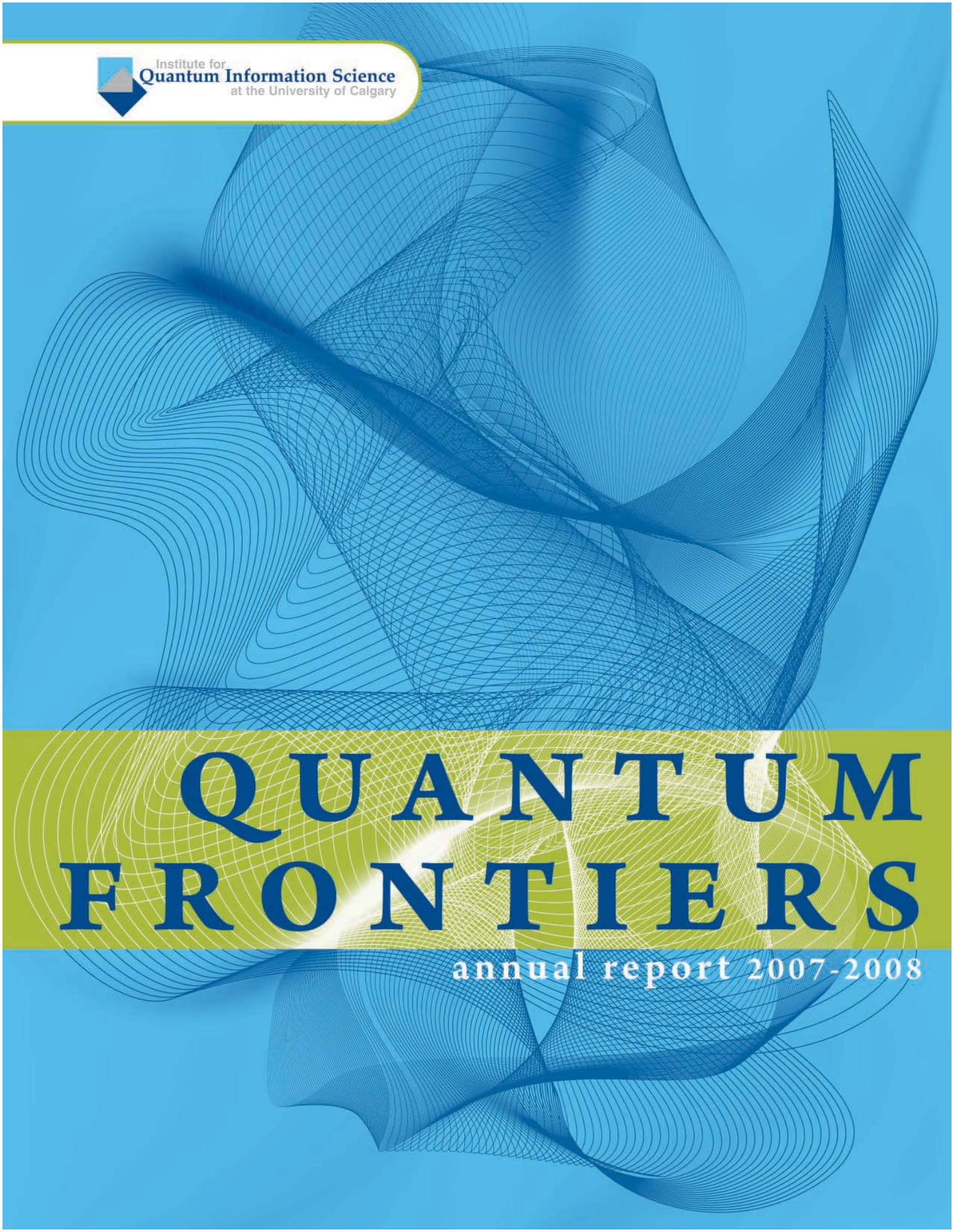
Institute for
Quantum Information Science
at the University of Calgary
QUANTUM
FRONTIERS
annual report 2007-2008

VISION

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

MISSION STATEMENT

To conduct world leading experimental and theoretical research in quantum information; to provide deep and diverse education and training for senior undergraduate and graduate students; and to conduct vigorous outreach and service to the public, the University, industry, and the quantum information science community.

KEY FACTS

- 10 postdoctoral research associates/fellows, 31 graduate students, and 9 undergraduate students
- 25 visiting researchers during the year including 3 long-term visiting professors and 2 long-term visiting students
- 24 publications in refereed journals and conference proceedings including 2 published in Physical Review Letters
- 26 invited talks at national and international conferences/workshops
- More than 50 posters and oral presentations done by students at national and international conferences/meetings/workshops
- Revenue $2.2M in 2007-08

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I DIRECTOR'S REPORT

The University of Calgary's Institute for Quantum Information Science continues to grow and mature. Full membership has increased from 55 to 69 members this past year. It is especially pleasing to see the newly established quantum information laboratories begin to produce outstanding results such as Lvovsky's storing and releasing of squeezed light – or, more light-heartedly, as putting less than nothing into quantum memory and getting less than nothing back out. The Institute's students are completing their graduate degrees and moving onto top institutions to undertake the next higher degree, postdoctoral research positions, or moving into industry. Former postdoctoral fellows have successfully transitioned to other research and teaching positions. The Institute is beginning to shine as a high quality research and training centre.

IQIS and its members have taken on a leading role in the national and international quantum information communities. The 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 was chaired by IQIS member Thompson and had 850 participants. Sanders chaired the Photons, Atoms, and Qubits conference at the Royal Society in London, which had 300 participants, and he co-chaired the First International Iran Conference on Quantum Information in September 2008, which had 100 participants.

Lvovsky was designated Chair of the long-running biennial Quantum Communication, Measurement, and Computation Conference, which will be held in Calgary in August 2008. The International Conference on Information Theoretic Security will also be held in Calgary in August 2008, co-chaired by Sanders and iCORE Chair Rei Safavi-Naini in the Department of Computer Science. Sanders became project leader of the Quantum Information Processing project of the National Centres of Excellence for the Mathematics of Information Technology and Complex Systems, and is leader of the Quantum Devices Theme in the NSERC Innovation Platform QuantumWorks.

The Institute especially encourages international linkage. Long-term academic visitors hail from India, Saudi Arabia, the Republic of Korea, the People's Republic of China, and Russia. Sergey Moiseev, who is visiting from Russia for two years, was awarded a prestigious iCORE Visiting Professorship.

In early 2008, IQIS and other University Institutes were transferred to Faculty's. In the case of IQIS, the natural home is the Faculty of Science. This transfer presents further opportunities for IQIS to bloom. In particular IQIS's relocation to the Faculty of Science provides greater opportunities to foster partnership with other Faculty-based Institutes and Centres and also with Departments to grow in strategic, mutually beneficial ways.

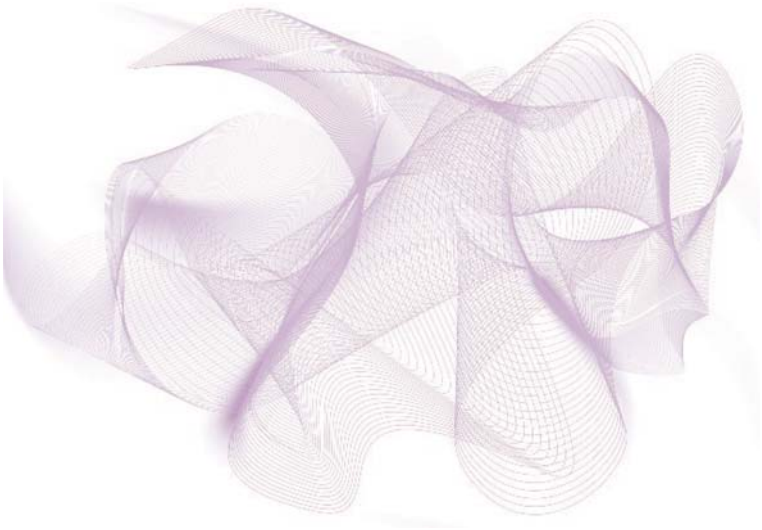
With growth of the Institute have come more administrative tasks. Both Tittel and Sanders have appointed part-time assistants to provide additional assistance to their respective groups. The Department of Physics & Astronomy now provides information technology support on a fee basis, which simplifies the administration of computer technical support to IQIS members. The web-based database continues to develop, thereby providing an efficient, easy-to-use shared resource for meeting IQIS members' onerous reporting requirements.

The 2008-09 year looks promising for the Institute. Two new faculty positions are being established in the Department of Physics & Astronomy, one in theoretical quantum optics and the other in quantum nanoscience. The quantum nanoscience position will be a partnership with the National Institute of Nanotechnology, which itself is a partnership of the Alberta Government, the National Research Council, and the University of Alberta, and the appointee will be seconded half-time to

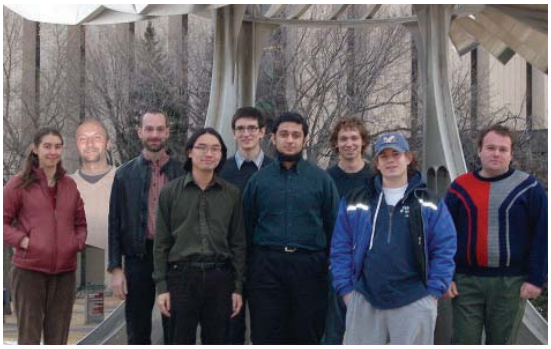
the Edmonton-based Institute. These two new positions will consolidate the world class strength of the quantum optics arm of quantum information at the University of Calgary and commence a new strand of research that ties quantum information with nanoscience and nanotechnology.

Of course there continue to be challenges for the Institute as well. Foremost among these challenges is the need for a multi-disciplinary research program led by tenured faculty members in the Departments of Computer Science, Mathematics & Statistics, Physics & Astronomy, and ultimately perhaps in Chemistry and Electrical and Computer Engineering as well. Originally the quantum information strength in Calgary was in Computer Science, and, in recent years, this has shifted to Physics & Astronomy. A priority for the Institute needs to be building strengths in all the allied disciplines of quantum information science. Of course with this goal comes other challenges, especially space and funds, but the rewards of a balanced, world-leading effort in quantum information science are worth the challenges.

Barry Sanders, Director, IQIS



II QUANTUM INFORMATION RESEARCH GROUPS AT THE INSTITUTE



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.

DR. GILAD GOUR

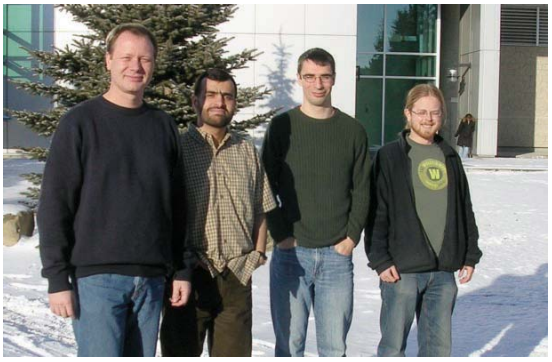
Quantum resources, like entanglement, are the key ingredients of quantum information processing tasks. They are needed in a many cases where quantum networks contain certain kinds of limitations or imperfections. For example, situations in which different parties in the network are not familiar with 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.

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 behavior 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).

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.



DR. PETER MARZLIN

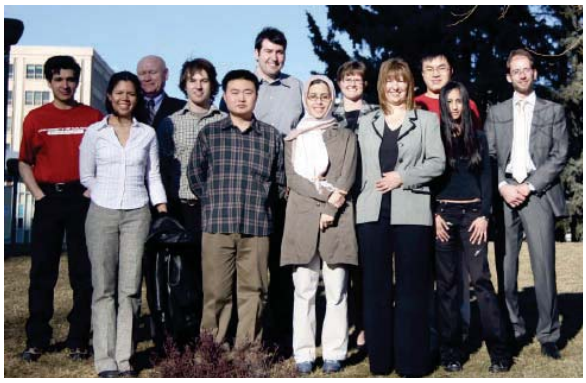
Atom-light interaction touches most fundamental aspects of quantum mechanics; many-particle effects in dense atomic gases, the nature of quantum states of light, and even relativity are relevant to understand it. Despite this conceptual depth it is also very close to experiments. We investigate novel 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.

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.

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.



III MANAGEMENT

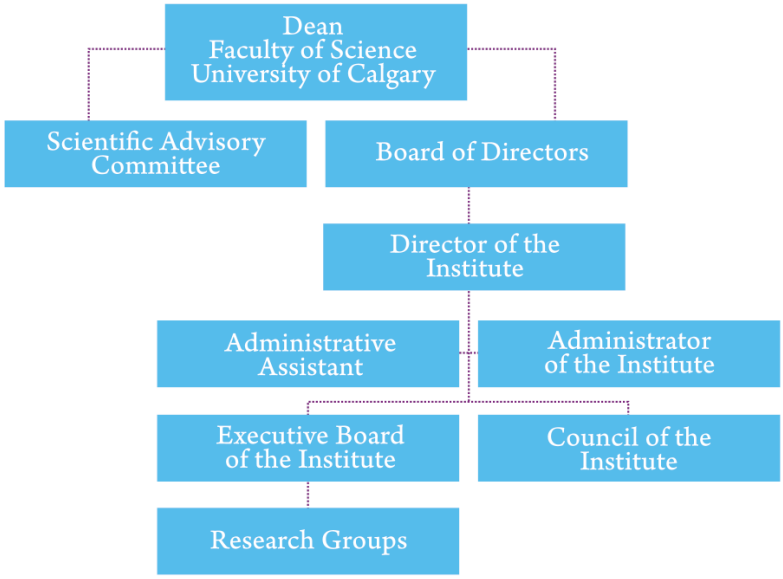
A. Structure

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 Dean, Faculty of Science. The Dean chairs the Board.

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

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

Organizational Chart – Institute for Quantum Information Science



B. Board of Directors

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

Dr. Brumer joined 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
Professor Sir Peter Knight
Principal, Faculty of Natural Sciences, Imperial College London

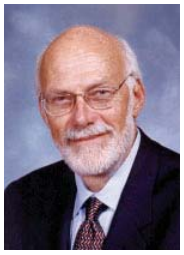
Professor Sir Peter Knight is Principal of the Faculty of Natural Sciences at Imperial College, London U.K., and is past Head of Imperial's Department of Physics. He is a past President of the Optical Society of America and a past Chair of the European Physical Society's Quantum Electronics and Optics Division, and has been Chief Scientific Advisor to the UK National Physical Laboratory. He is chair of the UK Government Defence Scientific Advisory Committee. 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. He is the 2008 winner of the Optical Society of America's Ives Medal.

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
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 the Netera Alliance, now called Cybera Inc. (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 Canadian 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.

IV PERFORMANCE & ANALYSIS

A. Research and Development

1. REFEREED PUBLICATIONS

J. Appel, E. Figueroa, D. Korystov, M. Lobino and A. I. Lvovsky, "Quantum memory for squeezed light", *Physical Review Letters* **100**(9): 093602 (4 pp.), 5 March 2008.

S. D. Bartlett, T. Rudolph, B. C. Sanders and P. S. Turner, "Degradation of a quantum directional reference frame as a random walk", *Journal of Modern Optics* **54**(13-15), pp. 2211 to 2221, 15 September 2007.

P. G. Brooke, K.–P. Marzlin, J. D. Cresser and B. C. Sanders, "Super- and subradiant emission of two-level systems in the near-Dicke limit", *Physical Review A* 77(3): 033844 (13 pp.), 25 March 2008.

V. I. Bužek, J. P. Marangos and B. C. Sanders, "Photons, atoms and qubits: On the occasion of the 60th birthday of Sir Peter L. Knight FRS, edited by B. C. Sanders, J. P. Marangos and V. Buzek - Foreword", *Journal of Modern Optics* **54**(13-15), p. 1657, 1 September 2007.

M. Garrett and D. L. Feder, "Cluster states from imperfect entanglement", *New Journal of Physics* **10**(3): 033009 (15 pp.), 6 March 2008.

S. Ghose and B. C. Sanders, "Non-Gaussian states for continuous variable quantum computation via Gaussian maps", *Journal of Modern Optics* **54**(6), pp. 855 to 869, 12 April 2007.

S. Ghose, B. C. Sanders, P. M. Alsing and I. H. Deutsch, "Nonseparability of continuously measured quantum systems in the classical limit", *Canadian Journal of Physics* **85**(6), pp. 633 to 640, 1 June 2007.

S. Ghose and B. C. Sanders, "Continuous measurement and the quantum to classical transition", *Physics in Canada* **63**(4), pp. 173 to 181, 1 October 2007.

J. Hakami, A. Kamli and M. Alamri, "Fluorescence spectrum due to surface plasmonpolariton emission in a three level atom", *Optics Communications* **279**(1), pp. 112 to 119, 1 November 2007.

P. Han, K. J. Jin, B. C. Sanders, Y. L. Zhou, H. B. Lu and G. Z. Yang, "Strong terahertz emission from superlattices via Zener tunneling", *Europhysics Letters* **79**(2): 27001 (5 pp.), 28 June 2007.

A. Kamli, J. Hakami, N. Bouarissa and M. Al-Amri, "Three level atom spectrum in metal film between $InP_{1-x}Sb_x$ alloys", *Physics Letters A* **372**(13), pp. 2208 to 2221, 24 March 2008.

R. Karasik, K.–P. Marzlin, B. C. Sanders and K. B. Whaley, "Multi-particle decoherence free subspaces in extended systems", *Physical Review A* **76**(1), 012331 (12 pp.), 27 July 2007.

K.–P. Marzlin, R. Karasik, B. C. Sanders and K. B. Whaley, "Decoherence-free subspaces and spontanenous emission cancellation", *Canadian Journal of Physics* **85**(6), pp. 641 to 645, 1 June 2007.

A. Morris and D. L. Feder, "Gaussian potentials facilitate access to quantum Hall states in rotating Bose gases", *Physical Review Letters* **99**(24), 240401 (4 pp.), 12 December 2007.

M. Oberst, F. Vewinger and A. I. Lvovsky, "Time-resolved probing of the ground state coherence in rubidium", *Optics Letters* **32**(12), pp. 1755 to 1757, 1 June 2007.

J. Rehácek, Z. Hradil, E. Knill and A. I. Lvovsky, "Diluted maximum-likelihood algorithm for quantum tomography", *Physical Review A* **75**(4): 042108 (5 pp.), 18 April 2007.

A. Roy and A. J. Scott, "Weighted complex projective 2-designs from bases: optimal state determination by orthogonal measurements", *Journal of Mathematical Physics* **48**(7), 072110 (24 pp.), 30 July 2007.

Z. Shaterzadeh Yazdi, P. S. Turner and B. C. Sanders, "SU(1,1) symmetry of multimode squeezed states", *Journal of Physics A: Mathematical and Theoretical* **41**(5): 055309 (11 pp.), 23 January 2008.

T. Tyc, B. Hamilton, B. C. Sanders and W. D. Oliver, "No approximate complex fermion coherent states", *Foundations of Physics* **37**(7), pp. 1027 to 1048, 1 July 2007.

T. Tyc, B. Hamilton, B. C. Sanders and W. D. Oliver, "No approximate complex fermion coherent states", *Foundations of Physics* **37**(11), pp. 1519 to 1539, 1 November 2007.

F. Vewinger, J. Appel, E. Figueroa and A. I. Lvovsky, "Adiabatic frequency conversion of quantum optical information in atomic vapor", *Optics Letters* **32**(19), pp. 2771 to 2773, 17 September 2007.

2. PROFESSIONAL MAGAZINES

E. Figueroa, "OSA student chapter at the University of Calgary starts activities", *Focal Point* (The OSA Local Section and Student Chapter Newsletter), 24 October 2007.

B. C. Sanders, "Science without borders: quantum information in Iran", *The Quantum Times* **2**(3), pp. 1 to 3, 1 September 2007.

3. BOOK CHAPTERS

D. W. Berry, G. Ahokas, R. Cleve and B. C. Sanders, "Quantum algorithms for Hamiltonian simulation", section in book: *Mathematics of Quantum Computation and Quantum Technology*, G. Chen, L. Kauffman, S. J. Lomonaco, eds., Published by Taylor & Francis, Oxford, United Kingdom, pp. 89 to 110, 2007

4. CONFERENCE PROCEEDINGS

A. Delfan, C. La Mela and W. Tittel, "Photon echo quantum memory and state transformation" (invited), Proceedings of SPIE , Advanced Optical Concepts in Quantum Computing, Memory and Communication **6903**, San Jose, United States of America, 19 Jan 2008 - 24 Jan 2008, Published by SPIE Publications, Bellingham, United States of America: 690308 (6 pp.), 29 January 2008.

P. Høyer, T. Lee and R. Špalek, "Negative weights make adversaries stronger", Proceedings of The 39th ACM Symposium on Theory of Computing (STOC 2007), San Diego, United Sates of America, 11 Jun 2007 - 13 Jun 2007, Published by ACM, New York, United States of America: Session 10B pp. 526 to pp. 535,13 June 2007

Z. Shaterzadeh Yazdi, P. S. Turner and B. C. Sanders, "Three-mode squeezing: SU(1,1) symmetry" (invited), Proceedings of SPIE: Noise and Fluctuations in Photonics, Quantum Optics, and Communications **6603**, La Pietra Conference Center, Florence, Italy, 20 May 2007 - 24 May 2007, Published by SPIE Publications, Bellingham, United States of America: 660317 (11 pp.), 7 June 2007.

5. PRESENTATIONS

(presenter is underlined)

1 Apr 2007, P. S. Turner, "Multimode squeezing in quantum networks", 10th International Conference on Squeezed States and Uncertainty Relations, Bradford, United Kingdom, 31 Mar 2007 - 4 Apr 2007.

3 Apr 2007, W. Tittel, "Quantum cryptography - distinguished lecture series - CISaC & CMSS", University of Calgary, Department of Mathematics and Statistics.

9 Apr 2007, B. C. Sanders, "Implementations of quantum information" (invited), Quantum Information Processing Workshop, Riyadh, Saudi Arabia, 9 Apr 2007 - 10 Apr 2007.

10 Apr 2007, B. C. Sanders, "Challenges of optical quantum information science" (invited), Quantum Information Processing Workshop, Riyadh, Saudi Arabia, 9 Apr 2007 - 10 Apr 2007.

4 May 2007, G. Gour, "Entanglement in quantum information", North-South Dialogue on Mathematics, University of Alberta.

10 May 2007, N. S. Babcock, R. Stock and B. C. Sanders, "Entanglement and rapid measurement of clock-state qubits in Yb or Sr for quantum information processing" (contributed), QThF2, 2007 CLEO/QELS, Baltimore, United States of America, 6 May 2007 - 11 May 2007.

22 May 2007, R. Stock, "Quantum computing with identical atoms and fewer loopholes for Bell", University of New Mexico, Department of Physics and Astronomy, Information Physics Group.

23 May 2007, B. C. Sanders, Z. Shaterzadeh Yazdi and P. S. Turner, "Multi-partite entangled Gaussian states and su (1,1) symmetry" (invited), Noise and Fluctuations in Photonics, Quantum Optics, and Communications, Florence, Italy, 20 May 2007 - 24 May 2007.

24 May 2007, W. Tittel, "Quantum cryptography" (invited), Canadian Applied and Industrial Mathematics (CAIMS 2007), Banff, Canada, 20 May 2007 - 24 May 2007.

24 May 2007, B. C. Sanders, "Efficiently simulating evolution of states on a quantum computer" (seminar), Università degli Studi di Pavia, Quantum Information Theory Group.

29 May 2007, R. Stock, "Entangling atoms via cold collisions" (invited), The Institute for Theoretical Atomic Molecular and Optical Physics, Ion-Atom Interactions Topical Group, Cambridge, United States of America, 28 May 2007 - 1 Jun 2007.

29 May 2007, A. Roy, "Association schemes in systems of lines and subspaces" (invited), 1st Canadian Discrete and Algorithmic Mathematics Conference (CanaDAM 2007), Banff, Canada, 28 May 2007 - 31 May 2007.

31 May 2007, M. Durocher, B. C. Sanders and J. Walgate, "Distinguishability of a tripartite unextendible product basis using local operations and classical communication" (poster), CMS-MITACS Joint Conference 2007 (CMS-MITACS 2007), Winnipeg, Canada, 31 May 2007 - 3 Jun 2007.

31 May 2007, N. Wiebe and B. C. Sanders, "Quantum simulation circuits for sparse Hamiltonians" (poster), CMS-MITACS Joint Conference 2007 (CMS-MITACS 2007), Winnipeg, Canada, 31 May 2007 - 3 Jun 2007.

1 Jun 2007, K.–P. Marzlin, R. Karasik, B. C. Sanders and K. B. Whaley, "Criteria for the existence of decoherence-free subspaces" (invited), CMS-MITACS Joint Conference 2007 (CMS-MITACS 2007), Winnipeg, Canada, 31 May 2007 - 3 Jun 2007.

1 Jun 2007, M. Skotiniotis, A. Roy and B. C. Sanders, "The Spekkens toy model revisited" (contributed), CMS-MITACS Joint Conference 2007 (CMS-MITACS 2007), Winnipeg, Canada, 31 May 2007 - 3 Jun 2007.

2 Jun 2007, J. A. Slater, F. Bussières, N. Godbout and W. Tittel, "Towards the production of entangled photon pairs in optical fiber via four-wave mixing" (contributed), Fourth Annual Canadian Quantum Information Students' Conference (CQISC 2007), Waterloo, Canada, 1 Jun 2007 - 5 Jun 2007.

2 Jun 2007, N. S. Babcock, R. Stock, B. C. Sanders and M. G. Raizen, "Entangling neutral atoms in optical dipole traps" (poster), Fourth Annual Canadian Quantum Information Students' Conference (CQISC 2007), Waterloo, Canada, 1 Jun 2007 - 5 Jun 2007.

2 Jun 2007, B. C. Sanders, "Information-theoretic security for authenticated long-distance quantum key distribution with partial trust networks" (invited), CMS-MITACS Joint Conference 2007 (CMS-MITACS 2007), Winnipeg, Canada, 31 May 2007 - 3 Jun 2007.

2 Jun 2007, G. Gour, "Quantum resource theories and super selection rules" (invited), CMS-MITACS Joint Conference 2007 (CMS-MITACS 2007), Winnipeg, Canada, 31 May 2007 - 3 Jun 2007.

2 Jun 2007, A. Roy and A. J. Scott, "Weighted complex projective

2-designs from bases", CMS-MITACS Joint Conference 2007 (CMS-MITACS 2007), Winnipeg, Canada, 31 May 2007 - 3 Jun 2007.

6 Jun 2007, R. Stock, N. S. Babcock, M. G. Raizen and B. C. Sanders, "Entangling operations and rapid measurement of atomic clock-state qubits for violating Bell inequalities" (contributed), C4.00002 , 38th Meeting of the Division of Atomic, Molecular and Optical Physics (DAMOP 2007), Calgary, Canada, 5 Jun 2007 - 9 Jun 2007. (http://meetings.aps.org/link/BAPS.2007.DAMOP.C4.2).

6 Jun 2007, J. J. Choquette, K.–P. Marzlin, R. Stock and B. C. Sanders, "Quantum electrodynamics of surface plasmons" (poster), D1.00113 , 38th Meeting of the Division of Atomic, Molecular and Optical Physics (DAMOP 2007), Calgary, Canada, 5 Jun 2007 - 9 Jun 2007. (http://meetings.aps.org/link/BAPS.2007.DAMOP.D1.113).

7 Jun 2007, Y. Sanders, H. A. Carteret and B. C. Sanders, "Discerning thermal properties of entanglement in qubit rings using n-concurrence" (poster), K1.00010, 38th Meeting of the Division of Atomic, Molecular and Optical Physics (DAMOP 2007), Calgary, Canada, 5 Jun 2007 - 9 Jun 2007. (http://meetings.aps.org/link/BAPS.2007.DAMOP.K1.10).

7 Jun 2007, S. Ghose, R. Stock, R. Lal and A. Silberfarb, "Studying chaos, entanglement and decoherence in the quantum kicked top with cold atoms" (contributed), H5.00007 , 38th Meeting of the Division of Atomic, Molecular and Optical Physics (DAMOP 2007), Calgary, Canada, 5 Jun 2007 - 9 Jun 2007. (http://meetings.aps.org/link/BAPS.2007.DAMOP.H5.7).

7 Jun 2007, F. Bussières, J. A. Slater, A. Rubenok, J. Nguyen, N. Godbout, S. Lacroix and W. Tittel, "Hybrid entanglement for optical quantum networks" (poster), K1.00008, 38th Meeting of the Division of Atomic, Molecular and Optical Physics (DAMOP 2007), Calgary, Canada, 5 Jun 2007 - 9 Jun 2007. (http://meetings.aps.org/link/BAPS.2007.DAMOP.K1.8).

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7 Jun 2007, I. Mahmoud, K.–P. Marzlin and B. C. Sanders, "Many-particle effects in the propagation of slow light through atomic gases" (poster), K1.00068 , 38th Meeting of the Division of Atomic, Molecular and Optical Physics (DAMOP 2007), Calgary, Canada, 5 Jun 2007 - 9 Jun 2007. (http://meetings.aps.org/link/BAPS.2007.DAMOP.K1.68).

7 Jun 2007, R. Karasik, K.–P. Marzlin, B. C. Sanders and K. B. Whaley, "Criteria for dynamically stable decoherence-free subspaces" (contributed), H5.00004 , 38th Meeting of the Division of Atomic, Molecular and Optical Physics (DAMOP 2007), Calgary, Canada, 5 Jun 2007 - 9 Jun 2007. (http://meetings.aps.org/link/BAPS.2007.DAMOP.H5.4).

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8 Jun 2007, W. Tittel, M. Afzelius, N. Gisin, S. R. Hastings-Simon and M. U. Staudt, "Towards quantum memory" (contributed), Q5.00008, 38th Meeting of the Division of Atomic, Molecular and Optical Physics (DAMOP 2007), Calgary, Canada, 5 Jun 2007 - 9 Jun 2007. (http://meetings.aps.org/link/BAPS.2007.DAMOP.Q5.8).

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9 Jun 2007, J. Appel, E. Figueroa, F. Vewinger, D. Korystov, G. Günter and A. I. Lvovsky, "Towards storage of squeezed light by electromagnetically induced transparency" (contributed), W2.00003 , 38th Meeting of the Division of Atomic, Molecular and Optical Physics (DAMOP 2007), Calgary, Canada, 5 Jun 2007 - 9 Jun 2007. (http://meetings.aps.org/link/BAPS.2007.DAMOP.W2.3).

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9 Jun 2007, M. Durocher, B. C. Sanders and J. Walgate, "Distinguishability of a tripartite unextendible product basis using local operations and classical communication" (contributed), W5.00005 , 38th Meeting of the Division of Atomic, Molecular and Optical Physics (DAMOP 2007), Calgary, Canada, 5 Jun 2007 - 9 Jun 2007. (http://meetings.aps.org/link/BAPS.2007.DAMOP.W5.5).

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13 Jun 2007, R. Stock, N. S. Babcock, M. G. Raizen and B. C. Sanders, "Entangling operations and rapid measurement of atomic clock-state qubits for violating Bell inequalities" (invited), Theory Canada III, Edmonton, Canada, 13 Jun 2007 - 16 Jun 2007.

13 Jun 2007, D. L. Feder, "Quantum algorithms with quantum walks", Theory Canada III, Edmonton, Canada, 13 Jun 2007 - 16 Jun 2007.

14 Jun 2007, W. Tittel, M. Afzelius, N. Gisin, R. Ricken, S. R. Hastings-Simon, V. Scarani, H. Suche, W. Sohler and M. U. Staudt, "Towards long-distance quantum communication" (invited), The International Conference on Quantum Information (ICQI 2007), University of Rochester, United States of America, 10 Jun 2007 - 13 Jun 2007.

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18 Jun 2007, M. Skotiniotis, A. Roy and B. C. Sanders, "The Spekkens toy model revisited" (poster), MO-POS-93, *Physics in Canada* **63**(2):p. 143, CAP Congress 2007 (CAPC 2007), Saskatoon, Canada, 17 Jun 2007 - 20 Jun 2007.

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18 Jun 2007, N. Wiebe and B. C. Sanders, "Quantum simulation circuits for sparse Hamiltonians" (poster), MO-POS-95, *Physics in Canada* **63**(2):p. 143, CAP Congress 2007 (CAPC 2007), Saskatoon, Canada, 17 Jun 2007 - 20 Jun 2007.

18 Jun 2007, I. Mahmoud, K.–P. Marzlin and B. C. Sanders, "Many-particle effects in the propagation of slow light through atomic gases" (poster), MO-POS-62, *Physics in Canada* **63**(2):p. 138, CAP Congress 2007 (CAPC 2007), Saskatoon, Canada, 17 Jun 2007 - 20 Jun 2007.

18 Jun 2007, I. Lucio Martinez, P. Chan, S. Hosier, X.F. Mo and W. Tittel, "Towards fast quantum secured communication" (poster), MO-POS-19, *Physics in Canada* **63**(2):p. 131, CAP Congress 2007 (CAPC 2007), Saskatoon, Canada, 17 Jun 2007 - 20 Jun 2007.

18 Jun 2007, A. Roy and A. J. Scott, "Weighted complex projective 2-designs from bases: optimal state determination by orthogonal measurements" (poster), Conference on Combinatorics and Optimization (C&O@40), Waterloo, Canada, 18 Jun 2007 - 23 Jun 2007.

18 Jun 2007, J. J. Choquette, K.–P. Marzlin, R. Stock and B. C. Sanders, "Quantum electrodynamics of surface plasmons" (poster), MO-POS-14, *Physics in Canada* 63(2):p. 130, CAP Congress 2007 (CAPC 2007), Saskatoon, Canada, 17 Jun 2007 - 20 Jun 2007.

18 Jun 2007, M. Underwood and K.–P. Marzlin, "Fermi-Frenet coordinates for space-like curves " (poster), MO-POS-85, *Physics in Canada* **63**(2):p. 142, CAP Congress 2007 (CAPC 2007), Saskatoon, Canada, 17 Jun 2007 - 20 Jun 2007.

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19 Jun 2007, G. Howard, W. Tittel and B. C. Sanders, "Real source quantum key distribution relays" (contributed), TU-P1-2, *Physics in Canada* **63**(2):p. 101, CAP Congress 2007 (CAPC 2007), Saskatoon, Canada, 17 Jun 2007 - 20 Jun 2007.

19 Jun 2007, K.–P. Marzlin, J. Appel and A. I. Lvovsky, "Slow photons as charged quasi-particles, and photonic Aharonov-Bohm effect" (contributed), *Physics in Canada* **63**(2):p. 94, CAP Congress 2007 (CAPC 2007), Saskatoon, Canada, 17 Jun 2007 - 20 Jun 2007.

20 Jun 2007, F. Bussières, J. A. Slater, A. Rubenok, J. Nguyen, N. Godbout

and W. Tittel, "Hybrid photonic entanglement using a PPLN crystal" (contributed), WE-P5-3, *Physics in Canada* **63**(2):p. 126, CAP Congress 2007 (CAPC 2007), Saskatoon, Canada, 17 Jun 2007 - 20 Jun 2007.

20 Jun 2007, J. A. Slater, F. Bussières, N. Godbout and W. Tittel, "Towards the production of entangled photon pairs in optical fiber via four-wave mixing" (contributed), WE-P5-2, *Physics in Canada* **63**(2):p. 126, CAP Congress 2007 (CAPC 2007), Saskatoon, Canada, 17 Jun 2007 - 20 Jun 2007.

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21 Jun 2007, B. C. Sanders, "Efficient quantum algorithm for simulating evolution of states" (invited), Identifying Quantum States and Operations: Theory and Applications, Budmerice, Slovakia , 20 Jun 2007 - 24 Jun 2007.

24 Jun 2007, B. C. Sanders, "Duality for monogamy of entanglement" (invited), 4th Central European Quantum Information Processing Workshop, Valtice, Czech Republic, 24 Jun 2007 - 27 Jun 2007.

28 Jun 2007, B. C. Sanders, "Efficient quantum algorithm for simulating state evolution" (seminar), Universität Ulm, Institut für Quantenphysik.

17 Jul 2007, K.–P. Marzlin, "Slow photons as charged Quasi-Particles, and photonic Aharonov-Bohm effect" (colloquium), University of Manitoba, Department of Physics and Astronomy.

22 Jul 2007, B. C. Sanders, "Efficient quantum algorithm for simulating state evolution on a quantum computer" (plenary), International Symposium on Quantum Theory and Symmetries (ISQTS 2007), Valladolid, Spain, 22 Jul 2007 - 28 Jul 2007.

11 Aug 2007, E. Figueroa, J. Appel, F. Vewinger, D. Korystov, G. Günter and A. I. Lvovsky, "Towards storage of non-classical light using electromagnetically induced transparency", AMO:I-3, CAM 2007, Montreal, Canada, 8 Aug 2007 - 11 Aug 2007.

24 Aug 2007, J. J. Choquette, "Quantum information with surface plasmons" (poster), iCORE Summit 2007 (iCORE 2007), Banff, Canada, 23 Aug 2007 - 25 Aug 2007.

25 Aug 2007, F. Bussières, J. A. Slater, A. Rubenok, J. Nguyen, N. Godbout, S. Lacroix and W. Tittel, "Hybrid entanglement for optical quantum networks" (poster), iCORE Summit 2007 (iCORE 2007), Banff, Canada, 23 Aug 2007 - 25 Aug 2007.

25 Aug 2007, B. C. Sanders, "Quantum information at the University of Calgary" (invited), iCORE Summit 2007 (iCORE 2007), Banff, Canada, 23 Aug 2007 - 25 Aug 2007.

25 Aug 2007, I. Lucio Martinez, P. Chan, S. Hosier and W. Tittel, "Towards fast quantum secured communication" (poster), iCORE Summit 2007 (iCORE 2007), Banff, Canada, 23 Aug 2007 - 25 Aug 2007.

26 Aug 2007, A. I. Lvovsky, "Sterring light by electromagnetically-induced transparency" (invited), Quantum Communication and Quantum Imaging V (QCQI), San Diego, United States of America, 26 Aug 2007 - 31 Aug 2007.

30 Aug 2007, B. C. Sanders, "Implementations of quantum information protocols I" (invited), International Summer School in Quantum Information Processing and Control, Maynooth, Ireland, 27 Aug 2007 - 31 Aug 2007.

30 Aug 2007, B. C. Sanders, "Implementation of quanum information protocols II" (invited), International Summer School in Quantum Information Processing and Control, Maynooth, Ireland, 27 Aug 2007 - 31 Aug 2007.

4 Sep 2007, Z. Shaterzadeh Yazdi, P. S. Turner and B. C. Sanders, "Multipartite squeezed states as SU (1,1) coherent states" (poster), Photons, Atoms and Qubits Conference 2007 (PAQ07), London, United Kingdom, 2 Sep 2007 - 5 Sep 2007.

4 Sep 2007, K.–P. Marzlin, J. Appel and A. I. Lvovsky, "Slow photons as charged Quasi-Particles" (poster), Photons, Atoms and Qubits Conference 2007 (PAQ07), London, United Kingdom, 2 Sep 2007 - 5 Sep 2007.

5 Sep 2007, B. C. Sanders, "Quantum algorithm for efficient simulating Hamiltonian evolution" (invited), Photons, Atoms and Qubits Conference 2007 (PAQ07), London, United Kingdom, 2 Sep 2007 - 5 Sep 2007.

6 Sep 2007, K.–P. Marzlin, "Slow photons as charged quasi-particles, and photonic Aharonov-Bohm effect" (seminar), Durham University, Department of Physics.

8 Sep 2007, S. Baghbanzadeh and A. T. Rezakhani, "Thermal effects on quantum cloning and entanglement broadcasting" (poster), International Iran Conference on Quantum Information (IICQI 2007), Kish Island, Iran, 7 Sep 2007 - 10 Sep 2007.

9 Sep 2007, Z. Shaterzadeh Yazdi, P. S. Turner and B. C. Sanders, "Multi-partite squeezed states and SU(1,1) symmetry" (contributed), International Iran Conference on Quantum Information (IICQI 2007), Kish Island, Iran, 7 Sep 2007 - 10 Sep 2007.

10 Sep 2007, B. C. Sanders, "Polygamy of entanglement of assistance: duality monogamy inequality for entanglement" (invited), International Iran Conference on Quantum Information (IICQI 2007), Kish Island, Iran, 7 Sep 2007 - 10 Sep 2007.

14 Sep 2007, A. I. Lvovsky, "Electromagnetically-induced transparency with classical and nonclassical light" (invited), Frontiers in Optics 2007 (OSA Annual Meeting), San Jose, United States of America, 16 Sep 2007 - 20 Sep 2007.

20 Sep 2007, F. Bussières, J. A. Slater, A. Rubenok, J. Nguyen, N. Godbout and W. Tittel, "Towards photonic hybrid entanglement" (contributed), Frontiers in Optics 2007 (OSA Annual Meeting), San Jose, United States of America, 16 Sep 2007 - 20 Sep 2007.

26 Sep 2007, F. Bussières, P. Chan, A. Delfan, S. Hosier, G. Howard, C. La Mela, I. Lucio Martinez, X.F. Mo, J. Nguyen, A. Rubenok, E. Saglamyurek, J. A. Slater, M. Underwood and W. Tittel, "Quantum communication in the QC2 lab" (invited), Second QuantumWorks Annual General Meeting, Calgary, Canada, 26 Sep 2007 - 27 Sep 2007.

26 Sep 2007, A. MacRae, Z.-B. Wang, K.–P. Marzlin and A. I. Lvovsky, "Giant optical nonlinearities using double electromagnetically induced transparency in Rubidium" (poster), Second QuantumWorks Annual General Meeting (QuantumWorks 2007), Calgary, Canada, 26 Sep 2007 - 27 Sep 2007.

26 Sep 2007, F. Bussières, P. Chan, A. Delfan, S. Hosier, G. Howard, C. La Mela, I. Lucio Martinez, X.F. Mo, J. Nguyen, A. Rubenok, E. Saglamyurek, J. A. Slater, M. Underwood and W. Tittel, "Quantum communication in the QC2 lab" (poster), Second QuantumWorks Annual General Meeting (QuantumWorks 2007), Calgary, Canada, 26 Sep 2007 - 27 Sep 2007. (The poster was presented by the whole group)

12 Oct 2007, J. Nguyen, F. Bussières and W. Tittel, "Optical fiber interferometer stabilization for time-bin qubit measurement" (contributed), Canadian Undergraduate Physics Conference (CUPC 2007), Vancouver, Canada, 11 Oct 2007 - 14 Oct 2007.

22 Nov 2007, D. Feder, "One-way quantum computing with ultracold atoms in optical lattices" (colloquium), University of Alberta, Department of Physics.

28 Nov 2007, F. Bussières, P. Chan, A. Delfan, S. Hosier, G. Howard, C. La Mela, I. Lucio Martinez, X.F. Mo, J. Nguyen, A. Rubenok, E. Saglamyurek, N. Sinclair, J. A. Slater, M. Underwood and W. Tittel, "Quantum cryptography in the QC2 lab" (poster), the CYBERPOL Project, Bow River Dialogues, Calgary, Canada, 28 Nov 2007 - 29 Nov 2007.

1 Dec 2007, B. C. Sanders, "Efficient algorithm for universal simulation" (invited), Quantum Information and Many Body Physics Workshop, Vancouver, Canada, 1 Dec 2007 - 3 Dec 2007.

7 Dec 2007, B. C. Sanders, "Efficient quantum algorithm for simulating state evolution on a quantum computer" (invited), International Conference on Recent Developments in Theoretical Physics (Theophys 07), Kolkata, India, 4 Dec 2007 - 7 Dec 2007.

15 Jan 2008, W. Tittel, "Quantum cryptography" (invited), QKD TDP Kickoff Meeting , Ottawa, Canada, 15 Jan 2008 - 15 Jan 2008.

23 Jan 2008, D. L. Feder, "Quantum mechanics can help analyze complex networks" (seminar), University of Calgary, Department of Physics and Astronomy . (Complexity Science Seminar).

23 Jan 2008, A. Delfan, C. La Mela and W. Tittel, "Photon echo quantum memory and state transformation" (invited), SPIE Photonics West 2008 (SPIE Photonics West 2008), San Jose, United States of America, 19 Jan 2008 - 24 Jan 2008.

25 Jan 2008, A. Delfan, C. La Mela, M. Underwood, K.–P. Marzlin, S. A. Moiseev and W. Tittel, "Relaxing symmetry in CRIB: Combining quantum state storage with data transformation" (contributed), Workshop on the Storage and Manipulation of Quantum Information in Optically-Addressed Solids (SMQIOAS 2008), Bozeman, United States of America, 25 Jan 2008 - 27 Jan 2008.

25 Jan 2008, S. A. Moiseev and W. Tittel, "Quantum compression/ decompression of light pulses using photon echo based quantum memory" (contributed), Workshop on the Storage and Manipulation of Quantum Information in Optically-Addressed Solids, Bozeman, United States of America, 25 Jan 2008 - 27 Jan 2008.

26 Jan 2008, M. Underwood, K.–P. Marzlin and W. Tittel, "Manipulation and storage of qubits via CRIB" (poster), Workshop on the Storage and Manipulation of Quantum Information in Optically-Addressed Solids (SMQIOAS 2008), Bozeman, United States of America, 25 Jan 2008 - 27 Jan 2008.

26 Jan 2008, A. Delfan, C. La Mela and W. Tittel, "Towards unambiguous quantum state discrimination in an optical memory" (poster), Workshop on the Storage and Manipulation of Quantum Information in Optically-Addressed Solids, SMQIOAS 2008, Bozeman,United States of America, 25 Jan 2008 - 27 Jan 2008.

15 Feb 2008, N. Wiebe, "Quantum computer simulations of time dependent Hamiltonians" (poster), Southwest Quantum Information and Technology 10th Annual Meeting (SQuInT 2008), Santa Fe, United States of America, 14 Feb 2008 - 17 Feb 2008.

15 Feb 2008, A. G. D'Souza and D. L. Feder, "SLOCC equivalence of graph states and Hamiltonian ground states" (poster), Southwest Quantum Information and Technology 10th Annual Meeting (SQuInT 2008), Santa Fe, United States of America, 14 Feb 2008 - 17 Feb 2008.

16 Feb 2008, B. C. Sanders, "Quantum walk on a circle in phase space via superconducting circuit" (contributed), Southwest Quantum Information and Technology 10th Annual Meeting (SQuInT 2008), Santa Fe, United States of America, 14 Feb 2008 - 17 Feb 2008.

17 Feb 2008, G. Gour, "Polygamy of entanglement of assistance: duality for monogamy of entanglement" (contributed), Southwest Quantum Information and Technology 10th Annual Meeting (SQuInT 2008), Santa Fe, United States of America, 14 Feb 2008 - 17 Feb 2008.

10 Mar 2008, A. Morris and D. L. Feder, "Topological entropy of quantum hall states in rotating Bose gases" (contributed), Bulletin of the American Physical Society **53**(2):D14.00005, APS March Meeting 2008 (APS March 2008), New Orleans, United States of America, 10 Mar 2008 - 14 Mar 2008.

11 Mar 2008, A. G. D'Souza and D. L. Feder, "Ground states as resources for universal measurement-based quantum computing" (contributed), Bulletin of the American Physical Society **53**(2):J15.00006, APS March Meeting 2008 (APS March 2008), New Orleans, United States of America, 10 Mar 2008 - 14 Mar 2008.

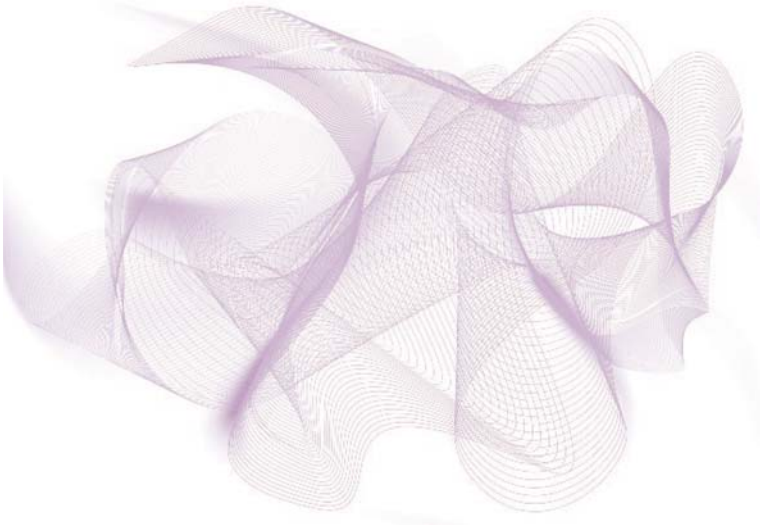
11 Mar 2008, M. Skotiniotis, A. Roy and B. C. Sanders, "Fully epistemic toy theory" (contributed), Bulletin of the American Physical Society **53**(2): L14.00002, APS March Meeting 2008 (APS March 2008), New Orleans, United States of America, 10 Mar 2008 - 14 Mar 2008.

12 Mar 2008, B. C. Sanders, P. Xue, A. Blais and K. Lalumière, "Quantum walk on a circle in phase space via superconducting circuit quantum electrodynamics" (contributed), Bulletin of the American Physical Society **53**(2): S15.00014, APS March Meeting 2008 (APS March 2008), New Orleans, United States of America, 10 Mar 2008 - 14 Mar 2008.

13 Mar 2008, R. Karasik, K.–P. Marzlin, B. C. Sanders and K. B. Whaley, "Decoherence-free subspaces and incoherently generated coherences" (contributed), Bulletin of the American Physical Society **53**(2): V15.00002, APS March Meeting 2008 (APS March 2008), New Orleans, United States of America, 10 Mar 2008 - 14 Mar 2008.

18 Mar 2008, A. Delfan, C. La Mela, M. Underwood, K.–P. Marzlin, S. A. Moiseev and W. Tittel, "Beyond CRIB-based memory: combining storage with data manipulation" (contributed), Workshop on Rare-Earth-Ion-Doped Solids for Quantum Information Processing, Darmstadt, Germany, 17 Mar 2008 - 19 Mar 2008.

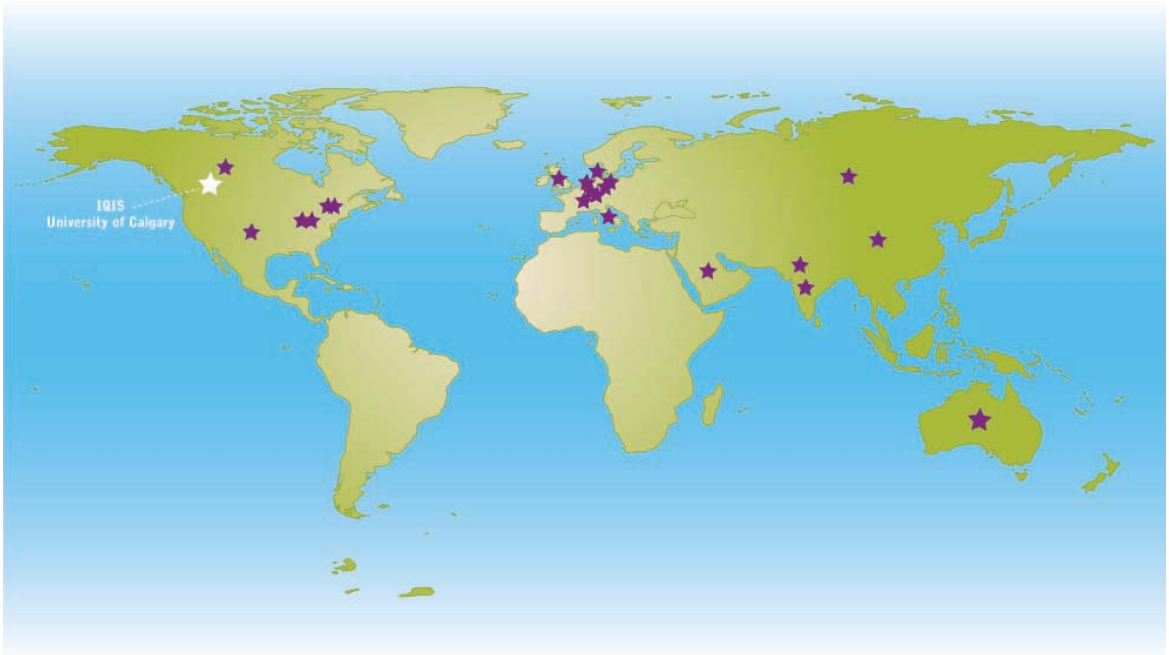
28 Mar 2008, K.–P. Marzlin, "Slow light and its application in quantum information" (colloquium), St. Francis Xavier University, Department of Physics.



6. COLLABORATIONS

Institution	Location
Australian National University	Canberra, Australia
Centrum voor Wiskunde en Informatica Amsterdam, The Netherlands	Amsterdam, The Netherlands
COMSATS Institute of Information Technology	Islamabad, Pakistan
East China Normal University	Shanghai, P. R. China
ENS de Chimie de Paris	Paris, France
Imperial College, London	London, United Kingdom
Institute of Physics, Chinese Academy of Science	Beijing, P. R. China
Jaypee Institute of Information Technology	Noida, India
King Khalid University	Abha, Saudi Arabia
Lincoln Laboratory, Massachusetts Institute of Technology	Lexington, United States of America
Macquarie University	Sydney, Australia
Masaryk University	Brno, Czech Republic
National Institute for Nanotechnology	Edmonton, Canada
Nicolaus Copernicus University	Torun, Poland
Politecnico di Milano	Milan, Italy
Polytechnique Montréal	Montréal, Canada
Southern Alberta Institute of Technology	Calgary, Canada
Universität Bonn	Bonn, Germany
Universität Kaiserslautern	Kaiserslautern, Germany
Universität Paderborn	Paderborn, Germany
Université de Montréal	Montréal, Canada
Université de Sherbrooke	Sherbrooke, Canada
Université Paris-Sud 11	Paris, France
University of California at Berkeley	Berkeley, United States of America
University of California at San Diego	San Diego, United States of America
University of Copenhagen	Copenhagen, Denmark
University of Geneva	Geneva, Switzerland
University of New Mexico	Albuquerque, United States of America
University of Sydney	Sydney, Australia
University of Toronto	Toronto, Canada
University of Waterloo	Waterloo, Canada
Wilfrid Laurier University	Waterloo, Canada
Zavoisky Kazan Physical Technical Institute of the Russian Academy of Science	Kazan, Russia

Map overlay of collaboration with IQIS



7. VISITORS

Name	Dates of Visit	Home Institution
Sun-Hyun Youn	15 Dec 2006 - 31 Aug 2008	Chonnam National University, Gwangju, Korea
Félix Bussières	16 Jan 2007 – 31 Dec 2008	Université de Montréal, Montréal, Canada
Magnus Hsu	9 - 15 Apr 2007	Australian National University, Canberra, Australia
Niko Antalffy	23 - 26 Apr 2007	University of New South Wales, Sydney, Australia
Benjamin Lavoie	23 - 26 Apr 2007	Lakehead University, Thunder Bay, Canada
Janet Chan	25 - 26 Apr 2007	University of New South Wales, Sydney, Australia
Vladimír Bužek	31 May - 6 Jun 2007	Slovak Academy of Sciences, Bratislava, Slovak Republic
Jörg Schmiedmayer	2 - 6 Jun 2007	Atominstitut der österreichischen Universitäten, Wien, Austria
Konrad Banaszek	17 - 21 Jun 2007	Uniwersytet Mikolaja Kopernika, Torun, Poland
Zijian Diao	3 Jul - 23 Aug 2007	Ohio University Eastern Campus, St. Clairsville, United States of America
Troy Lee	14 - 28 Jul 2007	Laboratoire de Recherche en Informatique, University Paris-Sud 11, Paris, France
Yibo Zhao	1 - 2 Aug 2007	University of Science and Technology of China, Hefei, P. R. China
Michael Revzen	7 - 12 Aug 2007	Israel Institute of Technology, Technion, Israel
Nolan Wallach	26 - 31 Aug 2007	University of California at San Diego, San Diego, United States of America
Ali Kamli	1 Sep 2007 – 31 Aug 2008	King Khalid University, Abha, Saudi Arabia

Name	Dates of Visit	Home Institution
Maarten van den Nest	16 - 21 Sep 2007	Institute for Quantum Optics and Quantum Information, Austrian Academy of Sciences, Innsbruck, Austria
Javaid Anwar	25 Sep - 11 Dec 2007	COMSATS Institute of Information Technology, Islamabad, Pakistan
Gilles Brassard	28 - 28 Sep 2007	Université de Montréal, Montréal, Canada
Chang Wang	22 Oct 2007 – 22 Oct 2008	East China Normal University, Shanghai, P. R. China
Niel de Beaudrap	19 - 23 Nov 2007	University of Waterloo, Waterloo, Canada
Hauke Häseler	26 Nov - 1 Dec 2007	University of Waterloo, Waterloo, Canada
James Cresser	6 - 13 Jan 2008	Macquarie University, Sydney, Australia
Jop Briët	7 - 25 Jan 2008	Centrum voor Wiskunde en Informatica (CWI), Amsterdam, The Netherlands
Thierry Chanelière	31 Jan - 25 Feb 2008	Laboratoire Aimé Cotton, Université Paris-Sud 11, Paris, France
Jonathan Walgate	17 - 29 Feb 2008	Perimeter Institute for Theoretical Physics, Waterloo, Canada

B. Teaching, Training and Education

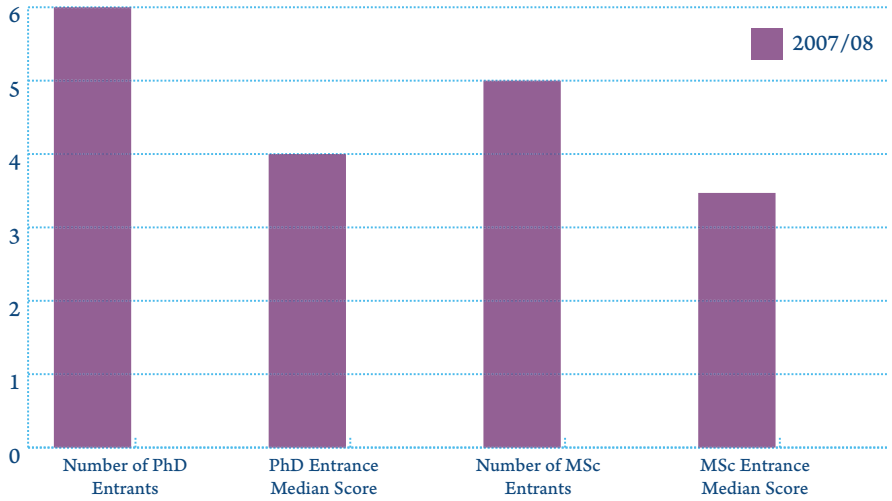
1. UNDERGRADUATE PROJECTS AND SUPERVISION

Name	Name of Project	Supervisor
Zenon Berg	Entanglement of atoms in double-well optical potentials (winter 08)	D. Feder
Zenon Berg	Loophole-free tests of Bell inequalities (fall 07)	K.–P. Marzlin
Robert Bossler	Locking a diode laser to a Doppler-free rubidium line (fall 07)	A. Lvovsky
Geoff Campbell	Squeezing via self-rotation (NSERC USRA)	A. Lvovsky
Monika Deviat	Transfer of orbital angular momentum from photons to atoms (NSERC USRA)	D. Feder
Christian Freier	Construction of electronics for data acquisition and experiment control (winter 07 & summer research – exchange student)	A. Lvovsky
Chris Healey	Construction of a magneto-optical trap (summer research)	A. Lvovsky
Dallas Hoffman	Construction of a laser beam profiler (summer research)	A. Lvovsky
Katanya Kuntz	Generating Bessel beams with conical mirrors (fall 07 & winter 08)	A. Lvovsky
Peter Gimby	Construction of external-cavity diode lasers (winter 07)	A. Lvovsky
Michael Lozinski	Construction of an external-cavity diode laser (NSERC USRA)	A. Lvovsky
Chris Petten	Construction of a magneto-optical trap (fall 07 & winter 08)	A. Lvovsky
Yuval Sanders	Squeezing of light in rubidium vapour (summer research)	A. Lvovsky
Yuval Sanders	The concurrence monotones as conditions for entanglement catalysis (winter 08)	G. Gour
Deyton Sehn	Imbalanced ultracold superfluid fermions in annular traps (NSERC USRA)	D. Feder
Jared Stang	Quantum walks with memory (NSERC USRA)	B. C. Sanders

2. QUANTUM INFORMATION RELATED GRADUATE COURSES

Course Name	Instructor	Description
CPSC 519 Introduction to Quantum Computation	P. Høyer	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.
CPSC 619 Quantum Computation	P. Høyer	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.
AMAT 601.19 Introduction to Quantum Information	G. Gour	Introduction to quantum information theory emphasizing the topics of quantum compression, quantum communication, entanglement, channels, coding, nonlocality, distinguishability, steering, and resources.
PHYS 615 Advanced Quantum Mechanics I	K.–P. Marzlin	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.
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.
PHYS 697.01 Quantum Cryptography	W. Tittel	Introduction to classical and quantum information theory with focus on channel capacity. Quantum key distribution, security proofs, technological issues and practical realizations.

3. GRADUATE STUDENTS: ENROLMENTS AND QUALITY OF ENTRANTS



As one PhD student was from Germany, his "Sehr Gut = very good" Vordiplom did not have an associated GPA so was not included in the calculation; instead the median is based on five other students.

C. Services and Outreach

1. CONFERENCE COMMITTEES

Member(s)	Committee	Conference/Workshop/Award	Location	Conference Dates
D. Feder	Co-organizer	Perimeter Workshop on "Quantum Information and Graph Theory: Emerging Connections"	Waterloo, Canada	28 Apr – 2 May 2008
D. Feder	Member, Local Organizing Committee	The Quantum Communication Measurement and Computing Conference 2008 (QCMC 2008)	Calgary, Canada	19 – 24 Aug 2008
G. Gour	Member, Local Organizing Committee	The Quantum Communication Measurement and Computing Conference 2008 (QCMC 2008)	Calgary, Canada	19 – 24 Aug 2008
P. Høyer	Co-organizer	Perimeter Workshop on "Quantum Information and Graph Theory: Emerging Connections"	Waterloo, Canada	28 Apr – 2 May 2008
A. Lvovsky	Convener AMO Physics session	9th Annual Meeting of the APS Northwest Section	Pocatello, United States of America	17 – 19 May 2007

Member(s)	Committee	Conference/Workshop/Award	Location	Conference Dates
A. Lvovsky	Member, Local Organizing Committee	38th annual meeting of the Division of Atomic, Molecular, and Optical Physics (DAMOP) of the American Physical Society	Calgary, Canada	5 - 9 Jun 2007
A. Lvovsky	Local Chair, Organizing committee	Second QuantumWorks Annual General Meeting	Calgary, Canada	26 – 27 Sept 2007
A. Lvovsky	Principal Organizer	The Quantum Communication Measurement and Computing Conference 2008 (QCMC 2008)	Calgary, Canada	19 – 24 Aug 2008
K.–P. Marzlin	Member, Local Organizing Committee	38th annual meeting of the Division of Atomic, Molecular, and Optical Physics (DAMOP) of the American Physical Society	Calgary, Canada	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
K.–P. Marzlin	Member, Organizing Committee	International Conference on Information Theoretic Security (ICITS 2008)	Calgary, Canada	10 – 13 Aug 2008
K.–P. Marzlin	Member, Local Organizing Committee	The Quantum Communication Measurement and Computing Conference 2008 (QCMC 2008)	Calgary, Canada	19 – 24 Aug 2008
B. C. Sanders	Member, Program Committee	SPIE Symposium "Fluctuations and Noise" (FAN)	Florence, Italy	20 – 24 May 2007
B. C. Sanders	Member, Program Committee	Quantum Entanglement and Decoherence: 2nd International Conference on Quantum Information (ICQI)	Rochester, United States of America	10 – 13 June 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	Member, Program Committee	SPIE Conference on Quantum Communication and Imaging V (part of SPIE Optics and Photonics 2007)	San Diego, United States of America	26 – 30 Aug 2007
B. C. Sanders	Chair, Steering Committee	Photons, Atoms and Qubits Conference (PAQ 07)	London United Kingdom	2 – 5 Sep 2007
B. C. Sanders	Member, Program Committee	Asian Conference on Quantum Information Science 2007 (AQIS 2007)	Kyoto, Japan	3 – 6 Sep 2007
B. C. Sanders	Co-Chair	International Iran Conference on Quantum Information (IICQI 2007)	Kish Island, Iran	7 – 10 Sep 2007
B. C. Sanders	Member, International Program Committee	2007 IEEE Congress on Evolutionary Computation (CEC 2007)	Singapore	25 – 28 Sep 2007

Member(s)	Committee	Conference/Workshop/Award	Location	Conference Dates
B. C. Sanders	Member, Technical Program Committee	The Second International Conference on Quantum, Nano, and Micro Technologies (ICQNM 2008)	Sainte Luce, Martinique	10 – 15 Feb 2008
B. C. Sanders	Members, Technical Program Committee	Quantum Entanglement and Decoherence: 3rd International Conference on Quantum Information (ICQI)	Boston, United States of America	13 – 16 July 2008
B. C. Sanders	General Chair, Organizing Committee	International Conference on Information Theoretic Security (ICITS 2008)	Calgary, Canada	10 – 13 Aug 2008
B. C. Sanders	Member, Program Committee	SPIE Conference on Optics and Photonics	San Diego, United States of America	10 – 14 Aug 2008
B. C. Sanders	Member, Local Organizing Committee	The Quantum Communication Measurement and Computing Conference 2008 (QCMC 2008)	Calgary, Canada	19 – 24 Aug 2008
W. Tittel	Member, Program Committee	The International Workshop on the Storage and Manipulation of Quantum Information in Optically-Addressed Solid	Bozeman, United States of America	25 – 27 Jan 2008
W. Tittel	Member, Program Committee	International Conference on Information Theoretic Security (ICITS 2008)	Calgary, Canada	10 – 13 Aug 2008

2. PROFESSIONAL SERVICES

Name	Role	Journal/Society/Network
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
B. C. Sanders	Project Leader, Quantum Information Processing Project	The Mathematics of Information Technology and Complex Systems
B. C. Sanders	Member, Research Management Committee & Theme Leader	QuantumWorks
B. C. Sanders	Vice-Chair, Division of Atomic and Molecular Physics and Photon Interactions	Canadian Association of Physicists
W. Tittel	Member	International Space-QUEST (Quantum Entanglement for Space Experiments)

3. APPEARANCES IN THE MEDIA

Source	Title of Article	Location	Date
Globe and Mail	A quantum leap in information security: Dr. Wolfgang Tittel		3 Apr 2007
Calgary Inc.	Innovation update: Dr. Barry Sanders, Dr. Alex Lvovsky, Dr. Wolfgang Tittel	P. 25	June 2007
Alberta Venture	The quest for the uncrackable code: Dr. Wolfgang Tittel	Vol. 11 issue 05	July 2007
Science Café	Quantum computing & the information explosion – Are we on the verge of information security? (Moderator: Eden Figueroa; guest experts: D. Wolfgang Tittel & Dr. Peter Marzlin)	Unicorn	23 Oct 2007
Harper's Magazine	Weekly review: Alexander Lvovsky's group is mentioned at the end	online	4 March 2008
Metro	Making something out of nothing, U of C research may pave way for quantum computers: Alexander Lvovsky, Mirko Lobino		6 March 2008
On Campus	Physics breakthrough much ado about "nothing": Alexander Lvovsky, Mirko Lobino	online	6 March 2008
Softpedia	Physicists achieve breakthrough by creating … Nothing? Form of squeezed vacuum created: Alexander Lvovsky	P. 1	6 March 2008
The Vancouver Sun	Physicists make a discovery in a vacuum: Alexander Lvovsky, Dmitry Korystove, Mirko Lobino		6 March 2008
Daily Tech	Quantum computer researchers store "Sub Zero" light vacuum - "less than nothing" is the new zero: Alex Lvovsky		7 March 2008
Calgary Herald	Research paves way to better computer - U of C team's findings reported by leading journal (Alex Lvovsky)	P. B5	10 March 2008
Gauntlet	Shining light on quantum mechanics - U of C physicists explore the future of computer… with lasers! (Alex Lvovsky)	P. 5	13 March 2008

V FINANCES

A. Institute Operations

1. OPERATING ACCOUNT: REVENUE AND EXPENDITURE

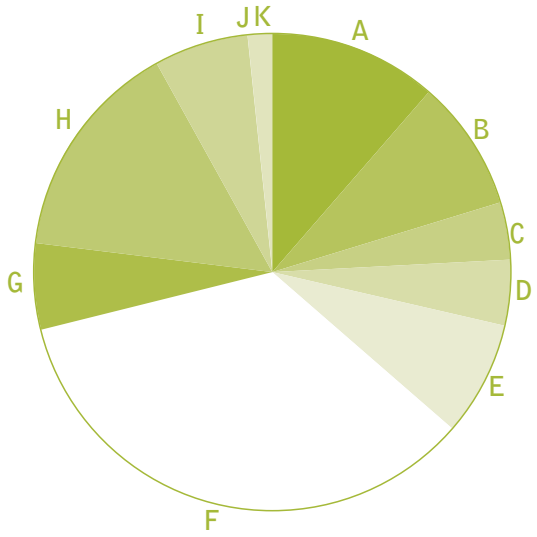
IQIS Income Statement for the Period 2007-08 Ending 31 March 2008

Revenue			
	University of Calgary	$	75,000.00
	MITACS QIP Seminars		8,000.00
	Total Revenue	$	83,000.00
Expenditures			
	Administrative Salaries	$	50,249.33
	Benefits		10,785.13
	Equipment		3,603.18
	Office Supplies		3,243.54
	IT Support - Materials		248.85
	Software		892.31
	Travel and Other Expenses - Visitors		2,120.28
	External MITACS QIP Seminars		3,603.86
	Postage, Phone, Fax and Courier		670.30
	Printing and Engraving Services		348.03
	Special Event and Meetings		5,486.83
	Maintenance		650.02
	Sponsorship		1,034.79
	IQIS Board & Annual Report		1,484.69
	Other Expenditures		3,524.16
	Total Expenditures	$	87,945.30
Net Operating Results		$	(4,945.30)

2. RESEARCH GRANTS: ESTIMATED REVENUE AND EXPENDITURE

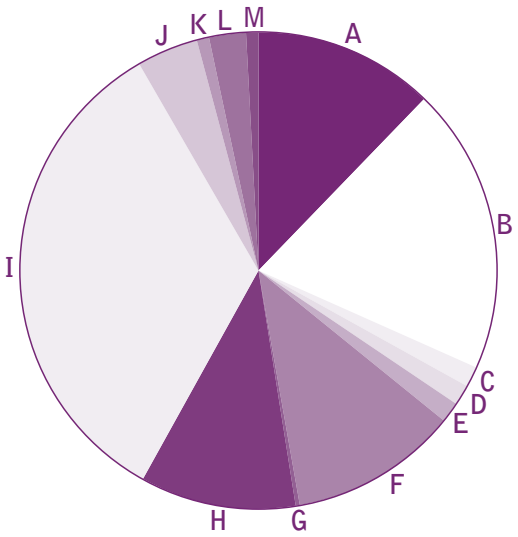
Total Income: $2,230 (in thousands)

A	AIF	$258,763.66
B	CFI	$199,118.19
C	CIFAR	$86,250.00
D	CRC	$100,000.00
E	GDC	$170,000.00
F	iCORE	$776,500.00
G	MITACS	$125,398.66
H	NSERC	$338,038.00
I	QW	$139,700.00
J	Other	$3,196.21
K	Interest	$ 33,060.62
	Total	$2,230,025.34



Total Expenditures: $2,942 (in thousands)

A	Student Salaries & Fees	$363,463.96
B	Research Fellows & Associates Salaries	$573,809.01
C	Visiting Research Associates Salaries	$38,465.22
D	Administrative Salaries	$39,184.13
E	Technical Support Salaries	$40,652.16
F	Faculty Salaries	$337,526.10
G	Benefits	$10,175.49
H	Office & Lab Administration	$312,461.26
I	Furniture & Equipment	$985,431.49
J	Travel	$124,103.87
K	Visitors	$22,293.41
L	Contracted Services	$76,898.83
M	Other	$18,155.78
	Total	$2,942,620.71



VI PLANS AND REQUIREMENTS FOR NEXT YEAR

A. Research Objectives

DR. PETER HØYER

The group's current research includes the above topics, and considers 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.

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 superselection 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.

DR. DAVID FEDER

We intend to investigate three main topics, all of which fall under the general category of 'quantum computation using ultracold atoms.' First, we will continue to investigate experimental strategies for performing measurement-based quantum computation using ultracold atoms in optical lattices. In particular, we are investigating the criteria for the ground state of such a system to be a resource for this approach to quantum computation. Second, we are studying the possibility of performing universal quantum computation through quantum walks, governed by local but time-dependent Hamiltonians. An important open question is what is the minimal set of control parameters for this approach to be feasible. Third, we will extend the numerical calculations of rotating Bose gases in the quantum Hall regime, in order to further investigate the possibility that certain ground states possess excitations with non-Abelian exchange statistics. These in turn could in principle be used to carry out intrinsically fault-tolerant quantum computation, where errors are suppressed for topological reasons.

DR. ALEX LVOVSKY

We are developing a principally new scheme of quantum process tomography. This scheme operates in the continuous-variable domain (but can also be applied to discrete-variable processes) and employs homodyne tomography for the output state characterization. It does not require nonclassical optical states as inputs, resulting in a much better scalability than all schemes implemented so far. Our plan is to complete the theoretical basis for our idea and then apply it to experimentally characterize a simple quantum-optical process. We will determine the superoperator, then make a prediction for the output of the process when the input is a nonclassical state of light. Then we will verify our prediction experimentally.

Nonlinear optical processes are essential for quantum-optical information processing. We plan to implement optical nonlinearity at single-photon intensity levels in atomic rubidium by means of double electromagnetically-induced transparency. We will match the group velocities of the two signal fields by applying a preparation pulse resonant with one of the signal transitions. Once this is achieved, we will observe and optimize giant optical nonlinearities in the pulsed regime. In a more distant perspective, we will employ these results to implement quantum logic, non-demolition detection and preparation of nonclassical optical states.

In parallel, we are constructing a magneto-optical trap for rubidium atoms. The unit will be used in experiments on interfacing quantum information carried by light and atomic ensembles, replacing the vapor cells we are using now. The atomic trap is a much "cleaner" system with less decoherence and will allow us to significantly improve the performance of our setups.

In the last three years, we reached a major milestone: quantum memory for squeezed light. In spite of this success, there remain a number of open questions. What are the factors limiting the memory fidelity? Why is the memory lifetime so short? How can these parameters be improved?

Once these questions are answered, we will make further steps towards practical implementation of our memory for quantum repeaters and communication. In particular, we would like to realize quantum memory for quadrature-entangled states.

DR. PETER MARZLIN

In our efforts to describe the propagation of light pulses at the few-photon level in complex dielectric media we have developed a 1D numerical simulation for classical light inside a gas of atoms with a specific level scheme, but this result does not allow conclusions about how the fidelity of the quantum state of light is affected by the medium. We will extend this analysis to simulate the evolution of a two-photon state interacting with a homogeneously distributed gas of few-level atoms. Furthermore, we believe that it will be possible to derive a very accurate analytical expression for the two-photon propagation amplitude, at least for relatively simple level schemes. These results will be of direct relevance for our efforts to build a quantum memory based on ion-doped optical waveguides and on atomic gases.

Recently we also developed an approach to combine Feynman perturbation theory of condensed matter physics with the concept of dressed states of quantum optics. We will use this method to describe a gas of Rydberg-excited atoms with a strong van der Waals interaction that generates atomic many-body correlations. The fact that the van der Waals interaction between Rydberg atoms scales like n11 , where n is the principal quantum number of the Rydberg state, makes large level shifts even for moderate densities feasible. We will extend our existing theory to include the effect of the van der Waals interaction in the atomic Green's function. The goal is to deduce the optical properties of the correlated gas by calculating one- and two-photon correlation functions by means of the Dyson and the Bethe-Salpeter equation. This will allow us to study the feasibility of optical quantum gates that exploit large atomic many-body correlations.

DR. BARRY SANDERS

Quantum-enhanced secure communication: Further development and numerical testing of the randomization protocol for probabilistic information-theoretic security proposed by Beals and Sanders, including studies of security over various network topologies and making the adversarial model more precise. Work with Tittel's group to implement the protocol in real-world quantum cryptography.

Giant optical nonlinearity: Complete simulations on giant optical nonlinearities in Rubidium gas with pulsed light, and devise pulse shapes that deliver effective photon number quantum nondemolition measurements. Finalize theoretical assessment of dense gases and plasmons as potential media for realizing controllable giant optical nonlinearities.

Efficient algorithms for quantum simulations: Obtain strict resource bounds for simulating time-dependent Hamiltonian evolution; develop algorithms for quantum computer simulation of time-dependent Hamiltonian evolution. Use these simulation techniques to develop simple, strict conditions for adiabaticity in quantum evolution.

Process characterization: Express adaptive quantum measurement methods in the language of machine learning. Compare various quantum measurement schemes, especially choices of alternative input states, by assessing the true informational costs of these schemes. Relate hypothesis spaces with typical physical assumptions. Develop a method by which optical homodyne tomography, using only coherent state inputs, yields the full completely positive map for a quantum promise, beginning with quantum memory.

Quantum nanoscience: Develop theoretical models for charge qubit dynamics on silicon surfaces and for coupling charge on surfaces to nanocantilivers.

DR. WOLFGANG TITTEL

Quantum Cryptography: (a) we will extend the polarization-based Quantum Key Distribution (QKD) system to a complete QC system, including classical post-processing. The laboratory-type setup will comprise standard single photon detectors and run at a clock frequency of a few MHz. It will be implemented on the University of Calgary (UofC)-Southern Alberta Institute of Technology (SAIT) test-bed link, and will allow the demonstration of the principles of QC plus yield important information for future packaging; (b) we will replace the bulky and expensive function generators used in the current QKD system by small and low cost Field Programmable Gate Arrays (FPGAs); (c) furthermore, we will demonstrate quantum key distribution based on encoding of quantum information in superposition of faint laser pulses located in different "time-bins".

Integration and Networks: (a) we will extend the use of the classical data header for stabilization of polarization transformation in polarization-based QKD to QKD based on time-bin encoding, and to entanglement based systems; (b) we will implement the data header into our polarization based system and demonstrate header determined optical switching between different receiver nodes.

Quantum Relays: (a) we will thoroughly characterize or source of versatile entanglement, and implement the source on the fibre optics test-bed link between the UofC and SAIT; (b) we will perform a proof-of-principle demonstration of entanglement-based QKD; (c) we will demonstrate the generation of non-classical photon pairs based on four-wave mixing in a photonic crystal fibre; (d) we will start work on a practical, small bandwidth source, and work on experiments with two photon pairs; (e) we will finish the "quantum relay simulator", which will allow optimizing experimental parameters such as laser power used to generate photon pairs, and quantum efficiency and noise of the single photon detectors.

Quantum Memory: (a) we will start work on storage of classical (strong) light pulses in cold rare-earth ion doped solids based on a standard photon echo approach, and conduct research into the individual steps required for Controlled Reversible Inhomogeneous Broadening (CRIB). The research will include spectroscopic investigations of various material properties; (b) we will emulate a generalized quantum measurement, which is generally performed with linear optical elements, using inter-atomic single qubit rotations based on a photon-echo approach; (c) furthermore, we will finalize our theoretical studies of pulse compression and qubit rotation based on CRIB.

B. Space

The Institute had 69 members on 31 March 2008 comprising 7 faculty members, 7 support staff (including part-time IT support staff and admin support staff), 10 postdoctoral research fellows/associates, 5 long-term visiting professors and students, and 40 undergraduate and graduate students. Amongst all students, the division between the Departments of Physics & Astronomy, Computer Science, and Mathematics & Statistics was 36:4:0. 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.

C. Institute Funding

The University of Calgary provides $75,000 funding p.a., and the cost of operating the Institute was $87,945.30 in 2007-08, and it is projected to be $100,000 in 2008-09.

D. Personnel

Institute personnel comprise the Administrator (1), group administrative assistants (2, support by individual researcher funding), IT support (part-time), and webmaster (part-time, support by research funding).

IQIS Administration Team

left to right: Nancy Jing Lu (IQIS Administrator),
Catherine Giacobbo (Part-Time Administrative Assistant to Dr. Barry Sanders),
Lucia Wang (Administrative Assistant to Dr. Barry Sanders),
Hyejeong Hwang (Part-Time Administrative Assistant to Dr. Wolfgang Tittel)

VII APPENDICES

A. Charter

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

Name

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

Supervising Officer

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

Approval and Review Bodies

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

Term of the Institute

4. Under the limited-term provision of the University's policy on Institutes and Centres (s. 4.4), the Institute is established for a 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 Dean of the Faculty of Science, an internal review after two years of the Institute's limited term.

- as required by the policy on Institutes and Centres, an external review during the final 18 months of the Institute's term.

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

Institute Board of Directors

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

b) Membership of the Board shall comprise:
   i. The Institute's "supervising officer" (or designate), who shall Chair the Board and appoint a Vice Chair from among other board members;
   ii. At least 4 "members at large," drawn from or nominated by
      - companies whose primary operations are synergistic with quantum information science
      - agencies that provide funding for quantum information science research in Alberta; and
      - leading members of the quantum information science academic community.

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

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

d) The Board shall be responsible for the overall success and governance of the Institute. More particularly, its responsibilities include:
   i. approving and/or amending this Charter under the provisions of clause 10 below
   ii. ensuring that relevant University policies are respected (see section 9 below)
   iii. appointing a Director for the Institute
   iv. approving the Institute's budget and strategic plans
   v. determining membership categories and requirements for the Institute
   vi. determining the procedures and requirements of general meetings of institute members (with at least one such meeting required annually)
   vii. helping to create opportunities for the Institute
   viii. facilitating the periodic reviews and external assessments of the Institute, as required by the University's policy on Institutes and Centres (s. 4.3).

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

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

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

Director

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

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

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

v. making any additional submissions or reports, as appropriate or requested, to the Board or the University of Calgary on any matter affecting the Institute;
vi. facilitating the periodic reviews and external assessments of the Institute required by the University's policy on Institutes and Centres (s. 4.3).

Policies and Procedures

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

Amendments

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

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

Service
- 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

B. Performance Indicators

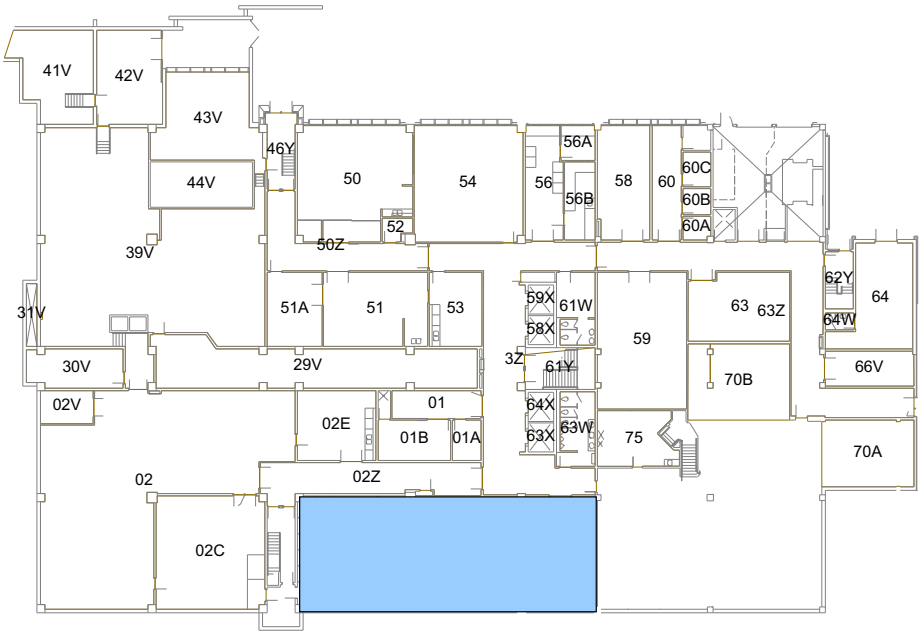
Key result areas /performance indicators	*Target (by 2010)*	*Achievements (2007/08)*
Highly Qualified Personnel		
Number of students	30 graduate students	31
Median GPA	30 graduate students with median entrance GPA >3.75 or equivalent - MSc - PhD	 3.47 4
External Awards	2 external awards for students annually	7
Number of postdoctoral associates	8 postdoctoral associates	10
External Fellowships	8 postdoctoral associates including 4 with external fellowships	1
Undergraduate student projects	4 annual undergraduate student projects	16
Number of summer students	5 summer students including at least 3 NSERC summer scholars	9 incl. 5 NSERC USRA
Number of tenured or tenure-track faculty in QIS	7 tenure-track faculty	6
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	7
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	Ongoing
Research Inputs		
Distinguished visitors per annum	8 distinguished visitors per annum	5
Number of visitors	5 visitors at PhD level or higher per annum who stay at least 4 weeks	7
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	24 2 0
Invitations to address conferences	30 invitations to give talks per annum including 3 keynote/plenary talks	26 incl. 1 Plenary
Number of student presentations	15 student oral or poster presentations per annum at QIS conferences	50

Key result areas /performance indicators	*Target (by 2010)*	*Achievements (2007/08)*
Collaborations		
Number of collaborations	Demonstrated collaboration with at least 5 leading QIS groups	9
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 (GDC)
Major experimental research project	Major experimental research project with leading international partner	0
Service		
Program committee membership	Membership of 8 conference/workshop program committees annually	17
Chair or Co-Chair	Chair or Co-Chair at least one conference biennially	4
Editorial board membership	At least 2 editorial board membership of QIS-related journals	3

C. Floor Plans for Existing Use of Space

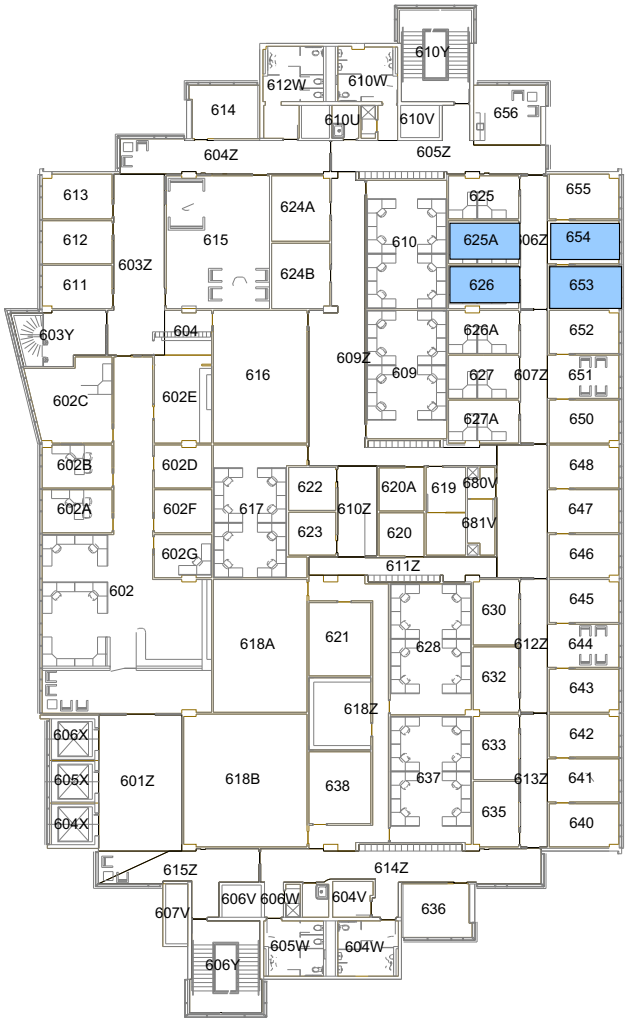
Earth Science Basement

IQIS



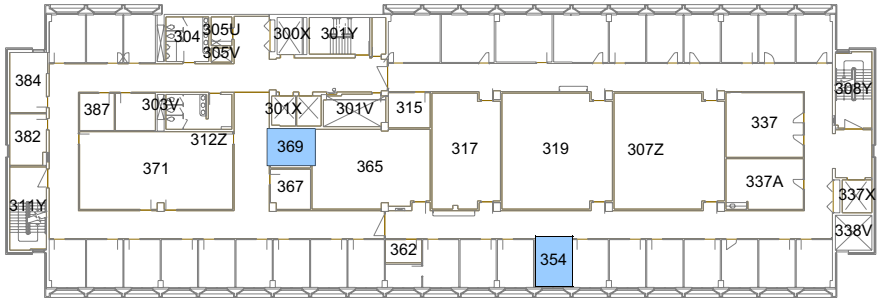
ICT Sixth Floor

IQIS



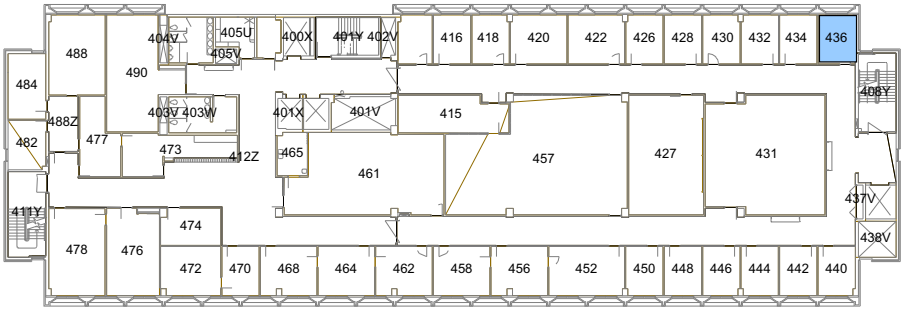
Mathematics Third Floor

IQIS



Mathematics Fourth Floor

IQIS



Science B Basement

IQIS

Science B Main Floor

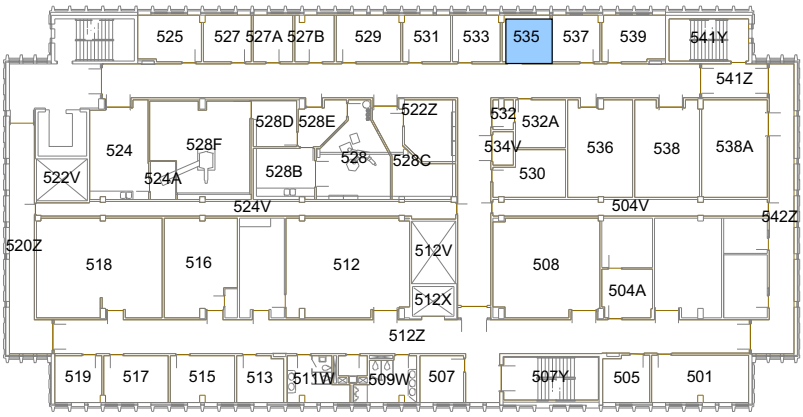
IQIS

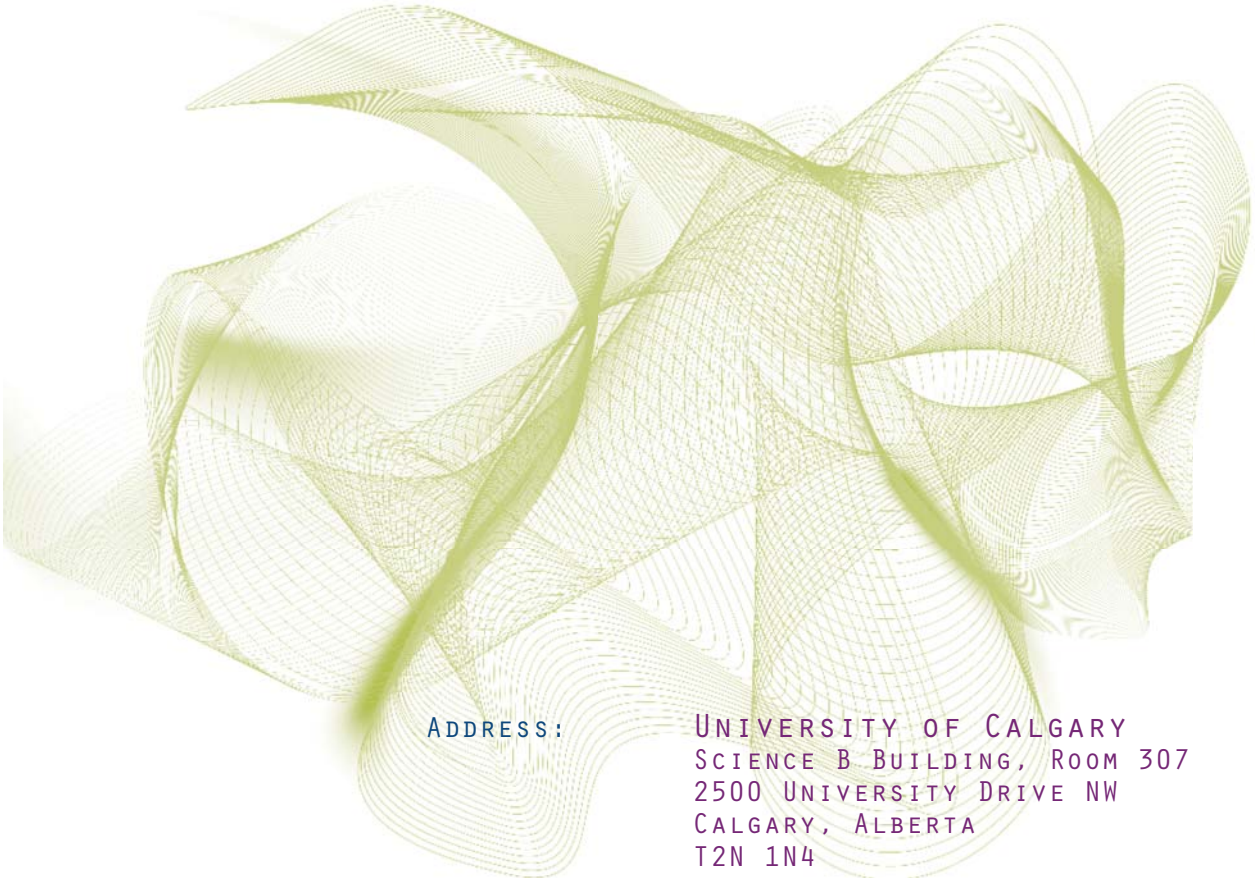
Science B Third Floor

IQIS

Science B Fifth Floor

IQIS





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