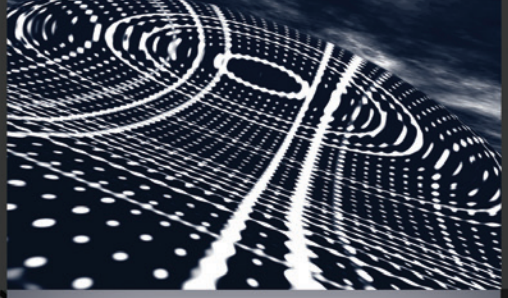
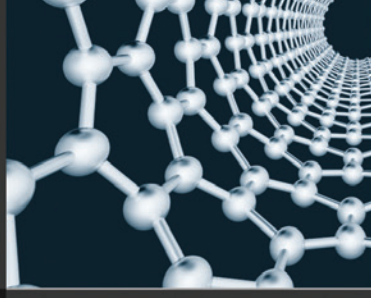
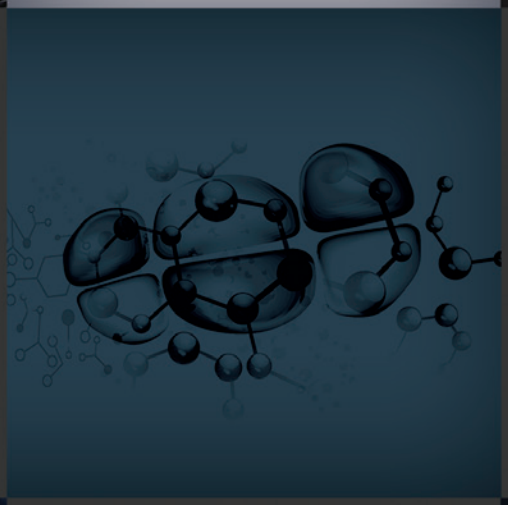
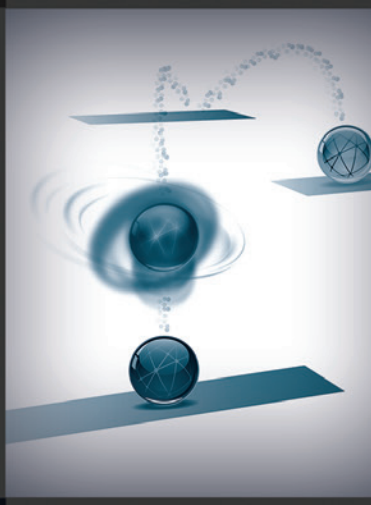



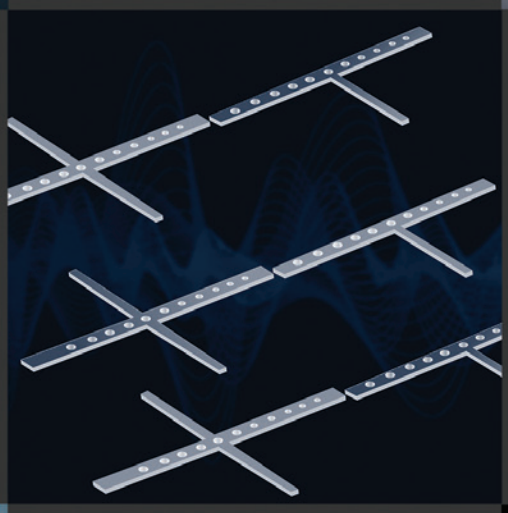

Institute for
QUANTUM SCIENCE AND TECHNOLOGY
at the University of Calgary

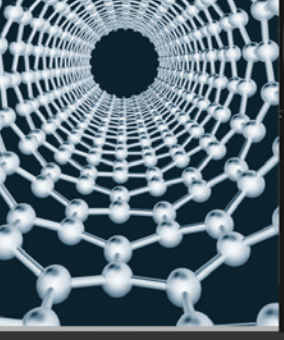
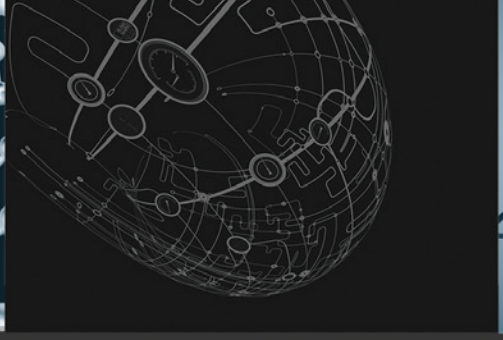



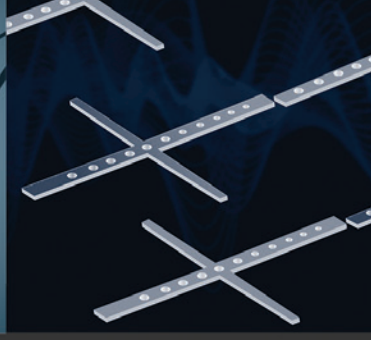
quantum frontiers




annual report 2014-2015





vision:

To be a world leader in research and education in pure and applied quantum science and technology.

mission statement:

To advance quantum science and technology through interdisciplinary research, teaching, and outreach.

key facts:

18 postdoctoral fellows

73 graduate students

29 undergraduate students

41 visiting researchers

60 publications in refereed journals and conference proceedings including *Journal of the American Chemical Society* (1), *Nature Photonics* (1), *Optica* (2), *Physical Review X* (1), *Physical Review Letters* (5)

31 invited talks at national and international conferences/workshops (1 keynote)

$3.91 million dollars revenue

contents

Director's Report

The Institute for Quantum Science Technology has had an excellent year for research and training outcomes as described in the Highlights section of this report. The fifteen groups produced 60 papers including 10 in the top tier journals *Journal of the American Chemical Society*, *Nature Photonics*, *Optica*, *Physical Review Letters*, and *Physical Review X*. 7 Masters and 6 Doctoral students completed their research and departed for illustrious universities and companies.

Two exemplary research highlights stand out, which I summarize here. Tittel's group demonstrated faithful storage and retrieval of telecommunications-wavelength photons in a commercial erbium-doped fibre, which was reported in *Nature Photonics*. Salahub's group reported multi-scale modelling of oil sands upgrading using molybdenum carbide nanoparticles, which appeared as a Spotlight article in the *Journal of the American Chemical Society*.

Two of the fifteen Institute professors received awards that recognize their high research standings, and one student won a prestigious award. Lvovsky has been appointed a Fellow of the Optical Society of America. Tieleman received a 2014 Killam Annual Professorship award, and Tittel has been appointed as a CIFAR Senior Fellow. Kusalik's Phd Student Kyle Hall received the NSERC Vanier Scholarship.

The Institute seeks to bring quantum science and technology to the Calgary community through its illustrious Annual Quantum Lecture series. In 2014 the Annual Quantum Lecture was delivered by John Clarke from the University of California at Berkeley. Professor Clarke has made seminal contributions to studies of superconducting for which he received the London Prize, the Keithley Award, the Comstock Prize for Physics, and the Hughes Medal. His lecture titled "The SQUID at 50: From cosmology to medicine" drew an audience of 200.

BARRY SANDERS

Another important outreach activity for the Institute is to host international conferences. These conferences draw leading researchers and students to Calgary and create awareness of the diversity and strengths of Institute research. In January 2016, the Institute will host the 19th International Conference on Quantum Information Processing, which is the premier conference for theoretical quantum information research. Since 1998, the conference has featured breakthroughs in the disciplines of computing, cryptography, information theory, mathematics and theoretical physics of quantum information. Five hundred participants are expected at the Banff Centre where the conference will be held 10-16 January 2016.

> These conferences ...create awareness of the diversity and strengths of Institute research.

The Institute organized the second Alberta Quantum-Nano (AQN) Workshop sponsored by Alberta Innovates Technology Futures (AITF). The first one-day AQN Workshop was held in Red Deer July 2011 and sponsored by AITF, and the second one-day AQN Workshop was in July 2014, again in Red Deer. Red Deer is particularly convenient as the midpoint between Calgary and Edmonton with approximately equal numbers of quantum researchers in both places. The most important outcome of the AQN Workshop in 2014 was an agreement to establish the Quantum Alberta Platform as an organization whose main aim is to create and expand a pan-provincial quantum community involving academic, government laboratory and industrial research and technology. AITF agreed in 2015 to provide $150,000 as one-year funding to support building up this Platform. A steering committee has been established to guide this Platform to a strong position for seeking long-term funding to build Alberta into a quantum powerhouse.

On an operational level, the Institute has faced challenges with respect to maintaining its web-enabled database. In September 2013, the Institute web site was compromised by an unknown

person who accessed and posted private data. Consequently the web site was shut down for some time while security issues were investigated and resolved. The strategy for maintaining the web site and its data are now to operate two web sites: operate a private site for Institute administrative use and migrate data to a highly secure public web site at iqst.ca. As well separate private sites are maintained to host the code and to test for security, and virtual machines can be set up to enable Institute members to access data for export to their own web sites. As a consequence of these efforts and structures, the Institute is now able once again to benefit from its web-enabled database and showcase its research and outcomes properly.

In closing, I would like to mention our sorrow at the passing of Institute Faculty Member Tom Ziegler on 24 March 2015. Tom was an outstanding scientist, exemplified by his recognition through an Alcan Lecture Award, a Canada Council Killam Professor, a Steacie Award, Fellowship of the Royal Society of Canada, Fellowship of the Royal Danish Academy of Sciences and Letters, a Tier I Canada Research Chair, and recipient of the Schrödinger Medal of the World Association of Theoretical and Computational Chemists. Tom set an example of outstanding research and personal integrity that others in the Institute will strive to follow.

Barry Sanders
Director, IQST

KEN BARKER

A Message from the Chair

In my final year as Chair of the Institute's Board of Directors, I reflect on the history of the Institute, which emerged from the erstwhile Institute for Quantum Information Science to become the Institute for Quantum Science and Technology and now its nascent expansion to the Quantum Alberta Platform. As Dean of Science, I encouraged the formation of interdisciplinary groups of researchers with a common underlying theme with this team being supported as a priority area in the Faculty of Science. The quantum area, embodied by this Institute, emerged as a highly successful, cohesive collective of outstanding quantum researchers.

> ...the province...can expect to reap the benefits of the "quantum age" in the 21st Century.

The Institute began as a team of eight groups undertaking quantum information research equal to the best in the country. Through the Faculty of Science priority selection process, these quantum information researchers combined with cognate quantum researchers in the Chemistry Department as well as including a wider group in Physics. The research focus broadened from solely concerning quantum information and quantum optics to including quantum nanotechnology and molecular modelling. I am pleased to see that the initial quantum information strength, both in research and in organization, has led to superb accomplishments and team building across a wider grouping of quantum science and technology.

The Quantum Alberta initiative is quite an important step and has the Faculty of Science's full support. Quantum activities are quite strong at the University of Alberta as well as in Calgary, and the University of Lethbridge has strengths in certain quantum areas. With the three universities collaborating on building a combined research capability that rivals large quantum centres elsewhere, Campus Alberta and the province as a whole can expect to reap the benefits of the "quantum age" in the 21st Century.

Ken Barker
Chair of the Board of Directors, IQST

Highlights

Research Achievements

The Institute has had a highly successful year of research outcomes. The chief highlights are reported here. In addition to these highlights, every research group continues to make great strides in research and has had substantial outcomes in the past year.

Dennis Salahub's student Xingchen Liu completed multi-scale modelling of oil sands upgrading using molybdenum carbide nanoparticles. This nanocatalyst work appeared as a *Spotlight* article in the *Journal of the American Chemical Society*, and the reported research accounts for benzene solvent and high temperature and notably reveals that the free energy of the system changes over the reaction timescale.

Peter Kusalik's group has provided key insights into the behaviour of the hydroxyl radical, which is a chemical species crucial in contexts ranging from nuclear reactors to cell death and aging. Additionally, the group introduced an approach to enhanced sampling of ordered arrangements in molecular simulations of liquids thereby giving rise to dramatically accelerated crystal nucleation rates, for example speeding up a process requiring a timescale of the age of the universe to succeed in just a picosecond.

> ...every research group continues to make great strides in research and has had substantial outcomes in the past year.

Wolfgang Tittel's group demonstrated measurement-device-independent quantum key distribution up to a record-breaking 60 dB loss thereby allowing secure quantum communication over 300 km. In another breakthrough, the group has demonstrated faithful storage and retrieval of photons at telecommunication wavelength in a commercially available erbium-doped fibre, which is a crucial building block for secure quantum communication in current telecommunication networks.

Christoph Simon's group and collaborators had two key results both published in *Physical Review Letters*. One of these important results is an enhanced procedure for effecting quantum gates between individual photons in a Rydberg-atom medium, and the second of these important results is a proposal for realizing macroscopic superpositions of Bose-Einstein-Condensate atomic-spin states of atomic spin.

Paul Barclay's group and collaborators reported in *Physical Review X* a silicon nanophotonic device that exploits dissipative optomechanical coupling to measure torque with ultrahigh sensitivity.

Lvovsky's group has significantly advanced experimental distillation of the optical Einstein-Podolsky-Rosen state by employing noiseless amplification and demonstrated recovery of the original entanglement from a channel with loss factor of twenty. This distillation procedure is valuable for creating a continuous-variable quantum repeater for long-distance quantum communication.

Tom Ziegler with coworkers applied his constricted variational method, which calculates excited states using density functional theory, to the lowest singlet excitations in cyanine dyes whose pi system is strongly delocalized. These results strongly agreed with accurate ab initio methods whereas the popular alternative approach of adiabatic time-dependent density functional theory does not provide accurate solutions.

Awards

INTERNATIONAL AWARDS

"QIAN REN" PROFESSOR, UNIVERSITY OF SCIENCE AND TECHNOLOGY OF CHINA (PEOPLE'S REPUBLIC OF CHINA)

Barry Sanders

HONORARY PROFESSOR, HENAN UNIVERSITY OF SCIENCE AND TECHNOLOGY OF CHINA (PEOPLE'S REPUBLIC OF CHINA)

Dennis Salahub

OPTICAL SOCIETY OF AMERICA FELLOWSHIP

Alexander Lvovsky

KING SAUD UNIVERSITY AWARD (SAUDI ARABIA)

Khulud Almutairi (ended July 2014)

PAAET AWARD (KUWAIT)

Hessa Alotaibi

TRANS-ATLANTIC SCIENCE STUDENT EXCHANGE PROGRAM

Aoife Plunkette

PROVINCIAL AWARDS

ALBERTA INNOVATES GRADUATE STUDENTS SCHOLARSHIP

Kyle Hall
Chris Healey
Hon-Wai Lau
David Lake
Thomas Lutz
Matthew Mitchell
Farokh Mivehvar
Eugene Moiseev
Neil Sinclair
Marcelo Wu

ALBERTA INNOVATES TECHNOLOGY FUTURES (AITF)/EYES HIGH POSTDOCTORAL FELLOWSHIP

Gabriel Aguilar
Joydip Ghosh
John Patrick Hadden
Florian Senn

ALBERTA GRADUATE STUDENT SCHOLARSHIP

Jonathan Johannes

NATIONAL AWARDS

MITACS GLOBALINK

Luis Hernandez Huerta
Mouktik Raha
Yanming Wang

NSERC ALEXANDER GRAHAM BELL CANADA GRADUATE SCHOLARSHIP – DOCTORAL

Neil Sinclair
Marcelo Wu

NSERC CANADA GRADUATE SCHOLARSHIPS – MASTER

Matthew Mitchell (ended August 2014)

NSERC USRA PROGRAM

Anna Danko
Steven Large
Stephen Wein

NSERC VANIER SCHOLARSHIP

Kyle Hall

UNIVERSITY OF CALGARY AWARDS

EYES HIGH DOCTORAL SCHOLARSHIP

Ehsan Zahedinejad

EYES HIGH DOCTORAL RECRUITMENT SCHOLARSHIP

Carlos Enriquez-Victorero
Sourabh Kumar

FACULTY OF SCIENCE RESEARCH EXCELLENCE AWARD

Christoph Simon

ZAAK WALTON KILLAM PRE-DOCTORAL SCHOLARSHIP

Kyle Hall

PURE AWARD

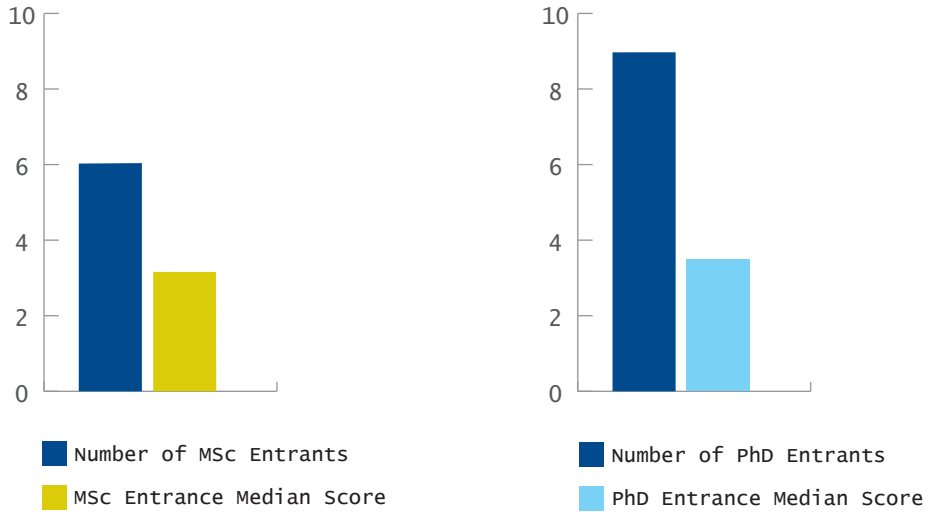
Stephen Wein

QUEEN ELIZABETH II GRADUATE SCHOLARSHIP

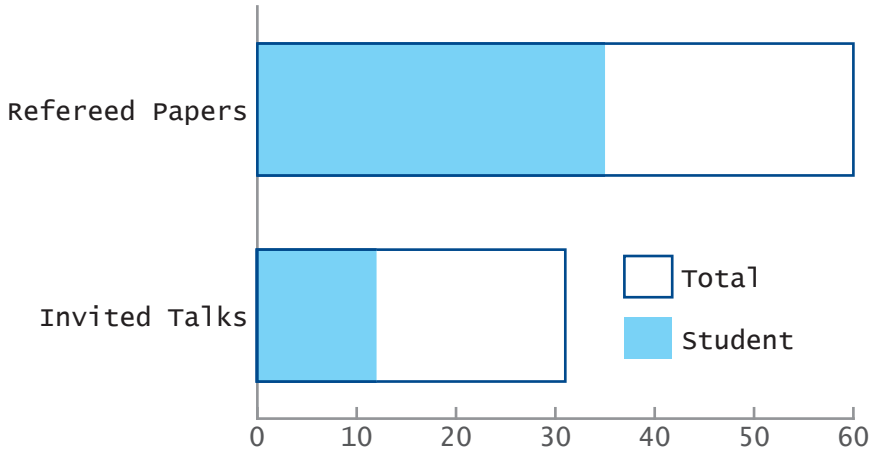
Sahar Sheybani-Deloui

Key Performance Indicators

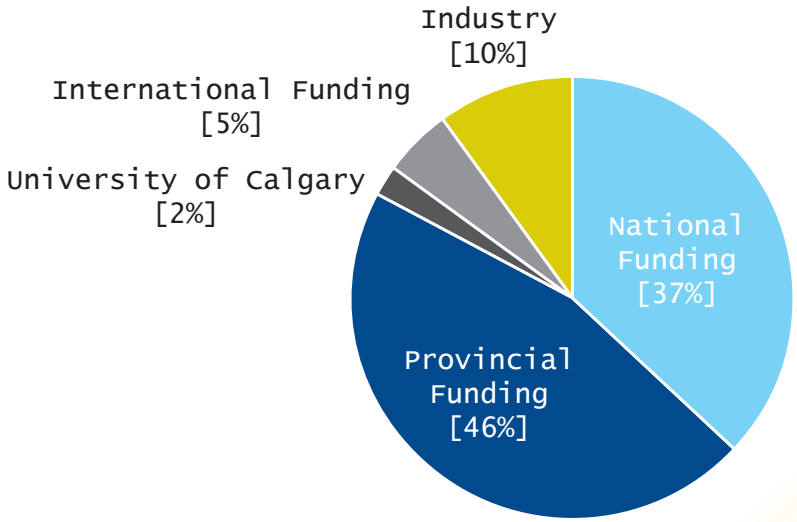
GRADUATE STUDENTS ENROLMENT AND QUALITY OF ENTRANTS



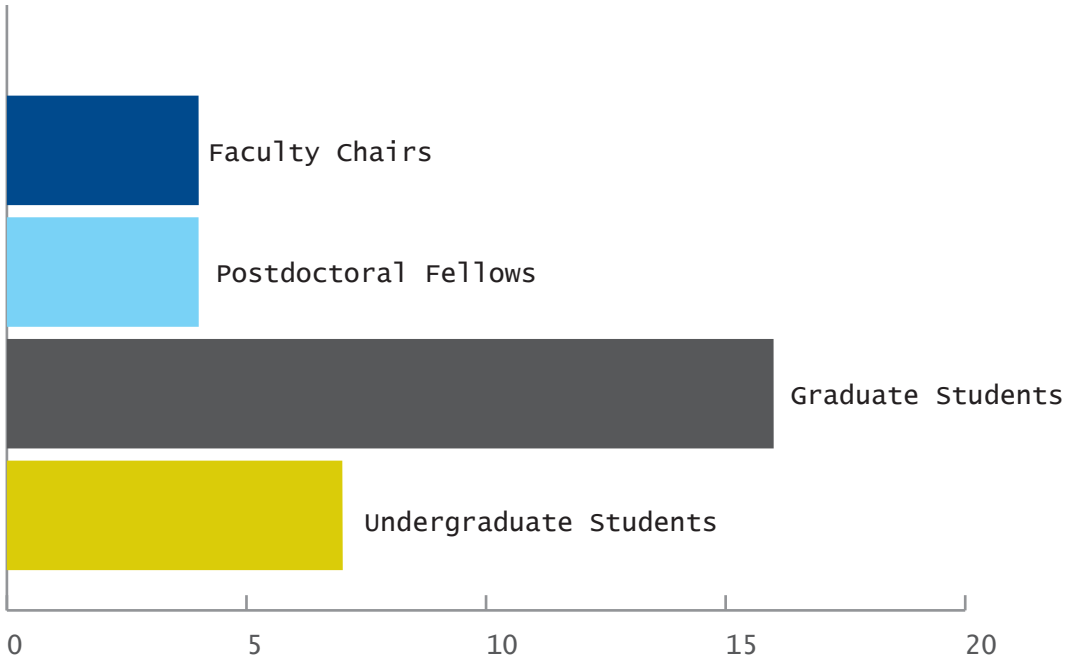
PUBLICATIONS AND PRESENTATIONS



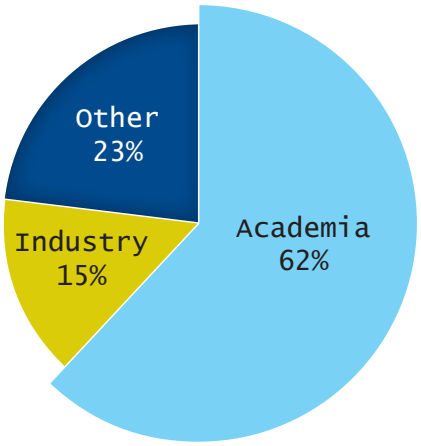
REVENUE (UNAUDITED)



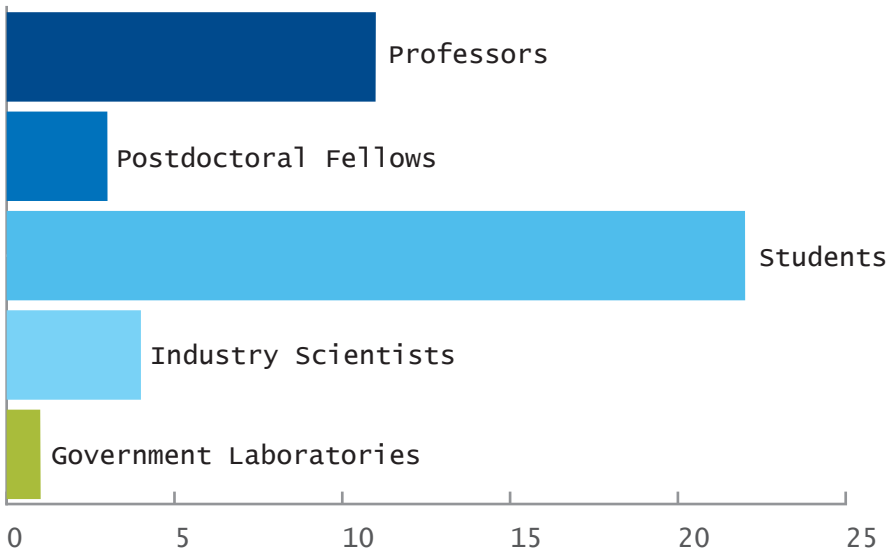
EXTERNAL AWARDS (CHAIRS, FELLOWSHIPS AND SCHOLARSHIPS)



IN THE WORKFORCE AND ACADEMIA



VISITORS

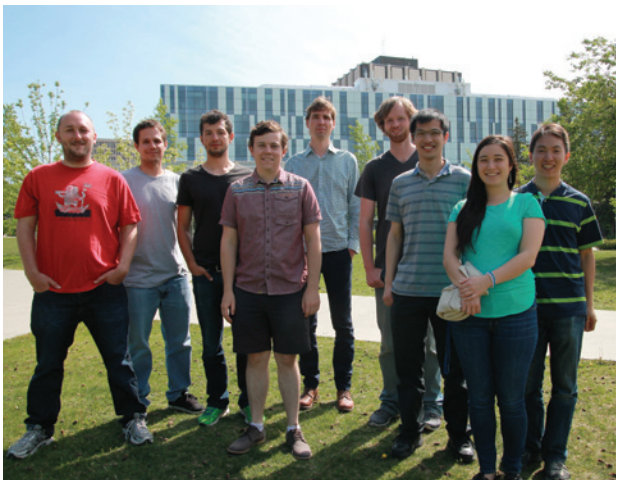


Research Groups

NANOSCALE OPTICS

DR. PAUL BARCLAY

Explores interactions between light and nanoscale systems such as single atoms, electron spins and nanomechanical structures. Employs nanofabrication methods to engineer optical properties of these systems in order to enhance light–matter coupling. The current focus couples single quantum emitters, or “artificial atoms”, to optical nanocavities. The labs are at the University of Calgary and at the NRC National Institute for Nanotechnology in Edmonton, which has advanced nanofabrication tools plus leading quantum optics and nanotechnology researchers.



PRACTICAL QUANTUM COMPUTATION

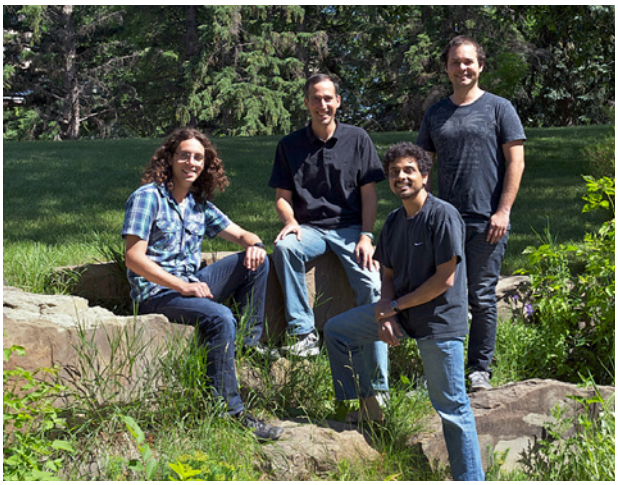
DR. DAVID FEDER

Focuses on understanding 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 addition, the group explores 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

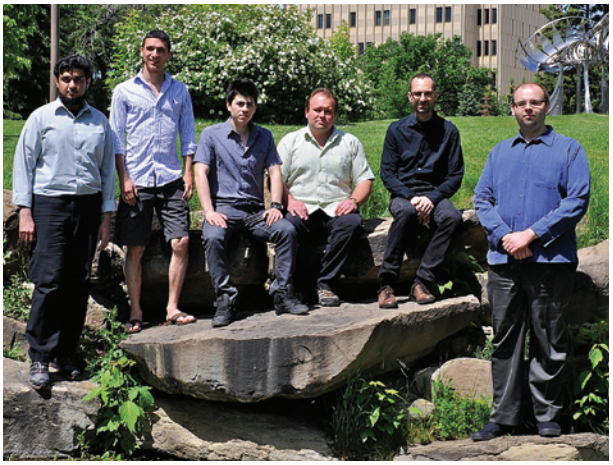
Employs sophisticated mathematical methods, such as algebraic geometry, matrix analysis, group theory and C*-algebras, to solve core problems in quantum information science.



QUANTUM COMPUTING

DR. PETER HØYER

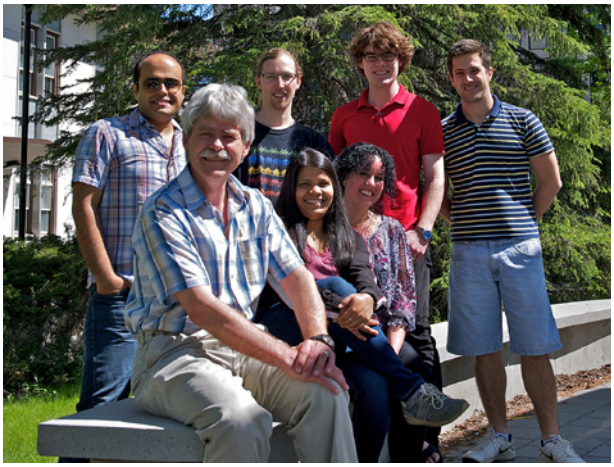
Explores the potential powers of quantum systems to develop quantum algorithms, quantum communication protocols, quantum cryptographic protocols, and quantum computer simulations of quantum mechanical systems. Characterizes the powers and their limitations by studying quantum complexity theory, non-locality, entanglement, and quantum information theory.



MOLECULAR SIMULATIONS OF LIQUIDS & SOLUTIONS, INTERFACES AND CRYSTALLIZATION

DR. PETER KUSALIK

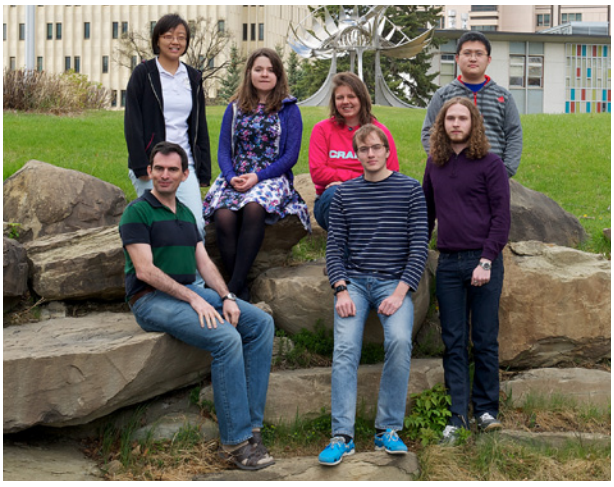
Molecular simulations to examine collections of molecules representing solid or liquid systems. Probes the molecular behaviour to understand properties of liquids and solids and their transformations including nucleation and crystallization. Applications range from atmospheric and materials sciences to molecular biology and glaciation of a cloud. Explores behaviour of the hydroxyl radical in various aqueous environments.



QUANTUM INFORMATION TECHNOLOGY WITH LIGHT AND EXPERIMENTAL QUANTUM OPTICS

DR. ALEX LVOVSKY

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, as well as causing photons to interact with each other.



SPECTROSCOPY OF HYDROCARBONS AND MOLECULAR CLUSTERS AND COMPLEXES

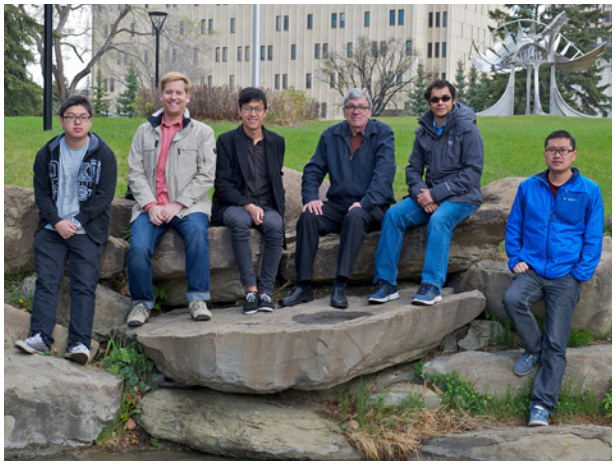
DR. NASSER MOAZZEN-AHMADI

Measures forces responsible for formation of atomic and molecular clusters. Investigates the intermolecular potential in the region of the potential minimum. Explores non-additive effects on the interaction energy and to determine possible condensation pathways. Relevant to a range of applications from atmospheric chemistry to molecular biology.

MULTISCALE MODELING OF (BIO) CHEMICAL REACTIONS IN COMPLEX ENVIRONMENTS

DR. DENNIS SALAHUB

Investigates mechanisms and rates of chemical reactions occurring in complex environments. Models enzymatic catalysis, electron transfer between proteins and/or heavy oil upgrading. Employs multiple techniques, from quantum chemistry, to molecular dynamics, to stochastic network analysis, are brought to bear on the problem in a context of High Performance Computing.



QUANTUM INFORMATION SCIENCE

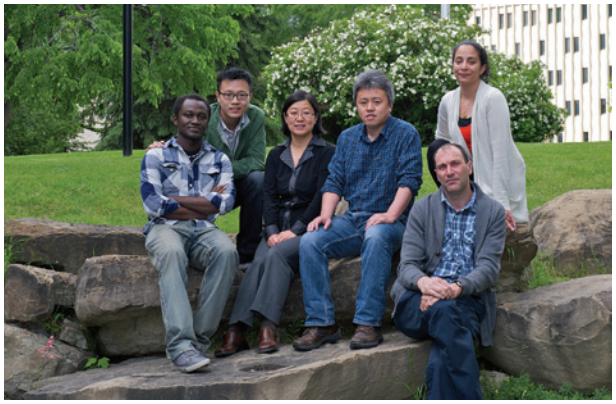
DR. BARRY SANDERS

Develops 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.

CHEMICAL VAPOR DEPOSITION CHEMISTRY

DR. YUJUN SHI

Focuses on chemical and physical processes underpinning the formation of silicon-containing semiconductor thin film materials using hot-wire chemical vapour deposition. Applies technically demanding laser ionization mass spectrometric and laser spectroscopic techniques to investigate this process at the molecular level. Explores gas-phase reaction chemistry in the formation of silicon carbide and silicon nitride and laser spectroscopy of silicon carbide clusters generated using pulsed discharge and laser ablation methods. Applications include superior-quality films for industrial applications.



THEORETICAL QUANTUM OPTICS

DR. CHRISTOPH SIMON

Applies fundamentally quantum phenomena. One application is the quantum repeater, which will be essential for long-distance quantum communication, and motivates implementations of quantum memories and of quantum gates between individual photons in various systems. Explores the quantum-classical transition such as quantum amplification of photons to macroscopic levels and controlling quantum optomechanical systems.

TRAPPED ION PHYSICS WITH ATOMS, MOLECULES, AND EXOTIC SPECIES

DR. ROBERT I. THOMPSON

Develops and measures low-density trapped atoms, molecules and exotic species, especially anti-matter Hydrogen. Collaboration with the Antihydrogen Laser Physics Apparatus (ALPHA) project at CERN involving 40 scientists across 16 institutions. Collaborates with TRIUMF's Ion Trap for Atomic and Nuclear (TITAN) Science, particularly on sympathetic and evaporative cooling.

QUANTUM CRYPTOGRAPHY AND COMMUNICATION

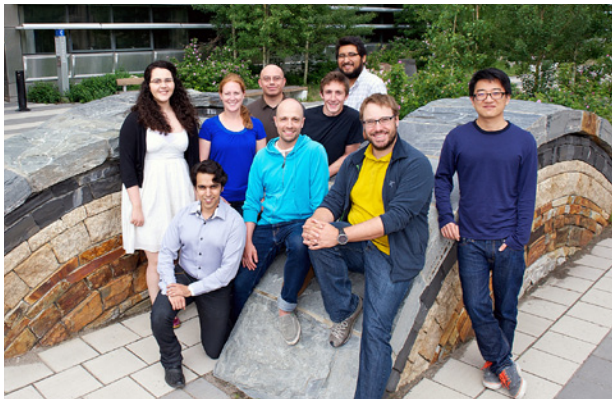
DR. WOLFGANG TITTEL

Builds 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. Develops novel techniques for practical photonic quantum communication primitives such as quantum teleportation, plus hitherto unrealized means for efficient and reversible transfer of quantum information between photons and atoms for temporal storage

NANOSCALED MATERIAL

DR. SIMON TRUDEL

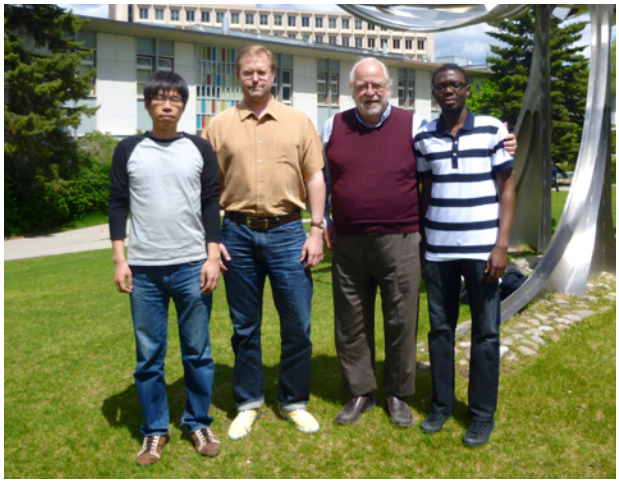
Investigates the synthesis, characterization, and structure-property relationships in inorganic solid-state nanomaterial, such as metal-oxide thin films and multimetallic nanoparticles. Develops high-performance materials in technologically and commercially relevant focus areas such as clean-energy conversion and spin-based electronics. Characterizes materials using state-of-the-art methods, such as electrochemical testing, electron microscopy, x-ray diffraction, and magnetometry based on superconducting quantum interference devices. Properties are analyzed to provide feedback for synthetic approaches for improvement.



PROBING EXCITED STATES FROM FIRST PRINCIPLES

DR. TOM ZIEGLER

Develops and applies new methods based on density functional theory describing structure and energetics of molecules in their excited state. Aims to describe photochemical processes and interpret experimental electronic spectra.



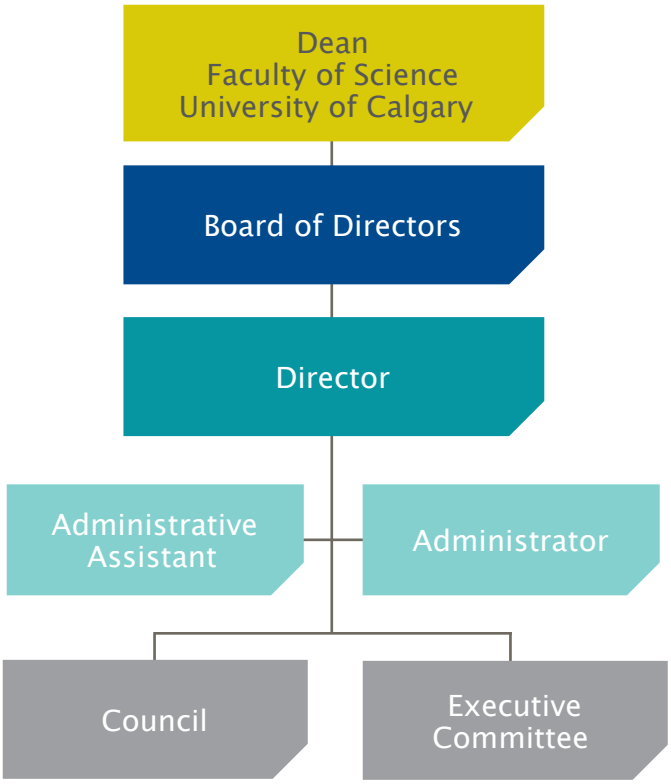
Management and Membership

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 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, Administrator and five faculty members other than the Director. The Executive meets monthly to discuss and make decisions on executive matters. The Executive receives advice and guidance from the IQST 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

Marie D'Iorio
Executive Director, National Institute for Nanotechnology (NINT)

Chip Elliott
Chief Engineer, Raytheon BBN Technologies

John Kendall
General Manager, Innovate Centres of Research Excellence (iCORE), Alberta Innovates Technology Futures (AITF)

Sir Peter Knight
Principal, The Kavli Royal Society International Centre

Sir Harold (Harry) W. Kroto
Francis Eppes Professor, Florida State University (resigned from Board October 2014)

Barry Sanders
Director, Institute for Quantum Science and Technology, University of Calgary

Carl Williams
Chief of the Quantum Measurement Division (QMD), Physical Measurement Laboratory, National Institute of Standards and Technology (NIST)

Mark Williams
Innovate Calgary

EXECUTIVE COMMITTEE

David Feder
Associate Professor, Department of Physics and Astronomy, University of Calgary

Gilad Gour
Associate Professor, Department of Mathematics and Statistics, University of Calgary

Barry Sanders
Director, Institute for Quantum Science and Technology, University of Calgary

Yujun Shi
Associate Professor, Department of Chemistry, University of Calgary

Wolfgang Tittel
Professor, Department of Physics and Astronomy, University of Calgary

Simon Trudel
Assistant Professor, Department of Chemistry, University of Calgary

COUNCIL COMMITTEE

FACULTY MEMBERS

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

Peter Høyer
Associate Professor, Department of Computer Science, University of Calgary

Peter Kusalik
Professor, Department of Chemistry, University of Calgary

Alex Lvovsky
Professor, Department of Physics and Astronomy, University of Calgary

Nasser Moazzen-Ahmadi
Professor, Department of Physics and Astronomy, University of Calgary

Dennis Salahub
Professor, Department of Chemistry, University of Calgary

Barry Sanders
Professor, Department of Physics and Astronomy, University of Calgary

Yujun Shi
Associate Professor, Department of Chemistry, 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

Wolfang Tittel
Professor, Department of Physics and Astronomy, University of Calgary

Simon Trudel
Assistant Professor, Department of Chemistry, University of Calgary

Tom Ziegler
Professor, Department of Chemistry, University of Calgary

AFFILIATE MEMBERS

David Hobill
Associate Professor, Department of Physics and Astronomy, University of Calgary

Michael Lamoureux
Professor, Department of Mathematics and Statistics, University of Calgary

Sergei Noskov
Associate Professor, Department of Biological Sciences, University of Calgary

Reginald Paul
Professor, Department of Chemistry, University of Calgary

Rei Safavi-Naini
Professor, Department of Computer Science, University of Calgary

Renate Scheidler
Professor, Department of Mathematics and Statistics, University of Calgary

Peter Tieleman
Professor, Department of Biological Sciences, University of Calgary

Richard Zach
Professor, Department of Philosophy, University of Calgary

Students

GRADUATE STUDENTS (PHD PROGRAM)

Hessa Muneef Alotaibi
Mohsen Falamarzi Askarani
Nathan Babcock (completed March 2015 → Postdoc, Simon Fraser University)
Ismail Badran (completed November 2014 → Assistant Professor, Birzeit University)
Philip Chan
Ish Dhand
Catalin Dohotaru
Raphael Dong
Carlos Enriquez-Victorero
Akihiko Fujii
Mark Girard
Kyle Hall
Chris Healey
Jeongwan Jin (completed September 2014 → Postdoc, University of Waterloo)
Hamidreza Kaviani
Behzad Khanaliloo
Mohammad Khazali
Sourabh Kumar
Hon-Wai Lau
Pascal Lefebvre
Xingchen Liu
Thomas Lutz
Armando Marenco
Itzel Lucio Martinez (completed August 2014 → Internship, ID Quantique, Geneva)
Matthew Mitchell
Farokh Mivehvar
Ali Mohandesi
Varun Narasimhachar
Ebenezer Owusu-Ansah
Pantita Palittapongarnpim
Marcel.lí Grimau Puigibert
Mojtaba Rezaei (completed October 2014 → Visiting Fellow, National Resources Canada's CANMET Energy)
Nafiseh Sang-Nourpour (co-tutelle with University of Tabriz)

GRADUATE STUDENTS (PHD PROGRAM) CONT'D

Issaka Seidu
Zahra Shaterzadeh Yazdi (completed May 2014 → Assistant Professor, University of Tehran)
Sahar Sheybani-Deloui
Neil Sinclair
Priyaa Varshinee Srinivasan
Arina Tashchilina
Dongsheng Wang
Marcelo Wu
Navid Yousefabadi
Ehsan Zahedinejad
Parisa Zarkeshian
Rui Zhang

GRADUATE STUDENTS (MSC PROGRAM)

Khulud Almutairi (completed July 2014 → PhD, University of Alberta)
Luvdeep Bandhari
John Travis Brannan (completed May 2014)
Aveek Chandra (completed August 2014 → PhD, École Normale Supérieure de Paris)
Di Chang
Chetan Deshmukh
Jennifer Emara (completed August 2014)
Jobin George
Abhirup Goswami
Daniel Hogg
Guosheng (Tom) Huo
Jonathan Johannes
Abdullah Khalid
Mahdi Yousefi Koopaee
David Lake
Hassan Mallahzadeh (completed March 2015)
Matthew Mitchell (transferred September 2014 → PhD, University of Calgary)
Eugene Moiseev
Ebenezer Owusu-Ansah (transferred May 2014 → PhD, University of Calgary)
Alireza Poostindouz
Adarsh Prasad (completed August 2014 → PhD, The Vienna Doctoral Program on Complex Quantum Systems — CoQuS)
Lohrasp Seify
Randy Squires
Venkata Ramana Raju Valivarthi
Tian Wang (completed August 2014 → PhD, Cornell University)
Weihuang Xu
Fan Yang
Luke Zhang

UNDERGRADUATE STUDENTS

Brian Andrade (PHYS 598)
Branko Bajic (Research Assistant)
Alex Cameron (PHYS 599)
Leonardo Cotta (Visiting Student)
Anna Danko (NSERC USRA & PHYS 598)
Cooper Duffin (PHYS 599)
Tobias Fischer (UNIV 402)
Modan Han (Research Assistant)
Jordan Herndier (PHYS 599)
Luis Hernandez Huerta (MITACS Globalink)
Adam Humerick (PHYS 598)
Jasper Halkjaer Jensen (PHYS 599)
Celeb John (Research Assistant)
Jessie Klein (PHYS 599)
Steven Large (NSERC USRA)
Robert Mereau (PHYS 599)
Steven Nich (PHYS 598)
Kurtis Niedling (Research Assistant)
Arlene Nijjar (Research Assistant)
Casey Platnich (CHEM 502)
Aoife Plunkette (Trans-Atlantic Science Student Exchange Program)
Mouktik Raha (MITACS Globalink)
Rafael Rebechi (Visiting Student)
Keenan Royce (PHYS 598)
Jachym Slaby (CHEM 502)
Alexander Tkalych (Research Assistant)
Wyatt Vine (CHEM 502)
Yanming Wang (MITACS Globalink)
Stephen Wein (NSERC USRA & PHYS 598)

Postdoctoral Fellows

Gabriel Aguilar
Joydip Ghosh
Lambert Giner (completed October 2014 → Postdoctoral Fellow, University of Ottawa)
Sandeep Goyal
John Patrick Hadden
Khabat Heshami (completed August 2014 → Research Associate, National Research Council Ottawa)
Aaron Hryciw
Harishankar Jayakumar (completed February 2015 → Postdoctoral Fellow, City College of New York)
Stephanie Moore
Daniel Oblak
Jalal Norooz Oliaee (completed December 2014)
Young Choon Park
Erhan Saglamyurek
Florian Senn
Joshua Slater (completed April 2014 → Postdoctoral Fellow, University of Vienna)
Lucile Veissier
Nathanael Wu
Qiang Zhou

Administration and Support

Arina Esmaeilpour (part-time, resigned March 2015)
Catherine Barrett (resigned November 2014)
Vladimir Kiselyov (part-time)
Nancy Jing Lu
Trang Pham (part-time)
Lucia Wang

Research Associates

Kristine Boone (completed February 2015)
Edelsys Codorniu-Hernández
Mykhaylo Krykunov
Rim Toukabri (completed June 2014)
Hristina Zhekova (completed April 2014)

Publications and Presentations

Refereed Journals

I. Badran and Y. J. Shi, "Promotion of exocyclic bond cleavages in the decomposition of 1,3-disilacyclobutane in the presence of a metal filament", *Journal of Physical Chemistry A* **119**(4): 590-600, 5 January 2015.

T. Brannan, Z. Qin, A. MacRae and A. I. Lvovsky, "Generation and tomography of arbitrary qubit states using transient collective atomic excitations", *Optics Letters* **39**(18): 5447-5450, 15 September 2014.

P. Chan, J. A. Slater, I. Lucio-Martinez, A. Rubenok and W. Tittel, "Modeling a measurement-device-independent quantum key distribution system", *Optics Express* **22**(11): 12716-12736 , 2 June 2014.

P. Chan, I. Lucio-Martinez, X. F. Mo, C. Simon and W. Tittel, "Performing private database queries in a real-world environment using a quantum protocol", *Scientific Reports* **4**: 5233 (7 pp.), 10 June 2014.

E. Codorniu-Hernández, K. Wm. Hall, D. Ziemianowicz, S. Carpendale and P. G. Kusalik, "Aqueous production of oxygen atoms from hydroxyl radicals", *Physical Chemistry Chemical Physics* **16**(47): 26094-26102, 22 October 2014.

H. de Guise, S.-H. Tan, I. P. Poulin and B. C. Sanders, "Coincidence landscapes for three-channel linear optical networks", *Physical Review A* **89**(6): 063819 (16 pp.), 23 June 2014.

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T. Decker, P. Høyer, G. Ivanyos and M. Santha, "Polynomial time quantum algorithms for certain bivariate hidden polynomial problems", *Quantum Information and Computation* **14**(91): 796-806, 1 July 2014.

I. Dhand and B. C. Sanders, "Stability of the Trotter-Suzuki decomposition", *Journal of Physics A: Mathematical and Theoretical* **47**(26): 265206 (15 pp.), 17 June 2014.

H. Dittmar and P. G. Kusalik, "Driving ordering processes in molecular-dynamics simulations", *Physical Review Letters* **112**(18): 195701 (5 pp.), 12 May 2014.

H. El-Sayed, C. Horwood, E. Owusu-Ansah, Y. J. Shi and V. I. Birss, "Gold nanoparticle array formation on dimpled Ta templates using pulsed laser-induced thin film dewetting", *Physical Chemistry Chemical Physics* **17**(11): 11062-11069, 16 March 2015.

L. Evangelisti, C. Perez, N. A. Seifert, B. H. Pate, M. Dehghany, N. Moazzen-Ahmadi and A. R. W. McKellar, "Theory vs. experiment for molecular clusters: Spectra of OCS trimers and tetramers", *Journal of Chemical Physics* **142**(10): 104309 (11 pp.), 12 March 2015.

I. A. Fedorov, A. E. Ulanov, Y. Kurochkin and A. I. Lvovsky, "Quantum vampire: collapse-free action at a distance by the photon annihilation operator", *Optica* **2**(2): 112-115, 2 February 2015.

J. George, A. R. W. McKellar and N. Moazzen-Ahmadi, "Infrared spectra of He-, Ne-, and Ar-C_6D_6", *Chemical Physics Letters* **610-611**: 121-124, 28 August 2014.

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J. Ghosh and A. Fowler, "Leakage-resilient approach to fault-tolerant quantum computing with superconducting elements", *Physical Review A* **91**(2): 020302(R) (5 pp.), 20 February 2015.

G. Gour and A. Kalev, "Construction of all general symmetric informationally complete measurements", *Journal of Physics A: Mathematical and Theoretical* **47**(33): 335302 (14 pp.), 4 August 2014.

B. He, A.V. Sharypov, J. Sheng, C. Simon and M. Xiao, "Two-photon dynamics in coherent Rydberg atomic ensemble", *Physical Review Letters* **112**(13): 133606 (5 pp.), 4 April 2014.

K. Heshami, C. Santori, B. Khanaliloo, C. Healey, V. M. Acosta, P. E. Barclay and C. Simon, "Raman quantum memory based on an ensemble of nitrogen-vacancy centers coupled to a microcavity", *Physical Review A* **89**(4): 040301(R) (5 pp.), 7 April 2014.

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M. Khazali, K. Heshami and C. Simon, "Photon-photon gate via the interaction between two collective Rydberg excitations", *Physical Review A* **91**(3): 030301(R) (5 pp.), 17 March 2015.

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X. Liu and R. Salahub, "Molybdenum carbide nanocatalysts at work in the in-situ environment: a DFTB and QM(DFTB)/MM study", *Journal of the American Chemical Society* **137**(12): 4249–4259, 16 March 2015.

M. Manjappa, S. S. Undurti, A. Karigowda, A. Narayanan and B. C. Sanders, "Effects of temperature and ground-state coherence decay on enhancement and amplification in a Delta atomic system", *Physical Review A* **90**(4): 043859 (6 pp.), 30 October 2014.

M. J. Mitchell, A. C. Hryciw and P. E. Barclay, "Cavity optomechanics in gallium phosphide microdisks", *Applied Physics Letters* **104**(14): 141104 (5 pp.), 9 April 2014.

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N. Moazzen-Ahmadi, A. R. W. McKellar, B. Fernandez and D Farrelly, "The infrared spectrum of the He-C_2D_2 complex", *Journal of Chemical Physics* **142**(8): 084312 (9 pp.), 26 February 2015.

C. de Oliviera, D. R. Salahub, H. de Abreu and H. A. Duarte, "Native defects in α-Mo_2C: Insights from first-principles calculations", *Journal of Physical Chemistry C* **118**(44): 25517–25524, 9 October 2014.

H. Qin, B. He, R. Ghobadi and C. Simon, "Fully quantum approach to optomechanical entanglement", *Physical Review A* **90**(2): 022309 (10 pp.), 11 August 2014.

M. Rezaei, J. George, L. Welbanks and N. Moazzen-Ahmadi, "Fundamental and combination bands of CO_2-C_2H_2 and CO_2-C_2D_2 in the mid-infrared region", *Molecular Physics* **112**(18): 2445–2450, 29 April 2014.

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D. R. Salahub, S. Y. Noskov, B. Lev, R. Zhang, V. Ngo, A. Goursot, P. Calaminici, A. M. Köster, A. Alvarez-Ibarra, D. Mejía-Rodríguez, J. Řezáč, F. Cailliez and A. de la Lande, "QM/MM calculations with deMon2k", *Molecules* **20**(3): 4780–4812, 16 March 2015.

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S. Sheybani-Deloui, M. Y. Koopaee, J. Norooz Oliaee, A. R. W. McKellar and N. Moazzen-Ahmadi, "Observation of mixed acetylene-nitrous oxide trimers: Infrared spectra of C_2H_2-$(N_2O)_2$ and $(C_2H_2)_2$-N_2O", *Journal of Molecular Spectroscopy* **306**: 6–10, 13 October 2014.

Y. J. Shi, "Hot wire chemical vapor deposition chemistry in the gas phase and on the catalyst surface with organonsilicon compound", *Accounts of Chemical Research* **48**(2): 163–173, 14 January 2015.

N. Sinclair, E. Saglamyurek, H. Mallahzadeh, J. A. Slater, M. George, R. Ricken, M. Hedges, D. Oblak, C. Simon, W. Sohler and W. Tittel, "Spectral multiplexing for scalable quantum photonics using an atomic frequency comb quantum memory and feed-forward control", *Physical Review Letters* **113**(5): 053603 (5 pp.), 29 July 2014.

M. Skotiniotis, B. Toloui, I. T. Durham and B. C. Sanders, "Quantum resource theory for charge-parity-time inversion", *Physical Review A* **90**(1): 012326, 18 July 2014.

J. A. Slater, C. Branciard, N. Brunner and W. Tittel, "Device-dependent and device-independent quantum key distribution without a shared reference frame", *New Journal of Physics* **16**(4): 043002 (20 pp.), 3 April 2014.

R. D. L. Smith, S. Trudel and C. P. Berlinguette, "Photochemical route for the preparation of complex amorphous water oxidation catalysis", *ECS Transactions* **58**(45): 67-76, 16 April 2014.

C. W. Thiel, R. M. Macfarlane, Y. Sun, T. Böttger, N. Sinclair, W. Tittel and R. L. Cone, "Measuring and analyzing excitation-induced decoherence in rare-earth-doped optical materials", *Laser Physics* **24**(10): 106002 (15 pp.), 5 August 2014.

C. W. Thiel, N. Sinclair, W. Tittel and R. L. Cone, "Optical decoherence studies of Tm^{3+}:$Y_3Ga_5O_{12}$", *Physical Review B* **90**(21): 214301 (7 pp.), 1 December 2014.

C. W. Thiel, N. Sinclair, W. Tittel and R. L. Cone, "Tm^{3+}: $Y_3Ga_5O_{12}$ materials for spectrally multiplexed quantum memories", *Physical Review Letters* **113**(16): 160501 (5 pp.), 13 October 2014.

R. Toukabri and Y. J. Shi, "Effect of pressure on the gas-phase chemistry when using MMS and DMS in hot-wire chemical vapor deposition", *Canadian Journal of Chemistry* **93**(1): 82-90, 17 July 2014.

R. Toukabri and Y. J. Shi, "Dominance of silylene chemistry in the decomposition of monomethylsilane in the presence of a heated metal filament", *Journal of Physical Chemistry A* **118**(12): 3866-3874, 12 May 2014.

C. Trail, K. Almutairi, D. L. Feder and B. C. Sanders, "Nonlinear phase shifts of light trapped in a two-component Bose-Einstein condensate", *Physical Review A* **89**(6): 063823 (8 pp.), 26 June 2014.

V. R. R. Valivarthi, I. Lucio-Martinez, A. Rubenok, P. Chan, F. Marsili, V. B. Verma, M. D. Shaw, J. A. Stern, J. A. Slater, D. Oblak, S. W. Nam and W. Tittel, "Efficient Bell state analyzer for time-bin qubits with fast-recovery WSi superconducting single photon detectors", *Optics Express* **22**(20): 24497-24506, 6 October 2014.

D.-S. Wang, "Weak, strong, and uniform quantum simulations", *Physical Review A* **91**(1): 012334 (7 pp.), 23 January 2015.

M. Wu, A. C. Hryciw, C. Healey, D. Lake, H. Jayakumar, M. R. Freeman, J. P. Davis and P. E. Barclay, "Dissipative and dispersive optomechanics in a nanocavity torque sensor", *Physical Review X* **4**(2): 021052 (11 pp.), 19 June 2014.

P. Xue, H. Qin, B. Tang and B. C. Sanders, "Observation of quasiperiodic dynamics in a one-dimensional quantum walk of single photons in space", *New Journal of Physics* **16**(5): 053009 (10 pp.), 6 May 2014.

E. Zahedinejad, S. Schirmer and B. C. Sanders, "Evolutionary algorithms for hard quantum control", *Physical Review A* **90**(3): 032310 (9 pp.), 8 September 2014.

R. Zhang, A. Bhattacharjee, M. J. Field and D. R. Salahub, "Multiple proton relay routes in the reactionmechanism of RNAP II: Assessing the effect of structural model", *Proteins* **83**(2): 268-281, 18 December 2014.

H. R. Zhekova, M. Krykunov, J. Autschbach and T. Ziegler, "Applications of time dependent and time independent density functional theory to the first π to π* transition in cyanine dyes", *Journal of Chemical Theory and Computation* **10**(8): 3299-3307, 9 June 2014.

T. Ziegler, M. Krykunov and J. Audretsch, "Derivation of the RPA (Random Phase Approximation) equation of ATDDFT (Adiabatic Time Dependent Density Functional Ground State Response Theory) from an excited state variational approach based on the ground state functional", *Journal of Chemical Theory and Computation* **10**(9): 3980-3986, 15 July 2014.

Conference Proceedings

T. Hill, B. C. Sanders and H. Deng, "The general solution of cooperative emission in arbitrary dimension", Proceedings of OSA Frontiers in Optics Laser Science (FiO/LS) **286**(3), Tucson, United States of America, 19 Oct 2014–23 Oct 2014, published by Optical Society of America.

X. Liu and D. R. Salahub, "Molybdenum carbide nanoparticles as catalysts for hydrogenation reactions, between the cluster and bulk perspectives", Proceedings of 14th International Conference on Computational and Mathematical Methods in Science and Engineering (2014 CMMSE), Cadiz, Spain, 3 Jul 2014–7 Jul 2014.

Book Chapters

A. Alvarez-Ibarra, P. Calaminici, A. Goursot, C. Z. Gómez-Castro, R. Grande-Aztatzi, T. Mineva, D. R. Salahub, J. M. Vásquez-Pérez, A. Vela, B. Zuniga-Gutierrez and A. M. Köster, "First principles computational biochemistry with deMon2k", section in book: *Frontiers in Computational Chemistry (eBook)*, Zaheer ul Haq, J. D. Madura, eds.: volume **1**: 281–325, published by Bentham Science Publishers in 2015.

P. E. Barclay, "Principles of quantum information processing (QIP) using diamond", section in book: *Quantum Information Processing with Diamond: Principles and Applications*, Steven Prawer, Igor Aharonovich, eds.: Chapter Part **1**: 3–20, published by Woodhead Publishing in 2014 (Series in Electronic and Optical Materials).

A. de la Lande, D. R. Salahub and A. M. Köster, "Extending the domain of constrained Density Functional Theory to large molecular systems", section in book: *Concepts and Methods in Modern Theoretical Chemistry: Electronic Structure and Reactivity*, Swapan Kumar Ghosh, Pratim Kumar Chattaraj, eds.: 201–219, published by CRC Press in 2014 (Book Series: Atoms, Molecules, and Clusters).

A. I. Lvovsky, "Squeezed light", section in book: *Photonics Volume 1: Fundamentals of Photonics and Physics*, D. Andrews, eds.: Chapter **5**: 121–164, published by Wiley in 2015.

Invited Conference/Workshop Presentations

(presenter is underlined)

3 Apr 2014, P. G. Kusalik, "Molecular simulations of crystallization: past, present and future", CECAM Workshop from Atoms to Clouds: Bridging the gap between atomistic simulation, surface science, atmospheric observation and climate modelling, Zurich, Switzerland, 2 Apr 2014–4 Apr 2014.

8 Apr 2014, B. C. Sanders, "BosonSampling with controllable distinguishability of photons" (keynote), Mini Workshop on the Frontiers of Quantum Information, Guelph, Canada, 8 Apr 2014–8 Apr 2014.

28 Apr 2014, D. R. Salahub, "deMon, quo vadis?", 14th Demon Developers Workshop, Los Cabos, Mexico, 27 Apr 2014–30 Apr 2014.

28 May 2014, E. Saglamyurek, N. Sinclair, J. A. Slater, K. Heshami, D. Oblak and W. Tittel, "An integrated processor for photonic quantum states using a broadband light-matter interface", Photonics North 2014, Montreal, Canada, 28 May 2014–30 May 2014.

29 May 2014, Z. Qin, A. S. Prasad, T. Brannan, A. MacRae, A. Lezama and A. I. Lvovsky, "Measuring the temporal wave function of a photon", Photonics North 2014, Montreal, Canada, 28 May 2014–30 May 2014.

30 May 2014, I. A. Fedorov, A. K. Fedorov, Y. Kurochkin and A. I. Lvovsky, "Multimode quantum black-box characterization", 4th Workshop ad memoriam of Carlo Novero: Advances in Foundations of Quantum Mechanics and Quantum Information with Atom and Photons, Turin, Italy, 26 May 2014–30 May 2014.

6 Jun 2014, B. C. Sanders, "A dash of adiabaticity, a pinch of permanents and a smidgeon of simulation for an interdisciplinary quantum information", CIFAR Quantum Information Science Program Meeting (QIP), Auberge Duchesnay, Sainte-Catherine-de-la-Jacques-Cartier, Canada, 3 Jun 2014–6 Jun 2014.

13 Jun 2014, C. Simon, "Extending the quantum domain with quantum optical systems", Theory Canada 9, Waterloo, Canada, 12 Jun 2014–15 Jun 2014.

26 Jun 2014, D. R. Salahub, "Multiscale modeling of chemical reactions in complex environments", High Performance Computing Symposium (HPCS 2014), Halifax, Canada, 25 Jun 2014–27 Jun 2014.

30 Jun 2014, G. Gour, "Towards a complete classification of multipartite entanglement", 2nd Seefeld Workshop on Quantum Information, Seefeld, Tyrol, Austria, 29 Jun 2014–4 Jul 2014.

30 Jun 2014, T. Ziegler, "Understanding complex calculations on large molecules in simple chemical terms", 15th International Conference on Theoretical Aspects of Catalysis (ICTAC15), London, United Kingdom, 30 Jun 2014–4 Jul 2014.

3 Jul 2014, X. Liu and D. R. Salahub, "Molybdenum carbide nanoparticles as catlalysts for hydrogenation reactions, between the cluster and bulk perpsectives", 14th International Conference Computational and Mathemacital Methods in Science and Engineering (2014 CMMSE), Rota, Cadiz, Spain, 3 Jul 2014–7 Jul 2014.

10 Jul 2014, G. Gour, "Towards a complete classification of multipartite entanglement", International Conference "Mathematics Days in Sofia", Sofia, Bulgaria, 7 Jul 2014–10 Jul 2014.

11 Jul 2014, P. G. Kusalik, "Molecular simulations of the crystallization of ice and gas hydrates", 26th Canadian Symposium on Theoretical and Computational Chemistry, Montreal, Canada, 6 Jul 2014–11 Jul 2014.

11 Jul 2014, T. Ziegler, "Constricted variational density functional theory. A new approach to the study of excited states", 26th Canadian Symposium on Theoretical and Computational Chemistry, Montreal, Canada, 6 Jul 2014–11 Jul 2014

14 Jul 2014, I. A. Fedorov, A. K. Fedorov, Y. Kurochkin and A. I. Lvovsky, "Quantum optical process tomography for the multimode case", 23rd International Laser Physics Workshop (LPHYS'14), Sofia, Bulgaria, 14 Jul 2014–18 Jul 2014.

14 Jul 2014, E. Saglamyurek, N. Sinclair, J. A. Slater, K. Heshami, D. Oblak and W. Tittel, "An integrated processor for photonic quantum states using a broadband light–matter interface", 23rd International Laser Physics Workshop (LPHYS'14), Sofia, Bulgaria, 14 Jul 2014–18 Jul 2014.

14 Jul 2014, C. W. Thiel, N. Sinclair, W. Tittel and R. L. Cone, "Spectroscopic investigation of Tm:YGG for optical quantum memory", 23rd International Laser Physics Workshop (LPHYS'14), Sofia, Bulgaria, 14 Jul 2014–18 Jul 2014.

14 Jul 2014, W. Tittel, "How to catch a photon", 2nd Alberta Quantum–Nano Workshop, Red Deer, Canada, 14 Jul 2014.

17 Aug 2014, X. Liu and D. R. Salahub, "Molybdenum carbide nanoparticles as catlalysts for hydrogenation reactions, between clusters and the bulk", XXIII International Materials Research Congress, Cancun, Mexico, 17 Aug 2014–21 Aug 2014.

20 Aug 2014, A. S. Prasad, Z. Qin, T. Brannan, A. I. Lvovsky, A. MacRae and A. Tashchilina, "Complete temporal characterization of single photons", SPIE Optics and Photonics 2014, San Diego, United States of America, 16 Aug 2014–21 Aug 2014.

5 Sep 2014, E. Saglamyurek, J. Jin, V. B. Verma, M. D. Shaw, F. Marsili, S. W. Nam, D. Oblak and W. Tittel, "Storage of entangled telecom–wavelength photons in an Er–doped optical fibre", 4th International Conference on Quantum Cryptography (Qcrypt 2014), Paris, France, 1 Sep 2014–5 Sep 2014.

9 Sep 2014, W. Tittel, "How to build a quantum repeater", Workshop on Quantum Non–Locality (GISIN'14), Riederalp, Switzerland, 8 Sep 2014–12 Sep 2014.

6 Oct 2014, D. R. Salahub, "Towards the multiscale modeling of chemical reactions in complex environments", 10th Congress of the World Association of Theoretical and Computational Chemists (WATOC 2014), Santiago, Chile, 5 Oct 2014–10 Oct 2014.

10 Oct 2014, T. Ziegler, "Constricted variational density functional theory. New Developments", 10th Triennial Congress of the World Association of Theoretical and Computational Chemists (WATOC 2014), Santiago, Chile, 5 Oct 2014–10 Oct 2014.

15 Oct 2014, P. G. Kusalik, "Molecular simulations of crystallization of ice and gas hydrates", Nordita Workshop: Water – the Most Anomalous Liquid, Stockholm, Sweden, 13 Oct 2014–7 Nov 2014.

18 Nov 2014, Z. Qin, A. S. Prasad, T. Brannan, A. MacRae, A. Lezama and A. I. Lvovsky, "A complete measurement of the photons' waveform", XII International Scientific and Technical Conference "Optical Technologies in Telecommunications — 2014" (OTT 2014), Kazan, Russia, 19 Nov 2014–21 Nov 2014.

26 Feb 2015, B. C. Sanders, "Quantum simulation of micro and macro frustrated quantum magnetism", Benasque Workshop on Quantum Simulations, 22 Feb 2015–27 Feb 2015.

12 Mar 2015, C. Simon, "Quantum memories and QND detectors for quantum repeaters", Second Workshop on Scalable Information Processing with Quantum Nano-Photonics (SIPQNP), Cambridge, United States of America, 12 Mar 2015-13 Mar 2015.

12 Mar 2015, B. C. Sanders, "Accurate and precise characterization of linear optical interferometers", Second Workshop on Scalable Information Processing with Quantum Nano-Photonics (SIPQNP), Cambridge, Massachusetts, United States of America, 12 Mar 2015-13 Mar 2015.

21 Mar 2015, D. R. Salahub and X. Liu, "Molybdenum carbide nanoparticles as catalysts for oil sands upgrading: dynamics and free-energy profiles", 11th International Conference on Computational Methods in Science and Engineering (ICCMSE 2015), Athens, Greece, 20 Mar 2015-23 Mar 2015.

Student Theses

K. Almutairi, "On optical self-phase modulation via collective atomic excitation in a Bose-Einstein condensate" (MSc Thesis), 1 July 2014.

I. Badran, "Hot wire chemical vapor deposition chemistry and kinetics of new precursors in the gas phase and on the wire surface" (PhD Thesis), 1 December 2014.

T. Brannan, "Engineering atomic and optical quantum states using four-wave mixing" (MSc Thesis), 1 May 2014.

A. Chandra, "Tapered optical nanofiber for light-atom interfacing" (MSc Thesis), 1 Aug 2014.

J. Emara, "Thermolysis route for accessing amorphous metal sulfide thin-film catalysts for the hydrogen evolution reaction" (MSc Thesis), 1 Aug 2014.

J. George, "Infrared spectroscopy of C_6D_6- Rgn (n= 1, 2)" (MSc Thesis), 1 Jan 2015.

J. Jin, "Photonic entanglement for a quantum repeater" (PhD Thesis), 1 Jul 2014.

M. Y. Koopaee, "Infrared spectroscopy of CS_2 and C_2D_2 binary and ternary complexes" (MSc Thesis), 1 Mar 2015.

I. Lucio-Martinez, "Real world quantum cryptography" (PhD Thesis), 1 Aug 2014.

H. Mallahzadeh, "Cavity-enhanced waveguide quantum memory" (MSc Thesis), 1 Jan 2015.

A. S. Prasad, "Complete temporal characterization of single photons" (MSc Thesis), 1 Sep 2014.

M. Rezaei, 'High-resolution pulsed slit jet spectrometer with QCL and OPO probes for infrared spectroscopy on van der Waals clusters" (PhD Thesis), 1 Oct 2014.

Z. Shaterzadeh-Yazdi, "Coherence of coupled dangling-bond pairs on the silicon surface" (PhD Thesis), 1 Apr 2014.

T. Wang, "Macroscopic quantum effects based on Kerr nonlinearities" (MSc Thesis), 1 Sep 2014.

Linkage

Collaboration

INTERNATIONAL INSTITUTIONS

California Institute of Technology, United States of America

Centro de Investigación y de Estudios Avanzados del Instituto Politécnico Nacional (CINVESTAV), Mexico

Centre National de la Recherche Scientifique (CNRS) – Orsay, Montpellier & Grenoble), France

City University of New York, United States of America

College of William and Mary, United States of America

Czech Academy of Science, Czech Republic

East China Normal University, People's Republic of China

Eötvös Loránd University, Hungary

Haverford College, United States of America

Huaqiao University, People's Republic of China

Institut de Biologie Structurale, France

Jacobs University, Germany

Kirensky Institute of Physics, Russia

Macquarie University, Australia

Montana State University, United States of America

Moscow Institute of Physics and Technology, Russia

Nanjing University, People's Republic of China

National Institute for Standards and Technology, United States of America

National University of Technology and Science, Pakistan

P. N. Lebedev Physical Institute of the Russian Academy of Science, Russia

Raman Research Institute, India

Saint Anselm College, United States of America

Shanghai Jiaotong University, People's Republic of China

Siberian Federal University, Russia

Singapore University of Technology and Design, Singapore

Southeast University, People's Republic of China

Swansea University, United Kingdom

The Russian Quantum Centre, Russia

Universität Innsbruck, Austria

Universität Paderborn, Germany

Universität Potsdam, Germany

Université de Genève, Switzerland

Université Paris-Sud, France

Universidad de la República, Uruguay

Universidade Federal de Minas Gerais, Brazil

Universidade Federal de São João del-Rei, Brazil

University College Dublin, Ireland

University of Arkansas, United States of America

University of Bologna, Italy

University of Bristol, United Kingdom

University of California at Berkeley, United States of America

University of California at San Diego, United States of America

University of California at Santa Barbara, United States of America

University of Chicago, United States of America

University of Melbourne, Australia

University of New Mexico, United States of America

University of Queensland, Australia

University of Santiago de Compostela, Spain

University of San Francisco, United States of America

University of Science and Technology of China, People's Republic of China

University of South Dakota, United States of America

University of Vienna, Austria

University of Virginia, United States of America

University of Wisconsin Madison, United States of America

Utah State University, United States of America

Vienna University of Technology, Austria

CANADIAN INSTITUTIONS

Lakehead University

National Institute for Nanotechnology

National Research Council of Canada Ottawa

TRIUMF

University of Alberta

University of British Columbia

INDUSTRY & GOVERNMENT

Battelle

BBN Raytheon Technologies

City of Calgary

ComDev

Hewlett-Packard Laboratories

IBM Almaden Research Center

UNIVERSITY OF CALGARY

Institute for Security, Privacy and Information Assurance

Visitors

NAME	INSTITUTION NAME
Ian Affleck	University of British Columbia
Mike Ashfold	University of Bristol
Eun-Ok Bae	Kyung Hee University
John Bartholomew	Australian National University
Louise Budzynski	École Normale Supérieure de Paris
Leonardo Cotta	Universidade Federal De Minas Gerais
Saurya Das	University of Lethbridge
Timothy DeWolf	University of Victoria
Thomas Harold Dunning	University of Illinois at Urbana-Champaign
Mariagrazia Fortino	University of Calabria
Akihiko Fujii	University of Waterloo
Fred Fung	Huawei Technologies Co. Ltd.
Mercedes Gimeno-Segovia	Imperial College London
Roohollah Ghobadi	Vienna University of Technology
Jiyuan Guo	Jiangsu University of Science and Technology
Daniel Hogg	McGill University
Ramakanth Illa	Technical University of Ostrava
Zubin Jacob	University of Alberta
Jakub Jadwiszczak	University of Dublin
Sajeev John	University of Toronto
Katanya Brianne Kuntz	University of New South Wales
Raymond W. K. Leung	Huawei Technologies Co. Ltd.
Wenqing Li	Jacobs University
Kenzo Makino	University of Tokyo
Tamiko Masuda	University of British Columbia
Christopher Monroe	University of Maryland
Casey Myers	The University of Queensland
Andal Narayanan	Raman Research Institute
Charles Neill	University of California at Santa Barbara
Bruno Neto	Universidade Federal do Estado do Rio de Janeiro (UNIRIO)
Lee Oesterling	Battelle
Mouktik Raha	Indian Institute of Technology, Kharagpur
Robert Raußendorf	University of British Columbia
Rafael Rebechi	Universidade Estadual de Campinas
Hyan da Silva Cardoso dos Santos	Bahia Federal Institute of Education, Science and Technology
Priyaa Varshinee Srinivasan	University of Waterloo
Yanming Wang	Tongji University
Carl Williams	National Institute of Standards and Technology
William Wooters	Williams College
Allen (Xinhua) Xiao	Huawei Technologies Co. Ltd.
Weiwei Zhang	Beijing University of Posts and Telecommunications

Teaching, Training and Education

Quantum Information Graduate Courses

COURSE NAME	INSTRUCTOR	DESCRIPTION
PHYS 673 Quantum and Nonlinear Optics	P. E. Barclay	Fundamentals of quantum and nonlinear optics including atom-photon interactions, coherence, electromagnetically induced transparency, open systems and decoherence, and applications to quantum information technology.
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 code, quantum cryptography, nonlocality and quantum communication complexity, and quantum computational complexity.
PHYS 677 Implementation of Quantum Information	B. C. Sanders	Proposals and realizations of quantum information tasks including quantum computation, quantum communication, and quantum cryptography in optical, atomic, molecular, and solid state systems.
CHEM 689 Modeling Multi-scale Systems	D. R. Salahub	The course will build on a basic knowledge of classical and quantum mechanics to explore modern methods of simulating complex systems in chemistry, physics, biology and materials science. The student will acquire an understanding of the main approaches in quantum chemistry, molecular dynamics and the kinetics of coupled systems of chemical equations (e.g. the Kinetic Monte Carlo method). Hands-on experience with some of the techniques will be obtained and the student will be able to taylor the applications to his or her areas of interest, for example, heterogeneous, homogeneous or enzymatic catalysis, genetic regulatory networks, integrated nano-systems, etc.
CHEM 627 Theoretical Inorganic Chemistry	T. Ziegler	Aspects of theoretical inorganic and organometallic chemistry including: quantitative and qualitative molecular orbital theory; the bonding and structure of molecules, clusters, and extended arrays; the fragments of organometallic species; orbital correlation diagrams in inorganic reactions; spectroscopic methods and their interpretation.

Services and Outreach

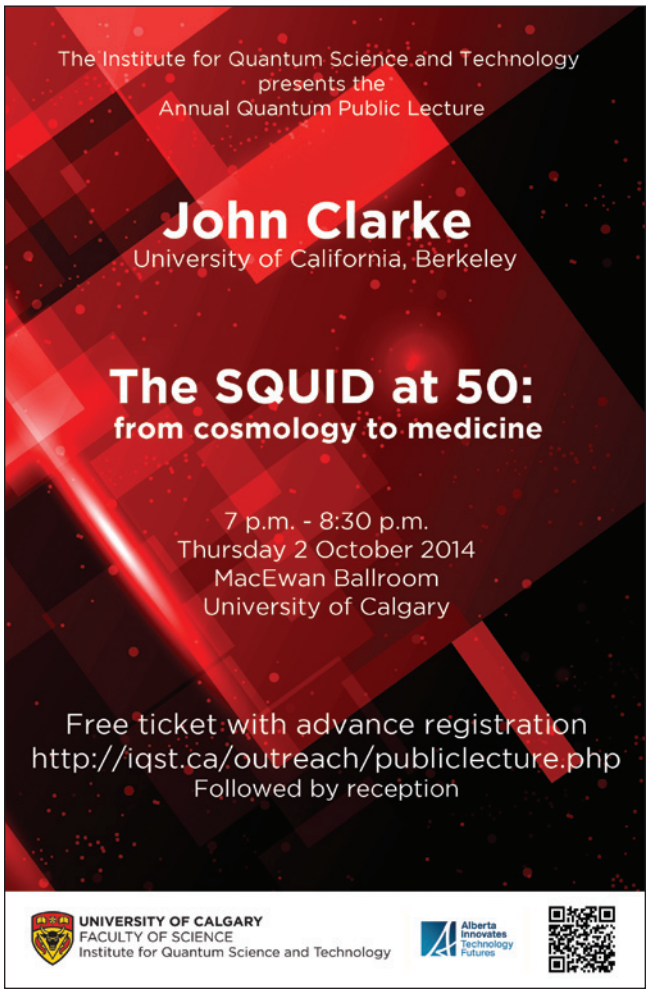
Conferences

MEMBER(S)	COMMITTEE	CONFERENCE/ WORKSHOP	LOCATION	DATES
B. C. Sanders	Chair, Organizing Committee	The 19th Conference on Quantum Information Processing (QIP2016)	Banff, Canada	10–16 Jan 2016
B. C. Sanders	Chair, Organizing Committee	Workshop on Multi-Photon Interferometry (MPI 2015)	Shanghai, P. R. China	7–10 May 2015

Professional Services

NAME	ROLE	JOURNAL/SOCIETY/INSTITUTION
P. G. Kusalik	Chair, Chemistry/Biochemist Resource Allocation Committee	Compute Canada
A. I. Lvovsky	Associate Editor	*Optics Express*
A. I. Lvovsky	Member, Scientific Committee	The Russian Quantum Center
D. R. Salahub	Member, Editorial Board	*Advances in Physical Chemistry*
D. R. Salahub	Member, Editorial Board	*Advances in Quantum Chemistry*
D. R. Salahub	Co-chair, Editorial Board	*Interdisciplinary Science: Computational Life Science*
D. R. Salahub	Member, Editorial Board	*Journal of Computational Chemistry*
D. R. Salahub	Member, Editorial Board	*PLOS-One*
B. C. Sanders	Member, Editorial Board	IOP ebooks™
B. C. Sanders	Member, Editorial Board	*Mathematical Structures in Computer Science*
B. C. Sanders	Associate Editor	*Physical Review A*
B. C. Sanders	Chair, Steering Committee	QIP Conference Series
B. C. Sanders	Chair	Quantum Africa Conference Series
Y. J. Shi	Associate Editor	*Canadian Journal of Chemistry*
R. I. Thompson	Director, Student Affairs	Canadian Association of Physicists
R. I. Thompson	Secretary-Treasurer, Division of Atomic, Molecular and Optical Physics	Canadian Association of Physicists
R. I. Thompson	Member, Editorial Board	*Physics in Canada*
R. I. Thompson	University of Calgary Representative	TRIUMF Board of Management
R. I. Thompson	Member, Board of Governors	University of Calgary
S. Trudel	Secretary, Materials Division	Canadian Society for Chemistry

Annual Quantum Public Lecture



Each year the Institute holds a Quantum Public Lecture, which has been sponsored by Alberta Innovates Technology Futures. In 2014, about 200 participants enjoyed John Clarke's wonderful lecture titled "The SQUID at 50: from cosmology to medicine". Professor Clarke is a fellow of the Royal Society of London, the American Physical Society, the American Association for the Advancement of Science, and the Institute of Physics (UK). He has been a Sloan Foundation Fellow, a Guggenheim Fellow and a Miller Professor. In 1987, he was named California Scientist of the Year and was awarded the Fritz London Prize for research in low-temperature physics. In 1998, he received the American Physical Society's Joseph F. Keithley Award for Advances in Measurement Science and, in 1999, the National Academy of Sciences' Comstock Prize for Physics. He was awarded the Hughes Medal of the Royal Society in 2004, and was the UC Berkeley Faculty Research Lecturer in 2005.

Media Coverage

SOURCE	TITLE OF ARTICLE	LOCATION	DATE
REACH	How to build a quantum computer: Barry C. Sanders	pp. 8–14	1 Apr 2014
UToday	Discovery opens door to efficiently storing and reusing renewable energy: Simon Trudel, Curtis Berlinguette	online	1 Apr 2014
Physorg.com	Micro–macro entangled 'cat states' could one day test quantum gravity: Roohollah Ghobadi, Christoph Simon	online	16 Apr 2014
UToday	New regional council to strengthen university's ties in the Middle East: Barry C. Sanders	online	7 May 2014
Telegraph India	Indians attempt quantum clean-up — experiment to right old error: Barry C. Sanders	online	24 Aug 2014
Physics	Focus: Curvy photo trajectories could be detectable: Barry C. Sanders	online	19 Sep 2014
UToday	The SQUID at 50: Renowned physicist John Clarke on campus	online	2 Oct 2014
MIT Technology Review	How entanglement-generating satellites will make the quantum internet global : Kristine Boone, Christoph Simon	online	30 Oct 2014
UToday	President hosts first Celebration of Entrepreneurship and Innovation: Simon Trudel	online	14 Nov 2014
CIFAR	CIFAR hosts prominent Chinese scientists at QIS meeting: Barry C. Sanders	online	12 Dec 2014
UToday	Advances in quantum internet moving at light speed: Wolfgang Tittel, Daniel Oblak, Erhan Saglamyurek	online	5 Feb 2015
CBC News	Chemist Axel Becke wins $1M Herzberg Medal: Alex Becke, Dennis Salahub	online	17 Feb 2015
Globe and Mail	Dalhousie chemist awarded top Canadian science prize: Tom Ziegler	online	17 Feb 2015
Physicsworld.com online	Two quantum properties teleported together for first time: Wolfgang Tittel	online	27 Feb 2015
NSERC (Success Stories)	Creating quantum computer networks: Wolfgang Tittel	online	1 Mar 2015
ScienceNews	Physicists double their teleportation power: Wolfgang Tittel	online	21 Mar 2015

Outreach Lectures

15 May 2014, A. I. Lvovsky, "Light as an object of quantum technology", Eureka!Fest, Novosibirsk, Russia, 15 May–18 May 2014.

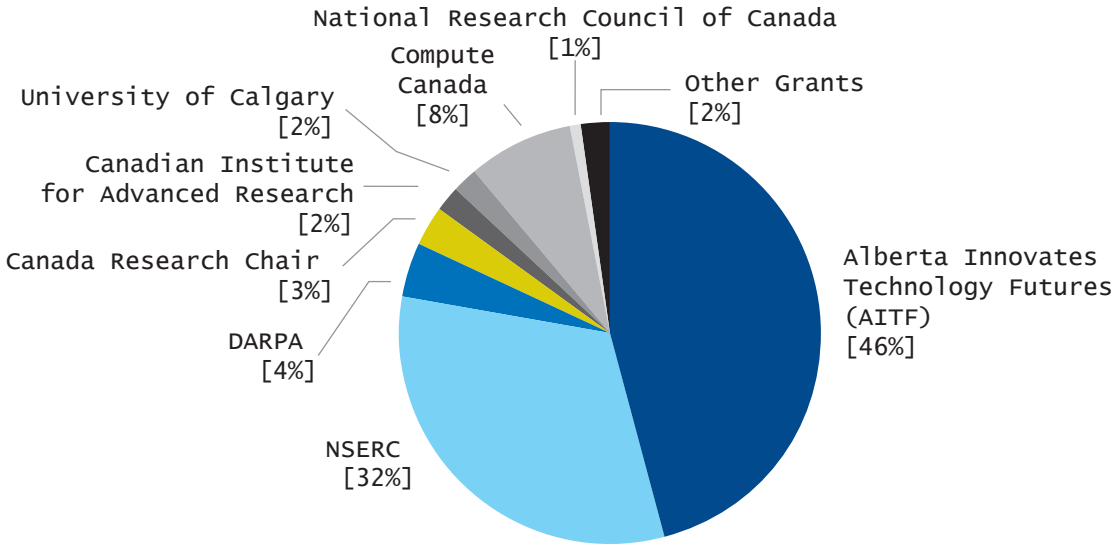
27 Nov 2014, B. C. Sanders, "Threats and opportunities for quantum computing", The Calgary Security Professionals Information Exchange Society (SPIE), Calgary, Canada.

16 Dec 2014, B. C. Sanders, "Quantum computers", PIR Live Event, Calgary, Canada, 26 Nov 2014–16 Dec 2014.

Finances

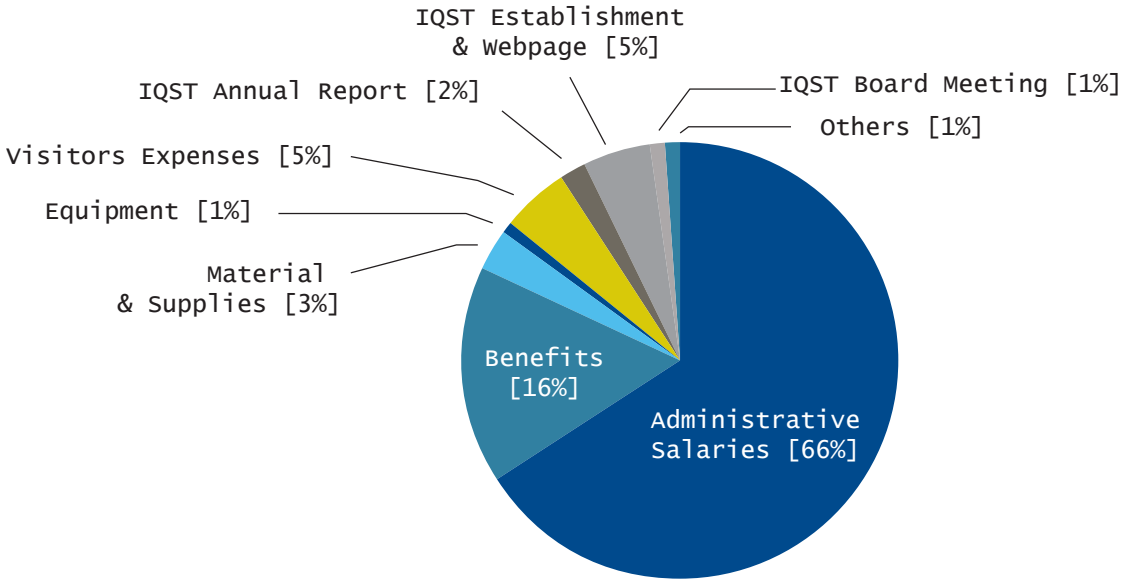
Research Grants (unaudited)

TOTAL REVENUE: $3,914K



Operating Account (unaudited)

TOTAL EXPENDITURES: $119K



Plans and Requirements for Next Year

PAUL BARCLAY:

- Demonstrate a high-performance nanophotonic torque magnetometer while operating in a practical ambient environment.
- Couple a nanophotonic cavity to a diamond nanomechanical resonator to enable light in a telecommunication fiber to control diamond quantum memory.
- Demonstrate a highly efficient, micron sized source of frequency doubled light operating at telecommunication and near-IR wavelengths.
- Measure enhancement of nitrogen vacancy centre emission in monolithic diamond nanocavities.

DAVID FEDER:

- Employ graph theory to determine the ground state and excitations of hard-core bosons in one-, two- and three-dimensional lattices.
- Investigate analytically and numerically photon-atom-interaction effects on the ground state and excitations of ultracold fermions and bosons for inhomogeneous gases or for coupling to an external cavity.
- Assess whether continuous-time quantum walks can exhibit topological order.
- Determine if symmetry-protected quantum teleportation for Haldane states remains robust in finite-size systems.

GILAD GOUR:

- Determine necessary and sufficient conditions for converting a mixed state to another under symmetric operations with applications to high-precision measurements in the presence of noise.
- Determine necessary and sufficient conditions for converting an incoherent athermal state to an athermal with coherence in the energy basis.
- Find an explicit example for non-additivity of the Holevo capacity of a quantum channel.
- Generalize the uncertainty principle from a lone system to a system entangled with quantum memory with applications to quantum cryptography.

PETER HØYER:

- Characterize existing distinct quantum-walk techniques for achieving quantum speedup over classical computation.
- Develop simple, near-optimal protocols to serve as quantum cryptographic primitives especially to address the gap between experimental and theoretical quantum cryptography.

PETER KUSALIK:

- Determine the local structure, stability and reactivity of hemi-bonded complexes of OH radical and Cl^- and Br^- anions.
- Develop and test an effective interaction potential for OH radical in water that faithfully reproduces that key structural features observed in ab initio simulations.
- Explore the behaviour of OH radical in heterogeneous environments such as the surfaces of water and ice, or a water/membrane interface.
- Further develop advanced visualization techniques to allow exploration and animation of complex data sets arising from simulation trajectories, featuring atomic coordinates, electronics structure, and/or local parameters (e.g. particle mobility, energy, local structure).
- Determine the key features of the nucleation process of a clathrate hydrate crystal from a mixed CH_4 and H_2S system.
- Characterize the primary steps involved in the ordering processes of metal-organic framework materials, specifically MOF-2 systems, utilizing a multi-scale modeling approach.
- Test the reliability of empirical potential models against accurately determination of the potentials of mean force for the interaction of carboxylate ligands with Zn^{2+} cations.
- Validate a non-equilibrium molecular dynamics simulation methodology for simulations of ice growth from vapour phase.
- Determine the impact of conjugate thermal fields on the propensity of supercooled liquid water and carbon dioxide systems to nucleate.

ALEX LVOVSKY:

- Build experimental capacity for distribution of Einstein-Podolsky-Rosen continuous-variable entanglement over large distances in free space and distillation of that entanglement
- Prepare single-quantum spin excitations in atomic ensembles by heralding on Raman-scattered photons and then convert these excitations to optical form for characterization by optical homodyne state tomography.

NASSER MOAZZEN-AHMADI:

- Record and analyse laboratory infrared spectra of hydrocarbon relevant to understanding the methane cycle in the atmospheres of Titan and the Giant Planets.
- Measure low-frequency intramolecular vibrational fundamentals of molecular clusters via combination bands.
- Provide high-resolution spectroscopic data for testing the onset of superfluidity in $CH_3COOH-(He)_4$.
- Record and analyse laboratory spectra of H_2- and He-hydrocarbons for elucidation of collisional processes between molecular hydrogen and rare gases with hydrocarbon trace species.
- Perform structural determination of complexes formed from carbon monoxide and carbon dioxide.
- Collaborate with theorists on constructing accurate potential-energy surfaces for characterizing intermolecular forces.

DENNIS SALAHUB:

- Advance multi-scale modelling methodologies and their implementation in efficient computer codes, with an immediate focus on code for GPUs and on the Cyclic Cluster Method for periodic boundary conditions
- Extend the study of RNA Polymerase to include the entropy and free-energy profiles, using the DFTB and ReaxFF methods.
- Investigate electron transfer and quantum decoherence in model peptides using Real-Time Time-Dependenent Density Functional Theory to propagate a two-level system of diabetic potentials calculated with Constrained DFT.
- Develop multiscale modelling of nanocatalysis for oil sands upgrading by extending our work on molybdenum carbide to include mixed-valence ceria-metal catalysts to split water, using the produced hydrogen for hydrocracking over molybdenum carbide.

BARRY SANDERS:

- Develop a procedure for accurate and precise characterization of multiphoton-interferometer parameters based on single- and two-photon counting.
- Propose a superconducting-circuit scheme for simulating a transition from paramagnetic to frustrated-magnetic phases at both microscopic and macroscopic levels.
- Employ Monte Carlo techniques for accurate modelling of long-distance quantum communication employing up to five intermediate entanglement swapping stations.
- Construct a quantum algorithm for simulating generic quantum-field scattering process based on an operational description of generic scattering and employing the Lagrangian description of scattering as an oracle.
- Develop a theory for double-double electromagnetically induced transparency with co-propagating, interacting signal and probe field pulses and determine conditions for cross-phase modulation between these pulses.
- Devise a globally optimized quantum-control procedure to realize general four-qubit gates by avoided level crossings in multilevel atoms.
- Construct a full theory of electromagnetic waveguides incorporating the duality arising from magnetic monopoles with the aim of using this theory to guide metamaterial waveguide experiments.

YUJUN SHI:

- Characterize the decomposition pathways of various aminosilane precursors on hot metal filaments followed by characterizing their reaction chemistry in the gas phase.
- Complete the benchmark experiments on multi-color resonance-enhanced multiphoton ionization (REMPI) using nitrous oxide.
- Develop the high-voltage pulsed discharge method to produce jet-cooled small silicon carbon clusters and hydrogenated silicon carbon species.
- Characterize the spectroscopy properties of small silicon carbon clusters and hydrogenated silicon carbon species using single- and multi-color REMPI techniques.

CHRISTOPH SIMON:

- Collaborate on experimental implementation of quantum nondemolition detection.
- Develop practical quantum repeater protocols with non-ideal components such as photon pair sources based on parametric down-conversion.
- Enhance efficiency of linear optical Bell state measurements with auxiliary photons.
- Assess potential for realizing quantum-repeater architectures with defect centers at liquid-nitrogen temperature.
- Quantify macroscopicity of quantum superposition states based on their sensitivity to various decoherence channels with applications to wavefunction-collapse models.
- Assess feasibility of creating macroscopic superposition states with Rydberg atom ensembles.

ROB THOMPSON:

- Perform laser spectroscopic measurements of the 1s-2p and 1s-2s transitions in antihydrogen with ALPHA team.
- Design and develop a system for gravitational studies of antihydrogen with ALPHA-g team.
- Develop capacity for sympathetic and/or evaporative-cooling and characterize ion throughput in Paul traps for the TITAN Collaboration at TRIUMF.
- Perform mass spectrometry and half-life studies of double-beta decay in ^{96}Zr to ^{96}Mo.

WOLFGANG TITTEL:

- Continue building secure communication systems based on the measurment-device independent quantum key distribution protocol, and assess their suitability over deployed fibres.
- Continue the development of quantum repeater technology, including quantum memory for light and non-destrictive photon detection, and work towards the implementation of large-scale quantum networks

SIMON TRUDEL:

- Employ advanced synchrotron spectroscopy to characterize the structure and redox behaviour of efficient amorphous water-splitting catalysts in situ.
- Improve an anodization method for creating nano-structure gold surfaces.

Appendices

IQST Charter

Name and Affiliation

1. The name of the organization shall be the Institute for Quantum Science and Technology (hereinafter referred to as "Institute"). The Institute formally reports to the Faculty of Science and is governed by the Faculty of Science Research Institutes Policy (hereinafter referred to as "Policy").

Reporting Structure

2. The Institute reports to the Dean, Faculty of Science (s. 4.7).

Approval and Review Bodies

3. The body responsible for approving, reviewing, and renewing the Institute under the Policy (s. 5.1) is the Faculty of Science Executive Committee.

Term of the Institute

4. Under the Policy Institutes are normally established for a five (5) year term (s. 4.3). The current term of the Institute ends 31 December 2018. The Institute is eligible for renewal upon favourable review (s. 4.4).

Goals

5. In keeping with the Policy (s. 4.1) the goals of the Institute shall be:
   a) to conduct leading research in key theoretical and experimental topics of quantum science and technology;
   b) to provide excellent education and training in quantum science and technology and cognate areas;
   c) to foster linkage between the Institute and other quantum science and technology institutes and with industrial partners.

Schedule of Review

6. The review process is specified in the Faculty of Science Research Institutes Procedures (hereinafter referred to as: "Procedures"). Reviews will occur as specified in the Procedures (s. 2.6). The Procedures call for notice of review to be given no later than 9 months before the end of term of the Institute, with a decision no later than 3 months before the end of the term.

The Institute shall submit an annual report (July 15) on its activities to the Dean of the Faculty of Science.

Institute Board of Directors

1. 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 Dean of Science (or designate) will 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 Dean of Science shall appoint "members at large". 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 Policy and Procedures of the Faculty of Science.

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

8. 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 Policy and Procedures of the Faculty of Science.

Policies and Procedures

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

Amendments

10. Amendments to this Charter shall require approval by the Dean and two-thirds of the Board. The Dean will refer proposed amendments to the Faculty of Science Executive Committee.

IQST Space

ROOM NUMBER	SIZE (SQUARE METRES)
BI 555	16
BI 556	17
BI 547 (partial)	223
ICT 625A	13
ICT 627	13
ICT 653	13
MS 372	13
MS 374	13
MS 376	12
MS 436	13
SA 111	71
SB 117	57
SB 135	18
SB 301	12
SB 303	24
SB 306	54
SB 307	12
SB 312	56
SB 313	12
SB 314	34
SB 315	16

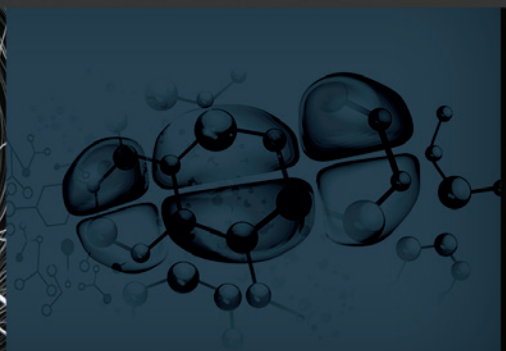
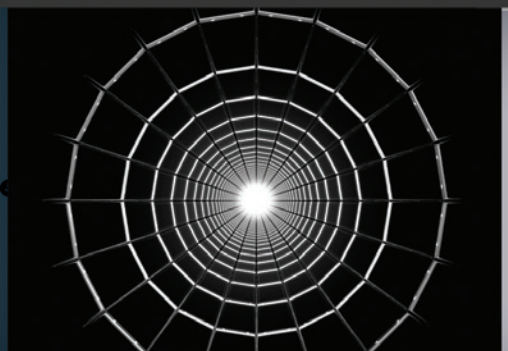
ROOM NUMBER	SIZE (SQUARE METRES)
SB 316	32
SB 317	9
SB 318	53
SB 319	19
SB 323	12
SB 325	12
SB 326	44
SB 333	16
SB 417	12
SB 427	25
SB 429A	12
SB 431	12
SB 508	55
SB 512 (partial)	64
SB 525	16
SB 531	12
SB 535	12
SB 605C	19

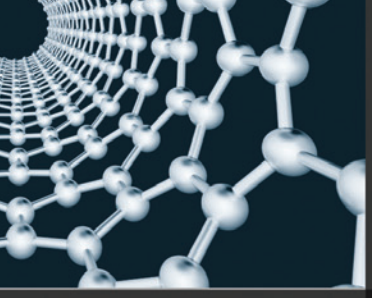
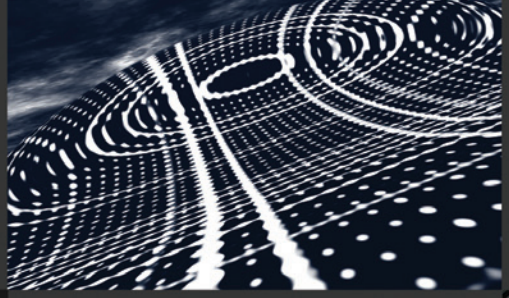
LABS

ROOM NUMBER	SIZE (SQUARE METRES)
ES 04	248
SB 03A	39
SB 08 & 09	61
SB 010	38
SB 126	61
SB 304	83
SB 416	62
SB 418	47
SB 432	21

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

- Enables multidisciplinary research through financial and logistical support
- Builds a quantum science and technology community through visitor, seminar, and colloquium programs
- Assists new faculty members to becoming productive researchers rapidly
- Publishes reports and web pages that showcase the Institute as a leader in quantum information science
- Supports recruitment of outstanding faculty, researchers, and graduate students
- Sponsors and supports leading conferences held locally
- Partners with other quantum institutes
- Enhances the University's reputation by delivering outstanding research results
- Benefits the wider community by contributing new knowledge in a strategic area

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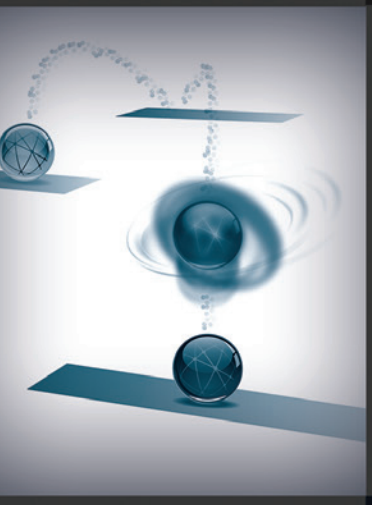

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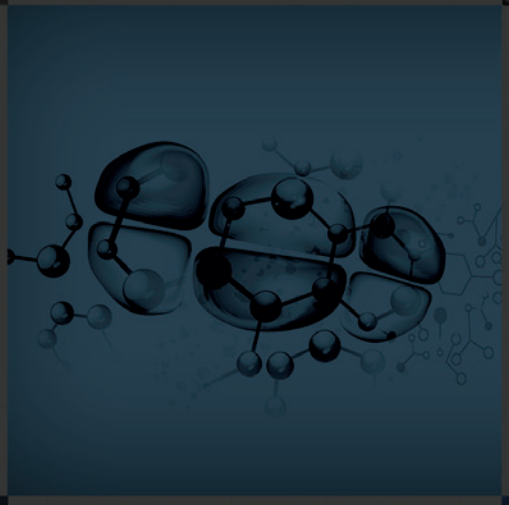
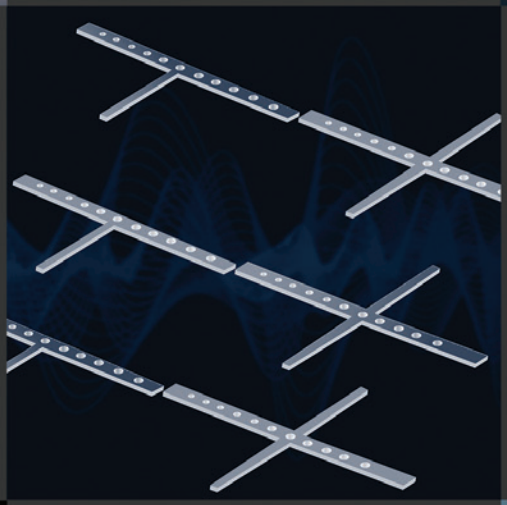

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