



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

# QUANTUM FRONTIERS

**2018–2019**

## *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.

## *key facts*

15 postdoctoral fellows

73 graduate students

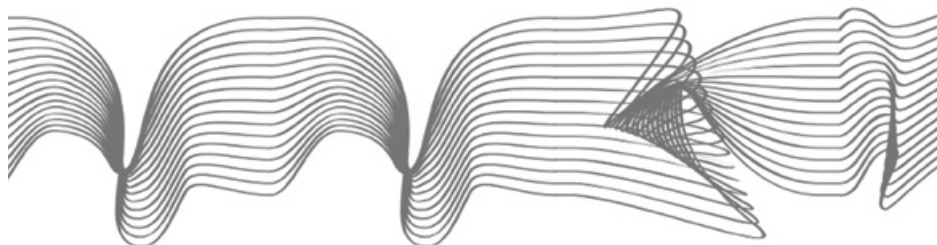
21 undergraduate students

59 publications in refereed journal and conference proceedings including *Nature* (2), *Nature Communications* (2), *Physical Review Letters* (3), *Physical Review X* (1), *Nano Letters* (1) and *Proceedings of the National Academy of Sciences of the United States of America* (1)

38 invited talks at national & international conference/ workshops including two keynote talks & one plenary talk

1.8M 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 123 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. In recent years, the Institute has effectively expanded to the provincial level through the growth of the *Quantum Alberta* initiative, which has three sites: the Universities of Alberta, Calgary and Lethbridge. The Institute for Quantum Science and Technology maintains a strong identity in Calgary but also exists as one of three *Quantum Alberta* branches.

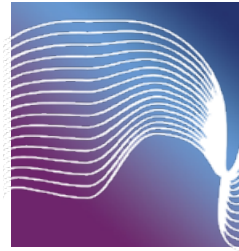
Two new members were welcomed in the past year. Daniel Oblak joined the faculty to lead the quantum communication program. After having been a long-term member of Wolfgang Tittel's group, Daniel was an excellent choice to build on the strengths left by Wolfgang Tittel when he chose to accept an offer to join Delft University of Technology in the Netherlands and leave Calgary. Alex Lvovsky accepted an offer to join the University of Oxford in the United Kingdom, and the University of Calgary moved swiftly to create a replacement position. Shabir Barzanjeh accepted the offer and will move from the Institute of Science and Technology in Austria to commence a faculty position at the University of Calgary in January 2020.

The Institute for Quantum Science and Technology has enjoyed a successful year of research and training during the 2018/2019 year. Members of the Institute had 59 papers published in refereed journals and proceedings including 10 papers appearing in the top-tier

journals of *Nature* (2), *Physical Review Letters* (3), *Nature Communications* (2), *Physical Review X* (1), *Nano Letters* (1) and *Proceedings of the National Academy of Sciences of the United States of America* (1). The Institute attracted thirteen new students into quantum graduate studies programs in 2018/2019. Seven masters students graduated and four doctoral students completed their degrees. The Institute hosted fifteen postdoctoral researchers with six being recipients of national and provincial postdoctoral fellowship including the NSERC Postdoctoral Fellowship (2), the PIMS Postdoctoral Fellowship (1), the Alberta Innovates Eyes High Postdoctoral Fellowship (2) and the T. Cheng Fong Postdoctoral Fellowship in Medical Imaging Science (1).

Success of the Institute is underpinned by support for training and infrastructure with especially notable support from the Natural Sciences and Engineering Research Council (NSERC) Collaborative Research and Training Experience (CREATE) Program called Quanta, which is headquartered at the University of Alberta. This program supports seven University of Calgary graduate students. Furthermore, quantum activity is advanced significantly by a Canada Foundation for Innovation (CFI) grant for quantum technology, led by the University of Calgary.

In 2019, the Alberta government's Economic Development and Trade Ministry chose to invest in three areas of major innovation under the Alberta Research and Innovation Framework. These three areas are \$6.3M for antimicrobial resistance led by the University of Calgary, \$7.1M for autonomous systems led by the University of Alberta, and \$5.8M for quantum technologies



## message from the chair

led by the University of Calgary. In addition to the major innovation fund, the Alberta Government is also supporting quantum technologies research and development through strategic research project grants, which support priority-driven research and innovation at Alberta post-secondary institutions.

The Institute continues to fulfill its mission as a Faculty of Science Institute. As an outcome of the Institute's provincial outreach, a dynamic, collaborative provincial quantum initiative, known as *Quantum Alberta*, has emerged. Resources are in place to enable continued success by the Institute's formidable team. The next year will be another strong year for quantum science and technology in Calgary.

### **BARRY SANDERS**

**Director, IQST**

Science is the foundation of sustainability, diversity, and economic prosperity; it's where discovery ignites innovation. As technological advances disrupt our core industries, we are leveraging our passion for science to adapt to, and lead this change—and the Institute for Quantum Science and Technology is a shining example. Researchers in IQST are catalysts for advancing the exciting multidisciplinary area of quantum science and growing the province's research and innovation ecosystem. The team brings a deep commitment for how quantum science applications can improve human existence.

In addition to the research strength of the Institute, the team is also educating the next generation of students and enable them to develop the curiosity, communication and critical thought, perspective and disciplinary excellence necessary to solve the challenges of the future. As a result, our students and alumni are engaged citizens and life-long learners who positively impact and change society.

My congratulations to IQST director Dr. Barry Sanders, PhD, on receiving significant support from the Alberta government's Major Innovation Fund, which invests in research and innovation to attract and retain top talent to support industries and local businesses. I am excited to see how the team will contribute to establishing Alberta as a hub for quantum technologies.

### **LESLEY RIGG**

**Dean  
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.

Gilad Gour had an excellent year of research achievements including publications in *Physical Review Letters* and in *Physical Review X*, which are the two American Physical Society flagship journals and regarded as the top society-published physics journals, and in *Nature Communications*. Gour's *Physical Review Letters* article connects memory capacity to quantum thermodynamics resources, and this emphasis on quantum thermodynamics is germane to Gour's *Nature Communications* article on entropic conditions for quantum thermodynamics. Rounding out this impressive set of achievements is Gour's *Physical Review X* article showing that transformations among pure multipartite entangled states via local operations are almost never possible.

Robert Thompson's work with the ALPHA collaborative team at the particle-physics research institute CERN has resulted in major experimental discoveries in antimatter research. Their characterization of the 1S-2S transition in antihydrogen and their observation of the 1S-2P Lyman- $\alpha$  transition in antihydrogen resulted in two *Nature* papers in 2018.

Christoph Simon and his group report in a *Physical Review B* article how to produce indistinguishable single photons in the solid-state setting by exploiting ultrasmall cavity-mode volumes. They suggest that a nanodiamond's negatively charged silicon-vacancy centre combined with a plasmonic Fabry-Perot hybrid cavity would serve as an excellent candidate system.

Alex Lvovsky collaborated on a project that shows two-level masers can operate as heat-to-work converters, which was published in

the *Proceedings of the National Academy of Sciences of the United States of America*. In beautiful experimental work, Lvovsky and his research group demonstrated entanglement and teleportation between polarization and wave-like encodings of an optical qubit, which appeared in *Nature Communications*.

Paul Barclay's group realized hexagonal boron-nitride cavity optomechanics, explained in their *Nano Letters* article, establishing a key step toward realizing integrated optomechanical circuits employing hexagonal boron-nitride.

Nasser Moazzen-Ahmadi's collaborative 2018 result on performing a detailed infrared spectrum of a weakly bound molecular complex has garnered significant attention. They obtain the infrared spectrum and potential energy surface for a dimer comprising a carbon-monoxide molecule weakly bound to an oxygen molecule. This report was designated a hot article in *Physical Chemistry Chemical Physics*.

Barry Sanders and collaborators performed ab initio characterization of coupling strength for all types of dangling-bond pairs on a "hydrogen-terminated silicon surface", which was published as an Editor's Pick in the *Journal of Chemical Physics*. Additionally, Sanders leads theoretical work for experimental quantum groups, with three especially notable results published as three separate *Physical Review Letters* articles. One result reports the observation of topologically protected edge states in a photonic two-dimensional quantum walk and establishes a well-controlled platform for exploring other types of nontrivial topological phases using light. A second result uncovers topology via quantum-quench spin dynamics on a two-dimensional Chern band, realized in an ultracold Rubidium-87 gas. The third result is on experimental quantum switching for exponentially superior quantum communication complexity by realizing a superposition of communication directions for a two-party distributed computation in up to 216 dimensions and demonstrates a communication complexity advantage over any causally ordered protocol.

# Awards

## INTERNATIONAL AWARDS

China Scholarship Council Award  
Zhengcai Zhang

Feodor Lynen Research Fellowship  
Martin Schon

## NATIONAL AWARDS

MITACS Scholarship  
Rishabh Shukla

MITACS Globalink  
Katelynn Daly  
Jianing Geng  
Zhe Liu

MITACS-Accelerate Graduate Research Internship Program

Seyed Shakib Vedaie

NSERC Alexander Graham Bell Canada Graduate Scholarship – Doctoral

David Lake  
Stephen Wein

NSERC Postdoctoral Fellowship

Ghazal Haji Salem  
Maryam Taheri

NSERC USRA

Alicia Anderson  
Dante Bencivenga  
Nathan Fischer  
Alex Hickey

NSERC Vanier Scholarship  
Carlos Enriquez-Victorero

Nova Chemicals Graduate Scholarship  
Rishabh Shukla

PIMS Postdoctoral Fellowship  
Yunlong Xiao

## PROVINCIAL AWARDS

Alberta Innovates Graduate Students Scholarship

Dante Bencivenga  
Sumit Goswami  
Faezeh Kimiaee Asadi  
Stephen Wein

## UNIVERSITY OF CALGARY AWARDS

Alberta Innovates Eyes High Postdoctoral Fellowship

Nikolai Lauk  
Namrata Shukla

Canadian Queen Elizabeth II Diamond Jubilee Graduate Scholarship

Nehad AttaElmanan AbdElrahim Mabrouk  
Joan Ngure

Curriculum Development Teaching Award (team award)

Simon Trudel

Entangled Hypothesis Graduate Scholarship in Mathematics & Physics

Archismita Dalal

Eyes High Doctoral Recruitment Scholarship

Andrew Evans

Faculty of Graduate Studies' Transformative Talent Internship Program

Hamza Qureshi

Izaak Walton Killam Doctoral Scholarship

Sumit Goswami

PURE Award

Zhan Yu  
Rana Zibakhshshabgahi

Queen Elizabeth II Graduate Scholarship

Aaron Barclay  
Stephanie Bovincini  
Katelynn Daly

Scholar of Scholars Academy

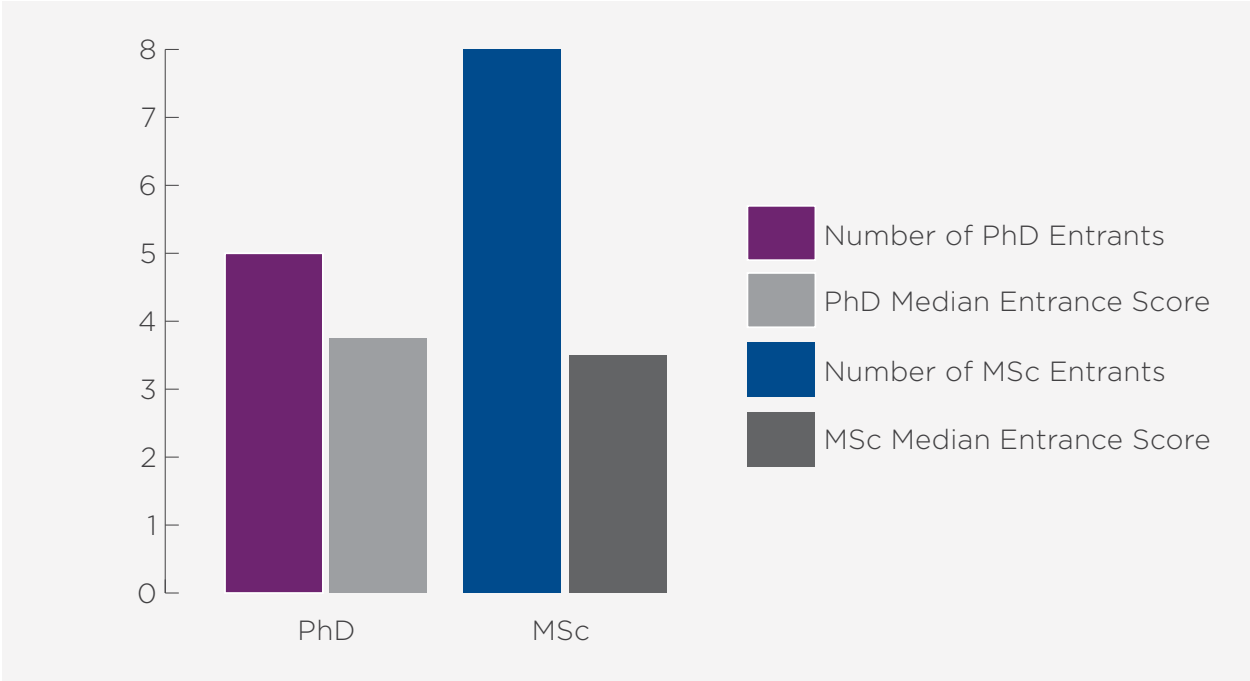
Dante Bencivenga  
Zhan Yu

T. Cheng Fong Postdoctoral Fellowship in Medical Imaging Science

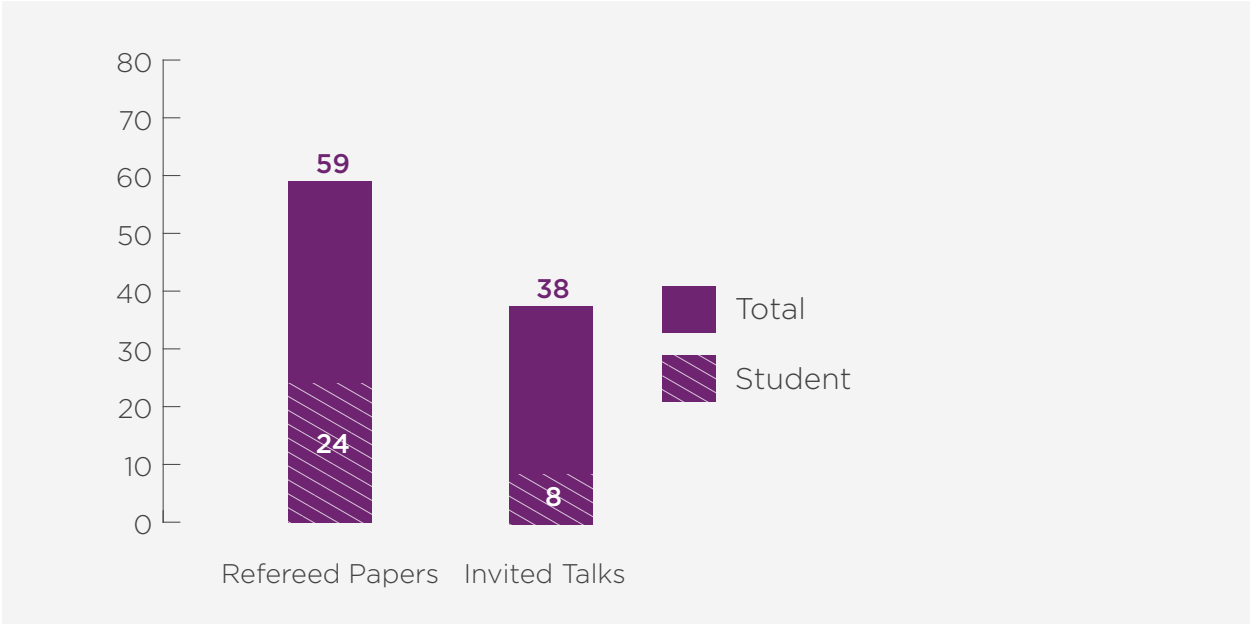
Ronnie Banerjee

# Key Performance Indicators

## GRADUATE STUDENT ENROLMENT AND QUALITY OF ENTRANTS

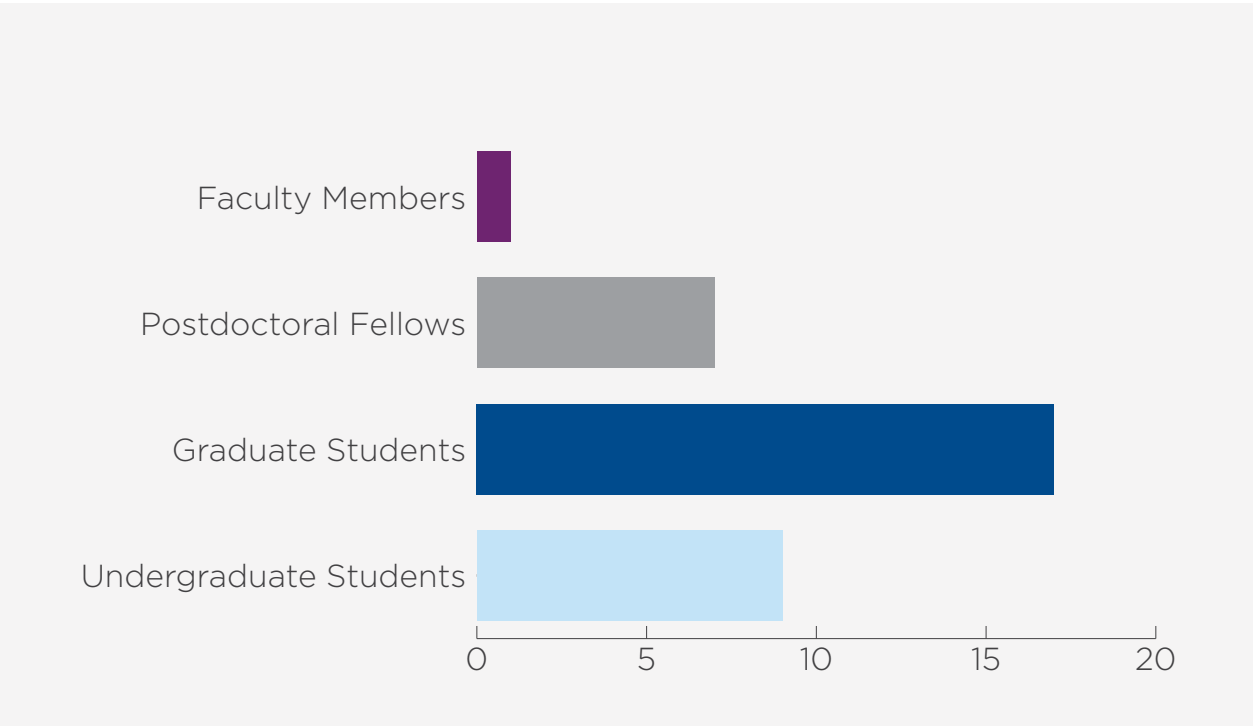


## PUBLICATIONS AND PRESENTATIONS

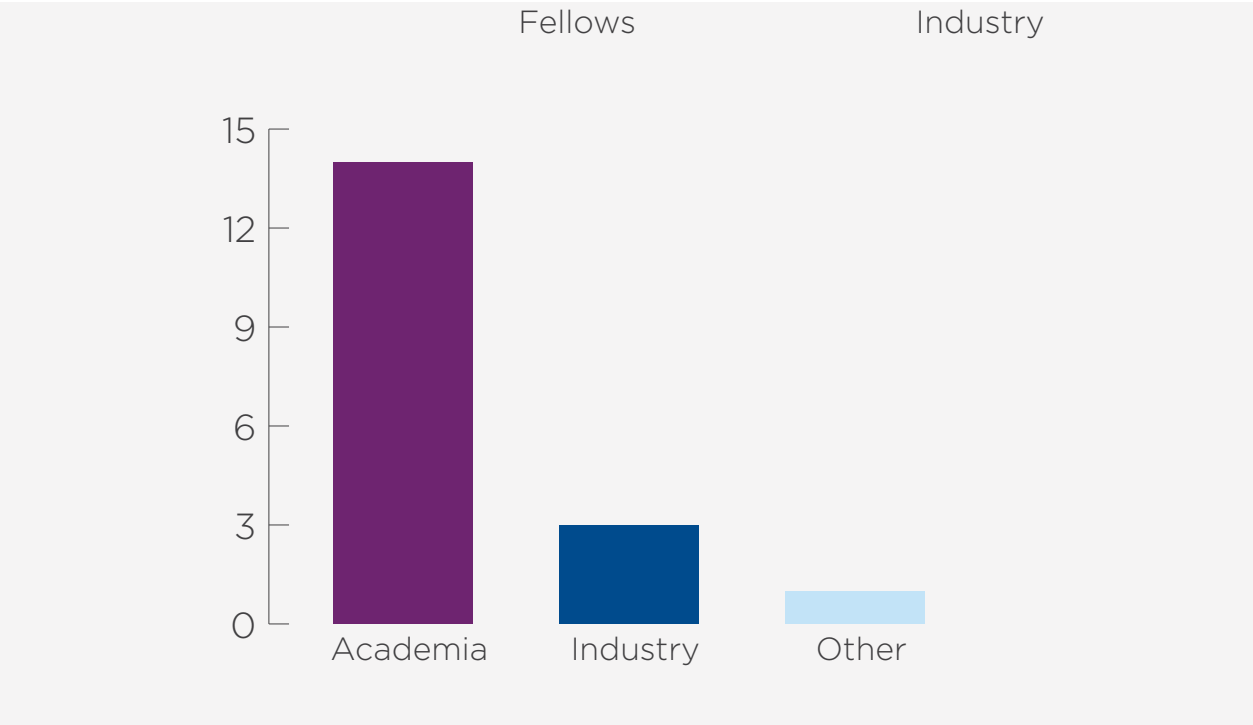




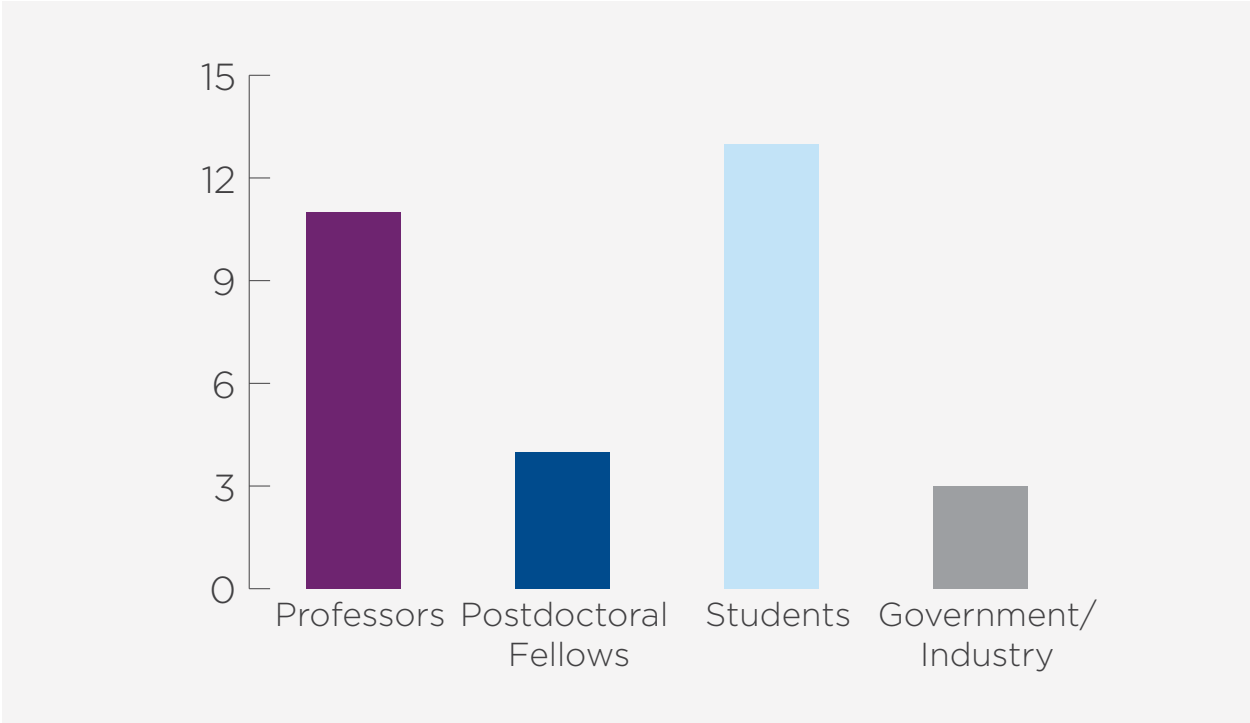
**AWARDS (CHAIRS, FELLOWSHIPS AND SCHOLARSHIPS)**



**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

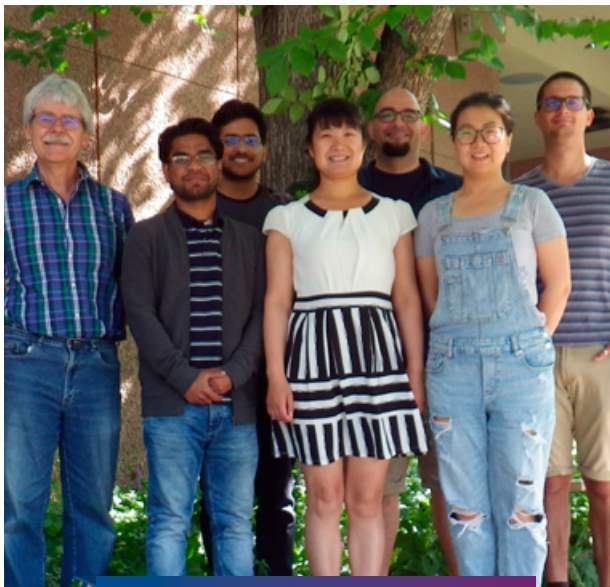
Employs sophisticated mathematical methods, such as algebraic geometry, matrix analysis, group theory and C\*-algebras, to solve core problems in quantum information science.



**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. DANIEL OBLAK**

## **QUANTUM CLOUD LAB**

In the Quantum Cloud Lab we aim to develop experimental capabilities that will lead to practical implementations of quantum links forming the basis of quantum networks that connect distant quantum devices. The goal involves research into quantum-key distribution over fibre and free-space channels, non-classical light sources, and quantum memory based on solid-state materials such as rare-earth ion doped crystals.



## 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.



## 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.





## 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.



## 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.



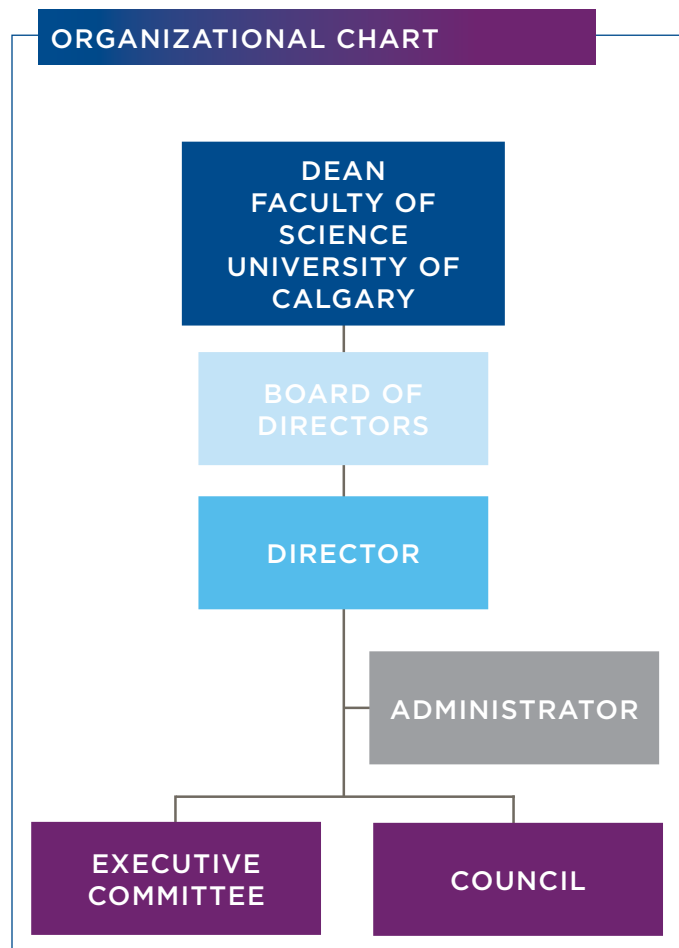
# management & membership

## 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 three 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'lorio

Senior Strategy Advisor, University of Ottawa

Chip Elliott

Chief Technology Officer, Raytheon BBN  
Technology

John Kendall

Sir Peter Knight

Principal, The Kavli Royal Society International  
Centre

Barry C. Sanders

Professor, Department of Physics and Astronomy,  
University of Calgary

Carl Williams

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

## 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

## 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

(resigned November 2018)

Professor, Department of Physics and Astronomy,  
University of Calgary

Nasser Moazzen-Ahmadi

Professor, Department of Physics and Astronomy,  
University of Calgary

Daniel Oblak

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

Dennis Salahub

Professor, Department of Chemistry, University of  
Calgary

Barry C. Sanders

Professor, Department of Physics and Astronomy,  
University of Calgary

## FACULTY MEMBERS (CONT'D)

### Yujun Shi

Professor, Department of Chemistry, University of Calgary

### Christoph Simon

Professor, Department of Physics and Astronomy, University of Calgary

### Robert I. Thompson

Professor, Department of Physics and Astronomy, University of Calgary

### Simon Trudel

Associate Professor, Department of Chemistry, University of Calgary

## AFFILIATE MEMBERS

### Robin Cockett

Professor, Department of Computer Science, University of Calgary

### David Hobill

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

### Sergei Noskov

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

## POSTDOCTORAL FELLOWS

Abhijeet Alase

Gustavo Amaral (resigned July 2018 →Postdoc, Delft University of Technology)

Ronnie Banerjee (completed December 2018 →Postdoc, University of Toronto)

Roohollah Ghobadi (completed June 2018 →Researcher, IQBit)

Nikolai Lauk (completed September 2018

→Postdoc, California Institute of Technology)

Gustavo de Oliveira Luiz

Ghazal Haji Salem

Carlo Maria Scandolo

Martin Schon

Namrata Shukla (completed February 2019

→Postdoc, Max Planck Institute for the Science of Light)

Maryam Taheri

Yunlong Xiao

Jun Zhang

Wei Zhang

Zhengcai Zhang

## RESEARCH ASSOCIATES/ COORDINATORS/ENGINEERS

Burke Brockelbank (Research Assistant)

## GRADUATE STUDENTS (PHD PROGRAM)

Pramodh Senarath Yapa Archchige

Mohsen Bagherimehrab

Aaron Barclay

Bishnupada Behera

Stephanie Bovincini

Oliver Calderon

Jesus Alejandro Marin Calzada

Archismita Dalal

Katelynn Daly

Carlos Enriquez-Victorero

Koorosh Esteki

Andrew Evans

Mohsen Falamarzi Askarani (transferred April 2018 →PhD, Delft University of Technology)

Jose da Costa Filho (transferred August 2018 →PhD, University of Oxford)

Alison Fulton

Sumit Goswami

Chris Healey

Jiawei Ji

Salini Karuvade

Hamidreza Kaviani

Abdullah Khalid (graduated September 2018 →Lecturer, Habib University)

Faezeh Kimiaee Asadi

Sourabh Kumar  
David Lake  
Pascal Lefebvre  
Nehad AttaElmanan AbdElrahim Mabrouk  
Adam Mayer  
Matthew Mitchell  
Eugene Moiseev  
James Moncreiff  
Mahmood Noweir  
Eduardo Páez  
Pantita Palittapongarnpim (graduated February 2019 →Postdoc, University of Warwick)  
Gaurav Saxena  
Janakan Sivasubramaniam  
Anastasia Pushkina (transferred August 2018 →PhD, University of Oxford)  
Priyaa Varshinee Srinivasan  
Arina Tashchilina  
Raju Valivarthi (graduated April 2018 →Postdoc, Institute of Photonic Sciences Barcelona)  
Seyed Shakib Vedaie  
Elena Vialych (graduated March 2019 →Postdoc, University of Colorado, Boulder)  
Lei Wang  
Yadong Wu  
Parisa Zarkeshian

## GRADUATE STUDENTS (MSC PROGRAM)

Eric Ampong  
Paul Anderson (graduated April 2018 →PhD, University of Waterloo)  
Behnam Ashrafkhani  
Alex Cameron  
Jacob Davidson (graduated May 2018 →PhD, Delft University of Technology)  
Nuiok Dicaire (graduated September 2018 →PhD, University of Edinburgh)  
Jake Flowerdew  
Masoud Habibi Davijani  
Shreyas Jalnapurkar (graduated April 2018 →Specialist, SB Technology)  
Jiawei Ji (graduated January 2019 →PhD, University of Calgary)  
Mojtaba Komeili  
Murali Krishna  
Prasoon Kumar Shandilya  
Tamiko Masuda (graduated August 2018 →PhD, Business Development Specialist, Universal Quantum Devices Inc.)  
Blaine Jeffrey McLaughlin  
Mahdi Mousaei  
Yasser Novo-Fernández  
Kimberley Ann Owen  
Hamza Qureshi

Mohammad Rahmati (graduated January 2019)  
Dante Renato Bencivenga  
Kuntal Sengupta  
Prasoon Shandilya  
Rishabh Shukla  
Prathwiraj Umesh  
Stephen Wein  
Taoche Wu  
Yufeng Wu  
Yanjuan Xiong

## UNDERGRADUATE STUDENTS

Alicia Anderson (NSERC USRA)  
Thomas Agnew (UofC PHYS598)  
John Burniston (UofC PHYS598)  
Nathan Fischer (NSERC USRA)  
Sebastian Garcia (UofC PHYS599)  
Rysa Greenwood (UofC PHYS598)  
Paul Herringer (UofC PHYS598)  
Alex Hickey (NSERC USRA & PHYS598)  
Janet Leahy (UofC CPSC502)  
Zhe Liu (MITACS Globalink)  
Nolan McMahon (UofC PHYS598)  
Thanh Nguyen (Canada-ASEAN Scholarship and Educational Exchange for Development-SEED)  
Austin Nhung (UofC PHYS598)  
Kyle Ostrander (research assistant)  
Maria Pettyjohn (UofC PHYS598)  
Arta Seify (undergraduate research)  
Sarvin Sepassi (UofC PHYS599)  
Amanda Torres (UofC PHYS599)  
Zhan Yu (UofC CPSC502 & PURE award)  
Rana Zibakhshshabgahi (UofC PURE Award & PHYS598)

## ADMINISTRATION

Xining Chen (Part-time Webmaster)  
Jing (Nancy) Lu (Administrator)



## REFEREED JOURNALS

M. Ahmadi, B. X. R. Alves, C. J. Baker, W. A. Bertsche, A. Capra, C. Carruth, C. L. Cesar, M. Charlton, S. Cohen, R. Collister, S. Eriksson, A. Evans, N. Evetts, J. Fajans, T. Friesen, M. C. Fujiwara, D. R. Gill, J. S. Hangst, W. N. Hardy, M. E. Hayden, C. A. Isaac, M. A. Johnson, J. J. Jones, S. A. Jones, S. Jonsell, A. Khramov, P. Knapp, L. Kurchaninov, N. Madsen, D. Maxwell, J. T. K. McKenna, S. Menary, T. Momose, J. J. Munich, K. Olchanski, A. Olin, P. Pusa, C. Ø. Rasmussen, F. Robicheaux, R. L. Sacramento, M. Sameed, E. Sarid, D. M. Silverira, G. Strutter, C. So, T. D. Tharp, R. I. Thompson, D. P. van der Werf and J. S. Wurtele, "Characterization of the 1S–2S transition in antihydrogen", *Nature* **557**: 71–75, April 2018.

M. Ahmadi, H. B. Dang, G. Gour and B. C. Sanders, "Quantification and manipulation of magic states", *Physical Review A* **97**(6): 062332 (9 pp.), June 2018.

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## REFEREED CONFERENCE PROCEEDINGS

A. J. Barclay, A. R. W. McKellar and N. Moazzen-Ahmadi, "Spectra of C<sub>6</sub>H<sub>6</sub>-Rgn (n=1,2) in the 3 micron infrared band system of benzene", Proceedings of 73rd International Symposium on Molecular Spectroscopy, Urbana-Champaign, United States of America, 18–22 June 2018.

H. Kaviani, M. Wu, A. C. Hryciw, R. Ghobadi, S. Vo, D. Fattal and P. E. Barclay, "Detection of orbital angular momentum of light using cavity optomechanics", Proceedings of CLEO: Science and Innovations 2018, FW4F. 6, San Jose, United States of America, 13–18 May 2018.

D. Lake, M. J. Mitchell and P. E. Barclay, "Demonstration of all-optical switching with dichromatic cavity optomechanics", Proceedings of Frontiers in Optics 2018, FW7B.2, Washington, DC, United States of America, 16–20 September 2018.

M. J. Mitchell, D. Lake and P. E. Barclay, "Demonstration of an optomechanically tunable optical buffer in diamond microcavities", Proceedings of Frontiers in Optics 2018, FW7A.6, Washington, DC, United States of America, 16–20 September 2018.

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S. Vedaie, P. Palittapongarnpim and B. C. Sanders, "Reinforcement learning for quantum metrology via quantum control", Proceedings of 2018 IEEE Photonics Society Summer Topicals Meeting Series (SUM 2018), pp. 163–164, Waikoloa, Hawaii, United States of America, 9–11 July 2018.

## BOOKS AND CHAPTERS

A. I. Lvovsky, "Quantum Physics: An Introduction Based on Photons" (book), published by Springer Berlin, 2018.

## STUDENT THESES

J. Davidson, "Storing quantum correlations in different rare earth ion-doped solids. A tale of two memories" (MSc Thesis), May 2018.

N. Dicaire, "Quantum resource theories of non-projectiveness" (MSc Thesis), September 2018.

T. Masuda, "Fibre-taper collected photoluminescence characterization of diamond microdisks" (MSc Thesis), May 2018.

P. Palittapongarnpim, "Evolutionary algorithm for adaptive quantum-channel control" (PhD Thesis), January 2019.

M. Rahmati, "Effect of quantum barrier on the performance of quantum dot light-emitting diode" (MSc thesis), January 2019.

E. Vialykh, "Functions of natural multicomponent organic mixtures as emergent properties influenced by environmental contaminants" (PhD Thesis), March 2019.

## INTELLECTUAL PROPERTY

S. Trudel, “Bifunctional imaging agent for combined magnetic resonance and fluorescence imaging” (provisional patent), US62700678, submitted July 2018.

## INVITED PRESENTATIONS AT WORKSHOPS/CONFERENCES

*(Speaker name is underlined for presentations with multiple authors)*

2 April 2018, C. Simon, “Could photons and entanglement play a role in the brain?”, The Science of Consciousness 2018 (TSC 2018), Tucson, Arizona, United States of America, 2–7 April 2018.

22 April 2018, P. E. Barclay, “Diamond optomechanics”, 13th Annual IEEE International Conference on Nano/Micro Engineered and Molecular Systems, Singapore, 22–26 April 2018.

9 May 2018, P. E. Barclay, “Diamond quantum nanophotonics and nanomechanics”, Emerging Technologies 2018, Whistler, Canada, 9–11 May 2018.

9 May 2018, S. Trudel, “Amorphous mixed-metal oxy(hydroxides) catalysts for the oxygen evolution reaction”, 25th Canadian Symposium on Catalysis, Saskatoon, Canada, 8–11 May 2018.

10 May 2018, S. Trudel, “Amorphous mixed-metal oxy(hydroxides) catalysts for the oxygen evolution reaction” (keynote), 2th Canadian Catalysis Symposium, Saskatoon, Canada, 8 -11 May 2018.

13 May 2018, M. Mitchell, D. Lake, P. E. Barclay, “Optomechanically mediated wavelength conversion in diamond microdisks”, CLEO 2018, San Jose, United States of America, 13–18 May 2018.

17 May 2018, D. Sychev, A. E. Ulanov, A. A. Pushkina, E. Tiunov, V. Novikov and A. I. Lvovsky, “Schrödinger cats for quantum internet”, CLEO 2018, San Jose, United States of America, 13–18 May 2018.

25 May 2018, G. Gour, “Monogamy of entanglement without inequalities”, Multipartite Entanglement, Benasque, Spain, 20–26 May 2018.

29 May 2018, P. G. Kusalik, “Characterizing key features in the nucleation of ice and gas hydrates”, 101st Canadian Chemistry Conference and Exhibition, Edmonton, Canada, 27–31 May 2018.

29 May 2018, Y. J. Shi, “Gas-phase reaction kinetics of silacyclobutane molecules in a hot-wire chemical vapor deposition process”, 101st Canadian Chemistry Conference and Exhibition, Edmonton, Canada, 27–31 May 2018.

5 June 2018, P. E. Barclay, “Diamond optomechanics for pulse storage and wavelength conversion”, Photonics North 2018, Montreal, Canada, 5–7 June 2018.

5 June 2018, J. Davidson, M. L. Grimau Puigibert, M. Falamarzi Askarani, G. Amaral, T. Lutz, N. Sinclair, D. Oblak and W. Tittel, “Hybrid quantum storage of correlated photon pairs in separate solid-state memories”, Photonics North 2018, Montreal, Canada, 5–7 June 2018.

5 June 2018, C. Simon, “Quantum networks: global, warm, biological”, Photonics North 2018, Montreal, Canada, 5–7 June 2018.

12 June 2018, A. I. Lvovsky, “Schrödinger cats in quantum optics”, Canadian Association of Physicists Annual Congress 2018, Halifax, Canada, 11–15 June 2018.

13 June 2018, P. G. Kusalik, “Big data and machine learning: A path to physical insight”, 2018 eSENCE-Multiscale Modelling Meeting, Uppsala, Sweden, 11–13 June 2018.

19 June 2018, P. G. Kusalik, “Gas clathrate hydrates: A playground for exploring ordering processes in materials”, CECAM IRL Workshop on Marie Curie Computer Simulation of Chemical Technologies involving Confined Liquids, Dublin, Ireland, 18–19 June 2018.

27 June 2018, G. Gour, “Quantum resource theories beyond states”, Rocky Mountain Summit on Quantum Information, Boulder, United States of America, 25–29 June 2018.

2 July 2018, G. Gour, “Comparison of quantum channels with superchannels”, 4th Seefeld Workshop on Quantum Information, Seefeld, Tyrol, Austria, 1–6 July 2018.

9 July 2018, D. R. Salahub, “Multiscale modeling: from clusters to nanoparticles in complex environments — insight into the mechanisms for heavy oil upgrading”, 18th International Conference of Computational and Mathematical Modeling Methods in Science and Engineering (CMMSE 2018), Rota, Cadiz, Spain, 9–13 July 2018.

16 July 2018, D. Sychev, A. E. Ulanov, A. A. Pushkina, E. Tiunov, M. W. Richards, V. Novikov, I. A. Fedorov and A. I. Lvovsky, “Interfacial discrete- and continuous-variable encodings in quantum optics”, 27th Annual International Laser Physics

Workshop (LPHYS'18), Nottingham, United Kingdom, 16–20 July 2018.

17 July 2018, D. Oblak, “Quantum Communication – principles, architectures, components and limitations”, Quanta Summer School, Calgary, Canada, 16–17 July 2018.

17 July 2018, K. Owen, V. R. R. Valivarthi, P. Umesh, Q. Zhou, W. Tittel and D. Oblak, “Coexisting MDI-QKD”, Quanta Summer School, Calgary, Canada, 16–17 July 2018.

19 July 2018, P. E. Barclay, “Diamond spin optomechanics”, Spin Canada 2018, Calgary, Canada, 19–20 July 2018.

19 July 2018, D. Oblak, J. Davidson, M. L. Grimaud Puigibert, M. Falamarzi Askarani, V. B. Verma, M. D. Shaw, S. W. Nam, N. Sinclair, T. Lutz, G. Amaral and W. Tittel, “Rare-earth ion doped materials – for quantum memory and transduction”, Spin Canada 2018, Calgary, Canada, 19–20 July 2018.

3 August 2018, D. Oblak, “Building blocks for quantum networks”, Progress in Electromagnetics Research Symposium (PIERS), Toyama, Japan, 1–4 August 2018.

21 August 2018, D. R. Salahub, “Simulating electron dynamics in polarizable environments”, 256th ACS National Meeting & Exposition (Symposium on Membrane Protein Simulations & Free Energy Approaches), Boston, United States of America, 19–23 August 2018.

25 August 2018, D. Oblak, “Quantum networks – key building blocks”, PAF INQNET Symposium 2018, Palo Alto, United States of America, 25 August 2018.

13 September 2018, A. I. Lvovsky, “Connecting discrete and continuous-variable quantum information”, International Conference “Quantum information, statistics, probability”, Moscow, Russia, 12–14 September 2018.

20 September 2018, B. C. Sanders, “Quantum technologies”, Advanced Digital Technologies Conference: Promoting Academic Industry Collisions, Lethbridge, Canada, 20 September 2018.

21 September 2018, C. Simon, “Quantum networks”, INQNET Quantum Transduction Workshop, California Institute of Technology, Los Angeles, United States of America, 21 September 2018.

12 October 2018, N. Moazzen-Ahmadi, “The CO-H<sub>2</sub>O complex: Hydrogen bonding, tunneling motion and intermolecular modes”, Canadian

Infrared Users workshop at the Canadian Light Source, Saskatoon, Canada, 12–13 October 2018.

25 October 2018, B. C. Sanders, “A tale of two quantum paths” (keynote), Quantum–GJM Conference, Brisbane, Australia, 24–26 October 2018.

13 November, 2018, S. Trudel, “Transmission and electron microscopy”, Electrochemical Student Society Analytical Techniques Workshop, Calgary, Canada, 13 November 2018.

21 November 2018, C. Simon, “Could quantum effects play a role in the brain?”, Workshop on Computational Neuroscience, Calgary, Canada, 21 November 2018.

13 December 2018, B. C. Sanders, “Differential evolution for ion-trap gate design”, Australian Institute of Physics Congress (AIP 2018), Perth, Australia, 9–13 December 2018.

14 December 2018, B. C. Sanders, “Topology of a quantum walk on a lattice with a SU(3) coin” (plenary), 8th Workshop on Quantum Simulation and Quantum Walks (QSQW2018), Perth, Australia, 14–16 December 2018.

18 December 2018, K. Owen, V. R. R. Valivarthi, P. Umesh, C. John, D. Oblak and W. Tittel, “Coexisting MDI QKD—cost-effective quantum cryptography”, Quantum Secured Communications 2 – kickoff meeting, Ottawa, Canada, 17–18 December 2018.

18 December 2018, D. Oblak, J. Davidson and W. Tittel, “Efficient quantum memory for quantum repeaters”, Quantum Secured Communications 2—kickoff meeting, Ottawa, Canada, 17–19 December 2018.

5 February 2019, P. E. Barclay, “Coherent optomechanical light manipulation in diamond”, SPIE Photonics West, San Francisco, United States of America, 2–7 February 2019.

11 March 2019, S. Trudel, “Magnetic nanomaterials: From unconventional magnetism to unexpected photoluminescence”, 1st Workshop on Luminescence & Magnetism in Molecules & Materials, Ottawa, Canada, 11 March 2019.

26 March 2019, P. E. Barclay, “Coherent optomechanical light manipulation in diamond”, 3rd Workshop on OptoMechanics and Brillouin Scattering: Fundamentals, Applications and Technologies (WOMBAT), Tel Aviv, Israel, 26–28 March 2019.



*linkage*

## Collaborations

### INTERNATIONAL INSTITUTIONS

Aarhus University, Denmark

Al-Nahrain University, Iraq

Beijing Computational Science Research Centre,  
People's Republic of China

Ben-Gurion University of the Negev, Israel

CAS-Alibaba Lab for Quantum Computation,  
People's Republic of China

Cardiff University, United Kingdom

California Institute of Technology, United States of  
America

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

Chinese Academy of Science's College of Earth  
Science, People's Republic of China

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

Chinese Academy of Science's Shanghai Institute  
of Microsystem and Information Technology,  
People's Republic of China

Cockcroft Institute, United Kingdom

Complutense University of Madrid, Spain

Duke University, United States of America

East China Normal University, People's Republic  
of China

Eastern Illinois University, United States of  
America

Griffith University, Australia

Henan University of Technology, People's  
Republic of China

Hokkaido University, Japan

Imperial College London, United Kingdom

International School for Advanced Studies, Italy

Isfahan University of Technology, Iran

Macquarie University, Australia

Missouri University of Science and Technology,  
United States of America

Montana State University, United States of  
America

Nagoya University, Japan

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

Nanyang Technological University, Singapore

National Research Council (CNR) Italy-Institute  
for Photonics and Nanotechnologies (IFN) Milano

National Research Council (CNR) Italy-Institute  
for Photonics and Nanotechnologies (IFN) Como

National Research Council (CNR) Italy-Istituto  
Officina dei Materiali (IOM)

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

National University of Singapore, Singapore

Peking University, People's Republic of China  
Purdue University, United States of America  
Politecnico di Milano, Italy  
Polish Academy of Science's Institute of Nuclear Physics, Poland  
Radboud University, The Netherlands  
Raman Research Institute, India  
Shandong University, People's Republic of China  
Shanxi Datong University, People's Republic of China  
Sharif University of Technology, Iran  
Soreq Nuclear Research Center, Israel  
Southeast University, People's Republic of China  
Stockholm University, Sweden  
Swansea University, United Kingdom  
Texas Technology University, United States of America  
Technische Universität München, Germany  
The Russian Quantum Center, Russia  
Tsinghua University, People's Republic of China  
Università Ca' Foscari Venezia, Italy  
Universität of Münster, Germany  
Universidade Federal do Rio de Janeiro, Brazil  
Universidad de la República, Uruguay  
University College Dublin, Ireland  
Université catholique de Louvain, Belgium  
Université Paris-Sud, France  
University of California at Berkeley, United States of America  
University of California at San Diego, United States of America  
University of Electronic Science and Technology, People's Republic of China  
University of Innsbruck, Austria  
University of Illinois, Urbana-Champaign, United States of America  
University of Liverpool, United Kingdom  
University of Manchester, United Kingdom  
University of New Mexico, United States of America  
University of Oxford, United Kingdom  
University of Pavia, Italy  
University of Science and Technology of China, People's Republic of China  
University of Sydney, Australia  
University of Technology Sydney, Australia  
University of Tehran, Iran  
University of Wisconsin, Madison, United States of America

Vienna University of Technology, Austria  
Zhejiang University, People's Republic of China

## NATIONAL INSTITUTIONS

Brock University  
Canadian Institute for Advanced Research  
Lakehead University  
National Institute for Nanotechnology  
National Research Council of Canada Ottawa  
Queen's University  
Simon Fraser University  
TRIUMF  
University of Alberta  
University of British Columbia  
University of Ottawa  
University of Victoria  
University of Waterloo  
University of Saskatchewan  
York University

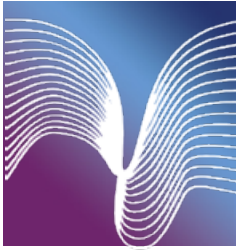
## INDUSTRIAL & GOVERNMENT

1QBit  
City of Calgary  
Hewlett-Packard  
Lumerical  
Natural Resources Canada (CanmetENERGY)  
Norcada  
Xanadu

## Visitors

Name	Institution
Abhijeet Alase	Dartmouth College
Saeid Asgarnezhad	Sharif University of Technology
Boris Braverman	University of Ottawa
Aashish Clerk	University of Chicago
Jacob Davidson	Delft University of Technology
Ish Dhand	Universität Ulm
Shane Eaton	Politecnico di Milano
TC Fraser	Perimeter Institute for Theoretical Physics
Mark Freeman	University of Alberta
Jianing Geng	Shandong University
Thomas Grégoire	Carleton University
Xianxin Guo	Hong Kong University of Science and Technology
Khabat Heshami	National Research Council Ottawa
Carmen Hsieh	University of Toronto
Can-Ming Hu	University of Manitoba
Mahnaz Jafarzadeh	Urmia University
Richard Lieu	University of Alabama at Huntsville
Na Lin	Shandong University
Jianlong Liu	University of Science and Technology of China

Name	Institution
Zhe Liu	Dalian University of Technology
Laleh Memarzadeh	Sharif University of Technology
William Murphy	Hicks & Associates Intellectual Property
Riley Nerem	Montana State University
Joan Ngure	African Institute for Mathematical Sciences Rwanda
Simanraj Sadana	Raman Research Institute
Joe Salfi	University of British Columbia
Hridya Meppully Sasidharan	S. V. National Institute of Technology
Urbasi Sinha	Raman Research Institute
Kartik Srinivasan	National Institute of Standards and Technology
Ming-Ming Wang	Xi'an Polytechnic University
Jianwei Xu	Northwest A&F University
Charles Zhaoxi Xiong	Harvard University
Siren Yang	Dalian University of Technology
Jeff Young	University of British Columbia



## *graduate courses*

Course Name	Instructor	Description
CPSC619 Quantum Computation	P. Høyer	Introduction to quantum computing. Quantum algorithms, quantum search, quantum fourier transforms, quantum error correcting codes, quantum cryptography, nonlocality and quantum communication complexity, and quantum computational complexity.
PHYS615 Non-relativistic Quantum Mechanics	D. Feder	Mathematical formalism of quantum mechanics. Topics may include addition of angular momenta, Clebsch-Gordan coefficients, Wigner-Eckart theorem; charged particles in electric and magnetic fields; quantum operators; approximation methods; scattering; quantum nonlocality, Einstein-Podolsky-Rosen paradox, Bell's theorem.
PHYS677 Implementations 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.
PHYS673 Quantum and Non-linear Optics	C. Simon	Theory of dispersion. Fast and slow light. Basics of nonlinear optics. Nonlinear optical crystals, phase matching. Coherence theory. Preparation, manipulation and measurement of quantum optical states and single-photon qubits. Elements of atomic physics, optical Bloch equation, rotating-wave approximation. Two-and three-level systems. Cavity quantum electrodynamics.



## *services and outreach*

### Conferences/Workshops

Members	Committee	Conference/ Workshop	Location	Dates
P. E. Barclay	Co-Chair	Spin Canada 2018	Calgary, Canada	19–20 Jul 2018
P. E. Barclay	Chair/Photonics Program (FiO4b)	Frontiers in Optics	Washington DC, United States of America	16–20 Sep 2018
B. C. Sanders	Organizer	BIRS Workshop on New Developments in Quantum Machine Learning	Banff, Canada	12–17 Jul 2020
S. Trudel	Symposium Organizer	25th Canadian Symposium on Catalysis	Saskatoon, Canada	8–11 May 2018



## Professional Services

Name	Role	Journal/Society/Institution
P. E. Barclay	Associate Editor	<i>Optics Express</i>
P. G. Kusalik	Member, Advisory Board, US Department of Energy Frontier Research Centre "Fluid Interface Reactions, Structures and Transport (FIRST)"	Oakridge National Laboratory
A. I. Lvovsky	Deputy Editor	<i>Optics Express</i>
N. Moazzen-Ahmadi	Member, Editorial Board & Guest Editor	<i>Journal of Molecular Spectroscopy</i>
D. R. Salahub	Member, Editorial Board	<i>Advances in Quantum Chemistry</i>
D. R. Salahub	College of Reviewers	Canadian Institutes of Health Research
D. R. Salahub	Member, Editorial Board	<i>Computation</i>
D. R. Salahub	Member, Resource Allocation Committee	Compute Canada
D. R. Salahub	Member, Review Panel	German Federal Government (for Universities of Excellence Competition)
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>
D. R. Salahub	Member, Grant Review Panel (CTMC Quantum Chemistry)	United States National Science Foundation
B. C. Sanders	Member, Editorial Board	IOP ebook™
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>
C. Simon	Guest Editor, Special Issue "Quantum Transduction"	<i>Quantum Science and Technology</i>
C. Simon	Guest Editor, Special Issue "Quantum Networks"	<i>Entropy</i>
S. Trudel	Chair, Materials Division	Chemical Institute of Canada

## Outreach Lectures

7 September 2018, B. C. Sanders, “Quantum information science”, Supply Chain Management Association Alberta Conference: Ahead of the Curve, Red Deer, Canada. (Gala dinner speaker on Artificial Intelligence & Advanced Manufacturing: AI’s Impact on Industry)

27 October 2018, D. R. Salahub, “Attracting talent to Henan Universities”, Zhengzhou, People’s Republic of China. (Panel discussion with 6 international experts).

9 November 2018, A. I. Lvovsky, “Quantum as an online technology trend”, Canadian Business Frontiers, Toronto, Canada.

14 November 2018, D. R. Salahub, “Multiscale modelling: from clusters to nanoparticles in complex environments – insight into mechanisms for heavy oil upgrading”, Synfuels China.

## Media Coverage

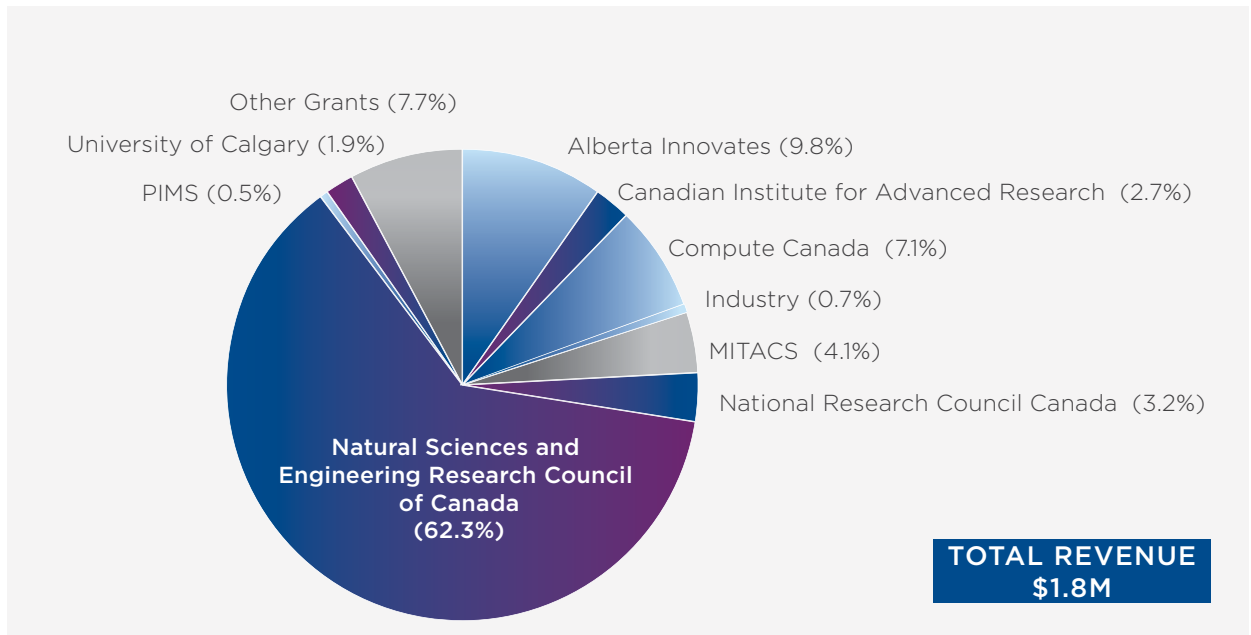
Source	Title of Article	Date
Global and Mail	Really want to end “manels”? Some conference organizers are offering childcare: S. Trudel	25 Jun 2018
Physicsworld.com	Magnetic model simulated in 3D by D-Wave quantum processor: B. C. Sanders	16 Jul 2018
Explore.ucalgary.ca	Can we be public and private at the same time? The coded thrill of cyberconnectivity: B. C. Sanders	1 Aug 2018
UToday	Industry, government and academia collaborate to advance cyber security, big data, and oil and gas water treatment: C. Simon	13 Aug 2018
CQNews	Quantum telecommunication conference held in Changshou: B. C. Sanders	17 Sep 2018
Chinanews	Chongqing starts a quantum project: B. C. Sanders	17 Sep 2018
Physicsworld.com	Superconducting and diamond qubits get a boost: B. C. Sanders	25 Sep 2018
Physicsworld.com	Journal editors share their views on the future of open-access publishing: B. C. Sanders	26 Oct 2018
Inside Science	Journal editors share their views on the future of open-access publishing: B. C. Sanders	30 Oct 2018
PLOS Blogs	Supercomputing 18: Pioneer spirit at the “Quantum Communication Networks and Technologies” panel: C. Simon	27 Nov 2018
TU Wien News	Quantum tricks to unveil the secrets of topological materials: B. C. Sanders	19 Dec 2018
Eureka Alert	Quantum tricks to unveil the secrets of topological materials: B. C. Sanders	21 Dec 2018
Stony Brook University News	Quantum immersion workshop to showcase research: B. C. Sanders	14 Feb 2019
UToday	Antimicrobial resistance and quantum technology dream teams receive \$12M in research funding: B. C. Sanders and MIF Quantum Technologies Team	8 Mar 2019



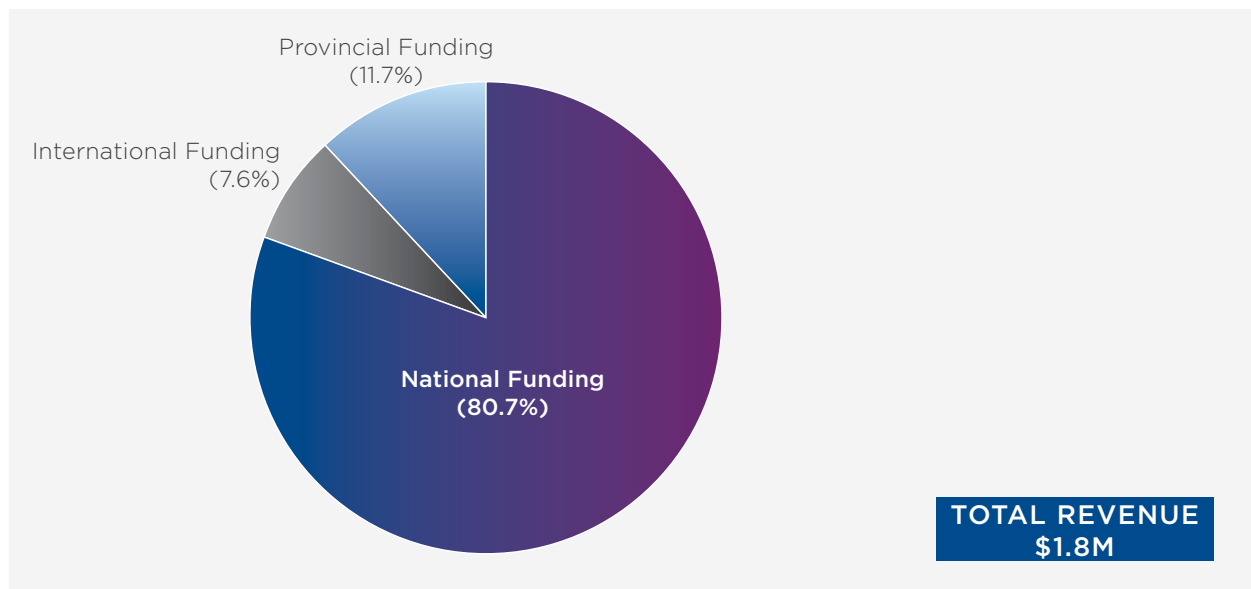
# finances

## Research Grants (unaudited)

### BY FUNDING AGENCY



### BY ORIGIN





## *objectives for next year*

### PAUL E. BARCLAY

- Demonstrate optomechanical switching for interfacing different wavelengths of light
- Develop optical memory for in-situ processing of stored information
- Create optomechanical devices for high frequency magnetometry
- 

### DAVID FEDER

- Determine the kinds of symmetry-protected topological states in quantum many-body systems that serve as resources for universal measurement-based quantum computation
- Explore topological phases of two-dimensional spin-orbit coupled quantum gases in the presence of interactions
- Uncover quantum phases of the extended Bose-Hubbard model in the presence of spin-orbit interactions in one dimension

### GILAD GOUR

- Determine necessary and sufficient conditions for converting one state to another under symmetric operations
- Derive necessary and sufficient conditions for converting an incoherent athermal state to an athermal state 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

### PETER HØYER

- Develop a quantum algorithm for sampling using quantum walks

### PETER KUSALIK

- Further develop and validate effective interaction potentials for the hydroxyl radical in water that faithfully reproduces structural features observed from ab initio simulations
- Determine stability and reactivity of hemibonded complexes of the hydroxyl radical with chloride or bromide anions
- Develop and test empirical and coarse-grain potential models appropriate for simulations of self-assembling processes in zinc/carboxylate metal-organic frameworks
- Use machine learning to identify appropriate measures for tracking formation of order during metal-organic framework self-assembly
- Determine key structural features in nucleation of ice and gas clathrate hydrates
- Examine the factors in the nucleation of gas hydrates from water-in-oil emulsions
- Develop novel approaches for molecular simulations of nucleation

### NASSER MOAZZEN-AHMADI

- Develop sensitive, compact, portable, and low-cost sensors for monitoring green-house gas emission
- Develop accurate global potential energy surfaces for molecular complexes
- Perform spectroscopic studies of microsolvation of carbon monoxide and carbon dioxide in water

## DANIEL OBLAK

- Demonstrate quantum memory with above 50% efficiency and greater than 100 MHz compatible with quantum repeaters
- Demonstrate quantum memory with more than 1 us storage time in thulium doped yttrium-gallium-garnet
- Commence construction of a quantum-satellite ground station
- Demonstrate spectrally multiplexed entangled pairs from a non-linear crystal
- Design components for a measurement-device-independent quantum-key-distribution prototype
- Identify rare-earth ion doped materials for quantum transduction from microwave to optical

## DENNIS SALAHUB

- Implement density functional theory with the Hubbard U-correction method in deMon2k for strongly correlated systems
- Extend oil-sands upgrading simulations to molybdenum sulfide as the nanocatalyst
- Initiate density functional theory with Hubbard U-correction calculations for the water gas shift reaction on nickel-ceria nanocatalysts
- Explore the use of machine learning to identify reaction coordinates (collective variables) for free-energy calculations

## BARRY C. SANDERS

- Formulate intelligent search for computational problems showing a quantum speed up
- Enhance quantum algorithms for preparing the ground state of free quantum field theories
- Propose faster lower-power pulse sequences for two and multi-qubit gates in various quantum computing implementations
- Commence collaboration with potential end users of quantum algorithms in epigenetics, block-chain, ab initio chemistry and/or facial recognition
- Complete surveys of status and challenges of a quantum-secure internet
- Install a functional quantum-satellite ground station in Calgary with Oblak

- Develop verification and validation protocols for quantum-communication tasks

## YUJUN SHI

- Further understand the chemical vapor deposition of silicon nitride using N-containing organosilicon precursors
- Apply chemical vapor deposition for the growth of Si-based nanostructures
- Develop pulse-laser dewetting method for formation of bimetallic nanoparticles

## CHRISTOPH SIMON

- Propose a quantum transducer based on optomechanical arrays
- Propose photonic communication between neurons based on oxygen and cytochrome oxidase
- Propose a quantum simulator based on Rydberg excitons in cuprous oxide
- Compare two-qubit quantum gates between individual defects in solids
- Write a review of approaches to quantum transduction
- Propose quantum networks based on individual erbium-167 ions in yttrium orthosilicate
- Compare approaches for quantum repeaters taking into account finite-memory lifetimes

## ROBERT THOMPSON

- Complete upgrade and commission ALPHA-g apparatus at CERN
- Resolve atomic structures of antihydrogen
- Commission plasma ion source for TITAN

## SIMON TRUDEL

- Understand structural evolution of catalysts using in operando, synchrotron based methods
- Develop printing methods for charge transport layers for use in organic light-emitting diodes
- Study mechanism for memristive behaviour in amorphous metal-oxide thin films



## *appendix*

# 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 14 September 2023. 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.



# *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 BECOME 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**



**iqst.ca**

 **@iqstucalgary**

**t: +1 403 220 4403**

**f: +1 403 210 8876**

**e: [iqstinfo@ucalgary.ca](mailto:iqstinfo@ucalgary.ca)**

**Room 307**

**Science B Building**

**University of Calgary**

**2500 University Drive NW**

**Calgary, AB T2N 1N4**

