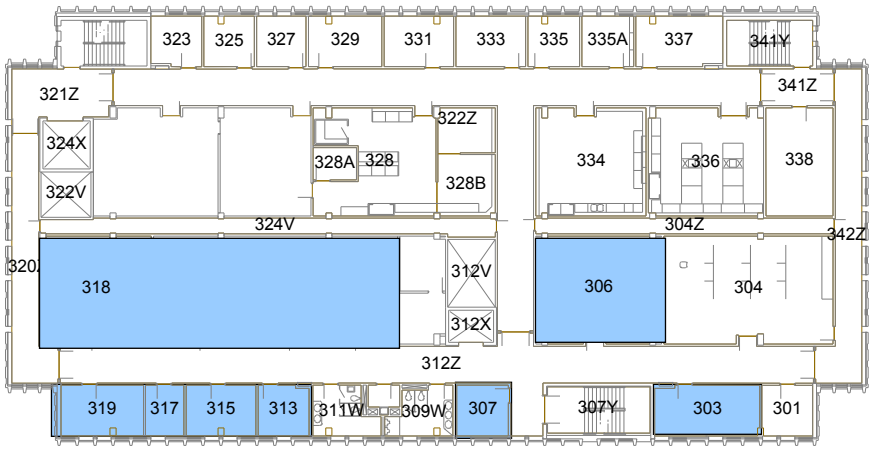
IQIS

Science B Main Floor

IQIS

Science B Third Floor

IQIS



Science B Fifth Floor

IQIS