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

QUANTUM FRONTIERS

ANNUAL REPORT 2021-2022

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

18 postdoctoral fellows

95 graduate students

20 undergraduate students

75 publications in refereed journal and conference proceedings including *Nature Communications* (1), *Nature Physics* (2), *Physical Review Letters* (2), *Nature Machine Intelligence* (1) *and Nanoscale* (1)

25 invited talks at national and international conference/workshops including one talk at plenary symposium

6 million dollars in research funds

CONTENTS

DIRECTOR'S REPORT

The Institute for Quantum Science and Technology hosts 18 research groups and about162 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.

The Institute is pleased to welcome Claudia Gomes da Rocha as a Faculty member. Claudia is in the Department of Physics and Astronomy. Her main research is on computational descriptions and modelling of nanoscale materials.

The Institute for Quantum Science and Technology has enjoyed a successful year of research and training during the 2021/2022 year. Members of the Institute had 75 papers published in refereed journals and proceedings including seven papers appearing in the top-tier journals of *Nature Communications* (1), *Nature Physics* (2), *Physical Review Letters* (2), *Nature Machine Intelligence* (1), and *Nanoscale* (1). The Institute attracted 19 new students into quantum graduate studies programs in 2021/2022. Twelve masters students graduated and five doctoral students completed their degrees. The Institute hosted 18 postdoctoral researchers with six being recipients of national and provincial postdoctoral fellowship including the PIMS Postdoctoral Fellowship, Eyes High Postdoctoral Scholar (2), Killam Postdoctoral Scholars, CONACYT Scholarship, and e2i Fellowship.

The Institute is home to the Alberta Government's Ministry of Job, Economy and Innovation's Major Innovation Fund, which supports quantum science and technology at the Universities of Calgary, Alberta and Lethbridge. This provincial funding supports 37 graduate students and 10 postdoctoral researchers at the University of Calgary.

The Institute continues to fulfill its mission as a Faculty of Science Institute and deliver outcomes matching Faculty expectations with respect to the Grand Challenge of "Unlocking Our Digital Future". Furthermore, the Institute has a provincial leadership role through the *Quantum Alberta* initiative, which brings together the province's quantum science and technology researchers under the umbrella of one consortium. As quantum research and development ramps up in Canada and globally, the Institute has a key role to play in ensuring that Calgary continues to be strong on the world stage for quantum science and technology.

MESSAGE FROM THE CHAIR

Alberta is an exciting place to be right now. With start-ups and global companies coming here at an exponential rate, we are in the midst of an increasingly robust and dynamic innovation ecosystem. Quantum research and technologies, in particular, are already leading the way to economic diversification and growth. By 2040, quantum is expected to represent over $16.5 billion in annual revenue and 26,500 jobs in Alberta.

This year, the University of Calgary, the Government of Alberta, and Mphasis (an information technology service provider) made an exciting announcement: a $23 million investment from the Government of Alberta to help fund UCalgary's Quantum City initiative. Quantum City will be a connection point for organizations in Calgary that are ready to participate in the quantum revolution. This amazing ecosystem will continue to empower our researchers IQST and across the university to develop bold new solutions to our most complex challenges.

We are proud of the IQST team and congratulate them on another highly successful year. Some highlights include:

- **Dr. Barry Sanders**, Faculty of Science professor and director of the IQST, was a recipient of the City of Calgary 2022 Calgary Award in the International Achievement category. The Calgary Awards are given yearly by the City of Calgary to celebrate and recognize outstanding achievements and contributions made by Calgarians.
- **Dr. Majid Taghavi Dehaghani**, supervised by IQST member **Dr. Shabir Barzanjeh**, joined the UCalgary Faculty of Science through the Eyes High Postdoctoral Match-Funding Program.
- **Dr. Paul Barclay**, professor in the Faculty of Science, recently became an Elected Optica Fellow, in recognition of his pioneering work in the field of diamond quantum nanophotonics and optomechanics and revealing new physical phenomena using nanophotonic resonators.

I look forward to seeing more great work in quantum being done at UCalgary and across the province.

Dr. Kristin Baetz
Chair, IQST Board of Directors,
Dean, Faculty of Science
University of Calgary

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.

Paul Barclay's group demonstrated an optomechanical interface between telecom photons and spin quantum memory, which utilises susceptibility of spin qubits to strain. This result was published in *Nature Physics*. In addition, the group had two results on hexagonal boron nitride, one harmonic generation with ultralow pump power and the other on high-Q microresonators; these results were published in two separate *ACS Photonics* papers.

Daniel Oblak and his group demonstrated a long-lived solid-state optical memory for high-rate quantum repeaters, which was published in *Physical Review Letters*. This result shows the potential of thulium yttrium gallium garnet for creating multiplexed quantum memories with long optical storage times and opens the path to repeater-based quantum networks with high entanglement-distribution rates

Christoph Simon and collaborators generated photon-number entanglement by sequential excitation of a two-level atom, which was published in *Nature Photonics*. This experimental achievement leverages the fact that, during spontaneous emission of light from an excited atom, here realised as a quantum dot, the atom briefly becomes entangled with the photonic field. They show theoretically that applying longer sequences of pulses to the atom can produce a series of multi-temporal mode entangled states with properties intrinsically related to the Fibonacci sequence.

Rob Thompson and Tim Friesen and collaborators demonstrated sympathetic cooling of positrons, which are antimatter electrons, to cryogenic temperatures for use in antihydrogen production. This landmark achievement was published in *Nature Communications*. Rob Thompson, in another collaboration, measured the mass of neutron-deficient ytterbium isotopes and nuclear structure at the extreme proton-rich side of the shell labelled by N=82. This *Physical Review Letters* article elaborates that this result extends measurements to two isotopes further away from stability than otherwise possible.

Gilad Gour and his collaborator investigated entropy and relative entropy from information-theoretic principles. This work was published in *IEEE Transactions on Information Theory*. In this work, they introduce an axiomatic approach to entropies and relative entropies that relies only on minimal information-theoretic axioms, and these axioms induce sufficient structure to establish continuity in the interior of the probability simplex and meaningful upper and lower bounds. The main result is a one-to-one correspondence between entropies and relative entropies.

In a *Nature Machine Intelligence* article, Dennis Salahub and collaborators develop their TransMut framework, which comprises TransPHLA for binding prediction and an automatically optimised mutated peptides program. Their framework aids with prediction of peptide and human leukocyte antigen binding, which can speed up immunogenic peptide screening and facilitate vaccine design.

Shabir Barzanjeh and collaborators wrote a review on optomechanics for quantum technologies, which appeared in *Nature Physics*.

AWARDS

INTERNATIONAL AWARDS

CONACYT SCHOLARSHIP – MEXICO

Maria Rossano-Tapia

SPIE OPTICS AND PHOTONICS EDUCATION SCHOLARSHIP

Kim Ann Owen

NATIONAL AWARDS

MITACS ACCELERATE FELLOWSHIP

Robert Riley Nerem

Seyed Shakib Vedaie

MITACS GLOBALINK RESEARCH AWARD

Avinash Manoj Sontakke

NSERC Canada Graduate Scholarships – Master's Program

Elijah Adams
Janet Leahy
Linh Ly
Zhan Yu

NSERC USRA

Taylor Cey
Emma Johnson
Marcus Kasdorf
Mark Lea
Seiji Oshie

PIMS POSTDOCTORAL FELLOWSHIP

Thomas Theurer

PROVINCIAL AWARDS

ALBERTA GRADUATE EXCELLENCE SCHOLARSHIP

Travis Gartner
Kim Ann Owen
Gaurav Saxena
Pramodh Senarath Yapa
Jordan Smith

ALBERTA INNOVATES GRADUATE STUDENTS SCHOLARSHIP

Bishnupada Behera
Salini Karuvade

UNIVERSITY OF CALGARY AWARDS

EYES HIGH POSTDOCTORAL SCHOLAR

Joseph Losby
Thomas Theurer

CANADIAN QUEEN ELIZABETH II DIAMOND JUBILEE SCHOLARSHIPS (ADVANCED SCHOLARS)

Nehad AttaElmanan AbdElrahim Mabrouk

EMERGING LEADERS IN THE AMERICAS PROGRAM

Dorcas Addo

e2i FELLOWSHIP

Sourabh Kumar

HELENA ROJEK GRADUATE SCHOLARSHIP

Aaron J. Barclay

J. B. HYNE RESEARCH INNOVATION SCHOLARSHIP

Aaron J. Barclay

KILLAM POSTDOCTORAL SCHOLARS

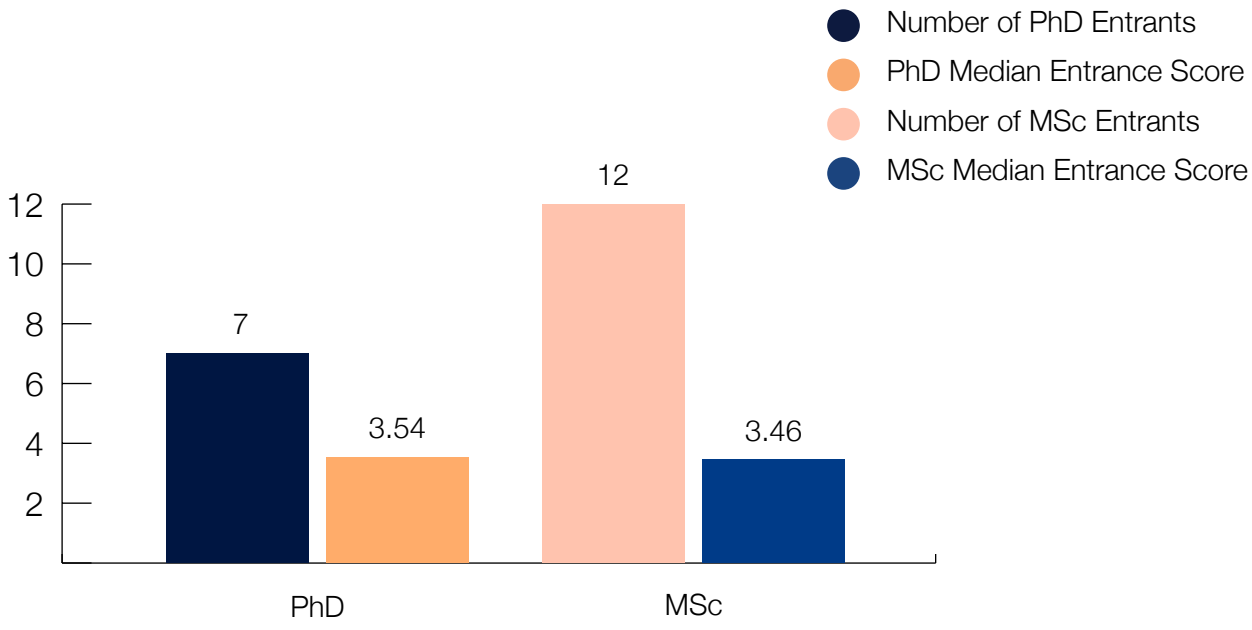
Abhijeet Alase

PURE AWARD

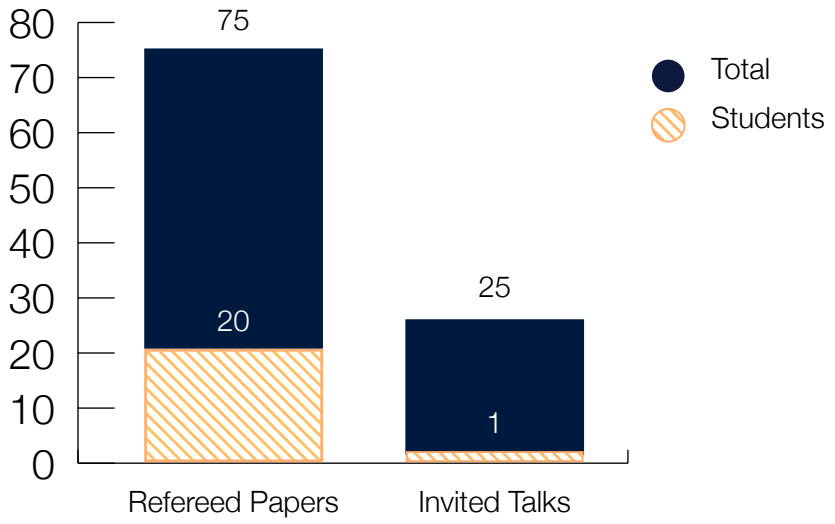
Emily Frede
Quinn Rupert
Salma Salhi
Abbygale Swadling

KEY PERFORMANCE INDICATORS

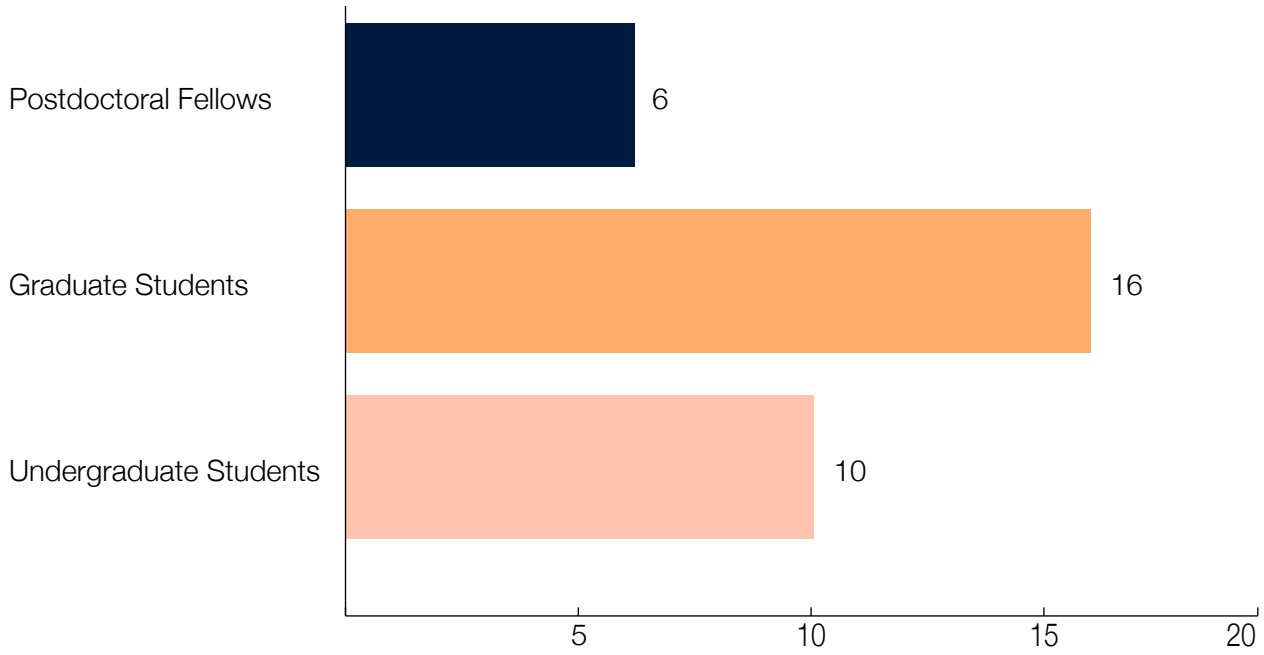
GRADUATE STUDENT ENROLMENT AND QUALITY OF ENTRANTS



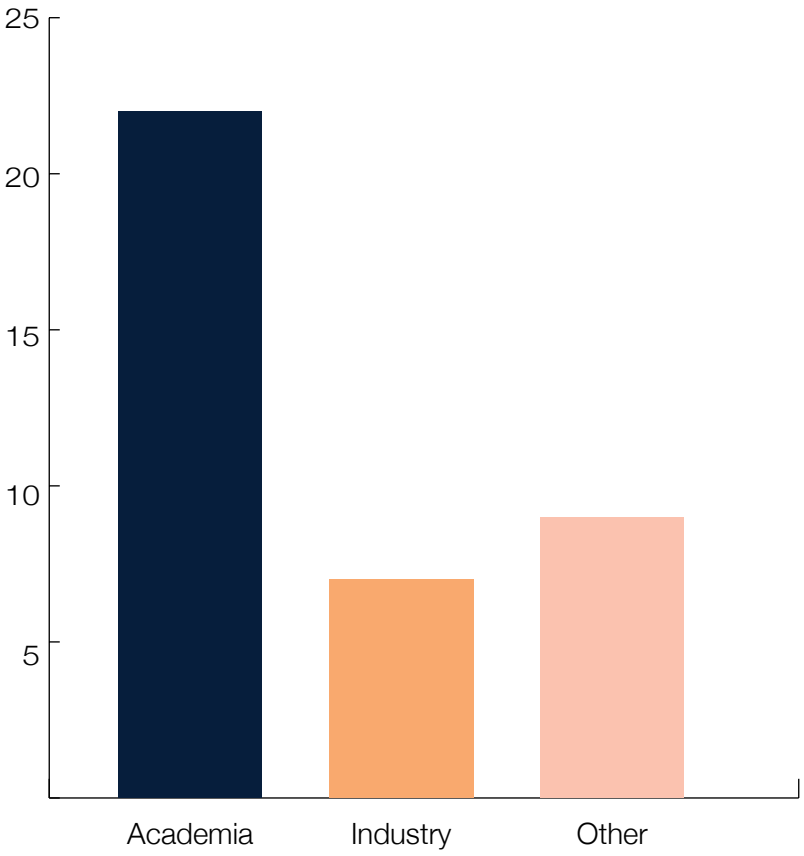
PUBLICATIONS AND PRESENTATIONS (HIGHLIGHTED PORTION WITH IQST STUDENT)



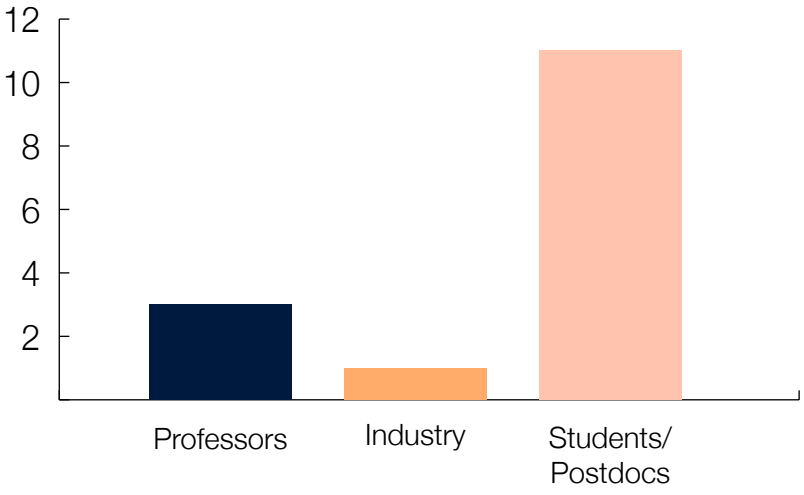
EXTERNAL AWARDS (CHAIRS, FELLOWSHIPS AND SCHOLARSHIPS)



TRAINEE DESTINATIONS AFTER IQST



VISITORS



RESEARCH GROUPS

PAUL BARCLAY

SHABIR BARZANJEH

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.

INTEGRATED HYBRID QUANTUM CIRCUITS

Focuses on the reversible quantum interface between the superconducting circuits and quantum optical systems. In our lab we develops quantum communication technology that is integrable with superconducting processors for building large-scale quantum networks.

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.

TIMOTHY FRIESEN

TESTING OF FUNDAMENTAL SYMMETRIES WITH ANTIMATTER

Experimental testing of symmetries between matter and antimatter primarily through study of (anti)hydrogen in collaboration with the ALPHA (Antihydrogen Laser Physics Apparatus) experiment at CERN. We focus on the development of particle traps, microwave techniques, and annihilation detection for high-precision spectroscopy and gravitational mass measurements on antihydrogen.

GILAD GOUR

PETER HØYER

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.

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.

PIERRE KENNEPOHL

MOLECULAR AND MATERIALS ELECTRONIC STRUCTURE

Explore the relationship between electronic structure of molecules and materials and their broader chemical properties and study the use of such interactions in molecular electronics and other applications. X-ray spectroscopies are the major tools for our exploration of electronic structure.

PETER KUSALIK

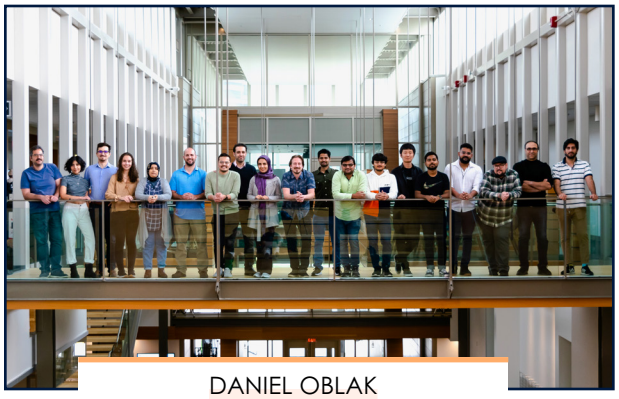
MOLECULAR SIMULATIONS OF LIQUIDS & SOLUTIONS, INTERFACES AND CRYSTALLIZATION

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.

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.



DANIEL OBLAK

QUANTUM CLOUD LAB

Develops experimental capabilities that will lead to practical implementations of quantum links forming the basis of quantum networks that connect distant quantum devices.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.

CLAUDIA GOMES DA ROCHA

COMPLEX NANO MATERIALS

Computational description and modelling of nanoscale materials for applications to neuromorphic computing, transparent conductors, and sensing; explore phenomena that emerge when matter is “packed” at the nanoscale at which quantum effects are present.

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 the context of high performance computing.

BARRY SANDERS

CARLO MARIA SCANDOLO

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.

QUANTUM INFORMATION AND FOUNDATIONS

Uses mathematical tools, such as matrix and convex analysis, to quantify quantum resources and optimize their use in information-theoretic protocols. Applies informational methods to foundational problems in quantum theory, especially using the framework of general probabilistic theories, which combine convex analysis with categorical methods.

YUJUN SHI

CHEMICAL VAPOR DEPOSITION CHEMISTRY

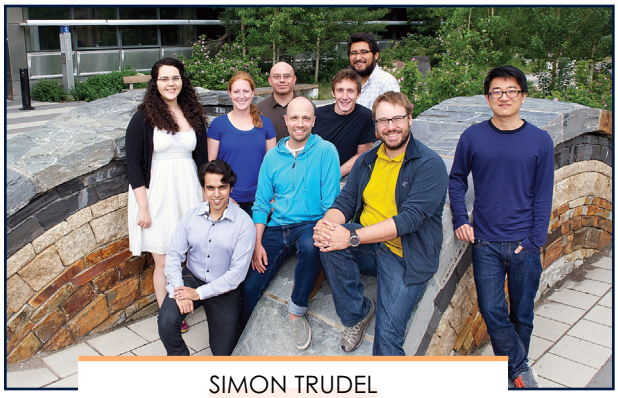
Focuses on chemical and physical processes underpinning the formation of silicon-containing semiconductor thin film materials using hot-wire chemical vapour deposition. Applies technically demanding laser ionization mass spectrometric and laser spectroscopic techniques to investigate this process at 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.

CHRISTOPH SIMON

THEORETICAL QUANTUM OPTICS

Applies 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).

ROBERT THOMPSON



SIMON TRUDEL

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

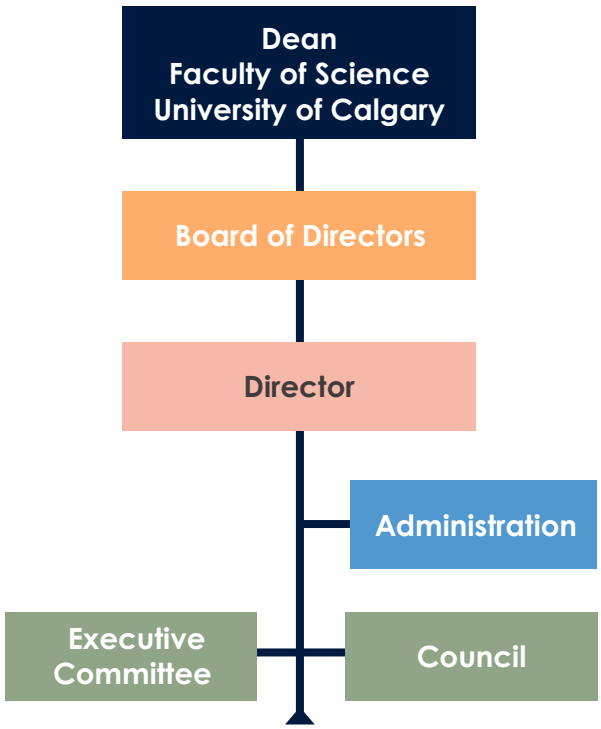
INSTITUTE STRUCTURE

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 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.

ORGANIZATIONAL CHART



GOVERNANCE

BOARD OF DIRECTORS

KRISTIN BAETZ

Dean, Faculty of Science, University of Calgary

MARIE D'IORIO

Chief Operating Officer, University of Ottawa

CHIP ELLIOTT

SIR PETER KNIGHT

Senior Fellow in Residence, The Kavli Royal Society International Centre

BARRY C. SANDERS

Professor, Department of Physics and Astronomy, University of Calgary

CARL WILLIAMS

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

EXECUTIVE COMMITTEE

PAUL E. BARCLAY

Professor, Department of Physics and Astronomy, University of Calgary

PETER KUSALIK

Professor, Department of Chemistry, University of Calgary

DANIEL OBLAK

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

BARRY C. SANDERS

Professor, Department of Physics and Astronomy, University of Calgary

COUNCIL

FACULTY MEMBERS

PAUL BARCLAY

Professor, Department of Physics and Astronomy, University of Calgary

SHABIR BARZANJEH

Assistant Professor

Department of Physics and Astronomy, University of Calgary

DAVID FEDER

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

TIMOTHY FRIESEN

Assistant Professor

Department of Physics and Astronomy, University of Calgary

CLAUDIA GOMES DA ROCHA

Assistant 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

PIERRE KENNEPOHL

Associate Professor, Department of Chemistry, University of Calgary

PETER KUSALIK

Professor, Department of Chemistry, 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 Emeritus, Department of Chemistry, University of Calgary

BARRY C. SANDERS

Professor, Department of Physics and Astronomy, University of Calgary

CARLO MARIA SCANDOLO

Assistant Professor, Department of Mathematics and Statistics, University of Calgary

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

Professor, Department of Chemistry, University of Calgary

AFFILIATE MEMBERS

ROBIN COCKETT

Professor, Department of Computer Science, University of Calgary

HUBERT DE GUISE

Professor, Lakehead University

KHABAT HESHAMI

National Research Council Canada

DAVID HOBILL

Professor Emeritus Department of Physics and Astronomy, 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

DANIEL TRAD

Associate Professor, Department of Geoscience, University of Calgary

RICHARD ZACH

Professor, Department of Philosophy, University of Calgary

POSTDOCTORAL FELLOWS

Shirin Afzal
Abhijeet Alase
Natália do Carmo Carvalho
Jiri Hostas
Faezeh Kimiaee Asadi
Youssef Kora
Sourabh Kumar
Renaud Miclette Lamarche
Joseph Losby (completed March 2022→ research associate, University of Calgary)
Trong Huynh Buu Ngo
Mahmood Noweir
Nicholas Randell
Vinaya Kumar Kavatamane Rathnakara
Saubhik Sarkar
Ashutosh Singh
Maryam Taheri (completed August 2021→lab scientist, CES Energy Solutions Corp.)
Thomas Theurer
Asha Yadav (completed August 2021)

RESEARCH ASSOCIATES/ COORDINATORS/ENGINEERS

Roohollah Ghobadi (research associate)
Erhan Saglamyurek (senior research associate)

GRADUATE STUDENTS (PHD PROGRAM)

David Amaro Alcalá
Shudipto Kazi Amin
Mohsen Bagherimehrab (graduated January 2022→postdoc, University of Toronto)
Aaron Barclay
Bishnupada Behera
Stephanie Bonvicini
Oliver Calderon
Archismita Dalal
Katelynn Daly
Danial Davoudi
Balarama Sridhar Dwadasi
Al-Waleed El-Sayed
Carlos Enriquez-Victorero
Leili Esmaeilifar
Koorosh Esteki
Andrew Evans (graduated December 2021)
Nasser Gohari Kamel
Sumit Goswami (graduated December 2021)
Pragati Gupta
Lizandra Barrios Herrera
Jiawei Ji
Mahsa Karimi
Prasoon Kumar Shandilya
Salini Karuvade
Pascal Lefebvre (graduated December 2021→postdoc, Sorbonne University)
Linh Ly
Nehad AttaElmanan AbdElrahim Mabrouk
Mahmood Noweir
Eduardo Paez
Adam Powell
Farhad Rasekh
Rishabh
Gaurav Saxena
Pramodh Senarath Yapa
Seyed Shakib Vedaie
Rishabh Shukla
Shahrzad Taherizadegan
Lei Wang
Pooja Woosaree
Hadi Zadeh Haghighi
Elia Zanoni
Parisa Zarkeshian (graduated December 2021→MITACS postdoc, 1QBit)
Elham Zohari
Joseph Zsombor-Pindera

GRADUATE STUDENTS (MSC PROGRAM)

Elijah Adams
Snehasis Addy
Ishra Afroze
Omid Aligholamioskooee

Jeas Grejoy Andrews
Aradhana Anil
Ashkan Bayat
Dante Renato Bencivenga
Parisa Behjat Khatouni
Fasiha Binat Zafar (graduated January 2022→ internship, Klue)
Ziheng Chang
Xining Chen
Ciara Chisholm
Anustup Das (graduated January 2022→PhD, University of Toronto)
Asma Farhat
Travis Gartner
Jianing Geng (graduated January 2022)
Mayte Li Gomez
Thomas Hujon
Santiago Jimenez Villegas
Pirouz Kiani
Mojtaba Komeili
Janet Leahy
Pengcheng Liao (graduated December 2021→PhD, University of Southern California)
Zhuohao (Ray) Liu
Linh Ly (transferred March 2022→PhD, University of Calgary)
Xinyuan Ma
Zachary Manson
Blaine Jeffrey McLaughlin (graduated January 2022)
Abdul Mohamed
Robert Riley Nerem
Joan Ngure
Yasser Novo-Fernández
Kim Ann Owen (graduated October 2021→PhD, York University & Toshiba Cambridge Labs)
Julian Palandri
Peyman Parsa
Mahkame Salini Moghadam
Nihari Sathsarani Pathirannehe
Anuj Sethia
Mehreen Shabbir
Sara Shafiei Alavijeh
Kenneth Sharman
Jordan Smith
James Stevenson
Armin Tabesh
Praveen Wakwella (graduated August 2021)
Taozhe (Evan) Wu (graduated April 2021)
Yufeng Wu (graduated August 2020→PhD, Yale University)
Yanjuan Xiong (graduated September 2021→engineer, OZ Optics)
Zhan Yu (graduated September 2021)
Elham Zohari (graduated April 2021→PhD, University of Calgary)

UNDERGRADUATE STUDENTS

Karabee Batta (visiting undergraduate student)
Taylor Cey (NSERC USRA)
Emily Frede (PHYS598 & PURE award)
Dareen Hallak (CHEM402)
Emma Johnson (NSERC USRA)
Eugene Kalionau (PHYS599)
Marcus Kasdorf (NSERC USRA)
Mark Lea (NSERC USRA)
Jizhong Liu (PHYS599)
Rubén Morales (PHYS 598)
Seiji Oshie (NSERC USRA)
Phillipine Pettitier (internship)
Quinn Rupert (PURE award)
Drake Rutherford (PHYS 599)
Salma Salhi (PURE award)
Amit Shalev (PHYS598)
Eli Sollid (PHYS598)
Avinash Manoj Sontakke (MITACS Globalink)
Stone Hanqi Sun (CHEM402)
Abbygale Swadling (PURE award)

ADMINISTRATION

Jing (Nancy) Lu (Administrator)
Sonali Keshava Murthy Naik (Part-time Webmaster)

PUBLICATIONS

REFEREED JOURNAL PUBLICATIONS (PUBLISHED)

N. Akhtar, B. C. Sanders and C. Navarrete-Benlloch, "Sub-Planck structures: Analogies between the Heisenberg-Weyl and SU(2) groups", *Physical Review A* **103**(5): 053711 (14 pp.), May 2021.

A. Alase and D. L. Feder, "Generating and detecting topological phases with higher Chern number", *Physical Review A* **103**(5): 053305 (12 pp.), May 2021.

C. J. Baker, W. A. Bertsche, A. Capra, C. L. Cesar, M. Charlton, A. Cridland Mathad, S. Eriksson, A. Evans, N. Evetts, S. Fabris, J. Fajans, T. Friesen, M. C. Fujiwara, P. Grandemange, P. Granum, J. S. Hangst, M. E. Hayden, D. Hodgkinson, C. A. Isaac, M. A. Johnson, J. M. Jones, S. A. Jones, S. Jonsell, L. Kurchaninov, N. Madsen, D. Maxwell, J. T. K. McKenna, S. Menary, T. Momose, P. Mullan, K. Olchanski, A. Olin, J. Peszka, A. Powell, P. Pusa, C. Ø. Rasmussen, F. Robicheaux, R. L. Sacramento, M. Sameed, E. Sarid, D. M. Silveira, G. Sutter, C. So, T. D. Tharp, R. I. Thompson, D. P. van der Werf and J. S. Wurtele, "Sympathetic cooling of positrons to cryogenic temperatures for antihydrogen production", *Nature Communications* **12**: 6139 (8 pp.), October 2021.

A. Banerjee, B. Blasiak, A. Dash, B. Tomanek, F. C. J. M. van Veggel and S. Trudel, "High-field magnetic resonance imaging: Challenges, advantages, and opportunities for novel contrast agents", *Chemical Physics Reviews* **3**(1): 011304 (25 pp.), January 2022.

A. J. Barclay, A. R. W. McKellar and N. Moazzen-Ahmadi, "New infrared spectra of CO_2–Ne: Fundamental for CO_2–^{22}Ne isotopologue, intermolecular bend, and symmetry breaking of the intramolecular CO_2 bend", *Chemical Physics Letters* **779**(13): 138874 (5 pp.), September 2021.

A. J. Barclay, A. R. W. McKellar, C. M. Western and N. Moazzen-Ahmadi, "New infrared spectra of CO_2–Xe: Modelling Xe isotope effects, intermolecular bend and stretch, and symmetry breaking of the CO_2 bend", *Molecular Physics* **119**(11): e1919325 (11 pp.), April 2021.

A. J. Barclay, A. R. W. McKellar, A. Pietropolli Charmet and N. Moazzen-Ahmadi, “Weakly-bound clusters of atmospheric molecules: infrared spectra and structural calculations of $(CO_2)_n$–$(CO)_m$–$(N_2)_p$, (n,m,p) = (2,1,0), (2,0,1), (1,2,0), (1,0,2), (1,1,1), (1,3,0), (1,0,3), (1,2,1), (1,1,2), *Physical Chemistry Chemical Physics* **24**: 7231–7242, March 2022.

S. Barzanjeh, A. Xuere, S. Gröblacher, M. Paternostro, C. A. Regal and E. M. Weig, “Optomechanics for quantum technologies”, *Nature Physics* **18**: 15–24, December 2021.

S. Beck, B. Kootte, I. Dedes, T. Dickel, A. A. Kwiatkowski, E. M. Lykiardopoulou, W. R. Plaß, M. P. Reiter, C. Andreoiu, J. Bergmann, T. Brunner, D. Curien, J. Dilling, J. Dudek, E. Dunling, J. Flowerdew, A. Gaamouci, L. Graham, G. Gwinner, A. Jacobs, R. Klawitter, Y. Lan, E. Leistenschneider, N. Minkov, V. Monier, I. Mukul, S. F. Paul, C. Scheidenberger, R. I. Thompson, J. L. Tracy, M. Vansteenkiste, H.-L. Wang, M. E. Wieser, C. Will and J. Yang, “Mass measurements of neutron-deficient Yb isotopes and nuclear structure at the extreme proton-rich side of the $N = 82$ shell”, *Physical Review Letters* **127**(11): 112501 (8 pp.), September 2021.

A. S. Bogomolov, A. Roucou, R. Bejjani, M. Herman, N. Moazzen-Ahmadi and C. Lauzin, “The rotationally resolved symmetric 2OH excitation in H_2O-CO_2 observed using pulsed supersonic expansion and CW-CRDS”, *Chemical Physics Letters* **774**(13): 138606 (5 pp.), April 2021.

S. N. Bonvicini, B. Fu, A. J. Fulton, Z.-T. Jia and Y.-J. Shi, “Formation of Au, Pt, and bimetallic Au–Pt nanostructures from thermal dewetting of single-layer or bilayer thin films”, *Nanotechnology* **33**(23): 235604 (14 pp.), March 2022.

S. Brandsen, I. J. Geng and G. Gour, “What is entropy? A perspective from games of chance”, *Physical Review E* **105**(2): 024117 (5 pp.), February 2022.

E. Chitambar, G. Gour, K. Sengupta and R. Zibakhsh, “Quantum Bell nonlocality as a form of entanglement”, *Physical Review A* **104**(5): 052208 (14 pp.), November 2021.

Y.-Y. Chu, X.-H. Wang, Q.-Y. Dai, Y.-J. Wang, Q.-K. Wang, S.-L. Peng, X.-Y. Wei, J.-F. Qiu, D. R. Salahub, Y. Xiong and D.-Q. Wei, “MDA-GCNFTG: identifying miRNA-disease associations based on graph convolutional networks via graph sampling through the feature and topology graph”, *Briefings in Bioinformatics* **22**(6): 1–19, May 2021.

Y.-Y. Chu, Y. Zhang, Q.-K. Wang, J.-Y. Zhang, X. Wang, D.-W. Wang, D. R. Salahub, Q.-R. Xu, S.-Y. Wang, X. Jiang and D.-Q. Wei, “A transformer-based model to predict peptide–HLA class I binding and optimize mutated peptides for vaccine design”, *Nature Machine Intelligence* **4**: 300–311, March 2022.

C. L. Cortes, P. Lefebvre, N. Lauk, M. J. Davis, N. Sinclair, S. K. Gray and D. Oblak, “Sample-efficient adaptive calibration of quantum networks using Bayesian optimization”, *Physical Review Applied* **17**(3): 034067 (17 pp.), March 2022.

A. Das, D.-J. Lee, P. K. Shandilya, S.-J. Kim, G.-M. Kang, D. P. Lake, B. Behera, D. D. Sukachev, I. Aharonovich, J.-H. Lee, J. Park and P. E. Barclay, “Demonstration of hybrid high-Q hexagonal boron nitride microresonators”, *ACS Photonics* **8**(10): 3027–3033, September 2021.

T. Delahaye, R. Armante, N. A. Scott, N. Jacquinet-Husson, A. Chédin, L. Crépeau, C. Crevoisier, V. Douet, A. Perrin, A. Barbe, V. Boudon, A. Campargue, L. H. Coudert, V. Ebert, J.-M. Flaud, R. R. Gamache, D. Jacquemart, A. Jolly, N. Moazzen-Ahmadi and S. Yurchenko, “The 2020 edition of the GEISA spectroscopic database”, *Journal of Molecular Spectroscopy* **380**(11): 111510 (26 pp.), July 2021.

F. A. Delesma, R. I. Delgado-Venegas, D. R. Salahub, J. M. del Campo, J. N. Pedroza-Montero, P. Calaminici and A. M. Köster, "Self-consistent auxiliary density perturbation theory", *Journal of Chemical Theory and Computation* **17**(11): 6934–6946, October 2021.

K. Esteki, H. G. Manning, E. Sheerin, M. S. Ferreira, J. J. Boland and C. G. Rocha, "Tuning the electro-optical properties of nanowire networks", *Nanoscale* **13**(36): 15369–15379, July 2021.

M. Falamarzi Askarani, A. Das, J. Davidson, G. Amaral, N. Sinclair, J. A. Slater, S. Marzban, C. W. Thiel, R. L. Cone, D. Oblak and W. Tittel, "Long-lived solid-state optical memory for high-rate quantum repeaters", *Physical Review Letters* **127**(22): 220502 (7 pp.), November 2021.

J. A. D. Flowerdew, I. Mukul, A. A. Kwiatkowski, M. E. Wieser, R. I. Thompson and J. Dilling, "Commissioning of a multi-purpose offline ion source at the TITAN experiment", *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment* **1005**(16): 165399 (8 pp.), July 2021.

B. Fu, G.-Z. Jian, W.-X. Mu, Y. Li, H.-Y. Wang, Z.-T. Jia, Y.-B. Li, S.-B. Long, Y.-J. Shi and X.-T. Tao, "Crystal growth and design of Sn-doped β-Ga_2O_3: Morphology, defect and property studies of cylindrical crystal by EFG", *Journal of Alloys and Compounds* **896**(16): 162830 (9 pp.), November 2021.

B. Fu, W.-X. Mu, Y. Li, Y.-J. Shi, Y.-B. Li, Z.-T. Jia and X.-T. Tao, "Investigation of the blue color center in β-Ga_2O_3 crystals by the EFG method", *CrystEngComm* **23**: 8360–8366, October 2021.

B. Fu, G.-Z. Jian, G.-H. He, B.-Y. Feng, W.-X. Mu, Y. Li, Z.-T. Jia, Y.-B. Li, S.-B. Long, S.-N. Ding, Y.-J. Shi and X.-T. Tao, "Investigation on β-Ga_2O_3 (101) plane with high-density surface dangling bonds", *Journal of Alloys and Compounds* **889**(16): 161714 (9 pp.), August 2021.

B. Fu, G.-H. He, W.-X. Mu, Y. Li, B.-Y. Feng, K.-H. Zhang, H.-Y. Wang, S.-J. Zhang, Z.-T. Jia, Y.-J. Shi, Y.-B. Li, S.-N. Ding and X.-T. Tao, "Laser damage mechanism and in situ observation of stacking fault relaxation in a β-Ga_2O_3 single crystal by the EFG method", *CrystEngComm* **23**: 3724–3730, April 2021.

A. N. Giakoumaki, G. Coccia, V. Bharadwaj, J. P. Hadden, C. H. Bennet, B. Sotillo, R. Yoshizaki, P. Olivero, O. Jedrkiewicz, R. Ramponi, S. M. Pietralunga, M. Bollani, A. Bifone, P. E. Barclay, A. Kubanek and S. M. Eaton, "Quantum technologies in diamond enabled by laser processing", *Applied Physics Letters* **120**(2): 020502 (11 pp.), January 2022.

R. Glorieux, C. Lauzin, A. J. Barclay, M. Herman and N. Moazzen-Ahmadi, "Spectroscopic study of the tunneling dynamics in N_2-water observed in the O–D stretch region", *Journal of Chemical Physics* **155**(17): 174309 (13 pp.), November 2021.

G. Gour and M. M. Wilde, "Entropy of a quantum channel", *Physical Review Research* **3**(2): 023096 (26 pp.), May 2021.

G. Gour and M. Tomamichel, "Entropy and relative entropy from information-theoretic principles", *IEEE Transactions on Information Theory* **67**(10): 6313–6327, May 2021.

G. Gour and C. M. Scandolo, "Entanglement of a bipartite channel", *Physical Review A* **103**(6): 062422 (21 pp.), June 2021.

G. Hajisalem, M. S. Shariatdoust, R. F. Ali, B. D. Gates, P. E. Barclay and R. Gordon, "Single nanoflake hexagonal boron nitride harmonic generation with ultralow pump power", *ACS Photonics* **8**(7): 1922–1926, June 2021.

W.-Y. He, D. D. Beattie, H. Zhou, E. G. Bowes, L. L. Schafer, J. A. Love and P. Kennepohl, "Direct metal–carbon bonding in symmetric bis(C–H) agostic nickel(ı) complexes", *Chemical Science* **12**: 15298–15307, November 2021.

J. Hostaš, A. Tchagang, M. P. Lourenço, A. M. Köster and D. R. Salahub, “Global optimization of ~1 nm MoS_2 and $CaCO_3$ nanoparticles”, *Theoretical Chemistry Accounts* **140**: 44 (11 pp.), April 2021.

H. Jayakumar, B. Khanaliloo, D. P. Lake and P. E. Barclay, “Tunable amplification and cooling of a diamond resonator with a microscope”, *Physical Review Applied* **16**(1): 014063 (8 pp.), July 2021.

J.-W. Ji, Y.-F. Wu, S. C. Wein, F. Kimiaee Asadi, R. Ghobadi and C. Simon, “Proposal for room-temperature quantum repeaters with nitrogen-vacancy centers and optomechanics”, *Quantum* **6:** 669 (20 pp.), March 2022.

S. Karuvade, A. Alase and B. C. Sanders, “Observing a changing Hilbert-space inner product”, *Physical Review Research* **4**(1): 013016 (11 pp.), January 2022.

P.-C. Liao and D. L. Feder, “Graph-state representation of the toric code”, *Physical Review A* **104**(1): 012432 (16 pp.), July 2021.

Z.-S. Lin, X. Tong, B. Patrick, P. Kennepohl and D. S. Grierson, “Reaction of 3-Cl/Ome-substituted 5-nitrobenzisothiazoles with hydrazine: structural and computational evidence for rearrangement pathways implicating intramolecular formation of pivotal Meisenheimer complexes”, *The Journal of Organic Chemistry* **86**(9): 6381–6389, April 2021.

M. P. Lourenço, B. R. L. Galvão, L. Barrios Herrera, J. Hostaš, A. Tchagang, M. X. Silva and D. R. Salahub, “A new active learning approach for global optimization of atomic clusters”, *Theoretical Chemistry Accounts* **140**: 62 (13 pp.), May 2021.

M. P. Lourenço, L. Barrios Herrera, J. Hostaš, P. Calaminici, A. M. Köster, A. Tchagang and D. R. Salahub, “Taking the multiplicity inside the loop: active learning for structural and spin multiplicity elucidation of atomic clusters”, *Theoretical Chemistry Accounts* **140**: 116 (10 pp.), August 2021.

L.-Q. Ly, A. J. Fulton, S. N. Bo Bonvicini and Y.-J. Shi, “Pulsed laser-induced dewetting and thermal dewetting of Ag thin films for the fabracation of Ag nanoparticles”, *Nanotechnology* **32**(33): 335301 (14 pp.), May 2021.

A. Mandwal, J. G. Orlandi, C. Simon and J. Davidsen, “A biochemical mechanism for time-encoding memory formation within individual synapses of Purkinje cells”, *PLOS ONE* **16**(5): e0251172 (34 pp.), May 2021.

E. S. Moiseev, A. Tashchilina, S. A. Moiseev and B. C. Sanders, “Broadband quantum memory in a cavity via zero spectral dispersion”, *New Journal of Physics* **23**(6): 063071 (12 pp.), June 2021.

S. Mukim, J. O’Brien, M. Abarashi, M. S. Ferreira and C. G. Rocha, “Decoding the conductance of disordered nanostructures: a quantum inverse problem”, *Journal of Physics: Condensed Matter* **34**(8): 085901 (9 pp.), December 2021.

R. Munir, E. Cieplechowicz, R. Miclette Lamarche, R. Chernikov, S. Trudel and G. C. Welch, “Air-processed organic photovoltaics for outdoor and indoor use based upon a tin oxide-perylene diimide electron transporting bilayer”, *Advanced Materials Interfaces* **9**(3): 2101918 (7 pp.), December 2021.

B. Nagarajan, Y.-N. Wang, M. Taheri, S. Trudel, S. Bryant, A. J. Qureshi and P. Mertiny, “Development and characterization of field structured magnetic composites”. *Polymers* **13**(17): 2843 (16 pp.), August 2021.

M. Naseri” J. Jalilian, D. R. Salahub, M. P. Lourenço and G. Rezaei, “Hexatetra-carbon: A novel two-dimensional semiconductor allotrope of carbon”, *Computation* **10**(2): 19 (9 pp.), January 2022.

M. Noweir, M. Helaoui, D. Oblak, W.-H. Chen and F. Ghannouchi, “Linearization of radio-over-fiber cloud-RAN transmitters using pre- and post-distortion techniques”, *IEEE Photonics Technology Letters* **33**(7): 339–342, April 2021.

C. M. Platnich, J. S. Slaby, D. O'Connell and S. Trudel, "Simple solvothermal approach to highly nanostructured hematite thin films", *Canadian Journal of Chemistry* **99**(4): 355–361, April 2021.

N. M. Randell, R. Miclette Lamarche, F. Tintori, R. Chernikov, G. C. Welch and S. Trudel, "Photodeposited polyamorphous CuO_x hole-transport layers in organic photovoltaics", *ACS Applied Energy Materials* **4**(11): 12900–12908, October 2021.

J. K. Saaswath, K. N. Pradosh, K. V. Adwaith, B. C. Sanders, F. Bretenaker and A. Narayanan, "Microwave-driven generation and group delay control of optical pulse from an ultra-dilute atomic ensemble", *Optics Express* **29**(11): 15940–15952, May 2021.

V. Salari, S. Rodrigues, E. Saglamyurek, C. Simon and D. Oblak, "Are brain-computer interfaces feasible with integrated photonic chips?", *Frontiers in Neuroscience* **15**(7): 780344 (16 pp.), January 2022.

R. Salzmann, N. Datta, G. Gour, X. Wang and M. M. Wilde, "Symmetric distinguishability as a quantum resource", *New Journal of Physics* **23**(8): 083016 (57 pp.), August 2021.

C. M. Scandolo, R. Salazar, J. K. Korbicz and P. Horodecki, "Universal structure of objective states in all fundamental causal theories", *Physical Review Research* **3**(3): 033148 (19 pp.), August 2021.

M. A. W. Schoen, O. Calderon, N. M. Randell, S. Jimenez Villegas, K. Daly, R. Chernikov and S. Trudel, "Local structural changes in polyamorphous $(Ni,Fe)O_x$ electrocatalysts suggest a dual-site oxygen evolution reaction mechanism", *Journal of Materials Chemistry A* **9**: 13252–13262, May 2021.

J. H. Selby, C. M. Scandolo and B. Coecke, "Reconstructing quantum theory from diagrammatic postulates", *Quantum* **5**: 445 (64 pp.), April 2021.

P. K. Shandilya, D. P. Lake, M. J. Mitchell, D. D. Sukachev and P. E. Barclay, "Optomechanical interface between telecom photons and spin quantum memory", *Nature Physics* **17**: 1420–1425, October 2021.

K. Sharman, F. Kimiaee Asadi, S. C. Wein and C. Simon, "Quantum repeaters based on individual electron spins and nuclear-spin-ensemble memories in quantum dots", *Quantum* **5**: 570 (21 pp.), November 2021.

N. Sinclair, D. Oblak, E. Saglamyurek, R. L. Cone, C. W. Thiel and W. Tittel, "Optical coherence and energy-level properties of a Tm^{3+}-doped $LiNbO_3$ waveguide at subkelvin temperatures", *Physical Review B* **103**(13): 134105 (15 pp.), April 2021.

J. M. Stevenson and Y.-J. Shi, "Theoretical study of decomposition kinetics and thermochemistry of bis(dimethylamino)silane—formation of methyleneimine and silanimine species", *Journal of Physical Chemistry A* **125**(57): 8175–8186, September 2021.

M. Taheri, B. Zanca, M. Dolgos, S. Bryant and S. Trudel, "Water-dispersible and ferroelectric PEGylated barium titanate nanoparticles", *Materials Advances* **2**: 5089–5095, June 2021.

P. Wakwella, A. R. W. McKellar and N. Moazzen-Ahmadi, "Infrared spectra of both isomers of CO_2-CO in the $CO_2 v_3$ region", *Molecular Physics* **119**(12): e1936251 (9 pp.), June 2021.

S.-H. Wei, B. Jing, X.-Y. Zhang, J.-Y. Liao, C.-Z. Yuan, B.-Y. Fan, C. Lyu, D.-L. Zhou, Y. Wang, G.-W. Deng, H.-Z. Song, D. Oblak, G.-C. Guo and Q. Zhou, "Towards real-world quantum networks: A review", *Laser & Photonics Reviews* **16**(21): 2100219 (29 pp.), January 2022.

Y.-L. Xiao, K. Sengupta, S.-R. Yang and G. Gour, "Uncertainty principle of quantum processes", *Physical Review Research* **3**(2): 023077 (11 pp.), April 2021.

H. Zadeh Haghighi and C. Simon, “Radical pairs can explain magnetic field and lithium effects on the circadian clock”, *Scientific Reports* **12**: 269 (12 pp.), January 2022.

H. Zadeh Haghighi and C. Simon, “Entangled radicals may explain lithium effects on hyperactivity”, *Scientific Reports* **11**: 12121 (10 pp.), June 2021.

W. W. Zhang, Y. R. Sanders and B. C. Sanders, “Channel discord and distortion”, *New Journal of Physics* **23**(8): 083025 (19 pp.), August 2021.

Z.-C. Zhang, P. G. Kusalik, G.-J. Guo, F.-L. Ning and N.-Y. Wu, “Insight on the stability of polycrystalline natural gas hydrates by molecular dynamics simulations”, *Fuel* **289**: 119946 (9 pp.), April 2021.

REFEREED CONFERENCE PROCEEDINGS

P. E. Barclay, “Optomechanical devices in diamond for classical and quantum information processing”, Active Photonic Platforms XIII: **117961P**, Proceedings of SPIE Nanoscience + Engineering 2021, volume 11796, San Diego, United States of America, 1–5 August 2021.

S. Chakraborty, P. Høyer, N. Mande, M. Paraashar and R. de Wolf, “Symmetry and quantum query-to-communication simulation”, pp. 20:1–20:23 Proceedings of 39th International Symposium on Theoretical Aspects of Computer Science (STACS), 15–18 March 2022, published by Schloss Dagstuhl–Leibniz-Zentrum.

T. A. Gartner, A. J. Barclay and N. Moazzen-Ahmadi, “A photonic gas sensor for the mid-infrared”, Proceedings of 2021 International Symposium on Molecular Spectroscopy (virtual), 21–25 June 2021.

G. Hajisalem, M. S. Shariatdoust, R. F. Ali, B. D. Gates, P. E. Barclay and R. Gordon, “Individual nanoflakes of two dimensional materials harmonic generation with ultralow pump power”, Proceedings of 2021 IEEE 16th Nanotechnology Materials and Devices Conference (NMDC 2021), Vancouver, Canada, 12–15 December 2021, published by IEEE.

G. Hajisalem, M. S. Shariatdoust, R. F. Ali, B. D. Gates, P. E. Barclay and R. Gordon, “Extraordinary nonlinear response of nanoparticles in double nanohole optical tweezers”, Optical Trapping and Optical Micromanipulation XVIII: **1179822**, Proceedings of SPIE Nanoscience + Engineering 2021, volume 11798, San Diego, United States of America, 1–5 August 2021.

S. Shafiei, E. Saglamyurek and D. Oblak, “Hour-long decay-time of Erbium spins in an optical fiber at milli-kelvin temperatures “, F2A.4, Proceedings of Quantum Information and Measurement VI (virtual), 1–5 November 2021, published by Optica Publishing Group.

BOOKS AND CHAPTERS

I. Ozier and N. Moazzen-Ahmadi, “Hindered internal rotation”, section in book: CRC Handbook of Chemistry & Physics 102: pp. 960–964, published CRC Press in 2021.

STUDENT THESES

M. Bagherimehrab, “Algorithmic quantum-state generation for simulating quantum field theories on a quantum computer” (PhD thesis), January 2022.

A. Das, “Hybrid high Q hexagonal boron nitride microresonators” (MSc thesis), January 2022.

A. Evans, “Laser cooling of antihydrogen” (PhD thesis), December 2021.

I. J. Geng, “Examination of the constant trace value condition of a SIC-POVM and various majorization relations from games of chance” (MSc thesis), January 2022.

S. Goswami, “Photonic quantum technologies: non-destructive photon detection and quantum simulation in solid-state systems” (PhD thesis), December 2021.

P. Lefebvre, “From bipartite to multipartite entanglement” (PhD thesis), December 2021

P.-C. Liao, “Graph representation of topological stabilizer states” (MSc thesis), December 2021.

B. McLaughlin, “Nonlinear optics in III-V photonic resonators” (MSc thesis), January 2022.

K. A. Owen, “Towards MDI QKD using quantum dot single photon sources” (MSc thesis), October 2021.

P. Wakwella, “Spectroscopic investigation of isomers of the CO_2-CO Dimer in the 4.27 micron region” (MSc thesis), August 2021.

Y.-J. Xiong, “Spectrally multimode photon pair source” (MSc thesis), September 2021.

Z. Yu, “Quantum walks on arc-transitive graphs with self-loops” (MSc thesis), September 2021.

F. Binat Zafar, “Conic linear programming in quantum information” (MSc thesis), January 2022.

P. Zarkeshian, “Photonic approaches to multi-party entanglement in solids and learning in the brain” (PhD thesis), August 2021.

INVITED PRESENTATIONS AT WORKSHOPS/ CONFERENCES

9 May 2021, P. E. Barclay, “Diamond cavity optomechanics: interfacing photons, phonons, and spins”, CLEO: Science and Innovations 2021 (virtual), 9–14 May 2021.

31 May 2021, P. E. Barclay, “Diamond cavity optomechanics: interfacing photons, phonons, and spins”, Photonics North 2021 (virtual), 31 May–2 June 2021.

1 June 2021, B. C. Sanders, “Quantum computing for data science”, Quantum Science Days, QWorld Association, Latvia (virtual), 1–2 June 2021.

2 June 2021, B. C. Sanders, “Feasible pulse-sequence design for quantum computing with atoms”, Photonics North 2021 (virtual), 31 May–2 June 2021.

8 June 2021, B. C. Sanders, “Classical and quantum control and learning”, Canadian Association of Physicists Congress 2021 (virtual), 7–10 June 2021.

29 June 2021, C. Simon, “Could quantum entanglement play a role in the brain?”, Big Quantum Meeting (virtual), 29 June 2021.

1 August 2021, P. E. Barclay, “Optomechanical devices in diamond for classical and quantum information processing”, SPIE Nanoscience + Engineering 2021 (virtual), San Diego, United States of America, 1–5 August 2021.

1 August 2021, G. Hajisalem, M. S. Shariatdoust, R. F. Ali, B. D. Gates, P. E. Barclay and R. Gordon, “Extraordinary nonlinear response of nanoparticles in double nanohole optical tweezers”, SPIE Nanoscience + Engineering 2021 (virtual), San Diego, United States of America, 1–5 August 2021.

25 August 2021, C. G. Rocha, “Emergence of winner-takes-all function in nanowire neuromorphic networks” (plenary symposium), 14th Canadian Neuroscience Meeting 2021 (virtual), 22–25 August 2021.

31 August 2021, D. R. Salahub, “deMon quo vadis?”, 20th deMon Developers Workshop (virtual), 31 August–2 September 2021.

31 August 2021, B. C. Sanders, “Quantum computing for big data”, Global Emerging Innovation Summit 2021, Melbourne, Australia (virtual), 29–31 August 2021.

4 October 2021, D. R. Salahub, “AI for simulation and design of nanocatalytic materials”, NRC Energy Materials Challenge Workshop (virtual), 4–6 October 2021.

14 October 2021, C. M. Scandolo, “Universal structure of objective states in all fundamental causal theories”, Quantum Boundaries 2021 (virtual), Nottingham, United Kingdom, 14–15 October 2021.

24 October 2021, D. R. Salahub, “Towards ML-accelerated discovery of nanocatalytic mechanisms”, Canadian Chemical Engineering Conference, Symposium on Modeling and Artificial Intelligence – Molecular modeling and simulation: From methods to applications (virtual), 24–27 October 2021.

17 November 2021, C. Simon, “Radical pairs in xenon-induced anesthesia and optical communication channels in the brain”, The Guy Foundation Autumn Quantum Biology & Bioenergetics Online Lectures (virtual).

18 November 2021, C. G. Rocha, “Random nanowire networks for neuromorphic and transparent conductor applications”, V Week of Physics and Physics Engineering (virtual), Lavras, Brazil, 16–18 November 2021.

23 November 2021, B. C. Sanders, “Quantum in Alberta”, CASCON x EVOKE Quantum Workshop Satellite Meeting (virtual), 23–24 November 2021.

2 December 2021, B. C. Sanders, “Quantum computing for quantum data”, 20th International Workshop on Advanced Computing and Analysis Techniques in Physics Research (ACAT 2021), IBS Science Culture Center Daejon, South Korea (virtual), 29 November–3 December 2021.

16 December 2021, D. R. Salahub, “Towards free-energy profiles for nano-catalyzed chemical reactions in complex environments”, Pacifichem, Symposium on Fusion of classical- and quantum-mechanical molecular simulations (virtual), 16–21 December 2021.

31 January 2022, C. Simon, “Could quantum entanglement play a role in the brain? (remote talk)”, Is the Brain (in part) a Quantum Computer Workshop, Santa Barbara, United States of America, 31 January–1 February 2022.

8 February 2022, S. Barzanjeh, “Applications of electromechanical resonators”, Quantum Days Canada Conference (virtual), 7–10 February 2022.

9 February 2022, C. Simon, “Hardware architectures for the quantum internet”, Quantum Days Canada Conference (virtual), 7–10 February 2022.

22 February 2022, C. Simon, “Architectures”, QEYSSat 2.0: A Roadmap for Canadian Quantum Satellites Missions Workshop (virtual), 15 February 2022.

14 March 2022, M. Bagherimehrab, “Nearly optimal quantum algorithms for generating the ground state of a quantum field theory on a quantum computer”, Fermilab HEP/QIS Forum (virtual),14 March 2022.

30 March 2022, C. Simon, “Quantum internet architectures”, QEYSSat 2.0: A Roadmap for Canadian Quantum Satellites Missions Final Seminar (virtual), 30 March 2022.

LINKAGE

ACADEMIC COLLABORATIONS

INTERNATIONAL INSTITUTIONS

Aarhus University, Denmark
Ben-Gurion University of the Negev, Israel
California Institute of Technology, United States of America
Carl von Ossietzky University of Oldenburg, Germany
Centro de Investigación y de Estudios Avanzados (CINVESTAV), Mexico
Cockcroft Institute, United Kingdom
European Organization for Nuclear Research (CERN), Switzerland
Harvard University, United States of America
Humboldt-Universität zu Berlin, Germany
Indian Statistical Institute, India
Institut Néel, Grenoble, France
Jagiellonian University Krakow, Poland
Korean Institutre of Science and Technology, South Korea
Missouri University of Science and Technology, United States of America
National Institute of Nuclear Physics – Pisa (INFN), Italy
National Institute of Standards and Technology, United States of America
Nova Southeastern University, United States of America
Polish Academy of Sciences, Poland
Politecnico di Milano, Italy
Purdue University, United States of America
Qingdao Institute of Marine Geology, People's Republic of China
Radboud University, the Netherlands
Soreq Nuclear Research Centre, Israel
Stockholm University, Sweden
Swansea University, United Kingdom
Tampere University, Finland
Trinity College Dublin, Ireland
Università Ca' Foscari Venezia, Italy
Universität Ulm, Germany
Université catholique de Louvain, Belgium
Université Paris-Saclay, France
Universidade Federal do Espírito Santo, Brazil
Universidade Federal do Rio de Janeiro, Brazil
University College Dublin, Ireland

University of Brescia, Italy
University of Bristol, United Kingdom
University of California at Berkeley, United States of America
University of Electronic Science and Technology of China, People's Republic of China
University of Gdańsk, Poland
University of Hong Kong, People's Republic of China
University of Liverpool, United Kingdom
University of Manchester, United Kingdom
University of Oxford, United Kingdom
University of Science and Technology of China, People's Republic of China
University of Science and Technology, South Korea
University of Strathclyde, United Kingdom
University of Technology Sydney, Australia
University of Warsaw, Poland
Western Michigan University, Untied States of America

NATIONAL INSTITUTIONS

British Columbia Institute of Technology
Institut National d'Optique (INO)
Lakehead University
Queen's University
Simon Fraser University
University of Alberta
University of British Columbia
Université de Sherbrooke
University of Victoria
University of Waterloo
York University

INDUSTRIAL/NON-PROFIT/GOVERNMENT COLLABORATION

COLLABORATIVE ENTITY	NAME	ROLE	NATURE			RESEARCH TOPIC
			COLLABORATION	SERVICE	TRAINING	
1QBit	Seyed Shakib Vedaie	Collaborator (scientific)	X			Quantum machine learning
ApexQubit	Barry Sanders	Scientific Advisory Board Member		X		Quantum Computing
Argonne National Lab	Daniel Oblak	Collaborator	X			Autonomous calibration of quantum networks
CMC Microsystems	Shabir Barzanjeh	Collaborator	X			Quantum computing
INO	Daniel Oblak	Collaborator	X			Optical fibre for quantum technology
Intelligent Quantum Networks Technologies (INQNET)	Daniel Oblak	Collaborator	X			Quantum networks
Jet Propulsion Laboratory	Christoph Simon	Collaborator	X			Quantum sensing with biophotons
Jet Propulsion Laboratory	Daniel Oblak	Collaborator	X			Superconducting nano-wire single photon detectors for bio-photon detection
Katal Energy Inc.	Dennis Salahub & Morteza Chehel Amirani	Researcher	X		X	Extending diesel fuel, molecular dynamic mechanisms
Katal Energy Inc.	Peter Kusalik	NSERC Alliance Grant		X		Nanobubbles in nanoemulsion fuels

COLLABORATIVE ENTITY	NAME	ROLE	NATURE			RESEARCH TOPIC
			COLLABORATION	SERVICE	TRAINING	
Lumerical/ANSYS	Paul Barclay	Collaborator	X			Optomechanical simulation
National Research Council of Canada	Paul Barclay	Collaborator	X			Diamond and silicon photonics and nanotechnology
National Research Council of Canada	Nasser Moazzen-Ahmadi	Collaborator	X			Spectroscopic investigation of molecular clusters & on-chip gas sensors
National Research Council of Canada	Christoph Simon	Collaborator	X			Quantum simulation with Rydberg excitons & quantum sensing with biophotons
National Research Council of Canada	Dennis Salahub, Jiri Hostas & Lizandra Barrios Herrera	Researcher	X		X	AI for Design, nanocatalysts
Natural Resources Canada Canmet ENERGY	Nasser Moazzen-Ahmadi	Collaborator	X		X	Investigation of intermolecular forces
Oxford Instruments	Paul Barclay	Collaborator	X			Diamond quantum technology
SBQuantum	Paul Barclay	Collaborator	X			Diamond magnetometry
Sustainable Development Technology Canada & National Research Council	Christoph Simon			X		Quantum science and technology
TRIUMF	Robert Thompson & Timothy Friesen	Collaborator	X		X	ALPHA project
Zapata Computing	Archismita Dalal	Collaborator	X			Noise tailoring for robust amplitude estimation

VISITORS

NAME	INSTITUTION
Dorcas Addo	Kwame Nkrumah University of Science and Technology
Hessa Nuneef Alotaibi	The Public Authority for Applied Education and Training, Kuwait
Karabee Batta	Birla Institute of Technology and Science (BITS Pilani)
Sarah Brandsen	Duke University
Ishan Gupta	Aligarh Muslim University
Linn Hamester	University of Hamburg
Gordon Harling	CMC Microsystems
Cherry Mangla	Chitkara University, Chandigarh
Aditya Morolia	International Institute of Information Technology, Hyderabad
Mosayeb Naseri	Islamic Azad University, Kermanshah Branch
Prince Osei	Quantum Leap Africa and AIMS Ghana
Yi Shen	Beihang University
Avinash Manoj Sontakke	Birla Institute of Technology and Science, Pilan
Chirag Wadhwa	Indian Institute of Technology, Roorkee
Yufeng Wu	Yale University

GRADUATE COURSES

COURSE NAME	INSTRUCTOR	DESCRIPTION
PHYS697 Topics I Contemporary Physics	S. Barzanjeh	The field of quantum optics underwent significant theoretical and experimental progress in recent years such as extensive effort towards building quantum computers or implementation of quantum networks. This course provides an introduction to the subject, covering the basic principles and applications of quantum technology. We begin by developing the basic tools of quantum optics and goes on to show the application of these tools in a variety of quantum optical systems, including quantum states (squeezed/coherent states), theory of decoherence and open systems, and atom-field interaction (Jaynes Cummings model). This course will be a great fit for the last year's undergraduate students interested to learn the advanced applications of quantum mechanics or planning to conduct research in quantum optics and quantum information.
PHYS609 Advanced Classical Mechanics	D. Feder	Variational principles, Lagrange's equations, Noether's theorem. Hamilton's equations and canonical transformations. Hamilton-Jacobi theory, action-angle variables. Perturbation theory.
PHYS 611 Statistical Physics	C. G. Rocha	Classical and quantum ensemble theory applied to interacting systems: real gases, spin lattices, phase transitions. Kinetic theory: Boltzmann equation, transport processes, irreversible processes and fluctuations.
PHYS617 Relativistic Quantum Mechanics	B. C. Sanders	Klein-Gordon and Dirac equations; Dirac spinor and the adjoint spinor; charge (C), parity (P) and time (T) transformations and CPT symmetry; relativistic corrections to atomic spectra.
PHYS675.03 Special Topics in Laser and Optical Sciences, Group Theory and Quantum Mechanics	N. Moazzen-Ahmadi	This course will deal with aspects of group theory most relevant to physics and chemistry (such as the theory of representations). Three main uses of group theory in quantum mechanics will be discussed. These are: (1) labeling of energy levels and the corresponding eigenstates; (2) qualitative discussion of splitting of energy levels as a result of external fields or higher order effects in the Hamiltonian; and (3) to provide general selection rules for the non-zero matrix elements of different kinds. Topics in the theory of atomic energy levels, the electronic, vibrations and rotation of molecules, and solid state physics will be covered.

SERVICES AND OUTREACH

CONFERENCES/WORKSHOPS

Members	Committee	Conference/Workshop	Location	Dates
P. E. Barclay	Chair, Quantum and Nonlinear Optics Committee	Advanced Photonics Congress	Maastricht, Netherlands	24–28 July 2022
P. E. Barclay	Co-Chair	NanoCanada International Conference: From Earth to Space	Edmonton, Canada	8–10 June 2022
B. C. Sanders	Chair, Program Committee	International Conference on Quantum Communication, Measurement and Computing	Lisbon, Portugal	11–15 July 2022

PROFESSIONAL SERVICES

Name	Role	Journal/Society/Institution
P. E. Barclay	Associate Editor	*Optics Letters*
D. L. Feder	Member, Editorial Board	*PLoS One*
D. Oblak	Member, Expert Group on Quantum Technology	Canadian Photonic Industry Consortium
C. G. Rocha	RAC Reviewer	Digital Research Alliance of Canada
D. R. Salahub	Member, Editorial Board	*Advances in Quantum Chemistry*
D. R. Salahub	College of Reviewers	Canadian Institutes of Health Research
D. R. Salahub	Member, Editorial Board	*Computation*
D. R. Salahub	Vice Chair, Editorial Board	*Interdisciplinary Science: Computational Life Sciences*
D. R. Salahub	Member, Editorial Board	*Journal of Computational Chemistry*
D. R. Salahub	Member, Academic Editorial Board	*PLoS One*
B. C. Sanders	Laboratory Scientist	Creative Destruction Lab–Rockies
B. C. Sanders	Chief Scientist	Creative Destruction Lab–Toronto
B. C. Sanders	Member, Core Task Force, Open Quantum Initiative	GESDA–Geneva Science and Diplomacy Anticipator
B. C. Sanders	Member, Editorial Board	IOP ebooks™
B. C. Sanders	Chair, Board of Directors	NanoCanada

Name	Role	Journal/Society/Institution
B. C. Sanders	Member, Program Focus Working Group, Applied Quantum Comp Challenge Program	National Research Council Canada
B. C. Sanders	Member, Evaluation Committee	Photonique Quantique Québec
B. C. Sanders	Member, Quantum Working Group 3, Cercle en recherche et innovation Québec-Europe (CRIQUE)	Québec Ministère des Relations internationales et de la Francophonie
B. C. Sanders	Advisor	SBQuantum
B. C. Sanders	Member, Mirror Committee ISO/TC 229	Standards Council of Canada
B. C. Sanders	Chair, Catalyst Grants Support Committee	University of Calgary
B. C. Sanders	Co-Chair, Quantum Computing Task Force	University of Calgary
Y. J. Shi	Associate Editor	*Canadian Journal of Chemistry*
S. Trudel	Member, Scholarship and Fellowship Committee	Natural Sciences and Engineering Research Council

OUTREACH LECTURES

27 May 2021, B. C. Sanders, “Untold history of Canada’s wide-ranging strengths”, Webinar: Canada’s Quantum Technologies, Canadian Embassy in Tokyo (virtual).

15 September 2021, B. C. Sanders, “Quantum in Calgary, transforming Calgary through quantum computing: Digital innovation and partnership”, Mphasis (virtual).

29 September 2021, B. C. Sanders, “Quantum@UCalgary”, University of Calgary Fall Counsellor Update (virtual).

MEDIA COVERAGE

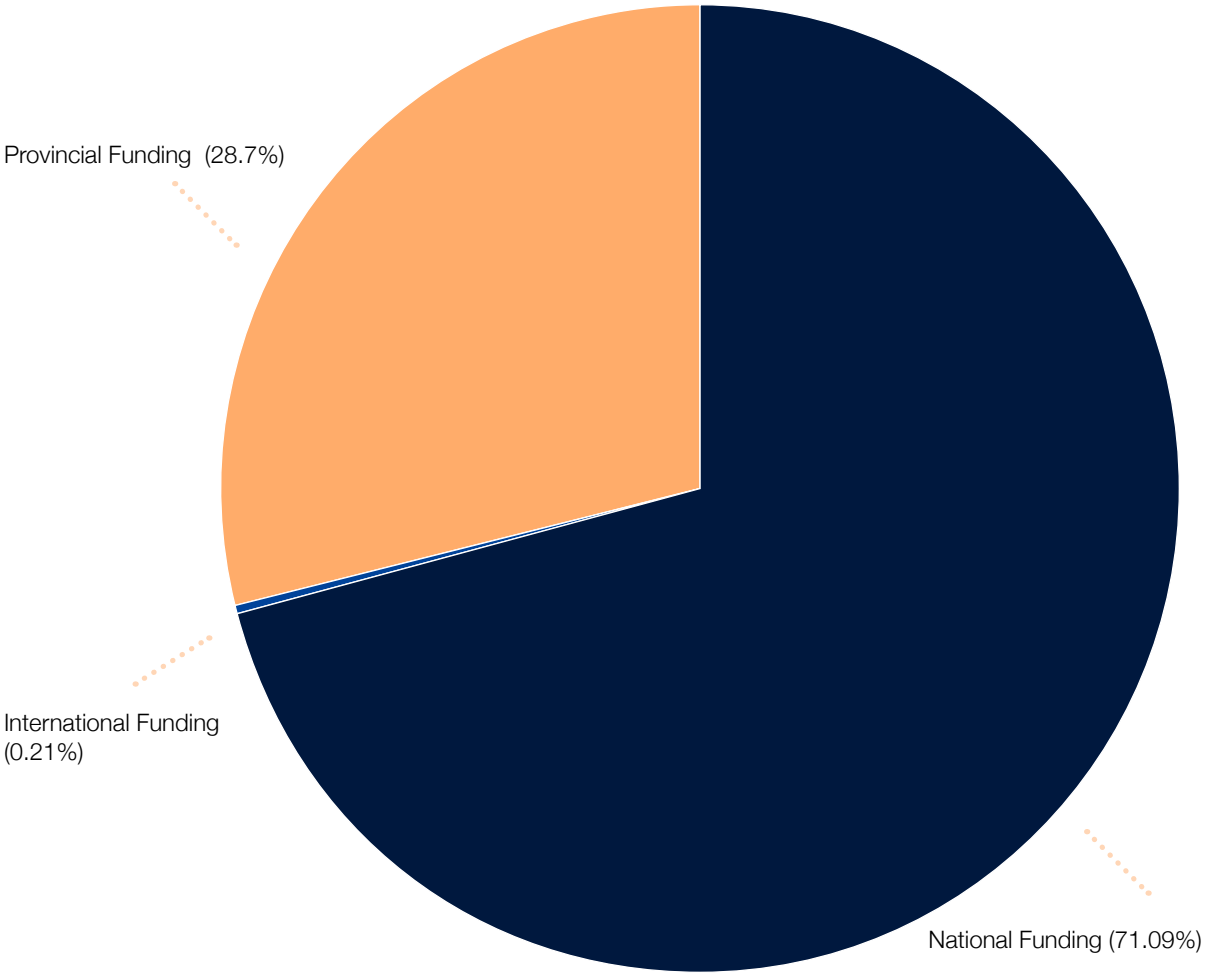
Source	Title of Article	Date
University of Padua	From Galilean student to professor: Interview with Carlo Maria Scandolo	16 April 2021
HPCwire	Canadian government commits $360 million for quantum research: Institute for Quantum Science and Technology	20 April 2021
UCalgary News	State of consciousness may involve quantum effects, University of Calgary scientists show: Christoph Simon & Hadi Zadeh-Haghighi	28 April 2021
Live Science	“Imaginary” numbers are real (sort of): Carlo Maria Scandolo	10 May 2021
Calgaryeconomicdevelopment.com	Calgary welcomes Mphasis, Government of Alberta and UCalgary launch “Quantum City COE”: Quantum City COE	2 June 2021
Calgary Herald	Varcoe: Global tech firm reveals plan to bring up to 1,000 jobs, Canadian HQ to Calgary: Quantum computing hub	2 June 2021
UCalgary News	UCalgary and Quantum City: Institute for Quantum Science and Technology	2 June 2021
UToday	International team including University of Calgary researcher proves “imaginary” numbers have real function in quantum world: Carlo Maria Scandolo	2 June 2021
Popular Science	What the heck is a quantum network?: Christoph Simon	18 June 2021
Canadian Light Source	A cheaper method for hydrogen-based fuels: Simon Trudel	21 June 2021
SASKTODAY	Seeking a cheaper method for hydrogen-based fuels: Simon Trudel	23 June 2021
UCalgary News	Researcher goes small to make big discoveries in computing: Pierre Kennepohl	11 August 2021
UCalgary News	Federal funding allows UCalgary researcher to investigate the base components of quantum computing: Shabir Barzanjeh	11 August 2021

Source	Title of Article	Date
Medium.com	All things quantum: Meet our PIMS PDF at the University of Calgary, Thomas Theurer	27 September 2021
UCalgary News	University of Calgary physicists develop novel approach to building a “quantum internet”: Paul Barclay	15 October 2021
ASET	NanoCanada ramps up for 2022 international conference in Edmonton with virtual launch celebration: Barry C. Sanders	18 October 2021
AsiaTimes	USTC researchers claim quantum breakthrough: Barry C. Sanders	30 October 2021
Livewirecalgary.com	Quanta for Quantum: Calgary seed fund seeks to build the foundation for theoretical physics in Alberta: Robert Thompson	3 November 2021
Global and Mail	UCalgary partnerships exploring how quantum research can help to address “hard problems”: Barry C. Sanders	19 November 2021
Nature	The future of quantum technology in Calgary is bright – A conversation with University of Calgary President and Vice Chancellor, Edward McCauley: Edward McCauley	4 December 2021
CBC News	University of Calgary gets $22M for research on infectious diseases, quantum computing: University of Calgary	6 December 2021
SPIE Newsroom	Searching for the brain’s quantum network: Christoph Simon	1 January 2022
AIP SciLight	Highlighting versatile contrast agents for high-field MRI: Simon Trudel	9 January 2022
The Wire China	The quantum edge: Barry C. Sanders	23 January 2022
Innovation.ca	University of Calgary partnerships exploring how quantum research can help to address “hard problems”: Barry C. Sanders	22 February 2022

RESEARCH GRANT (UNAUDITED)

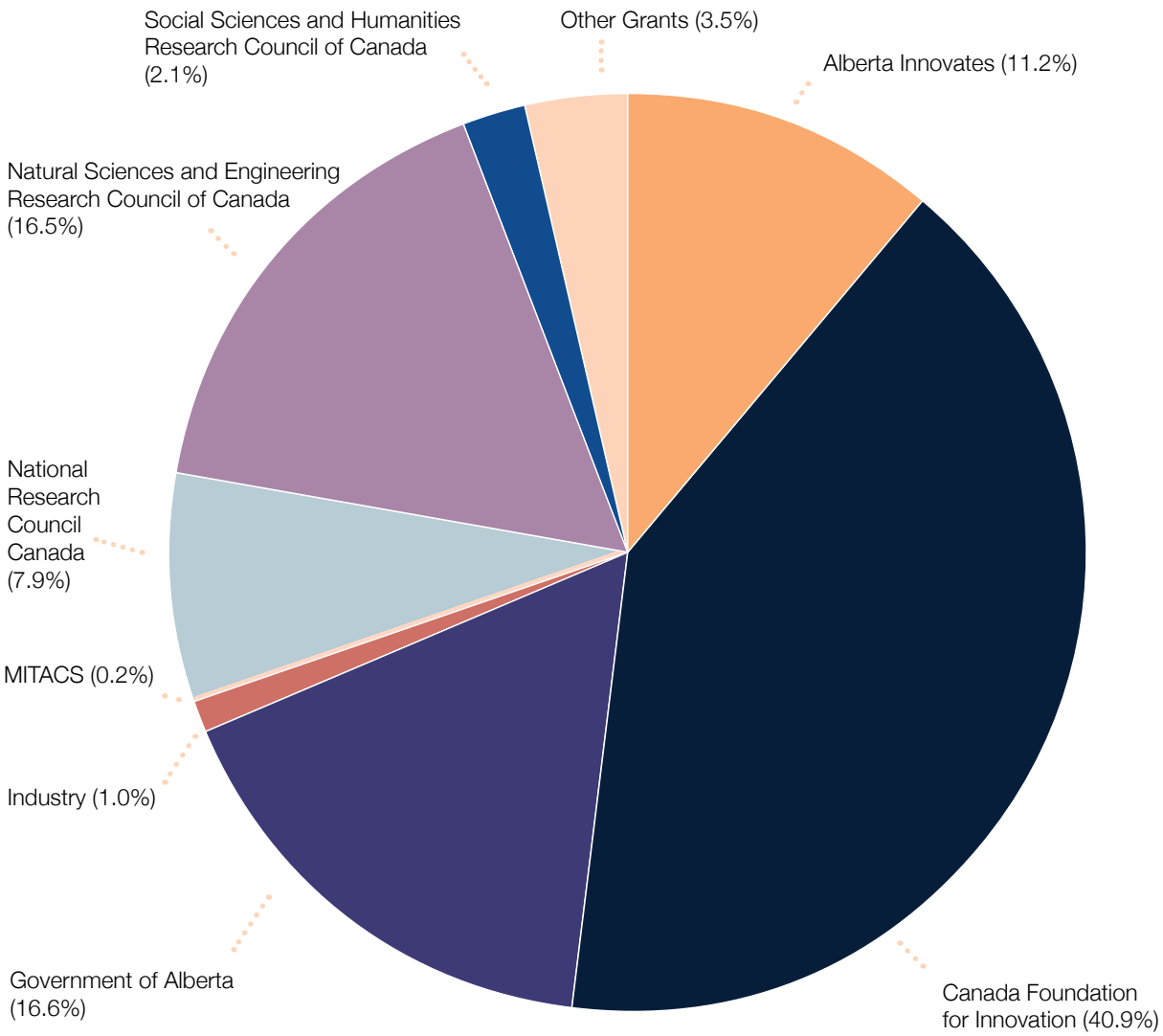
BY ORIGIN

TOTAL RESEARCH FUNDING: $6.01M



BY FUNDING AGENCY

TOTAL RESEARCH FUNDING: $6.01M



OBJECTIVES FOR NEXT YEAR

PAUL BARCLAY

- Demonstrate diamond optomechanical crystals for quantum spin-mechanics
- Study charge-state dynamics of diamond spin qubits
- Create high-frequency optomechanical torque sensors

SHABIR BARZANJEH

- Study theoretical modelling of photon conversion.
- Explore realization of photon conversion using electro-optics modulators

DAVID FEDER

- Develop a quantum algorithm for computing the matrix permanent
- Explore the role of particle interactions for topological states in Bose-Einstein condensates confined to optical lattices
- Identify families of resource states for measurement-based quantum teleportation without symmetry protected topological order
- Construct new families of topological low-density parity-check quantum error correction codes using graphs

TIM FRIESEN

- Trap and perform first gravitational free-fall experiments on antihydrogen
- Make first direct measurement of the Lamb shift in antihydrogen
- Develop precision magnetometry in ALPHA-g Penning traps
- Perform precision hyperfine spectroscopy of antihydrogen

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

- Give a quantum algorithm for a problem that simultaneously achieves all of space-optimality, high success probability, and quadratic speedup

PETER KUSALIK

- Examine the factors important in the stability and mechanism of formation of aqueous nanobubbles
- Develop and test empirical and coarse-grain potential models appropriate for simulations of self-assembly processes in zinc-carboxylate metal-organic frameworks
- Use machine learning approaches to characterize formation of order during metal-organic frameworks self-assembly
- Develop Markov-state models based on key structural events and their transitions during nucleation processes of ice and gas clathrate hydrates
- Apply novel molecular simulation approaches to identify nucleation pathways in mixed-gas hydrates
- Reveal how the aqueous solution structure of potassium dihydrogen phosphate impacts its crystal nucleation and growth

NASSER MOAZZEN-AHMADI

- Observe the completion of the first solvation shell of carbon dioxide in rare gases from rotationally resolved spectra
- Develop sensitive, compact, potable, and low-cost sensors for monitoring green-house gas emission
- Develop accurate global potential energy surfaces for molecular complexes
- Study microsolvation of carbon monoxide and carbon dioxide in water
- Develop quantum mechanical models of infrared band systems of ethane for remote sensing of terrestrial and planetary atmosphere

DANIEL OBLAK

- Detect ultraweak photon emission from biological samples using multimode fibre-coupled superconducting nanowire single-photon detectors
- Demonstrate storage of photons in ytterbium-doped material
- Perform spectroscopic measurements of ytterbium:yttrium–silicate at sub-Kelvin temperatures
- Perform spectroscopy of molecular lanthanide crystals
- Demonstrate quantum key distribution link between satellite and ground-station
- Demonstrate generation of multipartite entangled states.
- Develop proof-of-concept for measurement-device-independent quantum key distribution system with post-processing included

CLAUDIA GOMES DA ROCHA

- Develop a computational description of electronic quantum transport in metal-oxide-based nanomaterials that can be applied in next-generation neuromorphic systems
- Characterize the optical transmission and electrical resistance of metallic nanowire thin films to improve transparent conductor technologies
- Develop architectures for quantum neuromorphic networks

DENNIS SALAHUB

- Develop new quantum chemistry/machine-learning algorithms for global structure optimization
- Develop new quantum chemistry/machine-learning algorithms for transition states and molecular dynamics
- Advance the design of new nanocatalysts by machine learning for quantum chemistry
- Advance the design of new multi-elemental perovskite materials for thermal, optical and electrochemical production of hydrogen using advanced machine learning for quantum chemistry methods
- Coordinate an international collaboration on artificial intelligence for design of new materials producing improved methods and software

BARRY SANDERS

- Devise pulse engineering to enhance performance of ion-trap quantum computing
- Develop a simple yet complete model for clock networks to analyse if and how quantum enhancements could apply
- Complete a conceptual framework for interconnecting machine learning and control in both classical and quantum domains
- Construct, employ and characterize quantum-enhanced computer programs for solving problems in the energy and health sectors
- Develop a best-practice verification & validation framework for the quantum supply chain

CARLO MARIA SCANDOLO

- Achieve a mathematically rigorous treatment of PT-symmetric quantum mechanics
- Use categorical methods to extend resource monotones
- Use tools of resource theories beyond quantum information science, e.g. in dynamical systems, with possible experimental tests
- Formulate concrete examples of situations probabilistic behaviour that can be explained in terms of entanglement
- Develop protocols where imaginary numbers are advantageous
- Quantify the heating and cooling capabilities of quantum resources
- Describe how causality constrains the behaviour of physical theories
- Determine how and when the behaviour of decoherence in general physical theories differs from the quantum one
- Develop new ways to define resource theories

YUJUN SHI

- Explore the technique of solid-state thermal dewetting for fabricating bimetallic nanoparticles
- Develop a protocol to use pulsed laser-induced dewetting for large-area production of metal nanoparticles
- Develop a growth method for low-dimensional semiconductor nanostructures
- Study the gas-phase chemistry in the process of hot-wire chemical vapor deposition using precursors containing a silicon-nitride bond

CHRISTOPH SIMON

- Explore radical pair effects in biology, especially related to flavin autofluorescence, microtubule organization, and N–methyl–D–aspartate receptors
- Study the application of quantum reservoir computing to time series prediction
- Develop quantum memory and transduction protocols based on centres comprising two carbons and one hydrogen in silicon
- Study quantum transduction based on single atoms in cavities
- Study long-distance quantum teleportation via satellites, including the potential use of quantum memories (with Jennewein)
- Detect and characterize biophoton emission for quantum sensing and quantum biology applications (with Oblak, England, Iqbal, Moreno and Tauskela)
- Develop architectures for room-temperature quantum networks

ROB THOMPSON

- Perform gravitational free-fall experiments on antihydrogen in the ALPHA-g apparatus
- Resolve atomic structures of antihydrogen
- Develop laser-based ion-source options for TITAN

SIMON TRUDEL

- Develop photo-deposited charge transport layers in functional devices
- Explore novel catalytic and ion transport capabilities of photo-deposited metal oxides
- Study X-ray absorption spectroscopy of polyamorphism in metal oxides

IQST ADDS VALUE TO THE UNIVERSITY OF CALGARY IN THE FOLLOWING WAYS

Enables multidisciplinary research through finanacial 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

IQST.UCALGARY.CA
@IQSTUCALGARY

Phone: (403) 220-4403
Email: iqstinfo@ucalgary.ca

INSTITUTE FOR QUANTUM SCIENCE & TECHNOLOGY
University of Calgary
2500 University Drive NW
Calgary, AB T2N 1N4
Canada