QUANTUM FRONTIERS
FINAL ANNUAL REPORT 2012
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 fellows
49 graduate students
8 undergraduate students
45 visiting researchers from April to December 2012 including 5 long-term visiting professors and 8 long-term visiting students

31 publications in refereed journals & conference proceedings with 5 published in Physical Review Letters
26 invited talks at national and international conferences/workshops including 1 keynote
2.89 million dollars cash income from April to December 2012
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This annual report from the Institute for Quantum Information Science is the final annual report from this Institute, not because the Institute has been terminated but rather because the Institute has successfully germinated a new, larger, more broadly focused incarnation. This new Institute is financially supported by the Innovates Centre for Research Excellence (iCORE) unit within Alberta Innovates Technology Futures. This new Institute, which replaces the Institute for Quantum Information Science on 1 January 2013, represents all innovative quantum science and technology taking place at the University of Calgary and will maintain much of the administrative and executive structure of the outgoing Institute.

The new Institute for Quantum Science and Technology in the Faculty of Science will have about one hundred members in contrast to the seventy. Fifteen of these members are professorial and include two iCORE Chairs, two Canada Research Chairs (one Tier 1 and one Tier 2), and two Alberta Innovates Scholars plus the 2012 winner of the John C. Polanyi Award of the Chemical Institute of Canada. New research areas under the umbrella of this nascent institute are spectroscopy, quantum-nano research and ab-initio theoretical quantum chemistry.

For administrative reasons, this annual report covers only nine months from 1 April to 31 December 2012 when the Institute for Quantum Information Science ends. Despite only representing three-quarters of a year, the Institute’s achievements during this shortened year are quite strong.

As a major annual outreach activity, the Institute holds a Public Lecture, which has been sponsored each year by Alberta Innovates Technology Futures. In 2012, two hundred participants enjoyed Alain Aspect’s a wonderful lecture titled “From Einstein’s LichtQuanten to Wheeler’s delayed choice: wave particle duality for a single photon”. Professor Aspect is an internationally acclaimed physicist at the École Polytechnique in Paris and is a pioneer in the foundations of quantum physics and a recipient of the 2010 Wolf Prize in Physics.

The Institute hosted the prestigious annual International Laser Physics Workshop with over 600 participants and co-hosted with the Department of Physics & Astronomy the Canadian Association of Physicists Congress with 600 participants. The Institute has a long-standing history of holding major conferences, which provide the tangential benefit of showcasing the Institute’s activities to the broader community.

The Institute also plays a major role in national quantum information networks. Sanders is the principal investigator of the Pacific Institute for the Mathematical Sciences Collaborative Research Group for the Mathematics of Quantum Information, which brings together cognate researchers at the University of Calgary, the University of British Columbia, Simon Fraser University and the University of Washington. CryptoWorks21 is the new NSERC Collaborative Research and Training (CREATE) Program for cryptographic training to meet 21st Century threats, and Sanders is on the Management Committee and also serves as Chair of the Professional Skills Working Group. As for new networks, Simon and Tittel are part of a DARPA network supporting the effort to build a quantum repeater.

In summary the Institute for Quantum Information Science has a lot to be proud of in this nine-month period. Most of the Faculty members are in an early-career stage but have quickly established world-class reputations, and the Institute has played a key role in enabling this rapid progress to superb results and a strong reputation. The new Institute for Quantum Science and Technology can be expected to engender and enable stellar research in quantum areas including quantum information and beyond.

Barry Sanders
Director, IQIS
In my final Report from the Chair for the Institute for Quantum Information Science, I would like to commend the Institute Director Barry Sanders and the Institute Administrator Nancy Jing Lu for their outstanding work in making this unit so successful as a research and training centre within the Faculty. The Institute serves as an example and a template not only for the new Institute for Quantum Science and Technology, which will replace it, but also has many excellent practices that the Faculty will incorporate into other Faculty of Science Institutes.

In reading through one biannual and six annual reports since the Institute’s inception in 2005 – which are easily accessed from the web page http://www.iqst.ca/shared/reports.php – I am struck by how far the Institute has come since its beginning. The Institute was not simply formed as an aggregation of existing researchers in the Faculty of Science but rather played a key role in seeking and recruiting promising early-career researchers to join the University of Calgary. I can see how the Institute greatly assisted these newly appointed researchers to progress rapidly to having strong research groups and quickly functioning laboratories.

Mentoring served an important role in the Institute’s success, especially with research grants and linkage. The Institute also has an enviably strong database and set of web pages that promote the Institute’s strengths and successes well beyond the University of Calgary’s boundaries. Finally I note that the Institute has a lean but highly effective administrative team that delivers crucial support to researchers, postdocs and students so that they can channel their energy to delivering high-quality scientific results.

The University of Calgary’s strength and reputation has benefitted from the prowess of its quantum information team. The Faculty of Science is looking forward to seeing the Institute broaden to nurture and support all quantum research areas in the Faculty.

Ken Barker
Chair of the Board of Directors, IQIS
Research Achievements

The Institute for Quantum Information Science enjoyed excellent achievements between April and December 2012. Foremost among these achievements was the award from the Alberta Ingenuity Fund of $150,000 each year for three years to support developing and sustaining a new Institute for Quantum Science and Technology. This new Institute will add seven more Faculty Members, from Physics and Chemistry, to the eight Faculty Members from the former Institute for Quantum Information Science.

Some of the Institute’s high-profile research has received significant public attention. There was extensive media coverage of a Physical Review Letters proposal by Christoph Simon and Wolfgang Tittel and student Sadegh Raeisi to circumvent the no-cloning theorem of quantum mechanics. Their strategy is to clone, and then un-clone, so to speak, a photon. This proposal would enable tests of still-contentious micro-macro entanglement. In fact, subsequent to this micro-macro entanglement proposal, Alex Lvovsky and Christoph Simon and their groups demonstrated micro-macro entangled light experimentally with one photon in the micro state and more than a hundred million photons in the macro state.

The proposal for microwave-controlled on-demand microwave pulse storage and release, developed by Barry Sanders and postdoctoral researcher Patrick Leung and published in Physical Review Letters, was a highlighted achievement in Superconductor Week. This scheme provides a blueprint for controlling microwave fields entirely within the superconducting circuit without the need for coupling other materials, which can introduce inefficiencies in the architecture.

Christoph Simon collaborated with University of Waterloo researchers on an experiment that generalized the famous Einstein-Podolsky-Rosen paradox, which originally clarified the completeness problem of quantum theory. This new experiment extrapolated from the original case of two particles that are quantum correlated via a continuous parameter to the case of three entangled particles, thereby opening the door to new and exciting tests of quantum mechanics. This Nature Physics paper was reported by the popular site Science 2.0.

The Institute is proud of its many achievements, which are too numerous to mention here. In addition to the breakthroughs discussed above, a few more results deserve special attention.

Paul Barclay’s Nanoscale Quantum group, jointly located at the University of Calgary and at the National Institute for Nanotechnology (NINT), collaborated with NINT and University of Alberta to demonstrate a torsional sensor with unprecedented sensitivity, which was featured on an Applied Physics Letters cover and was highlighted by Nature.

In an IEEE Transaction on Information Theory paper, Gilad Gour and collaborator Shmuel Friedland addressed the important quantum information theory problem of whether entanglement between signal states can assist transmission of classical information through quantum channels. They showed that only a high degree of entanglement is enabling.

Barry Sanders collaborated with researchers from Singapore’s Agency for Science, Technology and Research and from Lakehead University to show that the recently proposed purpose-built problem-specific photonic quantum computer for efficiently solving the classically intractable boson sampling problem is in fact computing functions immanants rather than computing permanents, which are a special case of immanants. Only in the unattainable ideal of simultaneous input photons does the permanent emerge, but Sanders and collaborators show how to program this quantum computer to recover the permanent and more.
Awards

INTERNATIONAL AWARDS

CARLSBERG FOUNDATION AWARD (DENMARK)
Daniel Oblak

CHINESE TOP UNIVERSITY GRADUATE STUDENTS STUDYING ABOARD SCHOLARSHIP (PEOPLE’S REPUBLIC OF CHINA)
Jiying Zhang (ended September 2012)

KING SAUD UNIVERSITY AWARD (SAUDI ARABIA)
Khulud Almutairi

PAAET AWARD (KUWAIT)
Hessa Alotaibi

NATIONAL AWARDS

EMERGING LEADERS IN THE AMERICAS PROGRAM (ELAP)
Jhon Lozada Vera (ended July 2012)

IZAAK WALTON KILLAM MEMORIAL SCHOLARSHIP
Joshua Slater

NSERC ALEXANDER GRAHAM BELL CANADA GRADUATE SCHOLARSHIP – DOCTORAL
Connor Kupchak (ended August 2012)
Neil Sinclair
Joshua Slater
Marcelo Wu

NSERC ALEXANDER GRAHAM BELL CANADA GRADUATE SCHOLARSHIP – MASTER
Edouard Pelchat (ended August 2012)

NSERC POSTGRADUATE SCHOLARSHIP – DOCTORAL
Andrew MacRae (ended April 2012)

NSERC USRA PROGRAM
Michael Briscoe
Jeff Maki

PIMS POSTDOCTORAL FELLOWSHIP
Vlad Gheorghiu
Collin Trail

PROVINCIAL AWARDS

ALBERTA INNOVATES GRADUATE STUDENTS SCHOLARSHIP
Adam D’Souza (ended August 2012)
Connor Kupchak (ended August 2012)
Andrew MacRae (ended April 2012)
Neil Sinclair
Joshua Slater (ended August 2012)
Michael Underwood (ended August 2012)
Marcelo Wu

UNIVERSITY OF CALGARY AWARDS

QUEEN ELIZABETH II GRADUATE SCHOLARSHIP
Ish Dhand
Mark Girard
Khabat Heshami
Edouard Pelchat
Adarsh Prasad
Erhan Saglamyurek
Tian Wang
Key Performance Indicators

* Information provided for 2012 is for the period of 9 months from April to December 2012

GRADUATE STUDENTS ENROLMENT AND QUALITY OF ENTRANTS¹,²,³

¹ One MSc student registered in the year 2011/12, but, for confidentiality, the entrance score is not revealed.
² Median MSc GPA decline is largely due to admission of several students from India where GPAs are typically low compared to those of other countries.
³ One PhD student registered in September 2012, but, for confidentiality, the entrance score is not revealed.
DESTINATIONS OF GRADUATE STUDENTS AND POSTDOCTORAL FELLOWS AFTER LEAVING IQIS
Nanoscale Optics

**DR. PAUL BARCLAY**

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

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

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

Practical Approaches to Quantum Computation

**DR. DAVID FEDER**

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

DR. GILAD GOUR

The quantum information group in the Department of Mathematics and Statistics conducts research on the mathematics of quantum information. Theoretical research in quantum information relies on sophisticated mathematical methods, such as algebraic geometry, matrix analysis, group theory and C*-algebras. The goal of our group is to use the knowledge in these fields to solve core problems in quantum information science.

Quantum Computing

DR. PETER HØYER

The quantum computing research group within the Department of Computer Science conducts research in computational aspects of quantum mechanical systems. Quantum computers are in particular interesting because they offer a possibility to achieve computations that cannot be easily achieved on traditional computers. We utilize the potential powers of quantum systems to develop quantum algorithms, quantum communication protocols, quantum cryptographic protocols, and quantum computer simulations of quantum mechanical systems. We conduct work on characterizing these powers and their limitations by studying quantum complexity theory, non-locality, entanglement, and quantum information theory.
Quantum Information Technology with Light and Experimental Quantum Optics

DR. ALEX LOVEVSKY

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, store arbitrary quantum states of the electromagnetic field, as well as bring photons into interaction with each other.

Quantum Information Science

DR. BARRY SANDERS

Our aim is to develop quantum information technologies that have transformative applications and will be feasible within a decade. The research program is divided into five strands: (i) long-distance secure communication, (ii) simulations of complex systems, (iii) implementations of quantum information tasks, (iv) empirical characterization of quantum states and processes, and (v) determining and quantifying all resources for quantum information processing.
The interaction of light and matter at the quantum level played a major role in the development of quantum physics. Its detailed study in the field of quantum optics has led to the development of important applications such as the laser, and to the first experimental demonstrations of the most striking features of quantum physics, such as entanglement and quantum non-locality. However, quantum optics is not ready to rest on its laurels. There are two key future challenges. On the one hand, we strive to develop genuine applications of these fundamental quantum features. Our group is particularly interested in the development of quantum repeaters, which will be essential for long-distance quantum communication. This motivates us to study potential implementations of quantum memories and of quantum gates between individual photons in various systems. On the other hand, quantum optical systems are ideally positioned to explore the quantum-classical transition, allowing us to deepen our understanding of how the classical macroscopic world arises out of microscopic quantum behaviour. This motivates us to study the quantum amplification of photons to macroscopic levels, as well as quantum opto-mechanical systems.

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

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

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

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

BOARD OF DIRECTORS

KEN BARKER
Dean, Faculty of Science, University of Calgary

PAUL BRÚMER
Professor, Department of Chemistry, University of Toronto

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

SIR PETER KNIGHT
Principal, The Kavli Royal Society International Centre

GREG LUOMA
President, LuomaTech Inc.

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

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

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

EXECUTIVE COMMITTEE

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

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

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

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

COUNCIL

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

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

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

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

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

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

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

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

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

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

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

WOLFGANG TİTTEL
Professor, Department of Physics and Astronomy, University of Calgary

RICHARD ZACH
Professor, Department of Philosophy, University of Calgary
Students

GRADUATE STUDENTS (PHD PROGRAM)

Mark Adcock (completed December 2012 → Independent Consultant)
Hessa Alotaibi
Nathan Babcock
Philip Chan
Jérémie Choquette (completed April 2012 → Analyst, Baker Hughes)
Adam D’Souza
Catalin Dohotaru
Roohollah (Farid) Ghobadi
Mark Girard
Chris Healey
Khabat Heshami
Jeongwan Jin
Behzad Khanaliloo
Mohammad Khazali
Connor Kupchak
Ben Lavoie
Itzel Lucio Martinez
Andrew MacRae (completed November 2012 → Postdoc, University of California, Berkeley)
Hassan Mallahzadeh
Farokh Mivehvar
Varun Narasimhachar
Jibran Rashid (completed July 2012 → Postdoc, University of Lugano)
Erhan Saglamyurek
Zahra Shaterzadeh Yazdi
Neil Sinclair
Michael Skotiniotis (completed June 2012 → Postdoc, Institute for Quantum Optics and Quantum Information, Innsbruck)
Joshua Slater
Borzumehr Toloui Semnani (completed November 2012 → Postdoc, Haverford College)
Michael Underwood (completed December 2012)
Dongsheng Wang
Marcelo Wu
Ehsan Zahedinejad

GRADUATE STUDENTS (MSC PROGRAM)

Khulud Almutairi
Erick Barrios (completed April 2012 → PhD, National and Autonomous University of Mexico)
Kevin Van De Bogart (terminated December 2012)
Travis Brannan
Aveek Chandra
Ran Hee Choi (completed September 2012)
Ish Dhand
Mahdi Ebrahimii Kahou (completed December 2012 → PhD, University of Calgary)
Hamidreza Kaviani (completed December 2012 → PhD, University of Calgary)
Ranjeet Kumar (completed August 2012 → PhD, University of California, San Diego)
Pantita Palittapongarnpim (completed September 2012 → PhD, University of Calgary)
Edouard Pelchat
Adarsh Prasad
Terence Stuart
Ryan Thomas (completed September 2012 → Analyst, CGG Veritas)
Venkata Ramana Raju Valivarthi
Tian Wang
UNDERGRADUATE STUDENTS
Michael Briscoe (NSERC USRA)
Spencer Cameron (PHYS 599)
Deborah Chung (research assistant)
James Clark (PHYS 598)

Stephen Huang (research assistant)
Jeff Maki (NSERC USRA & PHYS 598)
Matthew Mitchell (PHYS 598)
Randy Squires (research assistant & PHYS 598)

Postdoctoral Fellows
Vlad Gheorghiu
Bing He
Morgan Hedges
Patrick Ming-yin Leung (completed September 2012 → Research Engineer, Infotoo International Ltd.)
Neil Lovett
Daniel Oblak
Yang Tan (completed September 2012)
Collin Trail
Yunjiang Wang
Jian Ming Wen (completed April 2012 → Associate Research Scientist, Yale University)

Administration and Support
Arina Esmaeilpour (part-time)
Catherine Barrett
Vladimir Kiselyov
Nancy Jing Lu
Lucia Wang
Refereed Journals


Conference Proceedings


Invited Conference/Workshop Presentations

(presenter is underlined)


16 Aug 2012, T. Brannan, A. MacRae, R. Achal and A. I. Lvovsky, “Tomography of a high-purity narrowband photon from four-wave mixing in atomic vapour”, Quantum Communications and Quantum Imaging X (SPIE O&P), San


M. Ebrahimi Kahou, “Spatial search via non-linear quantum walk” (MSc Thesis), 1 December 2012.

H. Kaviani, “Quantum storage and retrieval of light by sweeping the atomic frequency” (MSc Thesis), 1 December 2012.

R. Kumar, “Process tomography of photon creation and annihilation operators” (MSc Thesis), 19 July 2012.

A. MacRae, “An atomic source of quantum light” (PhD Thesis), 1 June 2012.


Patent

Collaboration

QIS and its members have strong linkage with various external organizations and research networks. Barry Sanders is the principal investigator of the Pacific Institute for the Mathematical Sciences Collaborative Research Group for the Mathematics of Quantum Information, which brings together cognate researchers at the University of Calgary, the University of British Columbia, Simon Fraser University and the University of Washington. Some IQIS Faculty are members of the Canadian Institute for Advanced Research (CIFAR) Quantum Information Processing Program. CryptoWorks21 is the new NSERC Collaborative Research and Training (CREATE) Program for cryptographic training to meet 21st Century threats, and Sanders is on the Management Committee and also serves as Chair of the Professional Skills Working Group. As for new networks, Christoph Simon and Wolfgang Tittel are part of a DARPA network supporting the effort to build a quantum repeater. IQIS has established linkage with Canada’s National Institute for Nanotechnology (NINT) in Edmonton through the appointment of Paul Barclay at the University of Calgary and his 50% secondment to NINT. Alex Lvovsky is a member of scientific committee of the Russian Quantum Center.

INTERNATIONAL INSTITUTIONS

Carnegie Mellon University, United States of America
China Southeast University, People’s Republic of China
ETH Zürich, Switzerland
Hewlett-Packard Laboratories, United States of America
Huaqiao University, People’s Republic of China
Indian Institute of Technology, Kharagpur, India
Jazan University, Saudi Arabia
Kazan Physical-Technical Institute of the Russian Academy of Science, Russia
Leiden University, The Netherlands
Macquarie University, Australia
Massachusetts Institute of Technology, United States of America
National University of Singapore, Singapore
Oklahoma State University, United States of America
Sharif University of Technology, Iran
The Institute for Photonic Sciences, Barcelona, Spain
The National Centre for Mathematics and Physics, KACST, Saudi Arabia
The Russian Quantum Centre, Russia
Université della Svizzera italiana, Switzerland
Universität Paderborn, Germany
Université de Genève, Switzerland
Université de Grenoble, France
Université Paris Diderot, France
Université Paris-Sud 11, France
University of Arizona, United States of America
University of Bristol, United Kingdom
University of California at San Diego, United States of America
University of California at Santa Barbara, United States of America
University of Cambridge, United Kingdom
University of Copenhagen, Denmark
University of Illinois at Chicago, United States of America
University of New Mexico, United States of America
University of New South Wales, Australia
University of Queensland, Australia
University of Suwon, South Korea
University of Sydney, Australia

CANADIAN INSTITUTIONS

National Institute for Nanotechnology
Perimeter Institute for Theoretical Physics
Southern Alberta Institute of Technology
Université de Montréal
University of Alberta
University of British Columbia
University of Toronto
University of Waterloo

UNIVERSITY OF CALGARY

Institute for Biocomplexity and Informatics
Institute for Security, Privacy and Information Assurance
<table>
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<tr>
<th>NAME</th>
<th>INSTITUTION</th>
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<tbody>
<tr>
<td>Alain Aspect</td>
<td>Institut d’Optique</td>
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<td>Dominic Berry</td>
<td>Macquarie University</td>
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<td>Leslie Bicknell</td>
<td>University of Oregon</td>
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<td>Agata Branczyk</td>
<td>University of Toronto</td>
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<td>Paul Brumer</td>
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<td>Nicolas Brunner</td>
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<td>Harry Buhrman</td>
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<td>Aveek Chandra</td>
<td>McGill University</td>
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<td>Aashish Clerk</td>
<td>McGill University</td>
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<td>Cécile Crosnier</td>
<td>École Normale Supérieure de Cachan</td>
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<td>Aleksey Fedorov</td>
<td>Bauman Moscow State Technical University</td>
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<td>Mark Girard</td>
<td>University of Freiburg</td>
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<td>Chris Godsil</td>
<td>University of Waterloo</td>
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<td>Abhirup Goswami</td>
<td>École Polytechnique</td>
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<td>Markus Grassl</td>
<td>National University of Singapore</td>
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<td>Hubert de Guise</td>
<td>Lakehead University</td>
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<td>Pawel Hawrylak</td>
<td>National Research Council Canada</td>
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<td>Amir Helmy</td>
<td>University of Toronto</td>
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<td>Amir Kalev</td>
<td>National University of Singapore</td>
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<td>Achim Kempf</td>
<td>University of Waterloo</td>
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<tr>
<td>Aeysha Khalique</td>
<td>National University of Science and Technology (NUST)</td>
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<td>Jeong San Kim</td>
<td>University of Suwon</td>
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<td>Leong Chuan Kwek</td>
<td>University of Singapore</td>
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<td>Yury Kurochkin</td>
<td>The Russia Quantum Centre</td>
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<td>Angela Lahee</td>
<td>Springer DE</td>
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<td>Soojoon Lee</td>
<td>Kyung Hee University</td>
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<td>Paul Lett</td>
<td>National Institute of Standards and Technology</td>
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<td>Arturo Lezama</td>
<td>Universidad de la República Uruguay</td>
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<td>Qing Lin</td>
<td>Huaqiao University</td>
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<td>Petr Lisonek</td>
<td>Simon Fraser University</td>
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<td>Dylan Mahler</td>
<td>University of Toronto</td>
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<td>Peter Marzlin</td>
<td>St. Francis Xavier University</td>
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<td>Kamil Michnicki</td>
<td>University of Washington</td>
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<td>John Miller</td>
<td>University of Houston</td>
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<td>Shahpoor Moradi</td>
<td>Razi University</td>
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<td>Andal Narayanan</td>
<td>Raman Research Institute</td>
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<td>Tayebeh Naseri</td>
<td>Sharif University of Technology</td>
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<td>Marcos Cesar de Oliveira</td>
<td>Universidade Estadual de Campinas</td>
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<td>Marella Venkata Panduranga Rao</td>
<td>Indian Institute of Technology, Hyderabad</td>
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<td>Andrew Sachrajda</td>
<td>National Research Council Canada</td>
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<td>Artur Scherer</td>
<td>Applied Communication Sciences</td>
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<td>Neil Turok</td>
<td>Perimeter Institute for Theoretical Physics</td>
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<td>Universidade Estadual de Campinas</td>
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<td>Fern Watson</td>
<td>Imperial College London</td>
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<tr>
<td>Jiying Zhang</td>
<td>University of Science and Technology of China</td>
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Quantum Information Graduate Courses

<table>
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<tr>
<th>COURSE NAME</th>
<th>INSTRUCTOR</th>
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<tbody>
<tr>
<td>PHYS 615</td>
<td>B. C. Sanders</td>
<td>Basic formalism of the theory and its interpretation, symmetry generators.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Scattering theory, Bound states, Changed particles in electric and magnetic</td>
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<td>fields. Approximation methods.</td>
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<tr>
<td>PHYS 673</td>
<td>A. I. Lvovsky</td>
<td>Fundamentals of quantum and nonlinear optics including atom-photon</td>
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<tr>
<td></td>
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<td>interactions, coherence, electromagnetically induced transparency, open</td>
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<td>systems and decoherence, and applications to quantum information technology.</td>
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TEACHING, TRAINING AND EDUCATION
Conference Leadership (CHAIR AND CO-CHAIR POSITION ONLY)

<table>
<thead>
<tr>
<th>MEMBER</th>
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<th>CONFERENCE/WORKSHOP</th>
<th>LOCATION</th>
<th>DATES</th>
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<tbody>
<tr>
<td>A. I. Lvovsky</td>
<td>Deputy Chair &amp; Principal Organizer</td>
<td>The Twenty First Annual International Laser Physics Workshop (LPHYS’12)</td>
<td>Calgary, Canada</td>
<td>23 – 27 July 2012</td>
</tr>
<tr>
<td>A. I. Lvovsky</td>
<td>Chair, subcommittee, QELS1: Quantum Optics of Atoms, Molecules and Solids</td>
<td>CLEO: Quantum Electronics and Laser Science Conference (QELS) 2013</td>
<td>San Jose, United States of America</td>
<td>9 – 14 June 2013</td>
</tr>
<tr>
<td>B. C. Sanders</td>
<td>Co-Chair</td>
<td>2012 Canadian Association of Physicists Congress</td>
<td>Calgary, Canada</td>
<td>10 – 14 June 2012</td>
</tr>
<tr>
<td>B. C. Sanders</td>
<td>Chair</td>
<td>The Twenty First Annual International Laser Physics Workshop (LPHYS’12)</td>
<td>Calgary, Canada</td>
<td>23 – 27 July 2012</td>
</tr>
<tr>
<td>B. C. Sanders</td>
<td>Program Chair</td>
<td>Quantum Africa 2</td>
<td>Northern Drakensberg, South Africa</td>
<td>3 – 7 Sep 2012</td>
</tr>
<tr>
<td>B. C. Sanders</td>
<td>Chair, Program Committee</td>
<td>International Iran Conference on Quantum Information (IICQI 2012)</td>
<td>Tehran, Iran</td>
<td>8 – 12 Sep 2012</td>
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Professional Services

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<tr>
<th>NAME</th>
<th>ROLE</th>
<th>JOURNAL/SOCIETY/INSTITUTION</th>
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<tbody>
<tr>
<td>A. I. Lvovsky</td>
<td>Associate Editor</td>
<td>Optical Express</td>
</tr>
<tr>
<td>A. I. Lvovsky</td>
<td>Member, Scientific Committee</td>
<td>The Russian Quantum Center</td>
</tr>
<tr>
<td>A. I. Lvovsky</td>
<td>Advisor</td>
<td>University of Calgary SPIE Student Chapter</td>
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<tr>
<td>B. C. Sanders</td>
<td>Reviewer, Atomic QUantum Technologies (AQUTE) Integrated Project, Information Society and Media, FET–Proactive</td>
<td>European Commission</td>
</tr>
<tr>
<td>B. C. Sanders</td>
<td>Member (Canadian representative)</td>
<td>International Council for Quantum Electronics</td>
</tr>
<tr>
<td>B. C. Sanders</td>
<td>Member, Editorial Board</td>
<td>Mathematical Structures in Computer Science</td>
</tr>
<tr>
<td>B. C. Sanders</td>
<td>Member, Advisory Board</td>
<td>NSF CCI Quantum Information Center for Quantum Chemistry</td>
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<tr>
<td>B. C. Sanders</td>
<td>Editor (until Sept 2012)</td>
<td>Optics Communications</td>
</tr>
<tr>
<td>B. C. Sanders</td>
<td>Principal Coordinator, Collaborative Research Group for Mathematics of Quantum Information</td>
<td>Pacific Institute for the Mathematical Sciences</td>
</tr>
<tr>
<td>B. C. Sanders</td>
<td>Associate Editor</td>
<td>Physical Review A</td>
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<tr>
<td>C. Simon</td>
<td>Guest Editor, Focus Issue on “Quantum Memories”</td>
<td>New Journal of Physics</td>
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</table>
IQIS Public Lecture

Each year the Institute holds a Public Lecture, which has been sponsored each year by Alberta Innovates Technology Futures. In 2012, two hundred participants enjoyed Alain Aspect’s wonderful lecture titled “From Einstein’s LichtQuanten to Wheeler’s delayed choice: wave particle duality for a single photon”. Professor Aspect is an internationally acclaimed physicist at the École Polytechnique in Paris and is a pioneer in the foundations of quantum physics and a recipient of the 2010 Wolf Prize in Physics.

Media Coverage

<table>
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<tr>
<td>University of Calgary Alumni News</td>
<td>Institute for Quantum Information Science Public Lecture: Alain Aspect</td>
<td>online</td>
<td>1 Apr 2012</td>
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<tr>
<td>New Scientist</td>
<td>Dodge ban on quantum clones to trap Schrödinger’s cat: Christoph Simon</td>
<td>online</td>
<td>13 Apr 2012</td>
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<td>UToday</td>
<td>A peek into the quantum world of light: Alain Aspect</td>
<td>online</td>
<td>16 Apr 2012</td>
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<td>UToday</td>
<td>NSERC CREATE program: Barry Sanders</td>
<td>online</td>
<td>26 Jun 2012</td>
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<tr>
<td>Superconductor Week</td>
<td>U Calgary devises method for microwave pulse storage: Patrick Leung</td>
<td>page 6</td>
<td>30 Jun 2012</td>
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<td>Physorg.com</td>
<td>A roll of the dice: Quantum mechanics researchers show that nature is unpredictable: Wolfgang Tittel, Renato Renner</td>
<td>online</td>
<td>9 Jul 2012</td>
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<td>Science Codex</td>
<td>A roll of the dice in quantum mechanics is better: Wolfgang Tittel, Renato Renner</td>
<td>online</td>
<td>9 Jul 2012</td>
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<td>Science Daily</td>
<td>A roll of the dice: quantum mechanics researchers show that nature is unpredictable: Wolfgang Tittel, Renato Renner</td>
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<td>10 Jul 2012</td>
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<td>Science2.0</td>
<td>God does play dice with the universe (and the dice are fair): Wolfgang Tittel, Renato Renner</td>
<td>online</td>
<td>11 Jul 2012</td>
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<tr>
<td>UToday</td>
<td>A roll of the dice: Wolfgang Tittel</td>
<td>online</td>
<td>11 Jul 2012</td>
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<td>CBC Radio (French)</td>
<td>Interview: La croisere de l’été avec Isabelle Rousseau: Wolfgang Tittel</td>
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<tr>
<td>Physorg.com</td>
<td>Can quantum theory be improved?: Terence Stuart</td>
<td>online</td>
<td>23 Jul 2012</td>
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<td>UToday</td>
<td>Laser physicists beam: Alex Lvovsky</td>
<td>online</td>
<td>9 Aug 2012</td>
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<tr>
<td>Science2.0</td>
<td>Quantum entanglement: A third entangled particle?: Christoph Simon</td>
<td>online</td>
<td>17 Dec 2012</td>
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Outreach Lectures


18 Sep 2012, W. Tittel, “Quantum cryptography in the QC2 Lab”, presentation to Raytheon, Calgary, Canada.

Research Grants (unaudited)

TOTAL REVENUE: $2,890 (IN THOUSANDS)

- University Of Calgary [2%]
- Other Grants [3%]
- NSERC [30%]
- PIMS [1%]
- Canada Research Chair [3%]
- Canadian Institute for Advanced Research [2%]
- Canada Foundation for Innovation [10%]

TOTAL EXPENDITURES: $1,999 (IN THOUSANDS)

- Visitors Travel [4%]
- Travel [6%]
- Equipment and Freight [5%]
- Materials and Supplies [6%]
- Benefits [6%]
- Support Staff Salaries [7%]
- Faculty Staff Salaries [16%]
- Research Fellows & Associates Salaries [17%]
- Students Salaries [32%]
- Other Expenditures [3%]

* Information provided is for the period of 9 months from April to December 2012
Operating Account (unaudited)

TOTAL EXPENDITURES: $61.8 (IN THOUSANDS)

- IQIS Annual Report [2%]
- Visitors Expenses [6%]
- Outreach And Marketing [1%]
- Equipment [9%]
- Materials And Supplies [3%]
- Benefits [14%]
- Administrative Salaries [65%]

- Other Expenditures [3%]
- Visitors Travel [4%]
- Travel [6%]
- Equipment and Freight [5%]
- Materials and Supplies [6%]
- Benefits [6%]
- Support Staff Salaries [7%]
- Faculty Staff Salaries [16%]
- Research Fellows & Associates Salaries [17%]
- Students Salaries [32%]

- Grants
  - Alberta Innovates Technology Futures [49%]
  - University Of Calgary [2%]
  - Other Grants [3%]
  - NSERC [30%]
  - Canada Foundation for Innovation [10%]
  - Canadian Institute for Advanced Research [2%]
  - Canada Research Chair [3%]
  - PIMS [1%]
In 2013 my group is adding a postdoctoral scholar, up to two graduate students, and hosting three undergraduate summer students (one at NIInd, two at UofC). Research efforts will focus on using recently developed optomechanical nanocavities to create sensors for probing properties of quantum systems, and on commencing experiments involving the mechanical manipulation of electronic spins in diamond. The necessary technical infrastructure and research expertise is in place to push forward this first goal.

Development of the diamond experiment is underway, and successful completion of this project will require increased efforts directed toward nanofabrication of diamond based devices plus setup of a single photon confocal microscope. The latter task is expected to make significant progress with the arrival of a recently hired postdoctoral scholar and installation of a custom cryostat scheduled to be delivered in summer 2013.

My group research efforts span topics in atomic, molecular, and optical (AMO) physics, quantum information theory, and condensed matter physics, with particular emphasis on the interfaces between these disciplines. The broad questions to be asked are: how can strong correlations induced in many-body ground states of AMO systems be used to perform quantum algorithms; and how can techniques in quantum information theory be used to probe the properties of condensed matter systems? The work to be conducted in 2013-2014 pursues three main topics along these lines.

One of these topics is: what are the characteristics of quantum many-body states that allow universal measurement-based quantum computation (MBQC)? A promising thread here is that in MBQC the quantum information resides at the surface of a state, much like topologically protected surface modes of symmetry-protected quantum phases. The Haldane phase in condensed matter physics seems to offer various clues here. A second topic is: Is it possible to induce topological insulator states using the strong atom-photon interactions present in cavity quantum electrodynamics?

Preliminary work by a PhD student in my group has recently shown that a single atom in a ring cavity naturally experiences spin-orbit interactions, which is a crucial ingredient in some symmetry-protected states. Future work will test if these states are robust against particle interactions in many-body systems.

Recent calculations by my undergraduate student show that the cavity itself strongly affects van der Waals interactions, which suggests that particle interactions will become very important in these systems. A third topic is: can one devise a real-space renormalization method for interacting quantum gases using graph theory? Preliminary calculations along these lines by my MSc student show that there is a deep connection (and likely a duality in one dimension) between hard-core (infinitely strongly interacting) bosons and non-interacting bosons. If this idea is successful, it should have important applications to understanding the properties of magnetic materials.

My group plan for 2013/14 is to study quantum resource theories (QRTs) and use this knowledge to solve open problems in (1) quantum information, (2) thermodynamics, and (3) quantum optics. Quantum information theory can be viewed as a theory of inter-conversion among different types of resources: classical or quantum, noisy or noiseless, static or dynamics.

Our group will explore inter-conversions between static quantum resources to understand multiparticle entanglement better and to improve the efficiency of important tasks in quantum information. Recently, QRTs have been also used to study thermodynamical systems that are in non-equilibrium states. We will therefore study the resource theory of quantum states out of thermal equilibrium. Finally, we will also explore the resource theory of non-Gaussianity in quantum optics.
DR. ALEX LOVOVSKY

In 2013, my group has started a new project on achieving giant optical nonlinear effects in atomic systems. Such nonlinearities can be useful for a variety of purposes, for example, quantum-optical information processing and long distance quantum communications. We will utilize highly nonlinear properties of ultracold atomic ensembles, and, to further enhance these properties, we will contain light in the evanescent field of a tapered optical nanofiber. This project involves several complex components, such as manufacturing optical nanofibers, a specially designed magneto-optical trap, a large number of mutually phase locked diode lasers, etc. We hope to assemble the core of the setup before the end of 2013.

We will continue to pursue our existing experiments involving generation of photon pairs by four-wave mixing in atomic ensembles. Among the goals for 2013/2014 is the preparation and characterization of the single-rail qubit form an atomic source as well as measuring the temporal wavefunction of the heralded photon prepared in this way. In a more distant future we will combine this experiment with quantum-optical memory, which will allow on preparing and measuring arbitrary states of an atomic ensemble.

Finally, we are continuing our line of research on quantum technology of light. Among the goals for 2013 are complete quantum tomography of a two-mode process and the distillation of the Einstein-Podolsky-Rosen state.

DR. BARRY SANDERS

Three decades ago, Richard Feynman motivated quantum computation through his speculation that the nature is not efficiently simulatable on a classical computer but would be efficiently simulatable with a quantum computer. My work has focused on algorithmic quantum simulation, which aims to deliver efficient bounded-error quantum-state generation. This year, in collaboration with Macquarie University, we plan to deliver an efficient circuit-generation algorithm for simulating completely positive maps for few-qubit systems, to initiate a study of quantum-field-simulation quantum algorithms based on manifestly covariant ordered-operator expansions, and to determine limitations to ordered-operator expansions due to finite machine precision.

Quantum simulation is doubly exciting because the problem being solved could be technologically relevant and also the computational resource demands are low compared to other applications of quantum computing hence suggesting that an interesting computational problem could be solved much sooner than expected. Another area of quantum computation has arisen recently: the BosonSampling problem, which is amenable to employing a problem-specific photonic quantum computer that is amenable to current technology. This year my research group will build on non-simultaneous photon-arrival work with co-workers at Singapore’s A*STAR and Lakehead University to develop photonic interferometers as matrix-immanant calculators with experimental collaborators at the University of Vienna.

In the area of quantum metrology, which aims to measure parameters like elapsed time or spatial translation with a precision surpassing the semiclassical limit, i.e., shot noise or partition noise, this limit is surpassed by exploiting entanglement. My group has made seminal contributions to adaptive quantum metrology by framing the adaptive algorithm as a decision-tree machine-learning policy and then using reinforcement machine learning to devise “policies” that far outperform previous algorithms and also accommodate real-world effects of noise and loss. Two goals in the coming year are to surpass our previous results by using superior evolutionary algorithms and to apply these techniques beyond quantum metrology to the more general problem of quantum control, which delivers tailored quantum states and transformations with applications to quantum computing and chemical reactions.

A hallmark of my group research has been the proposal of new ways to realize quantum information tasks in the laboratory on a few-year timescale as opposed to decades required for full-scale quantum
computing. In the coming year we will scrutinize opportunities in two different media: microwave pulse control in superconducting artificial atoms that are coupled to an open microwave transmission line (with Université de Sherbrooke and ETH Zürich collaborators) and also the creation of strong nonlinear interactions between two weak optical fields by converting these fields into two strongly interacting species of a Bose-Einstein condensate. The microwave pulse can serve as a quantum bus for mediating quantum information in a large-scale superconducting quantum computer, and the two-species condensate could serve as a few-photon cross-phase modulation element of a photonic interferometer.

Another area of the group’s studies of quantum-information implementation has been the multi-year collaboration with the National Institute for Nanotechnology: Wolkow’s group creates and controls dangling-bond pairs on the silicon surface. The group’s collaborate on characterizing and exploiting these dangling-bond pairs as quantum bits for quantum information processing. In the forthcoming year we will propose a technique for experimental characterization of the tunnelling and decoherence rates for electron transfer between the two nearest dangling bonds and initiate experimental investigation of this system.

My group is exploring electron transfer in a completely different system. Our collaboration with Salahub’s University of Calgary Chemistry group has revealed that a water bridge can play an indispensable role for enabling electron transfer between two proteins in a protein complex in contrast to the alternative of through-gap quantum tunnelling. In the coming year we will develop greatly enhanced algorithms for quantum-mechanical and molecular modelling of electron transfer in other protein complexes, and use these new approaches to start tackling the problem of electron transfer in other protein complexes.

The final highlighted goal for the coming year concerns generalized concatenated quantum codes, which we will propose as a systematic technique for constructing good quantum codes from short component codes. This collaboration with Xidian, Singapore National, and Guelph Universities employs the stabilizer formalism and introduces quantum coset codes, which we are using to determine code-distance lower bounds based on component code parameters as well as to exploit the error-correcting capacity of component codes to design good GCQCs efficiently.

DR. CHRISTOPH SIMON

In the area of quantum memories and quantum repeaters, my group is planning to develop new quantum repeater architectures that are well-matched to the current and near-future experimental capabilities of quantum memories based on rare-earth-doped crystals. We will also study the performance requirements on quantum memories for the implementation of heralded entangled photon pair sources. This work will be done in the context of a DARPA project for quantum communication involving Tittel’s and my groups. Further on quantum memories, we will study the implementation of photonic quantum memories with ensembles of nitrogen-vacancy centers in collaboration with Paul Barclay here in Calgary and with researchers at HP Labs in California. This approach holds great promise for on-chip integration.

In the area of quantum opto-mechanics, we will study the creation of opto-mechanical entanglement in experimentally relevant regimes that have so far been unaccessible theoretically. We will also study the creation of macroscopic opto-mechanical entanglement through the interaction of mechanical systems with macroscopically entangled states of light, such as those that were recently produced in Lvovsky’s lab in a project in which we collaborated on the theory side.

In the area of photon-photon interactions, we will study the interaction between stored photons in atomic ensembles using Rydberg states. We will also investigate the experimental requirements for observing Kerr non-linearities in Bose-Einstein condensates due to atomic collisions.

DR. WOLFGANG TITTEL

My group will focus on two research topics: (1) Quantum Cryptography: we will continue the development of a complete and fully automated measurement-device-independent quantum key distribution system and will also look into possibilities to expand our current point-to-point link into a real-world QKD network; (2) Quantum Repeaters: we will continue developing key primitives for a quantum repeater, including highly multimode quantum memories featuring readout on demand and frequency-multiplexed entangled photon-pair sources. We expect that these developments will lead to the teleportation of photon states into solid-state quantum memory during the coming year.
Charter

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

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

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

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

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

Goals
5. The goals of the Institute shall be:
   a) to establish and maintain leading quantum information science in the areas of quantum algorithms and processing, implications of quantum information on information security and communication complexity, development of physical implementations of quantum information tasks and protocols, and critically evaluate proposals and experimental results in the field;
   b) to educate and train persons with expertise at the frontiers of the allied disciplines of quantum information science;
   c) to bring together top researchers in the world in order to further the development of the field of quantum information science through a focused, multi-disciplinary effort;
   d) to identify promising research areas that will lead to valuable intellectual property and to conduct research in these areas;
   e) to collaborate in complementary research activities in the areas of computer science, engineering, mathematics and experimental and theoretical physics and chemistry.
Targets and Measures of Success
6. At the establishment and/or renewal of an institute, the University’s policy on Institutes and Centres (ss. 4.1 & 4.3) requires the setting of targets against which to measure success in adding value.

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

- at the discretion of the Dean of the Faculty of Science, an internal review after two years of the Institute’s limited term;

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

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

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

b) Membership of the Board shall comprise:
   i. The Institute’s “supervising officer” (or designate), who shall Chair the Board and appoint a Vice Chair from among other board members;
   ii. At least 4 “members at large,” drawn from or nominated by
      o companies whose primary operations are synergistic with quantum information science;
      o agencies that provide funding for quantum information science research in Alberta; and
      o 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.)
## IQIS Existing Use of Space

### OFFICES

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<tr>
<th>Room Number</th>
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### LABS

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IQIS ADDS VALUE TO THE UNIVERSITY OF CALGARY IN THE FOLLOWING WAYS:

Enables a multidisciplinary research through financial and logistical support

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

Assists new faculty members with a rapid transition to becoming productive researchers

Publishes reports and web pages that position the Institute as a leader in quantum information science

Supports recruitment of outstanding faculty, researchers, and graduate students

Sponsors and supports leading conferences held in Calgary

Partners with other quantum information institutes globally

Enhances the University’s reputation by delivering outstanding research results

Benefits the wider community by contributing new knowledge in a strategic area