

2017
2018

annual report

quantum frontiers



UNIVERSITY OF CALGARY
FACULTY OF SCIENCE
Institute for Quantum Science and Technology

vision

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

mission

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

21	postdoctoral fellows
68	graduate students
20	undergraduate students
67	publications in refereed journal and conference proceedings including <i>Nature</i> (1), <i>Nature Communications</i> (2), <i>Nature Physics</i> (1), <i>Nature Photonics</i> (1), <i>ACS Photonics</i> (1) and <i>Physical Review Letters</i> (6)
38	invited talks at national & international conference/workshops including two keynote talks & one plenary talk
8.6	million dollars research funding

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director's report

The Institute for Quantum Science and Technology hosts 14 research groups and a total of around 125 academic members including professors, research staff and students. The Institute has four research themes—molecular modelling, nanotechnology, quantum information and computing, and quantum optics—across the four departments of Chemistry, Computer Science, Mathematics and Statistics, and Physics and Astronomy. Strong Institute researchers have joined forces with equally strong counterparts at the University of Alberta, leading to the establishment of a joint Natural Sciences and Engineering Research Council (NSERC) Collaborative Research and Training Experience (CREATE) Program called Quanta and headquartered at the University of Alberta and a joint Canada Foundation for Innovation (CFI) grant headquartered at the University of Calgary. As mutually beneficial linkage grows between Alberta's universities, the Institute for Quantum Science and Technology is naturally morphing into a new entity called *Quantum Alberta*.

Strengths of the Institute for Quantum Science and Technology are exemplified by its formidable accomplishments in research and training exemplified by the quantity and quality of its publications and graduates. In the past year, 67 papers were published including 12 papers published in the top-tier journals of *Physical Review Letters*, *Nature Communications*, *Nature*, *ACS Photonics*, *Nature Physics* and *Nature*

Photonics. Ten new students enrolled in the graduate studies programs in 2017/2018. Two masters students graduated and eight doctoral students completed their degrees.

The Institute is especially proud of the recognition of its members through awards and prizes. Two postdocs received a fellowship from NSERC, two postdocs received PIMS postdoctoral fellowships, and two postdocs were supported by the University of Calgary Eyes High fellowships. One PhD student held a NSERC Vanier Scholarship and two PhD students held Alexander Graham Bell Canada Graduate Scholarships-Doctoral. One PhD student and one MSc student received a MITACS scholarship. Four students received NSERC Undergraduate Summer Research Awards. Eight students received Alberta Innovates graduate students scholarship, and two students received Canadian Queen Elizabeth II Diamond Jubilee Graduate Scholarship. Two PhD students received Eyes High Doctoral Recruitment Scholarship and one PhD student received an Eyes High International Doctoral Scholarship. Four students won Faculty of Graduate Studies Travel Awards. One PhD student received an Izaak Walton Killam Doctoral Scholarship. Five students had Queen Elizabeth II Graduate Scholarships. One PhD student received a Silver Anniversary Graduate fellowship. One postdoc was awarded a T. Cheng Fong Postdoctoral Fellowship in Medical Imaging Science. One undergraduate student won a PURE Award.

The Institute's Director Barry Sanders was elected a Fellow of the Royal Society of Canada, and Sanders received the Faculty of Science Excellence Award in Research (established career). Paul Barclay received a Faculty of Science Early Career Researcher Award and a Faculty of Graduate Studies Great Supervisor Award.

The Institute prioritizes outreach as well as research and training. Hosting conferences and holding Quantum Public Lectures serve as the main outreach instruments. The Institute was a partner of the deMon developers' conference in Calgary from 10 to 15 May 2017. The Workshop was successful and attracted 34 participants representing institutions from nine countries (Brazil, Canada, China, Czech Republic, France, Germany, Mexico, Sweden and USA).

The Quantum Public Lectures serve to convey leading breakthroughs in quantum science and technology to the public. Michael Roukes from the California Institute of Technology (Caltech) delivered a public lecture titled "Can we reverse-engineer the brain?" to about 200 persons on 6 June 2017. This lecture was co-sponsored by the Faculty of Science Alumni Relations team as a joint outreach event.

In summary IQST is fulfilling its mission to advance quantum science and technology through interdisciplinary research, teaching, and outreach. Furthermore, IQST is playing a leading

role in developing the *Quantum Alberta* initiative. IQST researchers are amongst the top global leaders in its focus areas, and continuing financial support from Alberta Innovates and the University of Calgary have enabled the Institute's many years of success.

BARRY C. SANDERS

Director

a message from the chair

The University of Calgary's Faculty of Science launched its five-year strategic plan "Curiosity Sparks Discovery!" in September 2017, which continues a venerable history of catalyzing change and inspiring discovery, creativity and innovation. As Dean of the faculty and Chair of the Institute's Board of Directors, I commend IQST for its fit to and furtherance of the faculty's mission.

One of the faculty's grand challenges, which aspire to transfer knowledge and contribute to growth through research, innovation and entrepreneurial thinking, is the challenge of unlocking our digital future. IQST is an early leader in quantum information, which seeks to unleash the power of quantum science on sensing, communication and computing, with beneficial disruptive impacts on society. Quantum information is one of the four planks underpinning this grand challenge, and the quantum team comprises faculty members and their groups from four departments: chemistry, computer science, mathematics and statistics, and physics and astronomy, all working to formulate and solve problems at the forefront of quantum science and technology.

IQST is a research powerhouse within the faculty but also excels with training and outreach. Undergraduate and graduate students and postdoctoral researchers are engaged with all aspects of discovery and innovation within the Institute and then move to enriching careers

with many Institute alumni joining industry, academic and government institutions. Outreach is exemplified by the long-standing Annual Quantum Public Lecture given by luminaries in a variety of quantum fields.

The Faculty of Science, along with IQST, is part of a university that is one of Canada's most dynamic and enterprising cities. Together, we will harness our current strengths, look to future opportunities and allow for the exploration of new discoveries. I encourage everyone to spend some time reviewing the annual report to learn more about IQST's achievements this past year.

LESLEY RIGG

**Dean, Faculty of Science
Chair, IQST Board of Directors**

research highlights

research achievements

The Institute for Quantum Science and Technology (IQST) has significant research achievements over the past year. The following exposition of achievements provides a sample of the kinds of activities and breakthroughs seen within IQST.

Together Feder and Sanders and their team reported in *Physical Review Letters* how to detect topological transitions in two dimensions by Hamiltonian evolution. Their novel quantum-walk approach reveal transitions between topological phases in the form of kink in the mean width of the particle distribution, which signals the closing of a band gap. These results had an immediate impact on cold-atom experiments. Also on the topic of quantum walks for detecting topological effects, Sanders collaborated with former IQST postdoc Peng Xue's group at Southeast University on two notable experiments. Both experiments probe topological effects for non-unitary quantum mechanics, with non-unitarity implying irreversibility. One experiment observed topological edge states in parity-time-symmetric quantum walks and was published in *Nature Physics*. The other experimental paper showed topological invariants in nonunitary discrete-time quantum walks and appeared in *Physical Review Letters*.

In an influential *Nature Photonics* paper, Lvovsky showed enlargement of optical Schrödinger cat states, which are important states both for exploring foundational perplexing issues in quantum mechanics as well as quantum-information applications for which Schrödinger cat states serve as quantum bits. Another of Lvovsky's major endeavours concerning hybridized continuous-discrete quantum information bore fruit, resulting in the group's *Physical Review Letters* article on quantum

teleportation between discrete and continuous encodings of an optical qubit.

Thompson is a member of the international Antihydrogen Laser Physics Apparatus (ALPHA) collaboration based at CERN, which is the European Organization for Nuclear Research. ALPHA creates trapped antihydrogen atoms and performs precise comparison with hydrogen to study symmetries between matter and antimatter. During the past year, Thompson and the ALPHA team reported significant new results including an observation of the hyperfine spectrum of antihydrogen in *Nature*, antihydrogen accumulation for fundamental symmetry tests in *Nature Communications*, and enhanced control and reproducibility of non-neutral plasmas in *Physical Review Letters*.

Barclay's group has become a leader with diamond microcavities. In their *ACS Photonics* paper, the group reports optomechanically induced transparency and cooling in thermally stable diamond microcavities. Their achievement is especially notable as they overcome the deleterious effect of thermo-optic instability by formidable engineering methods.

The group of Tittel and Oblak demonstrated heralded single photons based on spectral multiplexing and feed-forward control, and this significant achievement was reported in *Physical Review Letters*. In a notable tour de force, Tittel, Oblak, and Simon realized entanglement between more than two hundred macroscopic atomic ensembles in a solid. This work, reported in *Nature Communications*, achieves entanglement in Dicke states for which multipartite entanglement is realized as a single delocalized excitation in a crystal with many atoms having distinct resonance frequencies.

These scientific achievements are significant to quantum science and published in top journals. IQST is fortunate to have these scientists on board, and these achievements are not a complete list for IQST but rather a representative sample of the activities and quality seen in the Institute's research.

awards

INTERNATIONAL AWARDS

China Scholarship Council Award

Zhengcai Zhang
Haimin Zheng

Wenner-Gren Fellowship (Sweden)

Peter Kusalik

NATIONAL AWARDS

Alexander Graham Bell Canada Graduate Scholarships-Doctoral

David Lake
Matthew Mitchell

MITACS Scholarship

Archismita Dalal
Rishabh Shukla

MITACS Globalink

Mathurin Lagree
Matthew Robbins

NSERC Postdoctoral Fellowship

Ghazal Haji Salem
Mariam Taheri

NSERC USRA

Sebastian Garcia
Michael Grabowecy
Manak Singh
Connor Stephens

NSERC Vanier Scholarship

Carlos Enriquez-Victorero

PIMS Postdoctoral Fellowship

Mehdi Ahmadi
Hoan Bui Dang

PROVINCIAL AWARDS

Alberta Innovates Graduate Students Scholarship

Alex Cameron
Sumit Goswami
Chris Healey
Sourabh Kumar
David Lake
Matthew Mitchell
Stephen Wein
Parisa Zarkeshian

UNIVERSITY OF CALGARY AWARDS

Alberta Innovates/Eyes High Postdoctoral Fellowship

Nikolai Lauk
Namrata Shukla

Canadian Queen Elizabeth II Diamond Jubilee Graduate Scholarship

Archismita Dalal
Simanraj Sadana



Eyes High Doctoral Recruitment Scholarship

Andrew Evans
Sourabh Kumar

Eyes High International Doctoral Scholarship

Faezeh Kimiaee Asadi

Faculty of Graduate Studies Travel Award

Aaron Barclay
Jiawei Ji
Matthew Mitchell
Yadong Wu

Faculty of Science Early Career Researcher Award

Paul E. Barclay

Faculty of Science Excellence Award in Research (Established Career)

Barry C. Sanders

Faculty of Graduate Studies GREAT Supervisor Award

Paul E. Barclay

Izaak Walton Killam Doctoral Scholarship

Sumit Goswami

Program for Undergraduate Research Experience (PURE) Award

Alex Gherasim

Queen Elizabeth II Graduate Scholarship

Alex Cameron
Katelynn Daly
Hamidreza Kaviani
Tamiko Masuda
Taozhe Wu

Silver Anniversary Graduate Fellowship

Kyle Hall

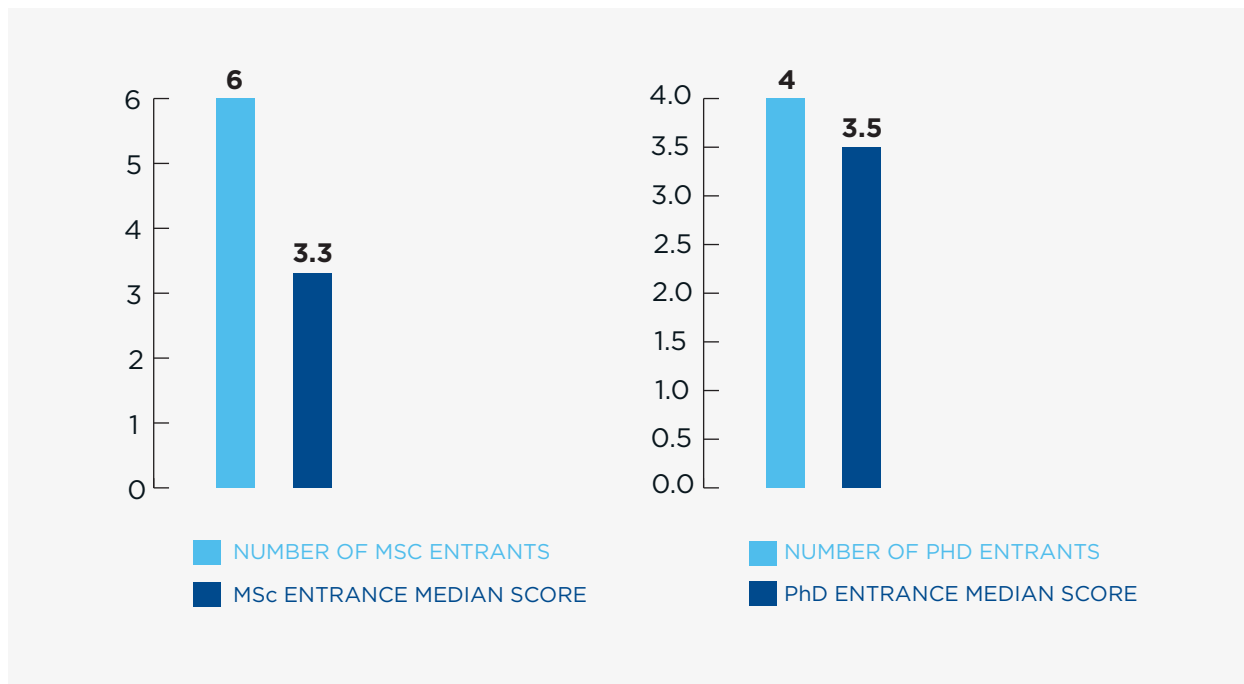
T. Cheng Fong Postdoctoral Fellowship in Medical Imaging Science

Ronnie Banerjee

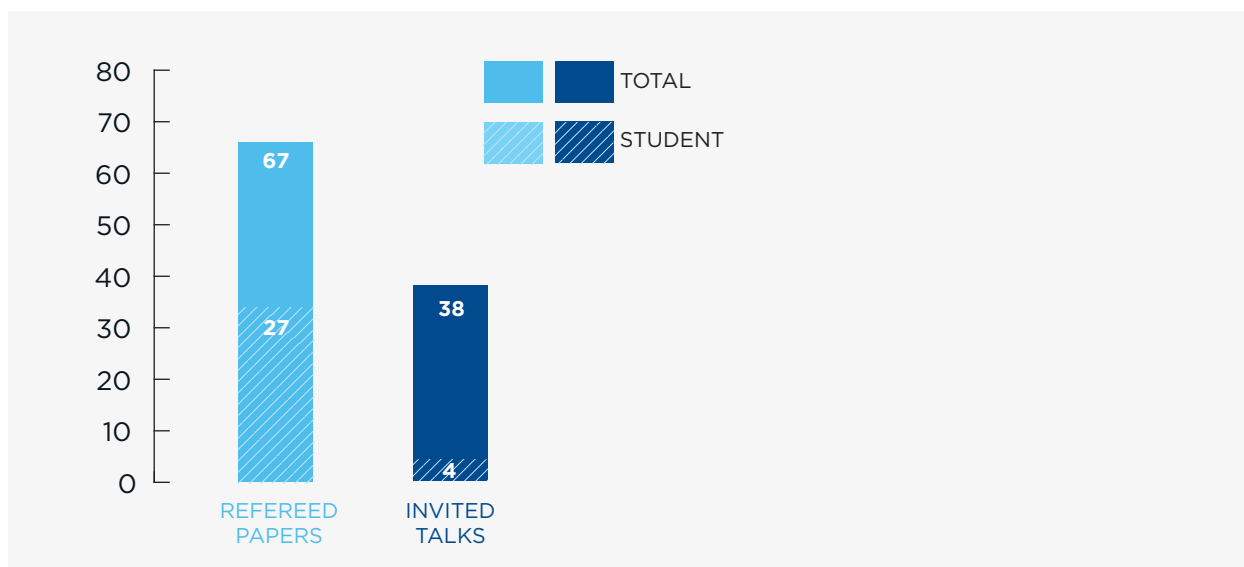


key performance indicators

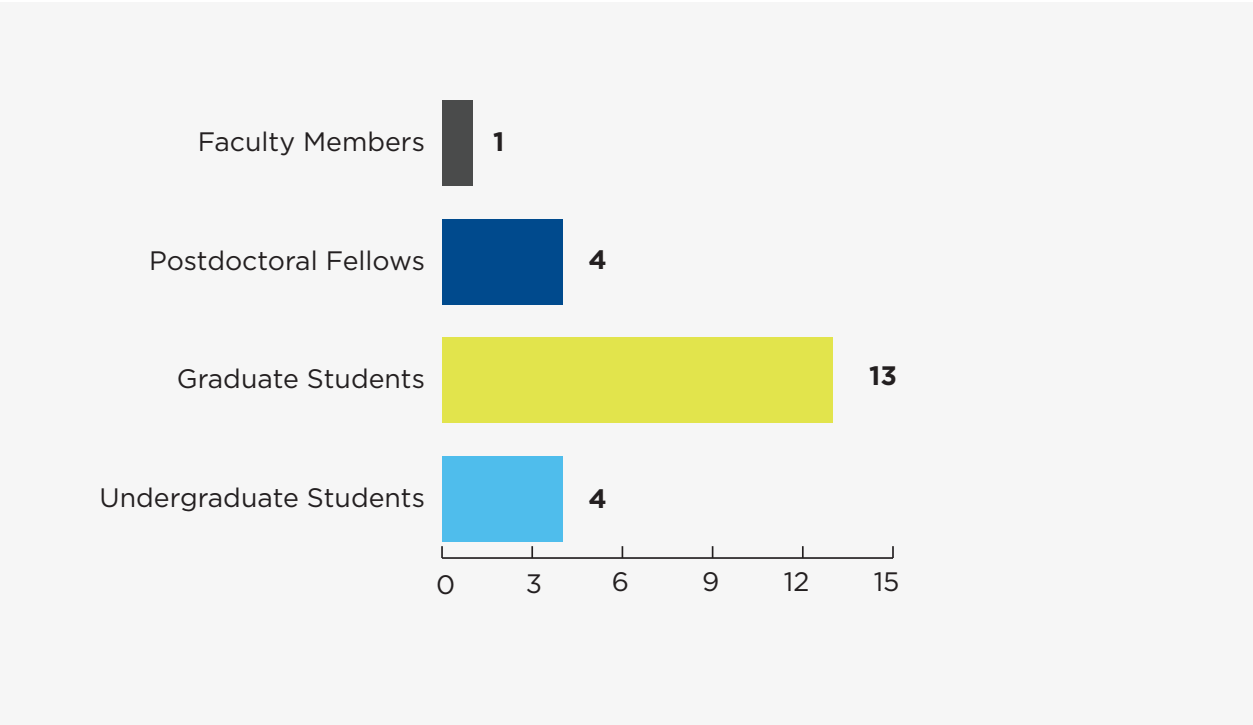
GRADUATE STUDENT ENROLMENT AND QUALITY OF ENTRANTS



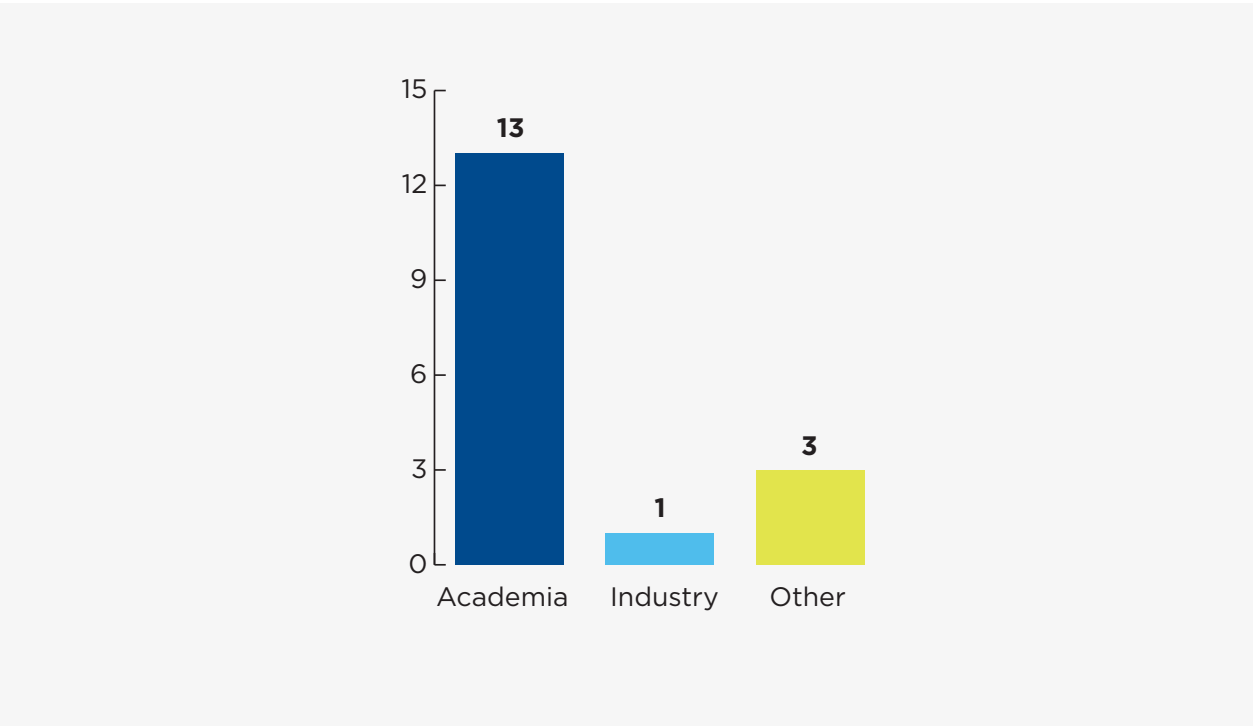
PUBLICATIONS AND PRESENTATIONS (HIGHLIGHTED PORTION WITH IQST STUDENT)



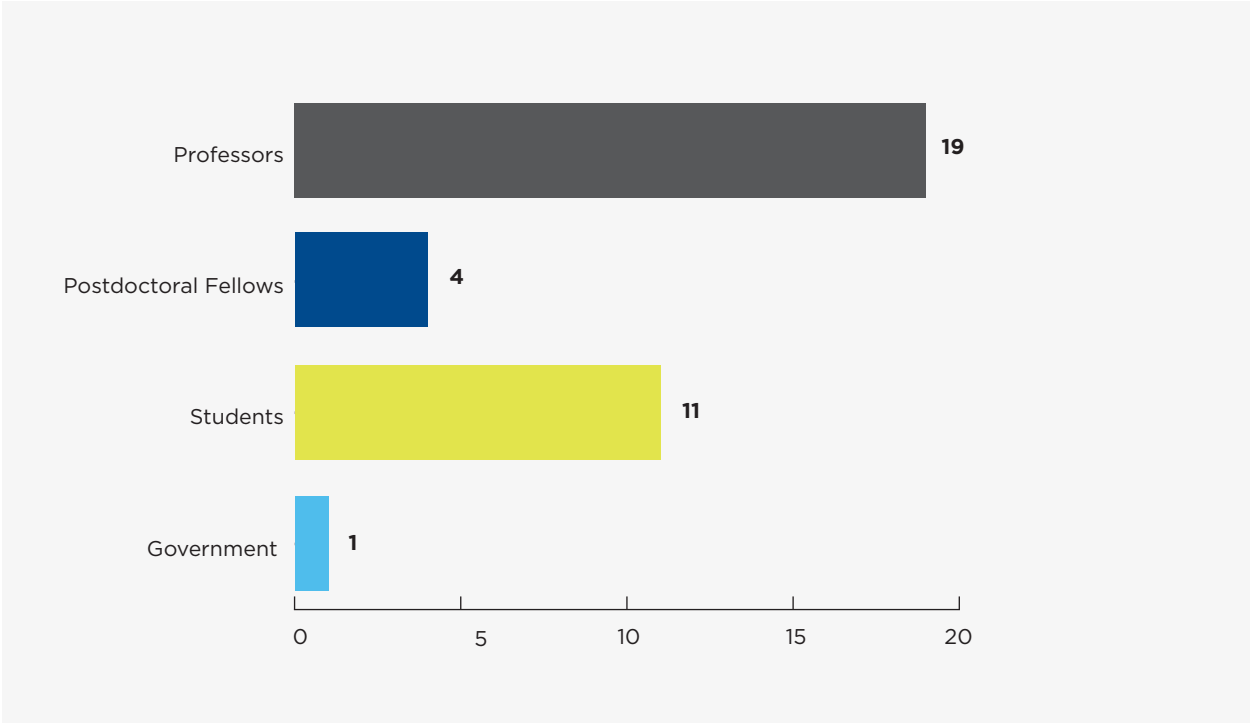
EXTERNAL AWARDS (CHAIRS, FELLOWSHIPS AND SCHOLARSHIPS)



TRAINEE DESTINATIONS AFTER IQST



VISITORS



research groups



Dr. Paul Barclay

NANOSCALE OPTICS

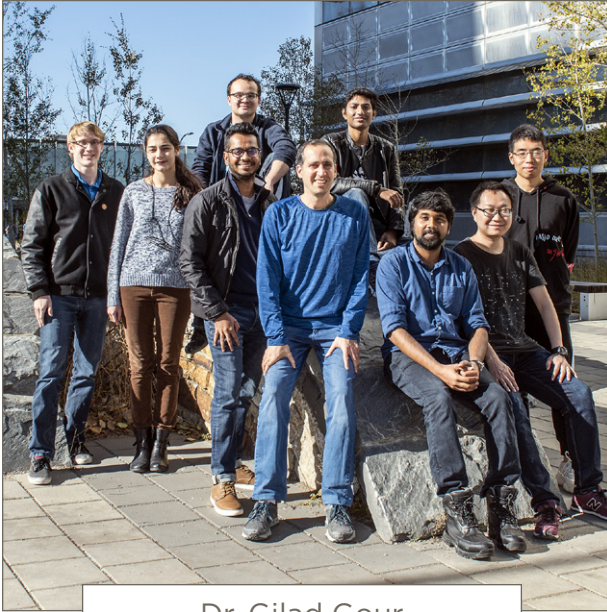
Explores interactions between light and nanoscale systems such as single atoms, electron spins and nanomechanical structures. Employs nanofabrication methods to engineer optical properties of these systems in order to enhance light-matter coupling. The current focus couples single quantum emitters, or “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.



Dr. David Feder

PRACTICAL QUANTUM COMPUTATION

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.



Dr. Gilad Gour

QUANTUM INFORMATION THEORY

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



Dr. Peter Høyer

QUANTUM COMPUTING

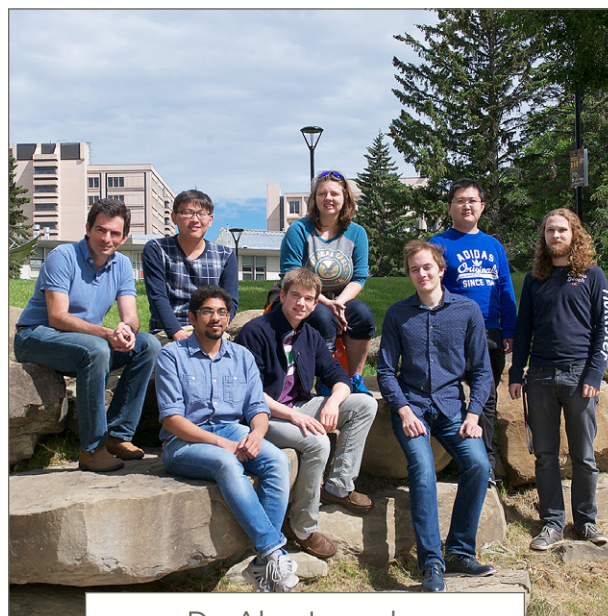
Explores the potential powers of quantum systems to develop quantum algorithms, quantum communication protocols, quantum cryptographic protocols, and quantum computer simulations of quantum mechanical systems. Characterizes the powers and their limitations by studying quantum complexity theory, non-locality,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



Dr. Peter Kusalik

MOLECULAR SIMULATIONS OF LIQUIDS & SOLUTIONS, INTERFACES AND CRYSTALLIZATION

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. Explores behaviour of the hydroxyl radical in various aqueous environments. Applications range from atmospheric and materials sciences to molecular biology and water treatment.



Dr. Alex Lvovsky

QUANTUM INFORMATION TECHNOLOGY WITH LIGHT AND EXPERIMENTAL QUANTUM OPTICS

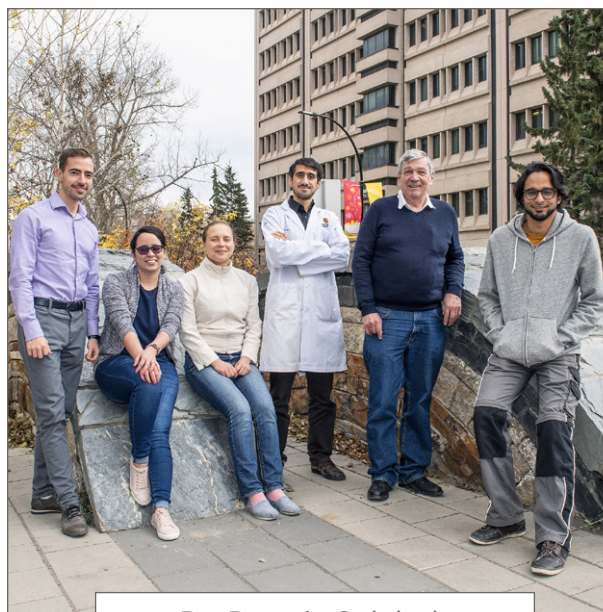
Concentrates on implementing light for the purposes of quantum information technology — that is, learning to synthesize, control, characterize, and store arbitrary quantum states of the electromagnetic field, as well as causing photons to interact with each other. We work on achieving sub-Rayleigh resolution of optical imaging using passive imaging devices.



Dr. Nasser Moazzen-Ahmadi

SPECTROSCOPY OF HYDROCARBONS AND MOLECULAR CLUSTERS AND COMPLEXES

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.



Dr. Dennis Salahub

MULTISCALE MODELING OF (BIO)CHEMICAL REACTIONS IN COMPLEX ENVIRONMENTS

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.



Dr. Barry Sanders

QUANTUM INFORMATION SCIENCE

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.



Dr. Yujun Shi

CHEMICAL VAPOR DEPOSITION CHEMISTRY

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.



Dr. Christoph Simon

THEORETICAL QUANTUM OPTICS

We use quantum optical approaches to study potential applications of unique quantum phenomena such as superposition and entanglement (e.g. a future “quantum internet”), to probe whether these phenomena are universal, and to investigate whether they could play a role in biology (e.g. in neuroscience). Our theoretical research is often done in close collaboration with leading experimental groups.



Dr. Robert Thompson

TRAPPED ION PHYSICS WITH ATOMS, MOLECULES, AND EXOTIC SPECIES

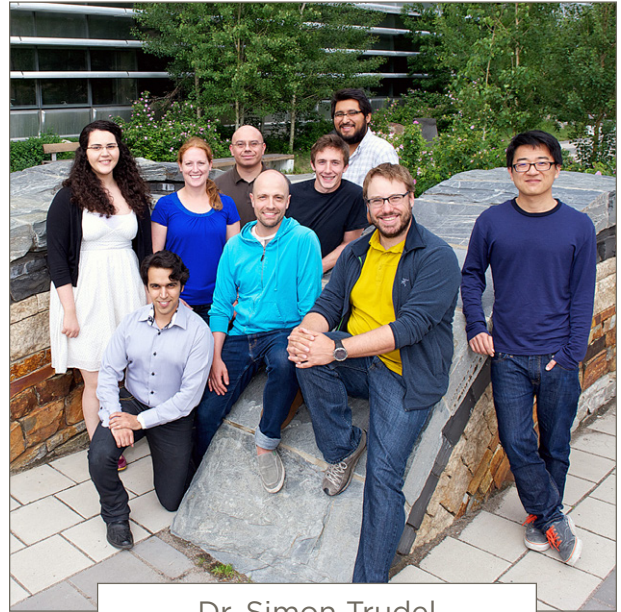
Develops and measures low-density trapped atoms, molecules and exotic species, especially anti-matter Hydrogen. Collaboration with the Antihydrogen Laser Physics Apparatus (ALPHA) project at CERN involving 40 scientists across 16 institutions. Collaborates with TRIUMF’s Ion Trap for Atomic and Nuclear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



Dr. Wolfgang Tittel

QUANTUM CRYPTOGRAPHY AND COMMUNICATION

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.



Dr. Simon Trudel

NANOSCALE MATERIAL

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.

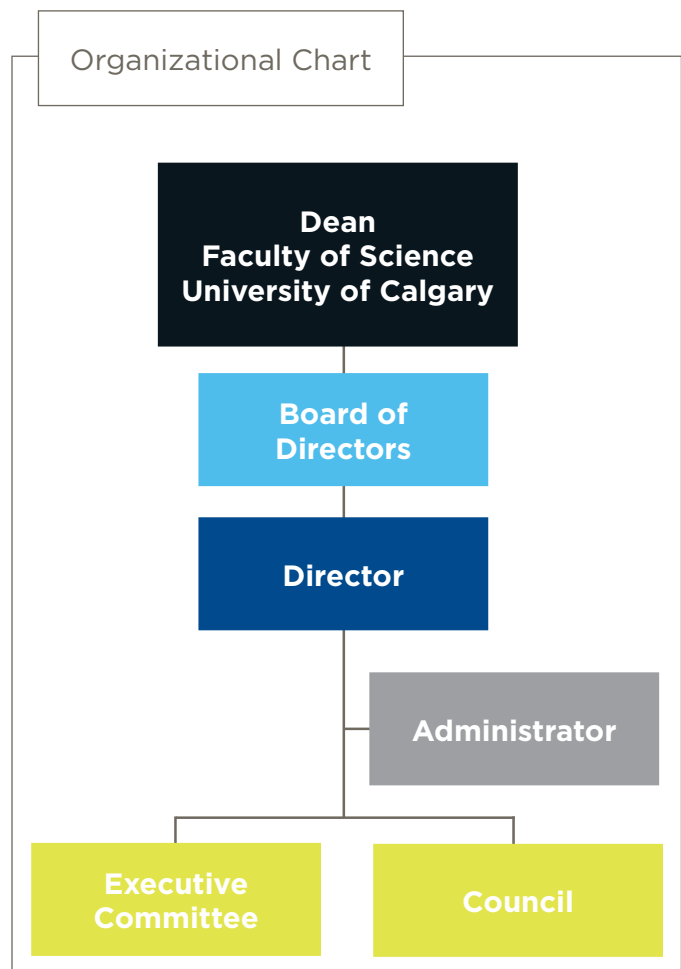
management & membership

institute structure

The Institute is managed on a day-to-day level by the Institute Director and the Institute Administrator. 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, 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

Lesley Rigg

Dean, Faculty of Science,
University of Calgary

Marie D'Iorio

Senior Strategy Advisor,
University of Ottawa

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Chief Scientist,
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Professor, Department of
Physics and Astronomy,
University of Calgary

Carl Williams

Deputy Director, Physical
Measurement Laboratory (PML),
National Institute of Standards
and Technology (NIST)

Mark Williams

EXECUTIVE COMMITTEE

Gilad Gour

Professor, Department of
Mathematics and Statistics,
University of Calgary

Barry C. Sanders

Professor, Department of
Physics and Astronomy,
University of Calgary

Yujun Shi

Professor, Department of
Chemistry, University of Calgary

Wolfgang Tittel

(resigned March 2018)
Professor, Department of Physics
and Astronomy, University of Calgary

COUNCIL

Faculty Members

Paul Barclay

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

David Feder

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

Gilad Gour

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 Emeritus,
Department of Chemistry,
University of Calgary

Barry C. Sanders

Professor, Department of
Physics and Astronomy,
University of Calgary

Yujun Shi

Professor, Department of
Chemistry, University of Calgary

Christoph Simon

Professor, Department of
Physics and Astronomy,
University of Calgary

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University of Calgary

Wolfgang Tittel

(resigned March 2018)
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University of Calgary

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Associate Professor, Department
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University of Calgary

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Professor, Department of
Biological Sciences, University of
Calgary

Richard Zach

Professor, Department of
Philosophy, University of Calgary

POSTDOCTORAL FELLOWS

Mehdi Ahmadi (resigned June 2017 → Adjunct Professor, Santa Clara University)
Shideh Ahmadi
Gustavo Amaral
Morteza Amirani (completed January 2018 → Postdoc, University of Calgary)
Ronnie Banerjee (completed December 2017)
Hoan Bui Dang (completed June 2017 → Consultant, Data Scientist, Capco Canada)
Roohollah Ghobadi
John Patrick Hadden (completed February 2018 → Postdoc, University of Cardiff)
Jiri Hostas
Nikolai Lauk
Jalal Norooz Oliaaee (resigned October 2017 → Postdoc, National Research Council Canada)
Gustavo de Oliveira Luiz
Thomas Lutz (resigned March 2018 → Postdoc, ETH Switzerland)
Young Choon Park
Ghazal Haji Salem
Namrata Shukla
Neil Sinclair (resigned July 2017 → Postdoc, Harvard University & California Institute of Technology)
Chukman So (completed March 2018)
Mariam Taheri
Yunlong Xiao
Zhengcai Zhang

RESEARCH ASSOCIATES/ COORDINATORS/ENGINEERS

Daniel Oblak

GRADUATE STUDENTS (PHD PROGRAM)

Shudipto Amin
Mohsen Bagheri Mehrab
Aaron Barclay
Lizandra Barrios
Stephanie Bovincini
Archismita Dalal

Katelynn Daly
Raphael Dong (graduated March 2018)
Carlos Enriquez-Victorero
Koorosh Esteki
Andrew Evans
Mohsen Falamarzi Askarani
Jose da Costa Filho
Akihiko Fujii (terminated December 2017)
Mark Girard (graduated August 2017 → Postdoc, University of Waterloo)
Sumit Goswami
Kyle Hall (graduated March 2018 → Postdoc, Temple University)
Chris Healey
Hamidreza Kaviani
Abdullah Khalid
Faezeh Kimiaee Asadi
Sourabh Kumar
David Lake
Hon-Wai Lau (graduated August 2017 → Postdoc, Max Planck Institute for Physics of Complex Systems)
Pascal Lefebvre
Thomas Lutz (graduated December 2017 → Postdoc, University of Calgary)
Adam Mayer
Matthew Mitchell
Ali Mohandesi
Eugene Moiseev
James Moncreiff
Yasser Novo-Fernández
Mahmood Noweir
Ebenezer Owusu-Ansah (graduated October 2017 → Postdoc, University of Calgary)
Eduardo Paez
Pantita Palittapongarnpim
Alireza Poostindouz
Marcel.li Grimau Puigibert (graduated February 2017 → Postdoc, University of Basel)
Anastasia Pushkina
Nafiseh Sang-Nourpour (graduated July 2017 → Postdoc, Institut National d'Optique)
Priyaa Varshinee Srinivasan
Arina Tashchilina

Raju Valivarthi
Shakib Vedaie
Lei Wang
Taozhe Wu
Yadong Wu
Parisa Zarkeshian

GRADUATE STUDENTS (MSc PROGRAM)

Eric Ampong
Paul Anderson (graduated February 2018 →
PhD, University of Waterloo)
Aaron Barclay (graduated August 2017 → PhD,
University of Calgary)
Alex Cameron
Cole Comfort
Jacob Davidson
Masoud Habibi Davijani
Nuiok Dicaire
Alison Fulton
Shreyas Jalnapurkar
Jiawei Ji
Mojtaba Komeili
Prasoon Kumar Shandilya
Tamiko Masuda
Hamza Qureshi
Mohammad Rahmati
Rishabh Shukla
Prathwiraj Umesh
Stephen Wein
Wei Huang Xu

UNDERGRADUATE STUDENTS

Russell Bate (UofC PHYS598)
Dante Bencivenga (UofC PHYS598)
Xining Chen (UofC PHYS598)
Sebastian Garcia (NSERC USRA & UofC
PHYS599)
Alex Gherasim (UofC PURE Award)
Michael Grabowecky (NSERC USRA & UofC
PHYS598)
Rysa Greenwood (UofC CHEM402)
David Ham (UofC PHAS598)

Yasmeen Kamaliddin (UofC PHYS598)
Linh Ly (UofC CHEM402)
Blaine McLaughlin (undergraduate research)
Kimberley Ann Owen (research assistant)
Charmaine Sablay (UofC CHEM402)
Arta Seify (undergraduate research)
Jonathan Shabash (undergraduate research)
Manak Singh (NSERC USRA)
Raunak Singh (UofC CHEM502)
Connor Stephens (NSERC USRA)
Roland Tran (UofC PHYS599)
Wei Zeng (UofC CHEM402)

ADMINISTRATION

Xining Chen (Part-time Webmaster)
Jing (Nancy) Lu (Administrator)
Priyaa Varshinee Srinivasan (Part-time
Webmaster/resigned December 2017)
Lucia Wang (Administrative Assistant,
transferred May 2017 → Cumming School of
Medicine, University of Calgary)

publications

REFEREED JOURNALS

S. Ahmadi, L. Barrios, M. Chehelamirani, J. Hostas, S. Jalife and D. R. Salahub, "Multiscale modeling of enzymes: QM-cluster, QM/MM, and QM/MM/MD – a tutorial review", *International Journal of Quantum Chemistry* **118**(9): e25558 (34 pp.), January 2018.

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T. S. Biswas, “Fabrication, characterization, and applications of nanomechanical resonators” (PhD Thesis), June 2017.

R. Dong, “Systematic study of parameters affecting unconventional magnetism in gold nanostructures” (PhD Thesis), March 2018.

M. Girard, “Convex analysis in quantum information” (PhD Thesis), July 2017.

K. Wm. Hall, “Interweaving computational chemistry and visualization: Explorations into molecular processes, simulation analysis, and visualization design” (PhD Thesis), May 2017.

S. Jalnapurkar, “Measuring decay rate of spontaneous emission from an ensemble of cold atoms by homodyne detection” (MSc Thesis), February 2018.

H. W. Lau, “Nonlinear dynamics of mathematical models and proposed implementations in ultracold atoms” (PhD Thesis), July 2017.

T. Lutz, “Engineered impurity-doped materials for quantum information and processing applications – nano-structures and disordered materials” (PhD Thesis), December 2017.

E. Owusu-Ansah, “Applications of nanosecond pulsed lasers: Electronic transitions of atomic Si to dewetting of Pt and Ag metal thin films” (PhD Thesis), October 2017.

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INTELLECTUAL PROPERTY

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INVITED PRESENTATIONS AT WORKSHOPS/CONFERENCES

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21 April 2017, D. R. Salahub, “Multiscale modeling of chemical reactions in complex environments”, Symposium on Computational Chemistry at the ICCMSE (International Symposium on Computational Methods in Science and Engineering), Thessaloniki, Greece, 21 April 2017–25 April 2017.

24 April 2017, A. I. Lvovsky, “Beating the Rayleigh limit”, Quantum Field Framework for Structured Light Interactions, Banff International Research Station, Canada, 24 April 2017–28 April 2017.

4 May 2017, P. E. Barclay, “Spin-optomechanics”, Alberta Nanosymposium, Calgary, Canada, 4 May 2017.

16 May 2017, G. Gour, “Single-shot quantum resource theories”, 2017 Langenhop Lecture and SIU Mathematics Conference, Carbondale, United States of America, 15 May 2017–16 May 2017.

21 May 2017, G. Gour, “Theories of Quantum Resources” (plenary), Calgary Applied and Industrial Mathematical Sciences Conference, Calgary, Canada, 21 May 2017.

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21 June 2017, D. R. Salahub, “Beyond structure: on the role of dynamics and entropy in nanocatalysis”, International Conference on Chemical Bonding (ICCB), Kauai, Hawaii, United States of America, 21 June 2017–26 June 2017.

27 June 2017, A. I. Lvovsky, “Hybrid discrete+continuous-variable quantum repeaters”, CIFAR Workshop on Quantum Networks, Calgary, Canada, 27 June 2017–28 June 2017.

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24 July 2017, B. C. Sanders, “Wavelets for quantum state generation”, Mathematical Congress of the Americas (MCA 2017), Montreal, Canada, 24 July 2017–28 July 2017.

14 August 2017, B. C. Sanders, “Introduction to quantum computing”, Mathematical and Numerical Methods for Time-Dependent Quantum Mechanics - from Dynamics to Quantum Information, Casa Matemática Oaxaca, Mexico, 13 August 2017–18 August 2017.

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20 August 2017, D. R. Salahub, “Beyond structure - Multiscale modeling of chemical reactions in complex environments” (plenary), International Materials Research Conference, Cancun, Mexico, 20 August 2017–25 August 2017.

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- 24 September 2017, [P. E. Barclay](#), “Quantum information processing with diamond”, Nano-Canada, Montreal, Canada, 25 September 2017—26 September 2017.
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- 2 October 2017, [D. R. Salahub](#), “Simulating electron dynamics in polarizable environments”, International Symposium on Atomic Cluster Collisions, Varadero, Cuba, 2 October 2017—6 October 2017.
- 5 October 2017, [A. I. Lvovsky](#), “Quantum as a worldwide technology trend “ (keynote), PriceWaterhouseCoopers Central and Eastern Europe Partner Conference, St. Petersburg, Russia, 5 October 2017.
- 5 October 2017, [D. Oblak](#), P. Zarkeshian, C. Deshmukh, P. Lefebvre, K. Owen, C. John, V. R. R. Valivarthi, M. L. Grimaud Puigibert, S. K. Goyal, K. Heshami, N. Sinclair, Q. Zhou, G. Aguilar, W. Tittel and C. Simon, “Building quantum networks”, Workshop on Quantum Innovators in Science and Engineering, Waterloo, Canada, 2 October 2017—5 October 2017.
- 24 October 2017, [Y. J. Shi](#), “Formation of metal nanoparticles by pulsed laser-induced thin film dewetting and their applications”, 7th Annual World Congress of Nano Science & Technology, Fukuoka, Japan, 24 October 2017—26 October 2017.
- 3 November 2017, [D. R. Salahub](#), “Simulating electron dynamics in polarizable environments”, Ions, Complexes, Biological Systems, Clusters and Surfaces in Catalysis – CAT-ICBSC 2017, Cosenza, Italy, 3 November 2017—4 November 2017.
- 13 November 2017, [B. C. Sanders](#), “Reinforcement learning for quantum control”, Workshop: Quantum artificial intelligence and quantum computing, Shanghai University, People’s Republic of China, 13 November 2017.
- 14 November 2017, [G. Gour](#), “Quantum majorization: From November of quantum channels to quantum thermodynamics”, International Workshop on Quantum Computing and Quantum Information Processing 2017, Beijing, People’s Republic of China, 1 November 2017—21 November 2017.
- 14 December 2017, [D. Oblak](#), K. Owen, C. John, M. Falamarzi Askarani, V. R. R. Valivarthi, M. L. Grimaud Puigibert, T. Lutz, L. Veissier, N. Sinclair, Q. Zhou, G. Aguilar and W. Tittel, “Quantum networks and repeaters”, 5th International Workshop on Engineering of Quantum Emitter Properties (EQEP 2017), Waterloo, Canada, 13 December 2017—15 Dec December.
- 14 December 2017, [B. C. Sanders](#), “Overview of quantum computing and communication for mining”, National Research Council Quantum Canada Industry Workshop on Quantum Mining, MaRS District, Toronto, Canada, 14 Dec 2017.
- 21 December 2017, [B. C. Sanders](#), “Reinforcement learning for quantum control”, 2017 International Workshop on Quantum Information, Quantum Computing and Quantum Control, Shanghai University, People’s Republic of China, 19 December 2017—21 December 2017.
- 8 January 2018, [A. I. Lvovsky](#), “Interfacing discrete and continuous variable encodings in quantum optical information”, Hong Kong Workshop on Quantum Information and Foundations, Hong Kong, 8 January 2018—12 January 2018.
- 9 January 2018, [P. G. Kusalik](#), “Characterizing key features in the formation mechanisms of ice”, 14th International Conference on the Physics and Chemistry of Ice, Zurich, Switzerland, 7 January 2018—12 January 2018.
- 9 January 2018, [C. Simon](#), “Quantum networks: Global, warm, biological?”, 48th Winter Colloquium on the Physics of Quantum Electronics (PQE-2018), Snowbird, United States of America, 7 January 2018—12 January 2018.
- 14 January 2018, [C. Simon](#), “Quantum networks: Global, warm, biological?”, Physics of the Universe Summit 2018 (POTUS 2018), Hawthorne & Pasadena, United States of America, 12 January 2018—14 January 2018.
- 27 January 2018, [P. E. Barclay](#), “Spin nano-optomechanics”, SPIE Photonics West 2018, San Francisco, United States of America, 27 January 2018—1 February 2018
- 1 February 2018, [P. E. Barclay](#), “Diamond cavity and waveguide optomechanics”, SPIE Photonics West 2018, San Francisco, United States of America, 27 January 2018—1 February 2018.
- 8 March 2018, [G. Gour](#), “Mathematical structures and features of quantum resource theories”, S26.00002, APS March Meeting 2018, Los Angeles, United States of America, 5 March 2018—9 March 2018.

linkage

collaborations

INTERNATIONAL INSTITUTIONS

Aarhus University, Denmark

An-Najah National University, Palestine

Beijing University of Posts and
Telecommunications, People's Republic of China

Ben-Gurion University of the Negev, Israel

California Institute of Technology, United States of
America

Centro de Investigación y de Estudios Avanzados
(CINVESTAV), Mexico

Chimie ParisTech, France

Chinese Academy of Sciences' Institute of
Geology and Geophysics, People's Republic of
China

Cockcroft Institute, United Kingdom

Collège de France, France

Czech Academy of Sciences, Czechia

Durham University, United Kingdom

East China Normal University, People's Republic
of China

Ghent University, Belgium

Henan University of Technology, People's
Republic of China

Instituto Potosino de Investigación Científica y
Tecnológica (IPICYT), Mexico

Indian Institute of Science Education and
Research - Mohali, India

Institut d'Optique, France

Institut Langevin, France

Institut Universitaire de France, France

Isfahan University of Technology, Iran

Kazan Quantum Center, Russia

Kuvempu University, India

Macquarie University, Australia

Marquette University, United States of America

Montana State University, United States of
America

Moscow Institute of Physics and Technology,
Russia

National Institute for Standards and Technology
(Boulder), United States of America

National University of Singapore, Singapore

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

Purdue University, United States of America

Raman Research Institute, India

Scuola Normale Superiore di Pisa, Italy

Soreq Nuclear Research Center, Israel

Southeast University, People's Republic of China

Stockholm University, Sweden

Swansea University, United Kingdom

Texas A& M University, United States of America

Technische Universität Wien, Germany
The Russian Quantum Center, Russia
Università della Calabria, Italy
Universidade Federal do Rio de Janeiro, Brazil
University Paris-Sud, France
University of California at Berkeley, United States of America
University of Electronic Science and Technology, People's Republic of China
University of Glasgow, United Kingdom
University of Louisville, United States of America
University of Leeds, United Kingdom
University of Liverpool, United Kingdom
University of Manchester, United Kingdom
University of Oxford, United Kingdom
University of Queensland, Australia
University of Science and Technology of China, People's Republic of China
University of Sussex, United Kingdom
University of Tokyo, Japan
Xidian University, People's Republic of China
Weizmann Institute of Science, Israel
Wolfgang Pauli Institute, Austria

NATIONAL INSTITUTIONS

Canadian Institute for Advanced Research
National Research Council of Canada Ottawa
Simon Fraser University
TRIUMF
University of Alberta
University of British Columbia
University of Victoria
University of Waterloo
Université de Sherbrooke
York University

INDUSTRIAL & GOVERNMENT

City of Calgary
Katal Energy Inc.
NASA Jet Propulsion Laboratory
Natural Resources Canada (CanmetENERGY)

visitors

name	institution	name	institution
Simon Apers	Ghent University	Alireza Marandi	Stanford University
Ken Brown	Georgia Institute of Technology	Evan Meyer-Scott	University of Paderborn
Alexandre Blais	Université de Sherbrooke	Jonathan Oppenheim	University College London
Chiangqiang Cao	Chinese Academy of Sciences' Institute of Geology and Geophysics	Bartosz Regula	University of Nottingham
Jason Crann	Carleton University	Simanraj Sadana	Raman Research Institute
Shmuel Friedland	University of Illinois at Chicago	Yuval Sanders	Macquarie University
Hubert de Guise	Lakehead University	David Sauerwein	University of Innsbruck
Yu Guo	Shanxi Datong University	Abhi Saxena	Indian Institute of Technology Delhi
John Hepburn	Canadian Institute for Advanced Research	Kumar Sharma	Louisiana State University
Pervez Hoodbhoy	Forman Christian College	John Sipe	University of Toronto
Said Jalife Jacobo	Centro de investigacion y de estudios avanzados (CINVESTAV)	Raymond Spiteri	University of Saskatchewan
Jianhua Jiang	Soochow University	Chunhao Wang	University of Waterloo
Salini Karuvade	Dartmouth College	Yunjiang Wang	Xidian University
Aeysha Khaliq	National University of Science and Technology	Lianao Wu	Basque Foundation for Science
Mathurin Lagree	Grenoble Institute of Technology - Phelma	Wanjun Wu	Fuzhou University
Nathalie de Leon	Princeton University	Charles Zhaoxi Xiong	Harvard University
Daniel Lidar	University of Southern California	Haider Zia	University of Electronic Science and Technology of China
		Haimin Zheng	China University of Petroleum

graduate courses

course name	instructor	description
CHEM701 Independent Study: Self-assembled Monolayers	S. Trudel	Independent study not directly related to the student's thesis project normally under the direction of any chemistry faculty member. A course information sheet must be provided and a student report must be submitted on completion of the course.
MATH667 Introduction to Quantum Information	G. Gour	Focus on the mathematical treatment of a broad range of topics in quantum Shannon theory. Topics include quantum states, quantum channels, quantum measurements, completely positive maps, Neumarkis theorem, Stinespring dilation theorem, Choi-Jamiolkowski isomorphism, the theory of majorization and entanglement, the Peres-Horodecki criterion for separability, Shannon's noiseless and noisy channel coding theorems, Lieb's theorem and the strong subadditivity of the von Neumann entropy, Schumacher's quantum noiseless channel coding theorem, and the Holevo-Schumacher-Westmoreland theorem.
PHYS543 Quantum Mechanics II	A. I. Lvovsky	Theory of angular momentum and applications, perturbation theory and applications. Identical particles. Introduction to relativistic wave equations.
PHYS615 Advanced Quantum Mechanics	B. C. Sanders	Formalism of quantum mechanics. Entangled systems and their applications. Quantum nonlocality, Einstein-Podolsky-Rosen paradox, Bell theorem. Interpretations of quantum mechanics. Second quantization. Quantum theory of the electromagnetic field. Addition of angular momenta, Clebsch-Gordan coefficients, Wigner-Eckart theorem.

services and outreach

conferences/workshops

members	committee	conference/workshop	location	dates
P. E. Barclay	Chair, Program Subcommittee, FiO4: Photonics	OSA Frontiers in Optics 2017	Washington DC, United States of America	18–21 Sep 2017
P. E. Barclay	Chair, Program Subcommittee, FiO4: Photonics	OSA Frontiers in Optics 2018	Washington DC, United States of America	16–20 Sep 2018
A. I. Lvovsky	Chair, Program Committee	International Conference on Quantum Technologies	Moscow, Russia	12–16 Jul 2017
D. Oblak	Co-chair, Organizing Committee	2nd Workshop for Quantum Repeaters and Networks	Seefeld, Austria	25–26 Sep 2017
S. Trudel	Co-organizer	25th Canadian Symposium on Catalysis	Saskatoon, Canada	8–11 May 2018
S. Trudel	Co-organizer	101st Canadian Chemistry Conference and Exhibition	Edmonton, Canada	27–31 May 2018

professional services

name	role	journal/society/institution
P. E. Barclay	Chair, Division of Atomic, Molecular and Optical Physics	Canadian Association of Physicists
P. E. Barclay	Associate Editor	<i>Optics Letters</i>
P. G. Kusalik	Reviewer, FIRST EFRC Red Team	Oakridge National Laboratory
A. I. Lvovsky	Member, International Advisory Board	<i>Journal of Physics B: Atomic, Molecular and Optical Physics</i>
A. I. Lvovsky	Deputy Editor	<i>Optics Express</i>
D. R. Salahub	Member, Editorial Board	<i>Advances in Physical Chemistry</i>
D. R. Salahub	Member, Editorial Board	<i>Advances in Quantum Chemistry</i>
D. R. Salahub	Member, Editorial Board	<i>Computation</i>
D. R. Salahub	Vice Chair, Editorial Board	<i>Interdisciplinary Science: Computational Life Sciences</i>
D. R. Salahub	Member, Editorial Board	<i>Journal of Computational Chemistry</i>
D. R. Salahub	Member, Academic Editorial Board	<i>PLOS-One</i>
B. C. Sanders	Member, Editorial Board	IOP ebooks™
B. C. Sanders	Chair, Steering Committee	Quantum Africa Conference Series
B. C. Sanders	Editor-in-Chief	<i>New Journal of Physics</i>
Y. J. Shi	Associate Editor	<i>Canadian Journal of Chemistry</i>
W. Tittel	Member, Editorial Board	<i>Quantum Science and Technology</i>
S. Trudel	Chair, Materials Chemistry Division	Chemical Institute of Canada

quantum public lecture

The Quantum Public Lectures serve to convey leading breakthroughs in quantum science and technology to the general public. There is indeed a public appetite for learning the latest advances in the quantum world. Professor Michael Roukes from California Institute of Technology delivered a public lecture titled “Can we reverse-engineer the brain?” to about 200 persons on 6 June 2017, and this event was supported by the Faculty of Science Alumni Relations team as a joint outreach effort.

outreach lectures

10 April 2017, D. R. Salahub, “Multiscale modeling of (bio)chemical reactions in complex environments: Today – RNA Polymerase”, Shenzhen University, 3rd Hospital.

21 April 2017, W. Tittel, “Being a Professor at the University of Calgary”, Calgary Youth Science Fair, Calgary, Canada, 21 April 2017.

8 May 2017, A. I. Lvovsky, “Superresolution in linear optical imaging”, EMN Open Access Week 2017, Chengdu, People’s Republic of China, 8 May 2017–12 May 2017.

10 May 2017, Q. Zhou, V. R. R. Valivarthi, M. L. Grima Puigibert, G. Aguilar, F. Marsili, M. D. Shaw, V. B. Verma, S. W. Nam, D. Oblak and W. Tittel, “Quantum teleportation through a metropolitan fibre networks”, EMN Open Access Week 2017, Chengdu, People’s Republic of China, 8 May 2017–12 May 2017.

23 June 2017, W. Tittel, “Smoke and mirrors. Science needs excitement” (keynote), TEDXYXC, Calgary, Canada.

2 October 2017, B. C. Sanders, “Solving the mysteries of the quantum world”, SNS Physics Society Public Lecture, Islamabad, Pakistan.

4 October 2017, B. C. Sanders, “Building a quantum computer” (plenary), International Mini-School on Quantum and Ultrafast Optics: Theory and Experiment (TUD-CIIT), Islamabad, Pakistan, 4 October 2017–6 October 2017.

6 October 2017, B. C. Sanders, “Machine learning for hard quantum control” (keynote), International Mini-School on Quantum and Ultrafast Optics: Theory and Experiment (TUD-CIIT), Islamabad, Pakistan, 4 October 2017–6 October 2017.

1 March 2018, A. I. Lvovsky, “Quantum: from paradox to technology” (keynote), Think and Drink Event, Moscow, Russia.

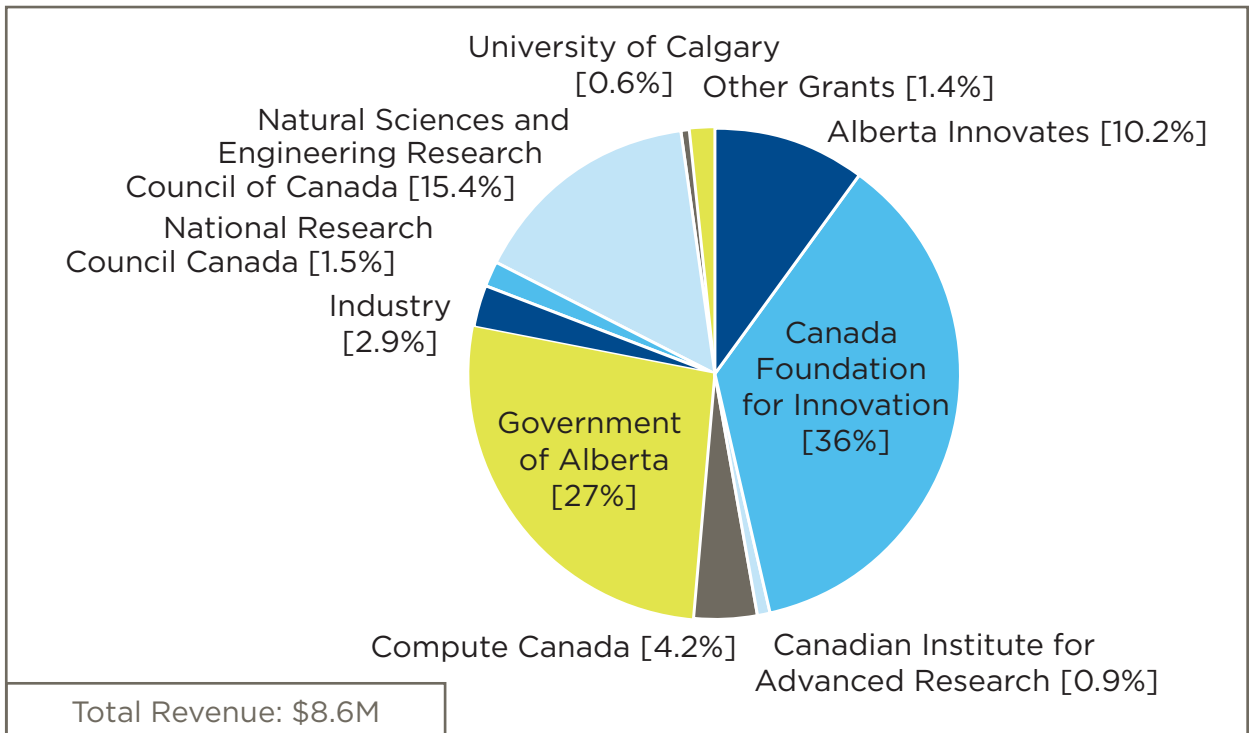
media coverage

source	title of article	date
Physorg.com	Physicists breeding Schrödinger cat states: A. I. Lvovsky	1 May 2017
Dailymail.co.uk	Physicists manage to “breed” Schrödinger’s cat in breakthrough that could help explain the quantum world: A. I. Lvovsky	2 May 2017
Express.co.uk	Scientists “BREED” Schrödinger’s cat in massive quantum physics breakthrough: A. I. Lvovsky	2 May 2017
Mail Online	Physicists manage to “breed” Schrödinger’s cat in breakthrough that could help explain the quantum world: A. I. Lvovsky	2 May 2017
Wired	Physicists “breed” largest ever Schrödinger’s cat – and it could help unlock the quantum world: A. I. Lvovsky	2 May 2017
CIFAR	How to breed Schrödinger’s cats: A. I. Lvovsky	17 May 2017
UToday	“Cats” bred by international scientific team help advance understanding of quantum mechanics: A. I. Lvovsky	25 May 2017
Explore.ualgary.ca	Beyond the final frontier: Exploring the mysterious quantum world: R. I. Thompson, B. C. Sanders, W. Tittel and C. Simon	30 Jul 2016
Futurism	World’s leading physicist says quantum computers are “tools of destruction, not creation”: A. I. Lvovsky	9 Aug 2017
MIT Technology Review	Are there optical communication channels in our brains?: P. Zarkeshian	6 Sep 2017
Bigthink.com	There are biophotons in the brain. Is something light-based going on?: P. Zarkeshian, S. Kumar, J. A. Tuszynski, P. E. Barclay and C. Simon	14 Sep 2017
UToday	Four UCalgary scholars named new Fellows of the Royal Society of Canada: B. C. Sanders	14 Sep 2017
Physorg.com	Cost effective quantum moves a step closer: R. Valivarthi, Q. Zhou and W. Tittel	19 Sep 2017
UToday	Faculty of Science physicists link billions of atoms in very large quantum entanglement : W. Tittel, C. Simon, N. Sinclair and P. Zarkeshian	13 Oct 2017
UToday	Minister Hehr announces more than \$20M in funding for health, science research: W. Tittel	13 Oct 2017
The Hindu	A quantum leap: A. Dalal and B. C. Sanders	5 Nov 2017
ualberta.ca	The second coming of quantum : P. E. Barclay, C. Simon and W. Tittel	27 Nov 2017
folio.ca	New grad program in quantum technologies to prepare students for entrepreneurship and industry: P. E. Barclay, C. Simon and W. Tittel	28 Nov 2017
CTV Calgary	Calgary remembers Stephen Hawking (video): D. Hobill	16 Mar 2018

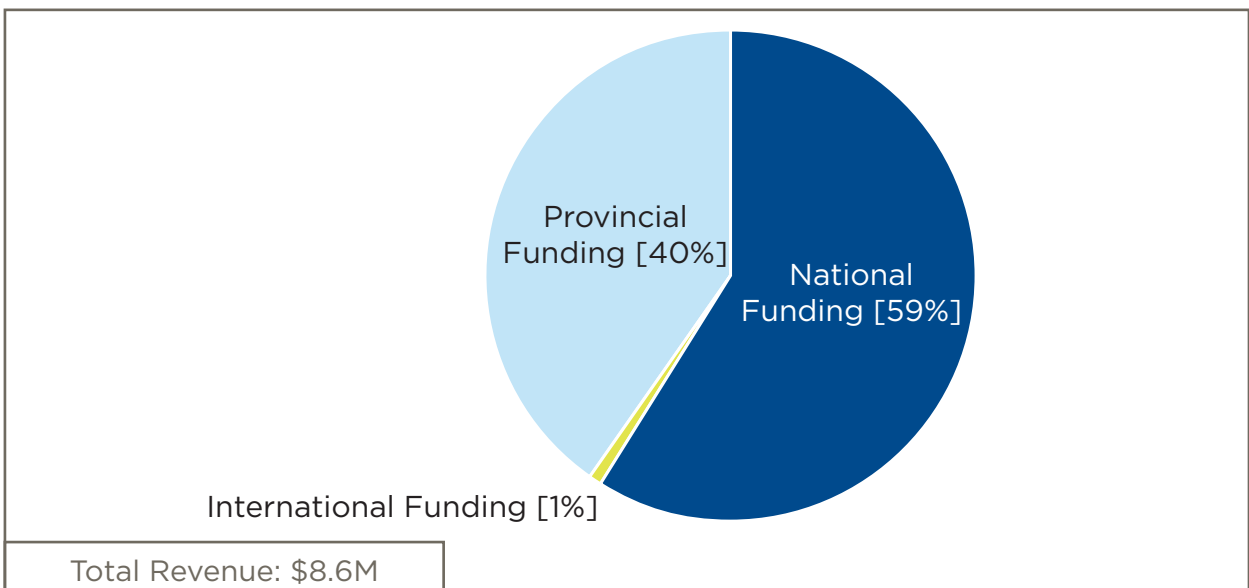
finances

research grants (unaudited)

BY FUNDING AGENCY



BY ORIGIN



objectives for next year

PAUL BARCLAY

- Demonstrate device exhibiting bichromatic optical switching.
- Demonstrate reservoir engineering in optomechanical quantum memories.
- Develop hybrid quantum optomechanical devices incorporating diamond colour centres for quantum transducers.

DAVID FEDER

- Determine the kinds of symmetry-protected topological states in quantum many-body systems that are resources for universal measurement-based quantum computation.
- Using the matchgate formalism, obtain the parameters under which the Fermi-Hubbard model can perform universal quantum computation.
- Explore the entanglement entropy scaling relationships for gapped and gapless one-dimensional systems at zero and finite temperature.
- Employ algebraic graph theory to the problem of determining the ground state of hard-core bosons on a graph.

GILAD GOUR

- Develop resource theories for quantum processes, including resource theory of entanglement, asymmetry, and athermality.
- Solve open problems in quantum information.
- Formalize the distinction between entanglement and Bell non-locality.

PETER KUSALIK

- Further develop and validate effective interaction potentials for OH radical in water that faithfully reproduces the structural features observed from ab initio simulations.
- Determine the stability and reactivity of hemi-bonded complexes of OH radical with Cl⁻ or Br⁻ anions.
- Develop and test empirical and coarse grain potential models appropriate for simulations studies of self assemble processes in Zn/ carboxylate MOFs.
- Identify appropriate measures for tracking formation of order during MOF self-assembly.
- Determine the key structural features in the nucleation processes of ice and gas clathrate hydrates.
- Examine the factors important in the nucleation of gas hydrates from water-in-oil emulsions.

ALEX LVOVSKY

- Apply the technique of far-field linear-optical superresolution microscopy to the problems of measuring the distance between two microscopic source emitters and full image reconstruction beyond the Rayleigh limit.
- Develop and characterize a nanofiber-based tactile sensor with position detection.
- Demonstrate a continuous-variable analogue of the Duan-Lukin-Cirac-Zoller protocol.

NASSER MOAZZEN-AHMADI

- Measure mid-infrared spectral signatures of weakly-bound complex CO-H₂O.
- Study halogen substitution on CO₂ micro-solvation.
- Employ infra-red multiphoton dissociation to selectively excite and break a particular bond in hydrocarbons in condensed phase.

DANIEL OBLAK

- Realize efficient quantum memory based on cavity assisted atomic frequency comb protocol in Tm:YAG.
- Develop protocol for optical to microwave transduction in rare-earth ion doped material.
- Set up measurement-device independent QKD system with quantum-dot based single photon sources.
- Demonstrate spectrally multi-mode entangled pair source based on cavity based spontaneous parametric down-conversion.

DENNIS SALAHUB

- Consolidate advances in multi-scale modelling methodologies and their implementation in efficient computer codes, with a focus on implementation of the GGA+U methodology for strongly correlated systems and quantum capping potentials for QM/MM calculations.
- Develop multiscale modelling of nanocatalysis for oil sands upgrading by extending our work on molybdenum carbide to include molybdenum sulfide for hydrogenation and mixed-valence ceria-metal catalysts to split water, using the produced hydrogen for hydrocracking over molybdenum carbide.
- Perform multiscale QM/MM studies of the mechanism of action of important enzymes; continue studies of the heme peroxidases in order to verify, or falsify, the presence of electron density circuits.
- Explore the interactions between oxygen species and hydrocarbons in the context of a process to extend the volume of diesel fuel.

BARRY C. SANDERS

- Develop a quantum algorithm for quantum computer simulation of a multi-scale renormalizable quantum field theory.
- Operationalize fundamental quantum protocols.
- Formalize the machine-learning description of quantum control.
- Develop plan for a quantum-satellite ground station in Alberta.
- Devise implementations of quantum computing on the cloud.

YUJUN SHI

- Develop understanding on the chemical vapor deposition of silicon nitride using aminosilane as precursors.
- Develop methods of forming Si-based nanostructures using chemical vapor deposition.
- Investigate the coke formation chemistry during ethane cracking.
- Explore pulsed laser dewetting method for the formation of metal nanoparticles.

CHRISTOPH SIMON

- Design microwave to optical transducers based on rare-earth doped crystals.
- Work towards designing a quantum network architecture involving superconducting qubits and transducers.
- Study the potential for entanglement creation in the brain due to the emission of photons by singlet oxygen molecules.
- Design a quantum repeater architecture based on single Erbium ions with non-zero nuclear spin.
- Work towards designing a quantum network architecture with single spins in diamond that can work at room temperature.

ROBERT THOMPSON

- Determine if antimatter falls up or down.
- Resolve atomic structures of antihydrogen.
- Develop precision ion source for TITAN.

SIMON TRUDEL

- Further development of in situ and in operando synchrotron spectroscopy methods for catalysts.
- Advanced spectroscopy of electrocatalysts.

appendices

appendix 1: charter of the institute for quantum science and technology

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.

Institute Board of Directors

7.
 - 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.

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

- 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.

appendix 2: IQST use of space

OFFICES

room number	size (square meter)
BI 547	35
BI 555	16
BI 556	17
ICT 653	13
MS 320	20
MS 326	13
MS 344	13
MS 352	13
SA 111	71
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
SB 316	32
SB 317	9
SB 318	53
SB 319	19
SB 323	12
SB 417	12
SB 501	25
SB 508 (partial)	55
SB 512 (partial)	64
SB 525	16
SB 531	12
SB 535	12

LABS

room number	size (square meter)
ES 04	248
SB 03A	39
SB 08 & 09	61
SB 126	61
SB 304	83
SB 416	62
SB 418	47

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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