



Stewart Blusson
Quantum Matter Institute
THE UNIVERSITY OF BRITISH COLUMBIA

ANNUAL REPORT 2019

QUANTUM MATERIALS BY DESIGN

CREATING THE BUILDING BLOCKS FOR FUTURE TECHNOLOGIES THAT WILL TRANSFORM THE WORLD

MISSION

The Stewart Blusson Quantum Matter Institute (SBQMI) fosters the discovery, understanding, and control of quantum materials and related novel materials and devices. We train the professionals who will translate this intellectual capital into economic benefits for Canada, and transfer the discoveries to industry to create next-generation technologies.

VISION

SBQMI aims to emerge at the forefront of its international peers in the field of quantum materials and devices, and aspires to nucleate an ecosystem of companies developing future technologies.



OUR FUNDERS

SBQMI is deeply indebted to the generous support of our funders, partners, and sponsors. Our research is made possible thanks in particular to the following individuals and organizations:

Stewart and Marilyn Blusson
The University of British Columbia (UBC)
Canada First Research Excellence Fund (CFREF)
Canada Foundation for Innovation (CFI)
British Columbia Knowledge Development Fund (BCKDF)
Natural Sciences and Engineering Research Council of Canada (NSERC)
Canada Research Chairs Program (CRC)
Canadian Institute for Advanced Research (CIFAR)
The Gordon and Betty Moore Foundation
Western Economic Diversification Canada

We wish to express our sincere gratitude and appreciation for their support as their contributions have enabled SBQMI to exponentially accelerate research excellence and technology translation.

LAND ACKNOWLEDGMENT

SBQMI is located on the UBC Vancouver campus, which sits on the traditional, ancestral, and unceded territory of the xwmə0-kwəy'əm (Musqueam) people.

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OUR RESEARCH THEMES

What's in a theme? Research themes help to frame approaches, concepts, and understanding of quantum phenomena. They can help guide discussion in a complex dialogue that can have many different entry points. Because SBQMI evolved out of collaborations among scientists with diverse backgrounds, cultures, and expertise, in 2018, we invested in the articulation of SBQMI's Quantum Materials by Design research strategy, and identified four thematic areas.

I Atomic Level Design of Quantum Materials

This area explores materials in which strong local atomic interactions play a dominant role in determining electronic behavior and physical properties. Combining multi-scale modelling and calculations with highly advanced experimental characterization techniques enables rational design of novel quantum materials.

II Emergent Electronic Phenomena at Interfaces

Heterostructures of atomically smooth interfaces of quantum materials exhibit emergent properties that do not exist in bulk. This extends the capacity for the rational atomic-level design of complex structures with tunable properties, creating a bridge from materials to devices, functionalities, and applications.

III Topologically Protected Quantum States

Materials with topologically protected conducting or superconducting surface states exhibit many exotic phenomena. Topological protection of quantum states offers the potential to create a new class of quantum electronic devices that can leapfrog current efforts towards realizing quantum computing.

IV Photonic Manipulation of Quantum States

This theme develops coherent light sources and photonic techniques to control spin, valley, and charge degrees of freedom in 2D van der Waals materials, oxide superconductors, and silicon photonic circuits, to explore unique approaches in quantum computing and discover optically driven states of matter.

BUILDING TO LAST

Founded in 2010, SBQMI is an internationally recognized multidisciplinary research institute at UBC with faculty members from physics, chemistry, and electrical and computer engineering, and expertise spanning theory, experiment, and device development in quantum materials. SBQMI's reputation has allowed us to form strong partnerships with renowned research institutes such as the Max Planck Society, the University of Tokyo, TRIUMF, the Canadian Light Source, the Canadian Centre for Electron Microscopy, and two other CFREF-funded institutes at the University of Waterloo and Université de Sherbrooke.

In 2019, SBQMI focused its resources on creating distinctive scientific opportunities through initiatives such as the “Grand Challenges” call for proposals launched in November 2018. As a result of the call, 3 Grand Challenges were identified: (1) Atomistic Approach to Emergent Properties of Disordered Materials, (2) Engineering Exotic Phases in 2-Dimensional Materials, and (3) Pushing the Boundaries of NISQ-Era Quantum Computing with Focus on Quantum Materials. The Grand Challenges leverage SBQMI's expertise and state-of-the-art infrastructure, while contributing to our scientific identity as we design materials with ideal properties to serve as building blocks for future high-performance technologies.

Thus, this year SBQMI took crucial steps toward the future by developing these flagship ideas—or Grand Challenges—to further rationalize and define the four research themes and formulate SBQMI's visionary research agenda for the next decade. Importantly, we also continued to prioritize our people by promoting an equitable, diverse, and inclusive community with the goal of attracting and training the best talent in the world. In short, we are building to last.

HISTORY

MAY Quantum Matter Institute (QMI) is established under the leadership of George Sawatzky

A group of faculty members at UBC establishes the Quantum Matter Institute (QMI). The group aims to break through boundaries around quantum material research through the collaborative effort of a multidisciplinary team that brings together physicists, chemists, and material scientists—a team of theoreticians, experimentalists, and engineers working closely together.

JANUARY QMI's international partnership expands

QMI and UBC sign a Memorandum of Understanding with the Max Planck Society and the University of Tokyo to expand the Centre for Quantum Materials to also include the University of Tokyo.

JULY QMI wins support to begin its transformative growth

QMI receives a \$66.5 million investment from the Government of Canada via the Canada First Research Excellence Fund (CFREF) to support its program, “Quantum Materials and Future Technologies.” The award allows QMI to become Canada's quantum materials science and technology institute, with a mission to broaden research, foster learning, and strengthen translational efforts.

APRIL Max Planck-UBC-UTokyo Centre for Quantum Materials

A signing ceremony in Tokyo formalizes a 2014 MOU to engage in a 3-way partnership involving the University of Tokyo, the Max Planck Society, and UBC, opening new possibilities for scientific collaboration through workshops, conferences, joint research projects, and student exchanges.

MAY New building opens

After moving into its new, purpose-designed building, SBQMI expands its materials synthesis, characterization, and device development capabilities and embarks on a major expansion and upgrade of its nanofabrication facilities, electron microscopy, and lithography infrastructure.

MARCH QMI becomes Stewart Blusson Quantum Matter Institute (SBQMI)

Vancouver-based diamond pioneer and philanthropist Stewart Blusson and his wife Marilyn donate \$11M to quantum materials research at UBC, enabling the institute to further broaden and deepen its research capabilities. In recognition of the gift, the Stewart Blusson Quantum Matter Institute (SBQMI) has been named in honour of the geology alumnus (BSc '60).

JANUARY New scientific direction

Andrea Damascelli succeeds George Sawatzky as the new Scientific Director of the Quantum Matter Institute and joins Bernhard Keimer as co-director of the Max Planck-UBC Centre for Quantum Materials. His vision is to continue building an institute that will propel Canada to the forefront of quantum materials science and technology.

FEBRUARY QMI broadens its international presence

George Sawatzky, Director of QMI, and Bernhard Keimer, Director of the Max Planck Institute for Solid State Research in Stuttgart, lead the creation of the Max Planck-UBC Centre for Quantum Materials. It is the only international Max Planck Centre focused on quantum materials research and one of the few Max Planck partnerships outside of Germany.

2010

2012

2014

2015

2016

2017

2018

JUNE First Canadian graduate quantum conference

Jointly hosted by the Canada First Excellence Research Fund (CFREF) institutes—SBQMI, Institute Quantique (IQ) at the Université de Sherbrooke, and the Transformative Quantum Technologies (TQT) program at the University of Waterloo—this 3-day conference showcases research from all three quantum research based institutes to foster early-career collaborations.

JULY Official opening of SBQMI's building extension

The new 20,000-square-foot wing, with its state-of-the-art laboratory space and equipment, including vibration-free facilities for microscopy experiments down to the subatomic scale, gives SBQMI the resources needed to break into new frontiers of quantum materials research.

OCTOBER Joint PhD program established

A MOU for a joint PhD program offered by the University of British Columbia and the University of Stuttgart is signed, with the Max Planck Society involved as a third partner in the agreement. The program is a natural extension of the Max Planck-UBC-UTokyo Centre for Quantum Materials. The agreement cements a collaborative and collegial relationship between SBQMI and the Max Planck Society of Germany, which has resulted in accelerated research excellence since the Centre was founded in 2012.

2019

NOVEMBER "Grand Challenges" call for proposals launched

Taking a crucial step towards our future by strategically investing in key research priorities, we launch the "Grand Challenges" call for proposals. Building upon the uniqueness of SBQMI's approach, the proposals are meant to identify bold ideas that will define SBQMI's research agenda for the next decade.

SEPTEMBER TO DECEMBER Canada First Research Excellence Fund (CFREF) midterm review and site visit

A comprehensive review of SBQMI's CFREF program takes place with a written assessment submitted in September and a visit from the Tri-agency Institutional Programs Secretariat in December. The review is an opportunity to share and showcase SBQMI's progress since 2015.

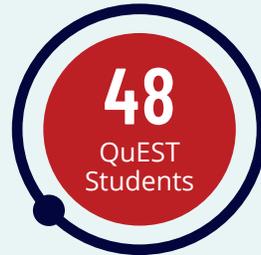
DECEMBER Scientific Director's term renewed

After having served since 2015 a first term as Scientific Director of SBQMI, Andrea Damascelli's appointment is renewed for another 5 years, ensuring continuity in the implementation of SBQMI's vision and long-term strategy.

DECEMBER Joint PhD agreement between UBC and the University of Stuttgart is formally signed

The agreement cements a collaborative and collegial relationship between SBQMI and the Max Planck Society of Germany. It formalizes the joint training effort and builds on the deep collaborative research ties dating back to 2012.

BY THE NUMBERS



Our goal is to ensure that SBQMI is comprised of the professional personnel necessary to build a world-class institute while prioritizing the development of programs that support equity, diversity, and inclusion. In 2019, female representation among students was 24%, which is above the 20% reported by the American Institute of Physics in 2017. Likewise, 48% of our students and 66% of our postdoctoral fellows are from other underrepresented groups.

MESSAGE FROM THE SCIENTIFIC DIRECTOR

2019 was another important and busy year for SBQMI. As a Canada First Research Excellence Fund recipient, we underwent a comprehensive midterm review. The thorough process provided an opportunity for reflection and self-examination as we evaluated our progress since 2015, and what we learned is that we've indeed come a very long way.

As a result of the 2018 Grand Challenges competition, this year we launched three new projects that will help shape our research agenda over the next decade. I am excited because these bold ideas have the potential to address many of the challenges facing Canada and the world today. We also launched our Project Management Office (PMO) to support and manage these large interdisciplinary and highly collaborative projects. Our goal is to establish a project management approach in all research conducted at SBQMI. The PMO will add crucial capabilities, as the Institute continues to mature and grow.

Our close partnership with the Max Planck Society and the University of Tokyo continued to expand. Our first Joint PhD program student has completed her first year in the program, and a second student has just enrolled. In August, Dr. Makoto Gonokami, President of the University of Tokyo, visited SBQMI to discuss strengthening the ongoing collaborations in ultrafast science between our two institutions. Also, the Max Planck-UBC-UTokyo Centre for Quantum Materials and CIFAR co-hosted a Summer School and Program Meeting on 2D materials and van der Waals heterostructures, bringing leading international experts in the area of 2D materials to Vancouver. The ongoing engagement between our institutions is key to the continued growth of the Max Planck-UBC-UTokyo Centre for Quantum Materials.

The strategic focus on translation and sustainability gained tangible momentum this year. Our first spin-off company, Dream Photonics, led by Lukas Chrostowski, was founded in 2019. In parallel, we've continued to work with the broader Canadian quantum community to formulate a national strategy that will allow Canada to maintain and even advance its world-leading position. It is clear that the investment made by the government is changing the landscape and creating sustainable opportunities for growth.

I'm extremely proud of the progress we've made towards creating an equitable, diverse, and inclusive culture at SBQMI. This year, Sarah Burke, was appointed Chair of our Equity, Diversity, and Inclusion (EDI) Committee tasked with supporting the implementation of our EDI strategy. In addition, our flagship multi-year undergraduate program, Quantum Pathways, designed for students from underrepresented groups, gained international recognition thanks in part also to Toni Feder's article *Ongoing mentorship works for retaining minorities in STEM*, published in the October 2019 issue of *Physics Today*. We have made a lot of progress, and we will continue to work to reach the EDI goals we set for SBQMI.

As I look back on 2019, I'm inspired by the commitment and enthusiasm of SBQMI's people: the students, postdocs, staff, and faculty, as well as our partners and collaborators. I want to extend my deepest gratitude to all who helped make this year a success. Lastly, in 2019 my appointment as SBQMI's Scientific Director was formally extended for another term. I look forward to the next five years with anticipation and excitement, as we continue building to last.

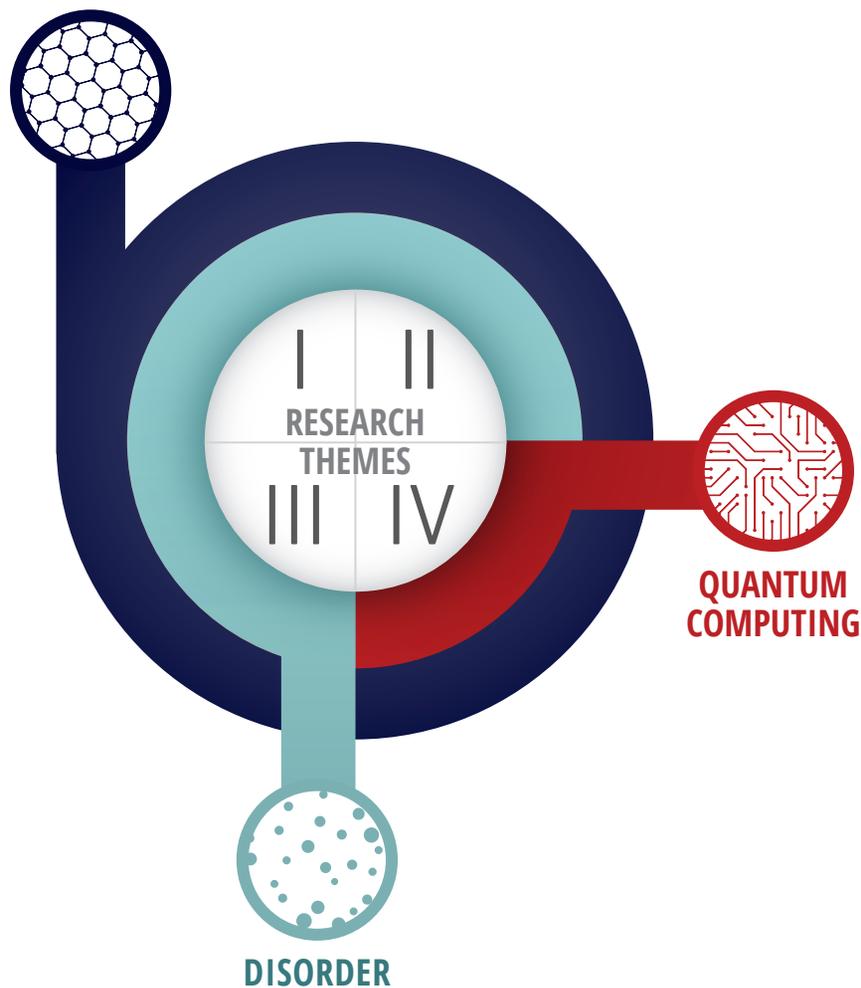
Andrea Damascelli
Scientific Director



GRAND CHALLENGES



2D MATERIALS



In November 2018, SBQMI launched an Institute-wide call for proposals to identify distinctive opportunities and focus strategic resources on a limited number of research priorities. These flagship ideas would fall under one or more of our four research themes and would emphasize SBQMI's unique collaborative approach, while propelling the Institute on a clear trajectory toward world-leadership.

After a thorough and extensive review, in 2019 three bold ideas emerged. These ideas leverage SBQMI's expertise and state-of-the-art infrastructure, and articulate a clear plan leading to ground-breaking achievements in the short-, medium-, and long-term. The successful Grand Challenges will set the Institute's research agenda for the next decade.

1 **ATOMISTIC APPROACH TO EMERGENT PROPERTIES OF DISORDERED MATERIALS**

Led by Joerg Rottler, this Grand Challenge falls under Research Themes I, II, and III.

2 **ENGINEERING EXOTIC PHASES IN 2-DIMENSIONAL MATERIALS**

Led by Doug Bonn, this Grand Challenge falls under Research Themes I, II, III, and IV.

3 **PUSHING THE BOUNDARIES OF NISQ-ERA QUANTUM COMPUTING WITH FOCUS ON QUANTUM MATERIALS**

Led by Robert Raussendorf, this Grand Challenge falls under Research Theme IV.

ATOMISTIC APPROACH TO EMERGENT PROPERTIES OF DISORDERED MATERIALS

The study of quantum materials often follows a well-tread path: a new material with remarkable macroscopic properties is discovered, and experimentalists labour intensively to grow ever-purer samples to ensure that what is being measured is, in fact, intrinsic to that material. On the theoretical side, models are sought to explain how the novel properties, often only manifest at low temperatures, can be understood as emerging from a particular arrangement of atoms in an ideal, crystalline lattice. In this paradigm, defects and disorder are inevitably the enemy. Understanding gained from iterative synthesis-measurement-modelling guides the search for ever more interesting new quantum materials. This story famously played out in the high temperature cuprate superconductors, where recent experimental triumphs are the direct result of decades of crystal growth optimization by Ruixing Liang, Doug Bonn, and Walter Hardy at SBQMI.

Conversely, most commercial materials are disordered, operate at room temperature or above, and their functionality depends crucially on that disorder. Although researchers are actively pursuing atomic-scale understanding of the macroscopic properties of these materials, progress has been relatively slow because modelling their behavior is computationally demanding due to the large number of atoms that must be included.

This Grand Challenge seeks to understand, at an atomic level, how novel material properties can emerge as the direct consequence of disorder. Under an overarching umbrella of theory and modelling, focus will be directed on two classes of strongly disordered systems:

1. High entropy materials that contain randomly distributed mixtures of five or more chemical elements on a regular lattice, and
2. Structurally amorphous materials, where atomic constituents, regardless of their chemical nature, are not arranged on a regular crystal lattice.

The plan is to apply the same synthesis-measurement-modelling approach that has been the key ingredient for success in pure, crystalline quantum materials development, to highly disordered materials. Recent advances in theoretical approaches suggest that this is indeed a *Grand Challenge*, but not an unrealistic one.

As part of the first thrust, team members are studying the structure of lithium nickel oxide (LiNiO_2), a precursor to a widely used lithium ion battery cathode material. In a recently published article, team members showed that LiNiO_2 should not be thought of as a crystalline ordered material but a high-entropy glassy material. This novel perspective may pave the way for designing new cathode materials with improved performance.

In the second thrust, Grand Challenge researchers are collaborating on the development of an improved mirror coating based on structurally amorphous materials for LIGO (the Laser Interferometer Gravitational-Wave Observatory) along with Jess McIver from UBC's Department of Physics and Astronomy. LIGO made headlines in 2016 for the experimental observation of gravitational waves and improved detector coatings have the potential to dramatically increase LIGO's sensitivity to astronomical events.

SBQMI brings a unique combination of theoretical expertise (Rottler and Sawatzky), materials synthesis capabilities (Berlinguette, Hallas, and Zou), and advanced characterization capabilities (Nojeh and Young) that will allow the team to take significant strides towards the goal of disordered materials by design.

ENGINEERING EXOTIC PHASES IN 2-DIMENSIONAL MATERIALS

The unusual physics of electrons in two dimensions (2D) has given rise to a half-century of novel physics and technology, historically emerging at interfaces between conventional semiconductors. Two breakthroughs in the 2000s dramatically broadened this field. One was the development of methods to grow atomically perfect stacks of less common materials, leading to phenomena such as magnetism and superconductivity that are elusive in semiconductors. The second was the discovery of graphene, single atomic layers of graphite, resulting in an explosion of work on compounds that could be exfoliated like graphene and assembled into “van der Waals” stacks. Such 2D materials offer access for engineering via a third spatial dimension, either by stacking dissimilar materials or local gating. They are also amenable to study by powerful techniques for probing surfaces, since they are mostly surface.

The field of 2D materials proliferated rapidly thanks to those two discoveries, with the development of new stacking controls such as strain and twisting of layers, and recipes to grow more exotic materials combinations. The discovery of novel phases of matter in 2D has also been fueled by ideas from SBQMI theorists, including Marcel Franz, Ian Affleck, George Sawatzky, and Mona Berciu, in step with SBQMI’s fundamental principle of quantum materials-by-design.

SBQMI will bring these new ideas to fruition with an array of new experimental capabilities under development within the Institute. Ke Zou’s team has established a lab for growing atomically precise heterostructures by molecular-beam epitaxy (MBE), combining growth capability for two challenging families of materials (transition metal oxides and chalcogenides) with experimental chambers where measurements can take place. In parallel, Ziliang Ye’s and Josh Folk’s groups have built a facility for exfoliating and stacking 2D materials, equipped with cutting-edge techniques to keep the Institute at the forefront of the

field. Through this Grand Challenge, we will connect these different growth capabilities with the expanding range of experimental probes being developed by Sarah Burke, Doug Bonn, Josh Folk, and Andrea Damascelli. The team is aiming at three target areas:

1. Flat band physics by design: engineering Moire and strain to create correlated phases from conventional materials, where kinetic and Coulomb energies of the electron system are comparable. For example, the phase diagram of cuprate high T_c superconductors mimics that observed in twisted bilayer graphene. Building on SBQMI’s expertise in the physics of cuprates, we will investigate connections between these two systems: one tuned by chemistry, the other by twist angle.
2. Building topological superconductors: van der Waals and MBE approaches to create 2D superconductors hosting Majorana excitations. We will grow a topological version of iron-based superconductors in monolayer form, aiming for a material that can serve as a basis for topological quantum computing. A parallel strategy, originating from within SBQMI, is to induce topological order into a well-known superconductor by clever stacking.
3. Bose-Einstein condensates from electron-hole pairs: Starting from stacked chalcogenide or oxide interfaces, we aim for a new generation of devices that promise orders-of-magnitude higher transition temperature and unprecedented maneuverability compared to earlier realizations in cold atom systems.

Out of the novel phases of matter that emerge from these experiments, we aim to develop devices that influence future generations of quantum technologies, and shed light on some of the deepest mysteries of quantum matter.

GRAND
CHALLENGE

2



PUSHING THE BOUNDARIES OF NISQ-ERA QUANTUM COMPUTING WITH FOCUS ON QUANTUM MATERIALS

Quantum physics has enormous potential to transform computing technology. When making the leap from classical computers to quantum computers, the logical processing and the physical basis both change in dramatic ways, opening the door to non-intuitive properties such as superposition and entanglement. The elementary unit of information changes from bit to qubit, allowing for entirely novel ways of data processing.

Beyond theoretical concept, quantum computation is also gradually becoming an experimental reality, with Google's quantum supremacy experiment in mid 2019 marking a very important milestone. Nonetheless, the difficulties in scaling up and in limiting the adverse effects of decoherence—a loss of quantum properties—are enormous, and it is expected that the quantum computers available in the next decade will be limited in the number of qubits, and the numbers of quantum gates they can execute. In this current situation, we ask: What can be computed with 100 qubits in 10,000 quantum gates?

Our goal is to devise one or several families of quantum algorithms that, in their simplest instances, can be demonstrated with existing or near-future hardware, and with moderate further scaling up can lead to computational gains beyond existing classical computer hardware.

The proposed approach is to: (i) focus on the area of quantum materials; (ii) expand capacity in quantum programming techniques, focussing on quantum simulation, quantum machine learning, and symmetry analysis; and (iii) build capacity in quantum hardware, specifically a quantum simulator for fermions in one and two-dimensional lattices.

To implement this approach, three capacities and knowledge reservoirs will form the pillars on which this

Grand Challenge is based, and the goal is to direct these tools to problems relating to quantum materials. The pillars are:

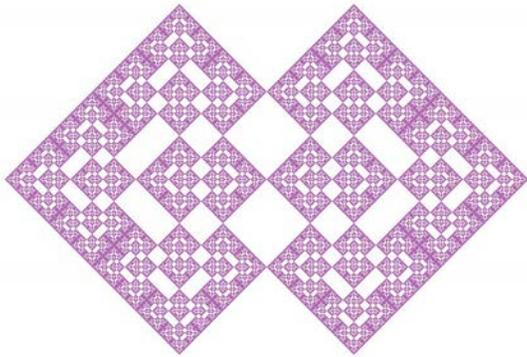
1. Machine learning for quantum problems and quantum machine learning—led by Roman Krems: Development of machine learning methods for inverse problems in quantum dynamics and extrapolation of quantum physics in the Hamiltonian parameter space; enhancement of machine learning models by kernels implemented on quantum hardware.
2. Quantum simulation—led by Joe Salfi: Development of a quantum dot-based quantum computer with full control and measurement capabilities, long coherence times, and natively fermionic qubits enabling more efficient quantum simulation of fermionic many-body systems. More broadly, this will lead to development of a new architecture for large-scale quantum computers.
3. Fundamental aspects of quantum computation—led by Robert Raussendorf: Investigation of the role of symmetry in quantum computing, through computational phases of matter in measurement-based quantum computation.

On the applications side, the inquiry into modelling quantum materials is led by Mona Berciu. Ian Affleck and Marcel Franz will contribute to the quantum simulation and fundamental-aspects-of-quantum-computation pillars, related to the theory of fermions. Joshua Folk and Sarah Burke will support the quantum simulation pillar on the experimental side. Lukas Chrostowski and Jeff Young will contribute modelling techniques for quantum computation using photons. External collaborator Eran Sela (University of Tel Aviv) contributes to the design of small-scale quantum algorithms and to the benchmarking of existing quantum computer hardware.

RESEARCH HIGHLIGHTS



A COMPUTATIONALLY UNIVERSAL PHASE OF QUANTUM MATTER



What is a computational phase of matter? Let's back up a little. Matter around us appears in several phases. For example, water at different temperatures can exist as gas, liquid and solid. Within these phases, characteristic properties vary only gradually. For instance, the densities of boiling water and of freezing water are not too different, but once a transition into the gaseous phase occurs, the density changes drastically.

Besides simple properties such as density or viscosity that are typically used to characterize phases, we observe that water in its liquid phase also gives rise to a highly complex property: life.

The Raussendorf group investigates different types of phases, namely quantum phases of matter at zero temperature and in the presence of symmetry. As it turns out, such phases also harbour complex phenomena, and in this case, they arise in the domain of computer science rather than biology. Namely, there are so-called symmetry-protected phases of quantum matter that give rise to universal quantum computation.

The term “computational phase of quantum matter” was coined by Bartlett, Doherty, Renes, Brennen, and Miyake (2009), when the stability of quantum computation under symmetry-preserving deformations was first observed. The notion applies to the scheme of measurement-based quantum computation, where the process of computation is driven by local measurements. In quantum mechanics, measurement is a dynamic process. Unlike in classical physics, it changes the measured object, and this measurement back-action can be used to compute.

The power of this computational scheme crucially depends on which initial quantum state is being measured. For this reason, a computationally useful quantum state is a resource, and several computationally universal resource states are known. “Universal” means that such states can be used to efficiently compute all there is to efficiently compute for quantum computers.

In 2019, the Raussendorf team identified entire phases of quantum that may facilitate universal computation, in spatial dimension 2. They showed that each ground state, in a suitable such phase, has the same universal computational power. It was previously known that symmetry protected phases in dimension 1 offer uniform computational power, i.e., the computational power is the same for every ground state in the phase. However, such one-dimensional spin systems cannot provide computational universality for measurement-based quantum computation.

Although the focus of the Raussendorf group's work is theoretical, these results may make it easier for experimentalists to create universal resource states for measurement-based quantum computation. Very little is known about the inner workings of quantum computation, and the team is elucidating them from the perspective of symmetry.

R. Raussendorf, C. Okay, D. Wang, D.T. Stephen, H.P. Nautrup. *Computationally Universal Phase of Quantum Matter*. Phys. Rev. Lett. **122**, 090501 (2019).

D.T. Stephen, H.P. Nautrup, J. Bermejo-Vega, J. Eisert, R. Raussendorf. *Subsystem symmetries, quantum cellular automata, and computational phases of quantum matter*. Quantum **3**, 142 (2019).

CASTING A WIDE NET IN SEARCH OF CLEAN ENERGY SOLUTIONS



Photograph of a collaborative experiment at Lawrence Berkeley National Laboratory to investigate fusion reactions, such as those which power our sun, at low energies. Through careful design and manipulation of advanced materials, the goal is to amplify fusion reactions within the lab. Photo credit: Phil Schauer, Berlinguette group.

The Berlinguette group is developing an electrochemical flow reactor that can store solar electricity by converting waste carbon dioxide into useful fuels and products. A carefully designed catalytic material sits at the heart of this reactor, and is key to the system's overall rate, efficiency, and selectivity. In 2019, and in collaboration with Marc Robert's laboratory (Université Paris Diderot), they demonstrated for the first time that organic compounds bonded to metal ions dispersed on a catalytic surface can significantly enhance the speed and selectivity of CO₂ conversion in the reactor relative to a metal-only system. This result is significant as it vastly broadens the scope of materials that can conceivably be used to mediate electrochemical energy storage, paving the way for more efficient reactor design.

In a more daring effort to find solutions to the global energy demand, Curtis Berlinguette joined Google staff and principal investigators from MIT, the University of Maryland, and Lawrence Berkeley National Laboratory to form a closed-doors peer group to investigate claims that abundant clean energy could be realized via cold fusion. The initial reporting of such findings by Fleischmann and Pons in 1989 was followed almost immediately by widespread debunking from the scientific community due to a pervasive inability to reproduce the result and errors found in the experimental approach. This included seminal work from SBQMI's Emeritus Professor Walter Hardy, published in 1990. In short order the topic was effectively barred from mainstream academic research. In 2015 the multi-institutional peer group—sponsored by Google—began investigating the underlying science of

cold fusion in an unbiased manner, free from the stigma of past studies and guided by rigorous internal peer review. The team made its findings public in a 2019 *Nature* article. Although they have found no evidence to date supporting cold fusion, they contend that in the face of an ever-growing global energy crisis, likely requiring out-of-the-box solutions, no area of scientific research should be considered off limits.

Revisiting the case for cold fusion has also inspired several impactful spin-off projects. One example is the development of a palladium membrane reactor which has many potential applications, including biofuel upgrading and energy storage. Another study demonstrates the importance of nanoscale geometry in materials for hydrogen storage and conversion. Cold fusion remains the elusive holy grail of clean energy production, but for now the search is yielding interesting science that advances multiple research topics.

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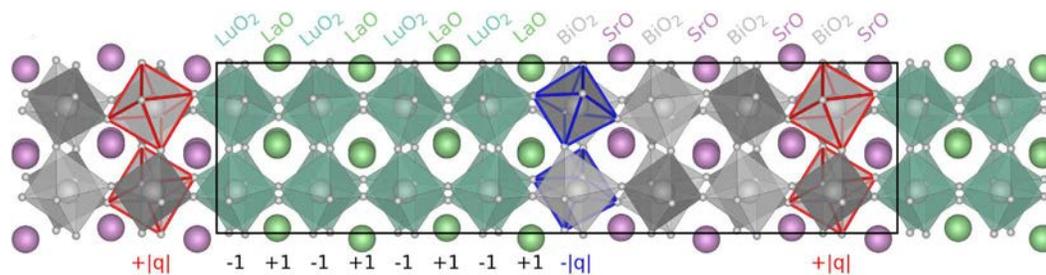
QUANTUM SANDWICHES: METHODS AND INGREDIENTS

State-of-the-art thin film growth techniques, such as molecular beam epitaxy (MBE) or pulsed laser deposition (PLD), have recently enabled the fabrication of high-quality heterostructures—“quantum sandwiches” made up of atomically thin layers—stacking oxides with sharp interfaces. These systems may display a variety of novel phenomena resulting from an intricate interplay between reduced dimensionality, lattice reconstruction, strain, and—in some cases—a “polar catastrophe” effect or “a sudden electronic reconstruction that compensates for the interfacial ionic polar discontinuity.” In 2004, Ohtomo and Hwang showed that the latter plays a key role in the formation of a highly mobile two-dimensional (2D) electron gas at the interface of two wide-gap insulators: the non-polar perovskite SrTiO₃ and the polar perovskite LaAlO₃ stacked along their crystallographic 100 direction.

Taking it a step further, researchers from the Sawatzky group interfaced a non-polar insulating perovskite oxide (Ba(Sr)BiO₃) with a suitable polar perovskite oxide (LaLuO₃). Bulk Ba(Sr)BiO₃ demonstrates many interesting properties including the presence of self-doped oxygen holes, bond-disproportionation, and a rich phase diagram as a function of chemical hole doping, which, in particular, hosts a high-transition temperature superconducting phase with possibly unconventional superconducting pairing. Using density functional theory calculations,

the team demonstrated that in the SrBiO₃/LaLuO₃ heterostructure coexisting 2D electron and hole gasses can appear at the two different types of interfaces. Importantly, they showed that the gasses’ densities are controllable by the thicknesses of each of the two oxides’ layers. Given the rich properties of bulk bismuthates and also the peculiar features of the calculated heterostructure’s band structure, the team argues that the discovered 2D electron and hole gasses may adopt one of a variety of exotic ground states, which include a superconducting condensate, an excitonic condensate, or a charge-density wave.

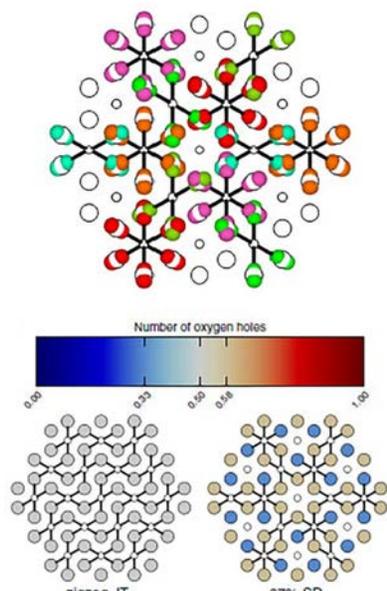
Making the heterostructure experimentally is a complex multi-step process led by experimentalists in the Zou group working in collaboration with Kateryna Foyevtsova, a Research Associate in the area of Density Functional Theory who works closely with Sawatzky’s group. First, the team had to carefully optimize the growth process for a single SrBiO₃ thin film. They used a molecular beam epitaxy (MBE) synthesis process involving two different growth methods: high-temperature co-deposition and the newly developed “recrystallization” growth method used for synthesizing bismuth oxide and producing thin films of a high quality. This new method, developed by the team, opens the door for using bismuth oxide as an ingredient in quantum heterostructures and has important implications for the study of superconductivity at the macro scale.



F. Li, B.A. Davidson, R. Sutarto, H. Shin, C. Liu, I. Elfimov, K. Foyevtsova, F. He, G.A. Sawatzky, K. Zou. *Epitaxial growth of perovskite SrBiO₃ film on SrTiO₃ by oxide molecular beam epitaxy.* Phys. Rev. Mater. **3**, 100802 (2019).

A. Khazraie, I. Elfimov, K. Foyevtsova, and G.A. Sawatzky. *Potential superconducting interfaces in polar ABO₃/Ba(Sr)BiO₃ heterostructures.* Phys. Rev. B **101**, 035135 (2020)

QUANTUM VIEW OF LITHIUM BATTERIES



The ongoing rapid development of modern technology places ever-increasing demands on rechargeable batteries. While extensive efforts are put into the development of new battery materials, there are important lessons we can learn from exploring the properties of the well-known cathode material LiNiO₂. Although LiNiO₂ dates back to the 1950s, studies investigating its suitability for use in lithium batteries began in earnest in the 1980s. LiNiO₂ has a layered structure favorable for efficient Li-ion diffusion, in which the NiO₆ octahedra form a triangular lattice. Using density functional theory calculations, the Sawatzky and Rottler groups were able to explain some of the previously poorly understood electronic and structural properties of this material. They found that the properties are governed by the interplay between a local Jahn-Teller effect, presence of self-doped holes occupying oxygen molecular orbitals, as well as near-degeneracy of multiple metastable phases. Based on these findings, the teams claim that the extraordinarily high-reversible capacity of LiNiO₂ can be linked to this system existing in a high-entropy state which is electronically—rather than structurally—driven. According to Research Associate and theorist Kateryna Foyevtsova, who led the study: “Recognizing the important role that entropy may play in stabilizing battery cathodes opens up the door for new approaches to rechargeable lithium battery development.”

In another approach, the Kiefl and MacFarlane groups looked into lithium ion (Li-ion) batteries. Batteries in general are being studied to mitigate the effects of climate change, as they can provide efficient electrical energy storage solutions and have long lives. Li-ion batteries, in particular, provide a higher energy return than other types of batteries. However, they do have some limitations, such as high cost and relatively fast battery aging. Experimental techniques capable of studying Li diffusion in different systems and under different conditions are needed to identify potential Li-ion battery materials with improved performance. In a

study led by PhD student Aris Chatzichristos, the teams developed the 8Li α -radiotracer method.

The researchers studied rutile titanium dioxide (TiO₂) with the α -radiotracer method at TRIUMF. Rutile is a candidate anode material but there are several unanswered questions regarding the Li⁺ motion in it: the energy barrier for Li diffusion observed experimentally is 10 times smaller than that predicted using density functional theory (DFT), and there is a lot of discrepancy in the diffusion rate of different experimental work. Also, little is known about why Li intercalation in rutile is so suppressed.

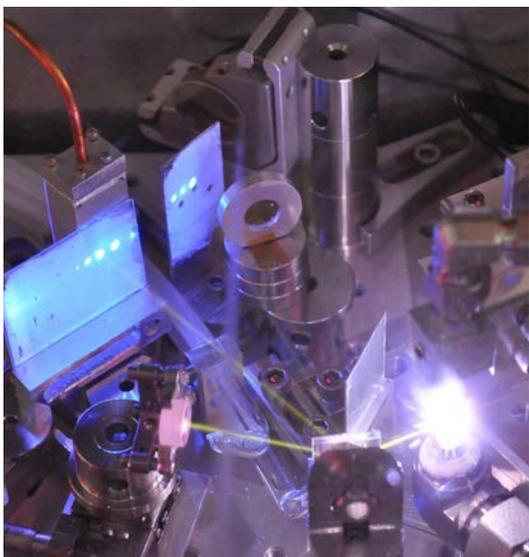
The SBQMI teams showed that Li⁺ often gets trapped at the surface of rutile instead of diffusing towards the bulk, and this may explain the suppressed Li uptake. They also found that the temperature dependence of the Li diffusion is more complex than expected. At low temperatures the diffusivity has an activation energy similar to the DFT prediction, whereas at high temperatures it is ten times larger, in agreement with other techniques. Using the α -radiotracer measurements in conjunction with their previous study of rutile using beta-detected nuclear magnetic resonance (β -NMR), the team argues that at high temperatures Li⁺ ions have to break apart from a Li-Ti-polaron complex in order to move, whereas at low temperatures a fraction of Li⁺ diffuse as simple interstitials with the energy barrier predicted by DFT.

β -NMR and α -radiotracer experiments can be performed in parallel and collect complementary information about the local hopping rate of Li⁺ and its nanoscale diffusivity, while also extracting easily the Li⁺ boundary condition at surfaces of materials; this new experimental method may shed light on the Li motion in Li-ion battery materials and across their interfaces, paving the way for the development of new Li-ion battery materials.

K. Foyevtsova, I. Elfimov, J. Rottler, G.A. Sawatzky. *LiNiO₂ as a high-entropy charge- and bond-disproportionated glass*. Phys. Rev. B **100**, 165104 (2019).

A. Chatzichristos, R.M.L. McFadden, M.H. Dehn, S.R. Dunsiger, D. Fujimoto, V.L. Karner, I. McKenzie, G.D. Morris, M.R. Pearson, M. Stachura, J. Sugiyama, J.O. Ticknor, W.A. MacFarlane, and R.F. Kiefl. *Bi-Arrhenius Diffusion and Surface Trapping of ⁸Li⁺ in Rutile TiO₂*. Phys. Rev. Lett. **123**, 095901 (2019).

SHEDDING LIGHT ON ELECTRONIC INTERACTIONS



With its direct correspondence to electronic structure, angle-resolved photoemission spectroscopy (ARPES) is a ubiquitous tool for the study of solids. When extended to the temporal domain, time-resolved (TR)-ARPES allows us to additionally explore a material's unoccupied electronic structure as well as its dynamical response under optical excitation.

Historically, ultrafast extreme ultraviolet (XUV) sources employing high-order harmonic generation (HHG) have required compromises that make it challenging to achieve the high energy resolution desirable for studying subtle changes in the nonequilibrium electronic response. This year, with the support of the Gordon and Betty Moore Foundation's Emergent Phenomena in Quantum Systems (EPiQS) Initiative, researchers from the Jones and Damascelli groups addressed this challenge by performing HHG inside a femtosecond enhancement cavity (fsEC), realizing a source with a close to one order of magnitude improvement in the energy resolution for TR-ARPES, while maintaining a good temporal resolution. This is the first time that researchers have been able to record, frame-by-frame, how an electron interacts with certain atomic vibrations in a solid.

Simultaneously achieving a repetition rate of 60 MHz, a flux of 10^{11} photons per second, and an energy and time resolution of 22 meV and 150 fs, respectively, this source is a unique, specialized tool for the study of nonequilibrium dynamics under perturbative excitation. The capabilities of the source are showcased in the study of electron-phonon coupling in graphite, where the team observed quantized energy-loss processes that correspond to the emission of strongly-coupled optical phonons by electrons optically excited above the chemical potential.

The authors showed that the characteristic timescale for spectral-weight transfer from the optically-excited electronic states to their phonon-induced replicas allows for the quantitative extraction of the electron-phonon matrix elements, for specific phonon modes, and with unprecedented sensitivity. "Using an ultrashort laser pulse, we excited individual electrons away from their usual equilibrium environment," said MengXing Na, the PhD student who led the study. "Using a second laser pulse as an effective camera shutter, we captured how the electrons scatter with surrounding atoms on timescales faster than a trillionth of a second. Owing to the very high sensitivity of our setup, we were able to measure directly—for the first time—how the excited electrons interacted with a specific atomic vibration, or phonon."

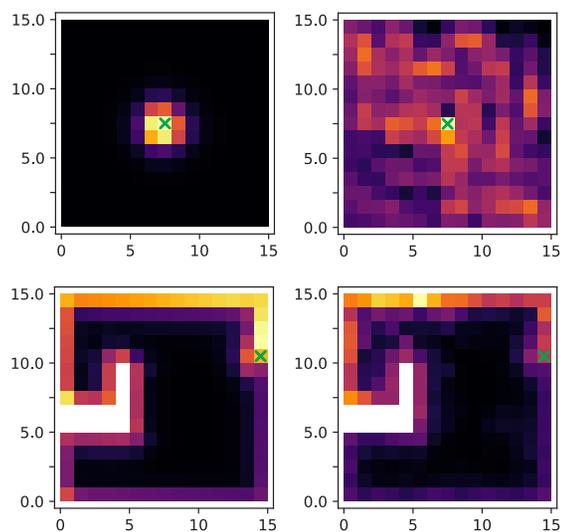
The cavity-based approach to HHG has enabled detailed studies of electronic structure under perturbative excitation. Using the source's combination of impressive experimental parameters, the team developed a new technique for the quantitative measurement of the electron phonon coupling. "This study highlights the potential for other discoveries enabled by our source for high-resolution TR-ARPES," adds David Jones who, together with Arthur Mills, led the ultrafast XUV laser development. The recent publication in *Science*—produced with theoretical support from the Devereaux (Stanford) and Kemper (North Carolina State University) groups—promises a new experimental perspective for pump-probe studies.

"By applying these leading-edge techniques, we're now poised to reveal the elusive mystery of high temperature superconductivity and many other fascinating phenomena of quantum matter," says Andrea Damascelli, scientific director of SBQMI and leader of the ARPES group.

A.K. Mills, S. Zhdanovich, M.X. Na, F. Boschini, E. Razzoli, M. Michiardi, A. Sheyerman, M. Schneider, T.J. Hammond, V. Süss, C. Felser, A. Damascelli, D.J. Jones. *Cavity-enhanced high harmonic generation for XUV time-resolved ARPES*. *Rev. Sci. Instrum.* **90**, 083001 (2019).

M.X. Na, A.K. Mills, F. Boschini, M. Michiardi, B. Nosarzewski, R.P. Day, E. Razzoli, A. Sheyerman, M. Schneider, G. Levy, S. Zhdanovich, T.P. Devereaux, A.F. Kemper, D.J. Jones, A. Damascelli. *Direct determination of mode-projected electron-phonon coupling in the time-domain*. *Science* **366**, 1231 (2019).

TOPOLOGY AND EMERGENCE



Since the discovery of the quantum Hall effect in 1980, the mathematical field of topology has provided important insights to modern condensed matter physics. Several prominent examples are quantum-mechanical in nature. Yet, recent research unearthed an abundance of classical systems—mechanic, acoustic, electric and more—in which topology is in the driver’s seat.

Work by PhD student Rafael Haenel, Master’s student Tim Branch, and Marcel Franz showed how Chern insulators—2D systems with protected edge states alongside an insulating bulk—can be emulated in classical electric circuits. Their design consists of standard circuit elements with operational amplifiers enabling the topological effects. A voltage pulse injected in the center of the circuit stays localized—its bulk is insulating—while a pulse injected at the edge propagates, even if the circuit’s boundary is deformed. Next, under the supervision of Franz and James Day, Haenel plans to put the theory to the test by building the circuits and taking measurements.

Topological superconductors are examples of a genuine quantum system in which topology is key. They also host edge states in the form of Majorana modes. These exotic quasi-particles hold promise for quantum computing applications, and in the past decade several experiments have reported tentative evidence of their existence, but no conclusive proof has been found yet.

Professors Eran Sela (Tel Aviv University) and Yuval Oreg (Weizmann Institute of Science), in collaboration with postdoctoral fellow Stephan Plugge and others from Joshua Folk’s group at SBQMI, have developed new methods for the detection and verification of Majorana modes. The work was carried out during Sela’s sabbatical

at SBQMI, with important discussions taking place when Oreg visited Vancouver in 2019 to participate in the International Synthetic Topological Matter workshop hosted at UBC.

The idea is to extend recent experiments on entropy measurements in quantum dots conducted by the Folk group, and use these dots as “entropy detectors” to interrogate the predicted topological states. Since the system’s physics are altered when charges hop between the dot and nearby reservoir, the interrogation is made possible by electrostatic coupling to the system hosting Majorana modes. At the same time, the system exerts a thermodynamic back-action on the dot, which leads to shifts in its equilibrium charge N by fractional amounts not permitted if the system were non-topological. These shifts are measured by a nearby charge detector, confirming the presence of Majorana modes in a way that is complementary to established schemes.

Just as the classical electric circuits emulate quantum systems described above, complex quantum matter itself can give rise to emergent phenomena otherwise found in different areas of physics. One example are anti-ferromagnetic spin chains. In fall 2019, SBQMI’s Ian Affleck, working with PhD student Samuel Gozel and Frederic Mila (EPFL), calculated static spin-correlation functions and the dynamic structure factor. The trio discovered that large-spin chains show emergent asymptotic freedom at short distances, a concept observed in quantum chromodynamics. Next, using neutron scattering experiments to verify their predictions will likely lead to new and important insights in low-dimensional magnetic materials.

S. Gozel, F. Mila, I. Affleck. *Asymptotic Freedom and Large Spin Antiferromagnetic Chains*. Phys. Rev. Lett. **123**, 37202 (2019).

R. Haenel, T. Branch, M. Franz. *Chern insulators for electromagnetic waves in electrical circuit networks*. Phys. Rev. B **99**, 235110 (2019).

E. Sela, Y. Oreg, S. Plugge, N. Hartman, S. Luescher, J.A. Folk. *Detecting the universal fractional entropy of Majorana zero modes*. Phys. Rev. Lett. **123**, 147702 (2019).

INFRASTRUCTURE



NEW CLEANROOM

The renovation of SBQMI's nanofabrication cleanroom was completed in 2019, with full occupancy of the new space taking place at the end of the year. Starting in early 2020, commissioning of all the tools and processes will take place in phases. As a result of the renovations, the available lab space was doubled to 1,700 sq. ft. (approximately 160 m²), cleanliness levels were improved by one Class to ISO 5, and the temperature and humidity environmental controls were also upgraded. These crucial improvements, along with the acquisition and commissioning of new tools, allow us to drastically expand existing process capabilities and improve reliability and reproducibility of the work performed.

Specifically, key processes were upgraded to accommodate industry-standard 8-inch / 200-mm wafers. Highlights of the renovated cleanroom include a state-of-the-art inductively coupled plasma reactive-ion etch tool for silicon etching; an industry-standard maskless photolithography tool which allows cost-effective, fast-turnaround patterning of wafers down to 1 micron resolution; new spinners, hot-plates; and optical microscope; three new wet benches for sample preparation, photolithography, metal lift-off, and wet etching. In addition, the recently acquired ultra-high vacuum hybrid evaporator, contact mask-aligner, and other micro- and nanofabrication tools pre-dating the renovation, will complement the processes offered in the new space. The resulting upgraded capabilities are versatile and, with our electron-beam lithography tool, cater to the demands of SBQMI nanofabrication research. At the same time, the facility will be available to the broader UBC community, as well as to our external academic and industry partners.

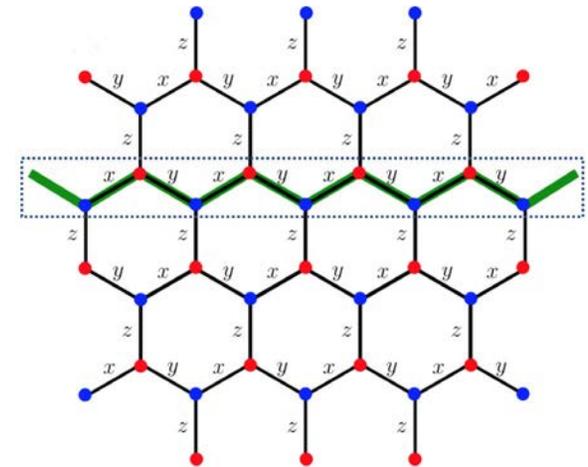
LISA and LISA-2

SBQMI's Laboratory for Interdisciplinary Science Application (LISA) is a high-performance computing infrastructure that provides users with the ability to perform advanced theoretical and computational modelling. LISA is equipped with approximately 1500 cores, 5 GB/core RAM, InfiniBand interconnects (56 GB), 4 GPU nodes each equipped with 4 Nvidia K80 cards (16 in total), and approximately 120 TB of storage. LISA is available to all SBQMI researchers at no cost.

The recently purchased LISA-2 cluster consists of 8 CPU nodes, 8 cores each with 64 GB memory RAM (Intel Xeon W-2145 CPU @ 3.70 GHz), and 160 TB of storage space. LISA-2 provides enhanced capabilities for serial large memory numerical simulations (no MPI, no Open MP hybrids, for which LISA is the best choice). Typical applications are exact diagonalization or numerical density matrix renormalization group calculations for models of quantum materials. With LISA-2, SBQMI is enhancing its advanced computing capabilities even further, and as with LISA, LISA-2 is available to all SBQMI members at no cost.

An example of recent computational work performed by LISA is the study of the Kitaev spin 1/2 model on honeycomb lattice, which has attracted intense interest by researchers studying Majorana fermions, anyons, quantum computations, and more. Using LISA, SBQMI researchers Alberto Nocera, Tarun Tummuru and Wang Yang (Affleck Group) studied a 1D version of the Kitaev model with an extra "Gamma" term by selecting one row on the honeycomb lattice as shown by the rectangle in figure (a). The team determined the phase diagram of the model by combining density matrix renormalization group simulations and analytical methods. The results, obtained using LISA, provide a starting point for extrapolation into 2D systems; the emergent $SU(2)_1$ symmetry phase unveiled in this study offers further insights into possible spin liquid phases, for instance in α -*RuCl₃* systems.

Using LISA-2, the team is currently exploring new quantum phases stabilized by the addition of a Heisenberg term to the model, as well as the elementary spin excitations in the emergent $SU(2)_1$ symmetry phase. These studies will provide theoretical predictions for future neutron and x-ray scattering experiments on Kitaev quasi-1D materials.



DIVING INTO THE FERMI SEA WITH chinook

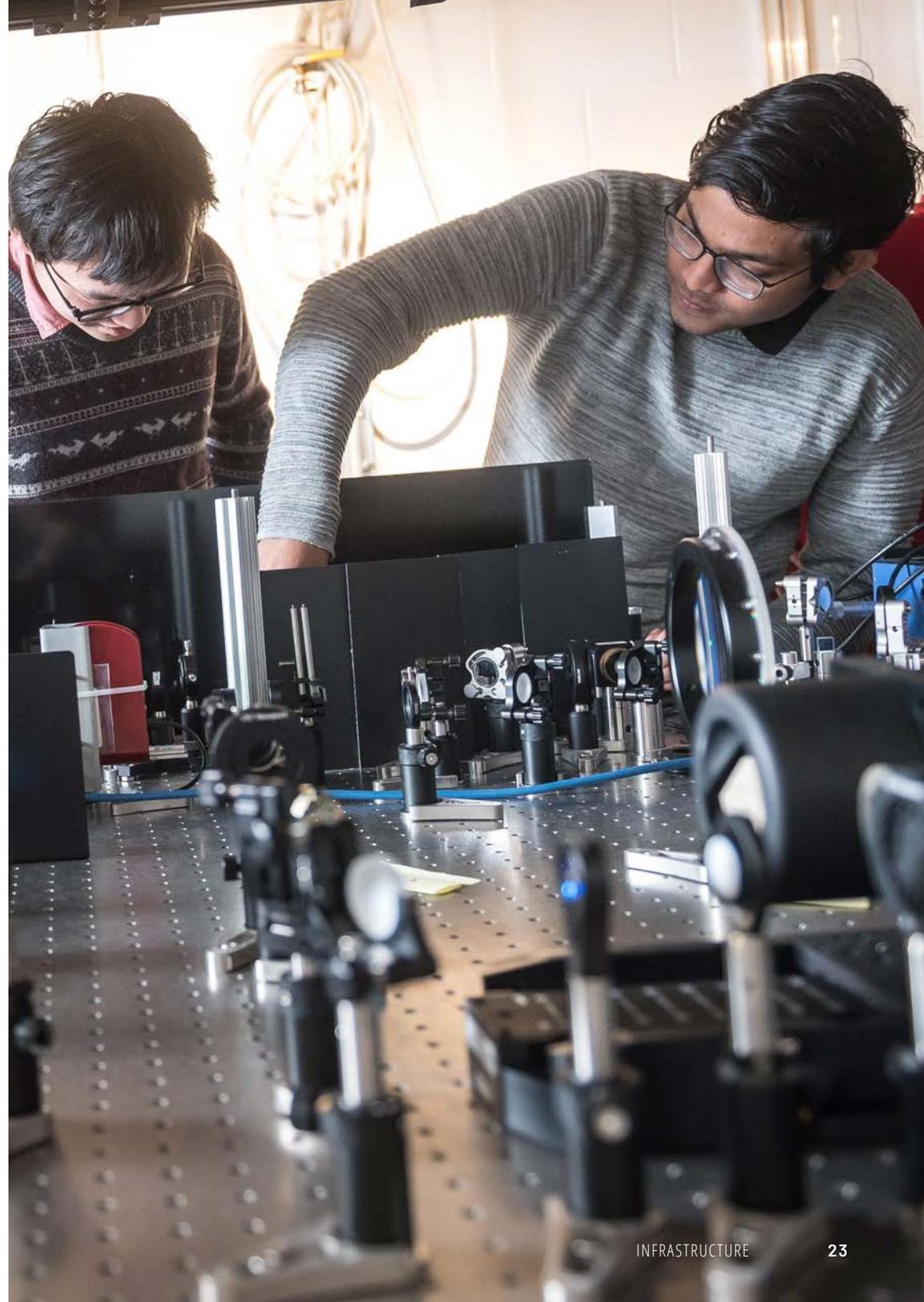


Developed by PhD student Ryan Day working with Berend Swartzsberg, Ilya Elfimov, and Andrea Damascelli, chinook is the name of a new Python-based software intended to facilitate the simulation and interpretation of experimental angle-resolved photoemission spectroscopy (ARPES) measurements of the electronic structure. "We were motivated to develop this as an open source package to provide a free toolkit for the ARPES community," clarifies Day. chinook was created to enhance researchers' ability to interpret experimental data while allowing them to design ARPES experiments that address specific electronic states of interest for a broad variety of materials. In addition, the framework built to support chinook makes it amenable to extension for many other experimental techniques. "We hope this project will grow as a community effort supporting experimental studies of the electronic structure across solid state physics," adds Day. For more information about chinook, visit: <https://chinookpy.readthedocs.io/en/latest/index.html>

ULTRAFAST NANO-OPTICS LAB

Quantum mechanics behave very differently in reduced dimensions. With recent breakthroughs in preparing atomically thin two-dimensional materials such as graphene—the thinnest material humans can make—and their heterostructures, it is possible to study a range of new physics with potential novel functionalities. Led by Ziliang Ye, who joined SBQMI in 2018 as an Assistant Professor, the Ultrafast Nano-Optics Lab is creating optoelectronic devices based on exfoliated two-dimensional quantum materials and exploring nontrivial topology, strong correlations, and other emergent phenomena.

Besides building a versatile transfer stage in an inert environment for high-quality device fabrication, Ye's group has set up a state-of-the-art ultrafast optical spectroscopy lab capable of studying the properties of these two-dimensional materials at femtosecond timescale. Powerful lasers with widely tunable colour are used to probe and control the electronic structure of microscopic materials at a low temperatures and under a strong magnetic field. Concurrently, the group is also developing a nearfield optical microscopy-spectroscopy technique, which can provide optical information with nanometer spatial resolution. In the future, they will combine these capabilities to further push the boundary of science and technology.





SCANNING PROBE MICROSCOPY + ANGLE-RESOLVED PHOTOEMISSION SPECTROSCOPY (SPM+ARPES)

The new combined instrument—funded by the Canada Foundation for Innovation and the British Columbia Knowledge Development Fund—allows the atomic scale characterization provided by scanning probe microscopy techniques, and the view into how the electrons travel in materials afforded by angle-resolved photoemission. Its enhanced capabilities include cooling temperatures as low as 1 Kelvin and in magnetic fields of up to 3 Tesla.

“By combining these tools and their complementary view on materials looking at the exact same samples, we will gain new insight into how atomic scale structure, charge, and electronic states influence the macroscopic properties of materials,” explains lead investigator Sarah Burke.

Commissioned in 2019, this tool will be applied to a range of systems, with a focus on engineering the electronic interactions that underlie the exciting properties of quantum materials.



photo: Pinder Dosanjh

QUANTUM MATERIALS SPECTROSCOPY CENTRE (QMSC) AT THE CANADIAN LIGHT SOURCE (CLS)

The QMSC is a state-of-the-art beamline facility dedicated to performing spin- and angle-resolved photoemission spectroscopy. Funded by the Canada Foundation for Innovation and the British Columbia Knowledge Development Fund, the beamline probes the low-energy electronic properties of solids and offers unique capabilities at the international level. According to Andrea Damascelli, who led the development of the beamline at CLS: “On a fundamental level, some of the most exciting questions in condensed matter physics concern the motion of electrons. On a practical level, the motion of electrons is vital as it imparts functionality to materials and devices. To exploit novel materials and transform them into new technologies, we need to understand and control how electrons move.”

A distinctive feature of QMSC is the combination of two independent endstations dedicated to high energy resolution angle-resolved photoemission spectroscopy (ARPES) and spin-resolved ARPES (S+ARPES), with the beamline full photon

polarization control. Our research priorities will be based on the utilization of these two state-of-the-art endstations, and will exploit several key concepts and methods, such as the “circularly polarized spin” CPS-ARPES approach pioneered by Damascelli’s group to unveil the importance of spin-orbit coupling in unconventional superconductors such as Sr_2RuO_4 , LiFeAs , and FeSe .

The facility has complete polarization control in both linear and circular modes over the highest possible photon flux within the available photon energy range (15 to 1200 eV). The ARPES endstation is fully operational at the moment and is actively being used by a number of groups within SBQMI. We are also rapidly expanding our count of international collaborations to fully leverage this new capability. The S+ARPES beamline is still under construction, but is expected to be operational at the end of 2020. Importantly, the CLS will start accepting formal proposals for the ARPES beamline in late summer 2020.

PARTNERSHIPS



Building successful partnerships allows us to pool and leverage our resources to more effectively address big scientific questions. Together, we are able to conduct cutting-edge research, build capacity, and accelerate research outputs. Our partners make our work better, and, in 2019, we bolstered existing partnerships while forging new ones.



*Santa Ono, President and Vice-Chancellor of the University of British Columbia, and Makoto Gonokami, President of the University of Tokyo
photo: Andrea Damascelli*

MAX PLANCK-UBC-UTOKYO CENTRE FOR QUANTUM MATERIALS

The international Joint PhD program established in 2018 is now well underway and a second student has recently joined the program. Also, in early 2019, we held the Summer School on 2D Materials and van der Waals Heterostructures at UBC. The Summer School was jointly organized by the MP-UBC-UTokyo Centre and the CIFAR Quantum Materials Program, which brought together world-leading experts in the area of 2D materials and about 110 students and postdocs. In December, the Centre's annual meeting was held at SBQMI and was attended by more than 100 participants from the three institutions; one of the key highlights was the poster session where all participants came together to share and discuss their collaborative work performed under the aegis of the Centre.

In August, the President of the University of Tokyo, Dr. Makoto Gonokami, received the President's Medal of Excellence from Professor Santa Ono, President and Vice-Chancellor of UBC, in recognition of Dr. Gonokami's advocacy for stronger international higher education alliances. During his visit, Dr. Gonokami joined Professor Ono at the UBC Collegiate Baseball Classic and participated in a workshop at SBQMI titled "Quantum Materials: from Frequency to Time Domain." The workshop provided a unique opportunity to showcase the success of the Max Planck-UBC-UTokyo Centre for Quantum Materials, while expanding the existing collaboration in ultrafast science.



1044 collaborations corresponding
to **430 papers** from 2015 to 2019

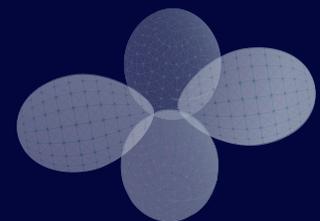




photo: Faculty of Applied Science

▲ UNIVERSITY OF TWENTE VISIT

In the summer a delegation of 26 students, and accompanying Professors Gertjan Koster and Hans Hilgenkam from the University of Twente in the Netherlands, visited UBC and SBQMI. Their visit was part of a three-week tour of universities and companies on the west coast of Canada and the United States. SBQMI Founding Director and Professor Emeritus George Sawatzky hosted the delegation at our Institute. The visit included a tour of our facilities as well as presentations from Robert Green, Joshua Folk, and PhD student Ryan Day. The visiting students explored opportunities for research internships and/or to enroll as UBC graduate students.

▶ JOINT RICE RCQM AND UBC SBQMI WORKSHOP

In October, SBQMI and Rice University's Center for Quantum Materials participated in a workshop at UBC titled *New Frontiers in Quantum Materials*. The goal was to bring researchers and trainees from each institution together to explore opportunities for new and synergistic research collaborations with a focus on:

1. unconventional superconductivity;
2. quantum criticality and novel phases of matter;
3. topological matter, low dimensional systems, and quantum coherence and dynamics.

We want to thank the Gordon and Betty Moore Foundation for providing travel support.

NEW FRONTIERS
IN QUANTUM MATERIALS RESEARCH
October 3 - 4, 2019
QMI, UBC, VANCOUVER

RICE | RCQM
Rice Center for Quantum Materials

Stewart Blusson
Quantum Matter Institute
THE UNIVERSITY OF BRITISH COLUMBIA

RICE SPEAKERS
Pulickel Ajayan
Pengcheng Dai
Rui-Rui Du
Sarah Grefe
Randy Hulet
Alex Kutana
Andriy Nevidomskyy
Qimiao Si
Boris Yakobson
Ming Yi

UBC SPEAKERS
Meigan Aronson
Mona Berciu
Doug Bonn
Andrea Damascelli
Joshua Folk
Alannah Hallis
Alireza Mojahed
George Sawatzky
Ziliang Ye
Ke Zou

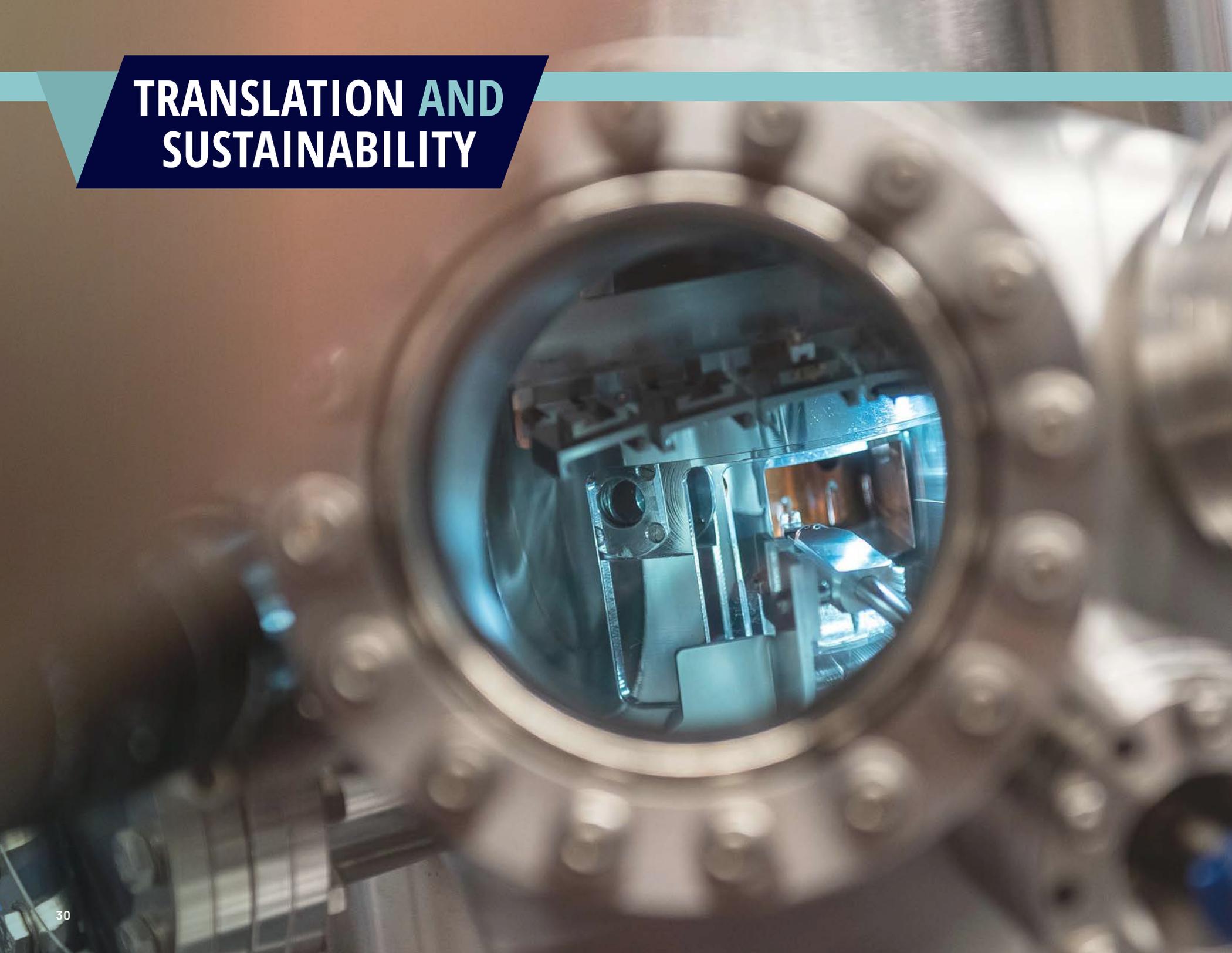
ORGANIZERS
Qimiao Si (Rice University)
Andrea Damascelli (UBC)
nfmqr2019.qmi.ubc.ca

GORDON AND BETTY
MOORE
FOUNDATION

UBC

Poster credit: Barbara Tevarotto

TRANSLATION AND SUSTAINABILITY



SiEPICfab

The Silicon Electronics-Photonics Integrated Circuits Fabrication (SiEPICfab) consortium led by SBQMI's Lukas Chrostowski brings together 11 companies and 4 universities with the goal of becoming Canada's first silicon photonics foundry. The companies involved span the entire lifecycle of silicon photonic chip research—design, testing, and application—and the consortium has implemented a shared IP model designed to allow streamlined prototyping of new circuit designs. In 2019, the consortium added two new partners, Ranovus and McMaster University, to enhance on-chip laser and isolator implantation. The official opening of SBQMI's new nanofabrication facility, which includes a dedicated silicon etcher and maskless lithography system, is scheduled for early 2020 and will further enhance the consortium's capabilities.

AweSEM

AweSEM is a compact, low-cost scanning electron microscope (SEM) that aims to revolutionize the microscopy market by providing a sub-micron imaging tool for a fraction of the cost of traditional SEMs. Led by Alireza Nojeh, the team successfully completed their first demonstration unit in December 2019, which includes professionally-designed housing intended to represent the finished product, and wireless connectivity to a smartphone app for system control and imaging. The prototype and demonstration were completed in collaboration with local professional engineering firms MistyWest and Tangram Design, and have been instrumental in attracting interest from potential early-stage investors. A market study supported by SBQMI and NSERC's Idea to Innovation program was also completed in 2019, and lays out a potential path to commercialization.



DREAM PHOTONICS

Founded in December 2019, Dream Photonics constitutes SBQMI's first fully incorporated spin-off company. The technology, which is based on research by founders Lukas Chrostowski (SBQMI) and Sudip Shekhar from UBC's Electrical and Computer Engineering Department, consists of a reflectance cancellation circuit for lasers on silicon photonic chips that negates the need for bulky and expensive laser isolators. This solution can potentially reduce the cost of laser integration onto chips by 3-5 orders of magnitude, and therefore reduces the overall chip manufacturing costs. Several large chip manufacturers have expressed strong interest in this technology as the demand for integrated photonic-electronic circuits escalates.

QUANTUM INFORMATION SYSTEMS (QIS)

SBQMI brought together a number of collaborative initiatives that address an ever-growing global effort to develop commercially viable quantum computers, and that are also closely linked to one of SBQMI's Grand Challenges, which seeks to discover useful applications of near-term quantum computers. UBC has made research in this area a priority by renewing the funding for the Quantum Computing Research Excellence Cluster through to 2022, and SBQMI is working closely with the cluster to ensure sustainable growth and long-term funding.

In April 2020, SBQMI and the Cluster will co-host a roadmapping workshop that brings together industry, students, and research faculty with the goal of generating a vision document for quantum hardware and software development in British Columbia (BC) for the next 10 years. This workshop will also be the cornerstone of a new joint graduate training program between UBC, Simon Fraser University (SFU), and the University of Victoria (UVic), that will train the next generation of highly-skilled workers in quantum computing.

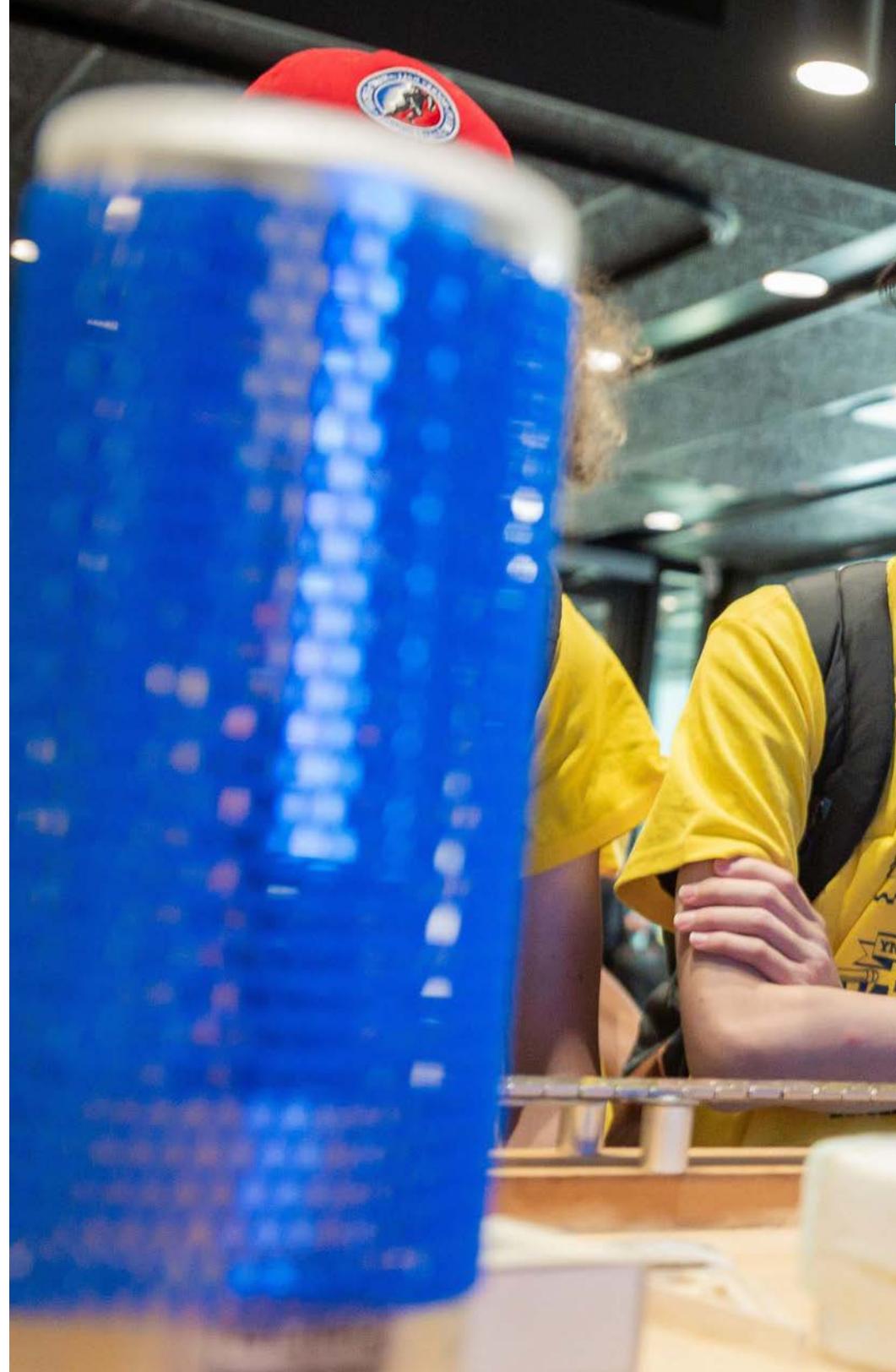
The Cluster is also leading a program funded by Canada's Digital Technology Supercluster. Working with local quantum computing company D-Wave Systems as well as UBC's Geering Up, which organizes summer camps for high school students, the Cluster is working to expand training efforts in quantum computing by targeting high school students with a specific focus on ensuring equal opportunities for underrepresented groups in the sciences.

QUANTUM STRATEGY FOR CANADA AND PROVINCIAL QUANTUM EFFORTS

SBQMI has been at the forefront of the effort to engage with the Government of Canada and develop and fund a national quantum strategy—a critical step to the long-term success of Canadian quantum science and technology. This past year has seen the full engagement of the national quantum research community, as well as the emerging quantum industry, in crafting and promoting a coherent strategy to support the nascent Canadian quantum ecosystem. The leadership committee briefed the relevant ministries, and a multiyear budgetary support announcement is anticipated in the upcoming federal budget.

In addition, in 2019 the Province of British Columbia announced a \$17M effort to start the BC Quantum Algorithm Institute. Located on the SFU campus in Surrey, BC, the Institute brings together BC-based quantum algorithm research and training from across the province. It includes academic institutions such as UBC, SFU, and UVic, as well as industry participants, such as 1QBit, D-Wave Systems, Microsoft, and IBM, to collaboratively accelerate the adoption of quantum algorithms and information science.

Students participating in Physics Day observing a quantum effect: when a high-temperature superconductor is set in motion over a magnetic track, as long as it is kept at a temperature lower than its transition temperature, it will float indefinitely.



EQUITY, DIVERSITY, AND INCLUSION

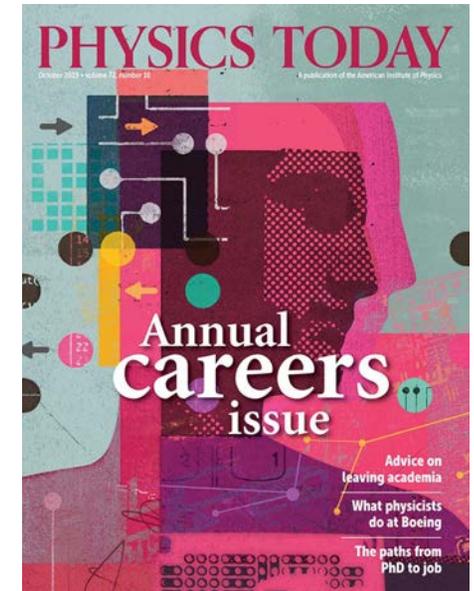


Equity, Diversity, and Inclusion (EDI) is critical to excellence, and SBQMI's excellence manifests in research and breakthroughs, as well as in the ability to attract and train world-class talent. This year the Institute continued to build towards an open, equitable, and inclusive culture by focussing on expanding existing programs and creating new initiatives.

SBQMI also continued to support outreach events and programs around campus such as hosting elementary school students participating in educational camps organized by the Department of Physics and Astronomy, or participating in professional development workshops for teachers organized by UBC's Geering Up program. Geering Up workshops are aimed at providing elementary and high school teachers with resources to bring quantum physics into their classrooms, and to inspire young talent while investing in the inclusion of underrepresented groups in quantum physics.

QUANTUM PATHWAYS

Quantum Pathways is a multi-year summer research undergraduate scholarship program for students from underrepresented groups. This year, a cohort of 12 students joined SBQMI's flagship program, which provides access to one-to-one mentoring in research, scientific writing, and public presentation skills. Students also participate in career events, workshops, and laboratory courses. In October 2019, Quantum Pathways was featured in a *Physics Today* story titled *Ongoing mentorship works for retaining minorities in STEM*.



EMERGING INDIGENOUS SCHOLARS SUMMER SCHOOL PROGRAM

Founded in 2007 by the Pacific Institute for the Mathematical Sciences (PIMS), the annual Emerging Indigenous Scholars Summer School Program aims to inspire indigenous high school students to pursue STEM careers by providing classroom learning, hands-on laboratory internships, and culturally relevant training. In 2019, SBQMI participated in the PIMS program by providing internships for four talented participants from Vancouver high schools. The students worked with the Chrostowski and Damascelli groups at SBQMI over a period of 6 weeks.



MENTORING PROGRAMS

SBQMI GRADUATE STUDENT AND POSTDOCTORAL FELLOW MENTORING PROGRAM

Now in its third year, this mentoring program matches SBQMI graduate students and postdoctoral fellows with mentors in academia, entrepreneurship, and industry. Over the course of the one-year program, participants meet with mentors regularly to discuss challenges and opportunities they may encounter during their studies and research, and seek advice as they plan their future careers.

Past participants have found the program very helpful and especially valued being able to speak with mentors who were former students in their field. They also report that they gained confidence in their job search processes, and the confidence to pursue their ambitions beyond their graduate or postdoctoral studies.

STUDENT PEER MENTORING PROGRAM

Launched in September 2019, the SBQMI Graduate Student Peer Mentoring program pairs each incoming graduate student with a more experienced peer graduate student who does not share the same supervisor. The mentor/mentee pairs meet at least twice per semester for coffee or lunch. Mentors are available to provide informal advice about life as a graduate student, ranging from practical advice about accessing information and resources at SBQMI to personal advice based on the individual's experience. While this is still a very new program, the initial feedback has been very positive. The program helps new students navigate life at UBC and SBQMI, helps create an inclusive environment for new graduate students, and provides the more senior students with mentorship experience.

SIGNATURE EVENTS

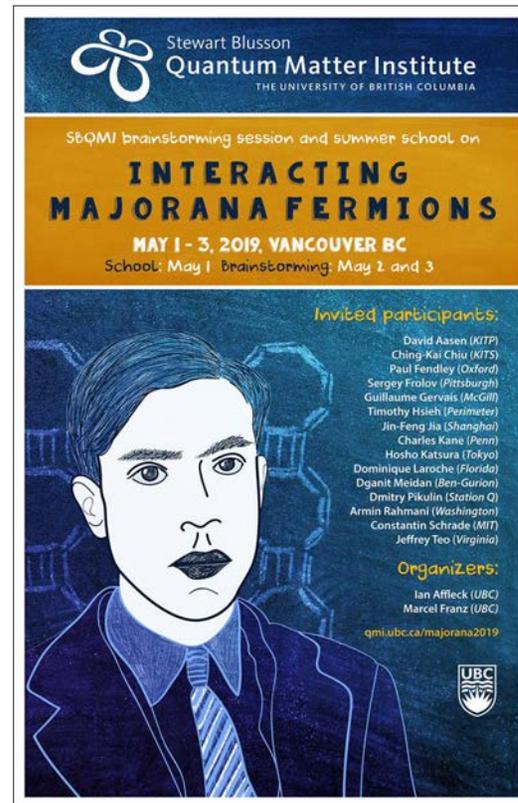




Poster credit: Barbara Tevarotto

SYNTHETIC TOPOLOGICAL MATTER

In February, SBQMI hosted a three-day workshop at UBC. Co-organized by Marcel Franz and Gil Refael from Caltech, the workshop focused on aspects of topological protection outside the traditional realm of electronic systems such as topological insulators and semimetals. It was centered around what has become known as “synthetic topological matter,” which stems from advances in applying concepts of topology to photonic, acoustic, cold atom, and mechanical structures, as well as electrical structures, Floquet, polariton, and various related systems. The workshop showcased recent experimental and theoretical successes and brought these new developments into focus.



Poster credit: Barbara Tevarotto

INTERACTING MAJORANA FERMIONS

Ian Affleck and Marcel Franz organized a two-day brainstorming session at SBQMI in May, which brought together experts to discuss recent advances in the field of interacting Majorana fermion systems in various geometries. Progress in experimental detection and manipulation of Majorana fermions in solid state devices promises that such interacting systems could soon be amenable to laboratory studies. Various exotic phenomena predicted in recent theoretical works, such as the emergent space-time supersymmetry, parafermions and Fibonacci anyons, could therefore become physical reality in the coming years. Discussions focused on summarizing these developments, assessing possibilities for experimental realization, and identifying the most exciting avenues for future research.

The brainstorming session was preceded by a one-day “summer school” aimed at graduate students, postdoctoral fellows, and researchers interested in learning more about the field.

PEOPLE





RAFAEL HAENEL

Inspiration leading the way

“Condensed matter theory is a rich and fascinating area of physics, and after how much I enjoyed Mona Berciu’s class it was only natural to join SBQMI,” said Haenel, who is now enrolled in a joint PhD program under the supervision of Marcel Franz (SBQMI) and Dirk Manske (MPI Stuttgart).

“The joint PhD program gives me the chance to get to know a second academic environment, meet interesting people, and participate in the collaboration between our two institutes,” said Haenel, who is working with Franz with whom he had proposed a classical realization of the so-called Chern insulating phase in an electrical circuit.

“Now I am studying a strongly interacting model of Majorana fermions,” said Haenel. “At MPI Stuttgart I will be working on non-equilibrium dynamics of superconductors.”

“I think we have a great scientific atmosphere at SBQMI,” said Haenel. “I am very happy about the great support that I have received from my supervisor, group members, fellow students, and staff.”



BECKY LIN

Thriving in a dynamic environment

As a graduate student under the supervision of Lukas Chrostowski, Becky Lin is working to design and automate testing methodology of multi quantum silicon photonic devices in the cryogenic temperature range.

Lin, who studied engineering physics at UBC, thrives in an interdisciplinary environment, and specifically chose to do her graduate studies at SBQMI for the dynamic, collaborative effort between theorists, experimentalists and engineers, not just locally but around the world.

“I wanted to be part of this exciting quantum information age,” she said.

For Lin, collaboration extends beyond research and the lab.

“I really enjoy the various seminars at SBQMI, whether they be scientific, career or personal growth-themed,” she said. “They have provided invaluable exposure to the different interests, options, and guidance for individual developments.”

Lin has found opportunities to share her excitement for learning and working together through programs such as the Emerging Indigenous Scholars Summer Camp, where she provided mentorship to a cohort of Indigenous high school students this past summer.

“Hearing the students from the program say that they would join again next year was meaningful to me,” she said.

“For students just beginning their programs at SBQMI, my advice is to observe, discuss, and don’t be afraid to ask questions,” said Lin. “There are many resources and opportunities provided by SBQMI.”



SAM MUGIRANEZA

Exploring new ideas to shape the future

Sam Mugiraneza is a third-year undergraduate student with a keen interest in crystal growth and synthesis of inorganic compounds. He is majoring in Chemistry, and through the Quantum Pathways program he has been exploring his research interests while gaining the laboratory experience to develop his skills as a researcher.

Mugiraneza is currently working with Alannah Hallas; he is in his second year with Quantum Pathways, and previously worked with Curtis Berlinguette. Under the direction of Hallas, he is working to understand how the crystal structure of materials leads to interesting electronic and magnetic properties.

“When I found the Quantum Pathways program, I realized that it offered an unlimited opportunity to explore my interest in materials synthesis,” said Mugiraneza. “I’m exploring a new field, solid-state research, that I hadn’t had a chance to explore in my academic program.”

For Mugiraneza, Quantum Pathways offers access to dedicated educators (professors, postdoctoral fellows) who are passionate about sharing their knowledge with emerging researchers.

“The program has boosted my interests in research and has helped me discover specific areas of interest to pursue after I finish undergrad,” said Mugiraneza. “This will help me choose courses that are relevant to my research interests.”

ALUMNI UPDATES



“ I had a lot of independence and resources, and when I was stuck there was always someone ready to help.

After completing a postdoctoral fellowship at SBQMI in September 2016, Eduardo H. da Silva Neto was appointed Assistant Professor in the Department of Physics at University of California (UC), Davis, where he established a research group focused on investigating the role of intertwined phases of quantum materials using a multi-technique approach. While at UBC, he worked on high-temperature superconductors—specifically cuprates—but more recently he has begun to study materials that are candidates for topological superconductivity.

“I continue to use many of the techniques that I learned as a postdoc,” he explains. At SBQMI, he used angle-resolved photoemission spectroscopy (ARPES) techniques and frequently traveled to synchrotron facilities like the Canadian Light Source (CLS) to use resonant x-ray scattering (RXS) facilities. In 2019, his group was one of the first external groups to generate data at the recently commissioned Quantum Materials Spectroscopy Centre—a CLS beamline developed by his SBQMI supervisor Andrea Damascelli.

Scientific research can be an insular endeavour. What attracted him to SBQMI was the opportunities for collaboration.

“I was looking for an environment that promoted and encouraged collaborative work within the institute and internationally as well. At the time, I really didn’t know of many places like that, but a colleague who knew about SBQMI encouraged me to apply.”

The rest is history.

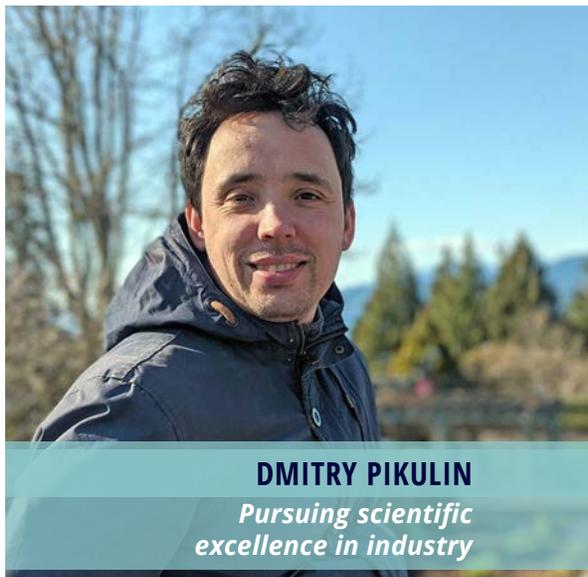
At SBQMI, and as a Max Planck-UBC Postdoctoral Fellow, da Silva Neto worked closely with Professor Bernhard Keimer’s group in Stuttgart, Germany. He also conducted experiments at BESSY, the synchrotron facilities in Berlin.

“It’s like having a foot in two continents. There is always an engaging talk or an interesting visitor. You meet new people, develop new collaborations and are exposed to science from around the world, which is very important when your goal is to become an independent researcher.”

For da Silva Neto, one of the benefits of his time at SBQMI was feeling like he had the Institute behind him every step of the way.

“I had a lot of independence and resources, and when I was stuck there was always someone ready to help,” he said. Whether through support to attend conferences, or in connecting with other researchers, da Silva Neto always felt that there was a vested interest in helping him succeed at SBQMI and beyond. “I think that is rare, and unique to this place.”

Today, most of the collaborations developed during da Silva Neto’s time at SBQMI are still active and productive. Soon, he will start preparing to move his group from UC Davis to Yale University where he begins a new position as Assistant Professor within the Department of Physics in July 2020.



SBQMI Alumnus Dmitry Pikulin is building a topological quantum computer for Microsoft, taking theoretical physics into real world applications that may improve computing and enable the computers of the future to process data more efficiently.

Pikulin completed his postdoctoral fellowship under the supervision of Ian Affleck and Marcel Franz, where he worked on the theory of Majorana zero modes in the presence of interactions and in their effects on 0-, 1-, and 2-dimensional arrays of Majorana zero modes.

“The basic ingredient of a topological quantum computer is a Majorana zero mode,” explained Pikulin. “At Microsoft, we’re trying to identify the conditions that are most favorable to obtain the Majorana zero modes; we’re also working on the theory and experimental characterization of devices designed to probe the physics of the Majorana zero modes on the path to the topological quantum computer.”

Majorana particles are the building blocks of topological quantum computing. Every particle has an antiparticle—for every proton, for example, there is an antiproton. Majorana particles are special because

they are their own antiparticles, and they can be bound to a defect at zero energy; the combined objects are called Majorana zero modes. With Marcel Franz, Pikulin and colleagues proposed the platforms to study the interacting Majorana zero modes experimentally.

Pikulin came to SBQMI after completing a PhD in Europe, partly out of a desire to work in North America, but also to work specifically with Franz and Affleck.

“I liked working with both Marcel and Ian and their groups. They have quite different styles of mentorship and collaboration, and it was a treat to learn from both of them,” said Pikulin. “There is a large change of mentoring style when going from a PhD program into postdoctoral studies. It took patience to adjust, but also opened me to the different styles and ideas in research.”

Some of those different ideas included a project with Franz on “pseudo-fields” in Weyl semimetal that, for Pikulin, had the most far-reaching influence.

“It launched theoretical and experimental collaborations, and was one of the pioneering works in the field of spatially modulated topological semimetals that is rapidly evolving now,” said Pikulin.

The opportunity to explore new interests is what led Pikulin to industry; his advice to current and future SBQMI trainees is to enjoy the multiple available opportunities for internal and external collaborations.

“Don’t be afraid of leaving academia for industry: counterintuitively, industry can sometimes allow for even more academic freedom and require more scientific rigor,” said Pikulin.

“ Don’t be afraid of leaving academia for industry: counterintuitively, industry can sometimes allow for even more academic freedom and require more scientific rigor.



(left to right) Steven Gou, Pedro L. S. Lopes, Vis Naidoo, Haris Amiri, Jasmine Chipman Koty

PROJECT MANAGEMENT OFFICE LAUNCH

In 2019, SBQMI established the Project Management Office (PMO) to support the increasingly important functions of:

- Managing complex projects and programs
- Strengthening industry engagement
- Developing and fostering local and international partnerships
- Centralizing data analysis and reporting

One of the main goals of the PMO is to create a community of practice around project management for all SBQMI members, including staff, Research Associates, scientists, and Postdoctoral Fellows interested or engaged in project management activities.

The PMO team will guide SBQMI members through training programs and activities, project management templates and tools, and sharing best practices.

Since the PMO launched with guidance from Paul Blomerus, UBC Industry Partnerships Advisor, and Vis Naidoo, SBQMI Chief Operations Officer, four project managers have joined the PMO.

Haris Amiri is a project manager on the Quantum Computing Outreach project, aiming to diversify talent within quantum computing. He works with the team to bring quantum computing education to K-12 youth across BC through workshops, events, online courses, and summer camps, with a particular focus on reaching young women, Indigenous youth, and other underrepresented groups. Amiri also assists in SBQMI's STEM outreach projects.

Jasmine Chipman Koty is centralizing data management for SBQMI, facilitating data collection, analysis, and information sharing to support reporting and communications. She also supports the development of project management training within the institute.

Steven Gou manages SBQMI projects in the fields of nanofabrication, electron beam lithography, and integrated photonics. These include SiEPICfab, the Canadian Silicon Photonics Foundry, and the Silicon Quantum Leap Project.

Pedro L. S. Lopes is a former SBQMI postdoc who manages the Institute's Grand Challenges projects, supporting the establishment of their guidelines and priorities, communication coordination, budget evaluation, and hiring processes. He also participates in the development of project management capabilities within SBQMI.

ANNUAL RETREAT

The 2019 retreat was held at the end of September at Loon Lake Lodge located in Maple Ridge, BC. The purpose of this annual event is to foster greater formal and informal discussions, to develop new ideas and projects, and to engage in team building activities.

This year, we were joined by several guest speakers. Dr. Stephen Murgatroyd, President and CEO of futureTHINK Press, presented a talk titled “Understanding science and innovation in the context of global challenges.” In addition, Andrea

Damascelli moderated a panel discussion on “Communicating our science to peers and the public.” Panelists included Dr. Donovan Hall (Associate Editor, *Physical Review Letters*), Dr. Andrea Taroni (Chief Editor, *Nature Physics*), and Mr. Kurt Kleiner (CIFAR, Director of Communications).

Approximately 150 members participated in the weekend activities, which included scientific presentations, institutional development and strategy discussions, as well as team building and self-guided activities.



AWARDS AND RECOGNITION

Doug Bonn

2019 Canadian Association of Physicists Medal for Lifetime Achievement in Physics

This Medal for Lifetime Achievement in Physics, introduced by the Canadian Association of Physicists in 1956, recognizes “distinguished service to physics over an extended period of time, and/or recent outstanding achievement.” Bonn was recognized for his accomplishments in quantum materials, which have advanced our understanding of high-temperature superconductors, as well as the development of innovative approaches to teaching introductory physics laboratories that emphasize students’ ability to reason quantitatively with data, improving learning outcomes for students, rather than simply teaching basic physics concepts.

Curtis Berlinguette

2019 TechConnect Innovation Award

The TechConnect Innovation Awards “identify the top 15% of submitted technologies as ranked by the TechConnect Corporate & Investment Partner Committee and the rankings are based on the potential positive impact the submitted technology will have on a specific industry sector.” This award recognizes the development of “Ada,” the world’s first integrated self-driving laboratory for thin-film materials discovery. Ada is automated, autonomous, and adaptable for a variety of materials systems. Advanced robotics and AI equip self-driving platforms like Ada with the capacity to make, test, and learn from new materials on the

fly. Leveraging automation in materials science enables higher research throughput, and AI-driven autonomy facilitates more efficient exploration. The Ada team’s approach embraces versatility, and allows for rapid and ongoing design and implementation of flexible hardware and software.

Lukas Chrostowski

Member of the Royal Society of Canada’s College of New Scholars, Artists and Scientists

The prestigious College of New Scholars from the Royal Society of Canada is “Canada’s first national system of multidisciplinary recognition for the emerging generation of Canadian intellectual leadership.” Chrostowski was recognized for his leadership in both research and education in the design of silicon photonic devices and systems for application in optical communications and biosensors.

Walter Hardy and Doug Bonn

Global Highly Cited Researchers 2019 list by Clarivate Analytics

The list recognizes “the world’s most influential researchers of the past decade demonstrated by the production of multiple highly-cited papers ranking in the top 1% by citations for field and year in Web of Science.” Only 3.1% of the Global Highly Cited Researchers list are physicists and only 0.1% of the world’s total population of scientists and social scientists make the list.



(left to right) Ehsanur Rahman and MengXing Na

MengXing Na and Ehsanur Rahman

Vanier Canada Graduate Scholarship Recipients

The Vanier Canada Graduate Scholarships were launched in 2008 to enhance Canada’s ability to attract and retain the top doctoral students in the world and establish Canada as a “global centre of excellence in research and higher learning.” Only 166 scholarships are awarded annually and recipients must exhibit academic excellence, exceptional research potential, and outstanding leadership qualities.

Co-supervised by Andrea Damascelli and David Jones, MengXing Na’s research is focused on the coherent control of ultrafast dynamics of materials studied with time- and angle-resolved photoemission spectroscopy.

Ehsanur Rahman is supervised by Alireza Nojeh. His research focus is the enhancement of thermionic electron emission performance from reduced dimensional materials such as Vertically Aligned Carbon Nanotube ensembles, and its application in electron source and static heat-to-electricity conversion.

PRINCIPAL INVESTIGATORS





**IAN
AFFLECK**

RESEARCH FOCUS

One method we have applied with great success is conformal field theory. While its original development was motivated by string theory, we have applied it to quantum spin chains, quantum wires, and various types of quantum impurity problems including the Kondo effect and junctions of quantum wires. We also use the renormalization group, which straddles high energy and condensed matter physics, and have frequently applied large scale numerical techniques to these problems, especially the Density Matrix Renormalization Group. Our collaborators include Steven White at UC Irvine Frederic Mila at École Polytechnique Fédérale de Lausanne and Charles Kane at U. Pennsylvania.

CURRENT PROJECTS

- Self-interacting Majorana modes (the Majorana-Hubbard model)
- A Majorana mode interacting with a multi-channel Luttinger liquid
- Quantum spin chains with SU(n) symmetry
- Phase diagram of the generalized Kitaev spin chain model
- Gapless phases in integer spin chains
- Observing impurity entropy in the multi-channel Kondo effect (in collaboration with Joshua Folk)
- The Kitaev spin model

CAREER HIGHLIGHTS

PhD Harvard University 1976 – 1979
Asst. Professor Princeton University 1981 – 1987
Professor UBC 1987 – present

GRADUATE STUDENTS

Samuel Gozel (EPFL), Mobin Shakeri, Tarun Tummuru, Kyle Wamer

POSTDOCTORAL FELLOWS

Pedro Lopes, Wang Yang

SCIENTIFIC STAFF

Alberto Nocera

SELECTED PUBLICATIONS

Z. Shi, E. Nica, I. Affleck. *Kondo effect due to a hydrogen impurity in graphene: a multichannel Kondo problem with diverging hybridization*. Phys. Rev. B **100**, 125158 (2019).

S. Gozel, F. Mila, I. Affleck. *Asymptotic Freedom and Large Spin Antiferromagnetic Chains*. Phys. Rev. Lett. **123**, 037202 (2019).

I. Affleck, J.B. Marston. *Large- n limit of the Heisenberg-Hubbard model: implications for high- T_c superconductors*. Phys. Rev. B **37**, 3774 (1988).



**MEIGAN
ARONSON**

RESEARCH FOCUS

Our group is focused on finding new materials that are at or near a quantum phase transition, where new phases of matter—including novel order—emerges at zero temperature. We carry out measurements of fundamental quantities, such as the transport of charge and heat, and especially their magnetic properties using a combination of lab-based techniques and also neutron scattering facilities. These materials form the basis of a number of different collaborations that leverage the experimental strengths within QMI.

CURRENT PROJECTS

- Search for metallic quantum spin liquids
- Moment compensation in topological materials
- Dimensional crossover in 1D and 2D heavy fermions
- Strongly interacting surface states in topological insulators

CAREER HIGHLIGHTS

PhD University of Illinois 1988
Postdoc. Fellow Los Alamos National Laboratory 1987 – 1989
Asst. Professor University of Michigan 1990 – 1996
Assoc. Professor University of Michigan 1996 – 2002
Professor University of Michigan 2002 – 2006
Professor Stony Brook University 2007 – 2015
Group Leader, Brookhaven National Laboratory 2007 – 2015
Professor and Dean, Texas A&M University 2015 – 2018
Professor and Dean, UBC 2018 – present

GRADUATE STUDENTS

Joern Bannies

POSTDOCTORAL FELLOWS

Xiyang Li, Jannis Maiwald, Om Prakash, Dalmau Reig-i-Plessis

SCIENTIFIC STAFF

William Gannon

SELECTED PUBLICATIONS

W.J. Gannon, I.A. Zaliznyak, L.S. Wu, A.E. Feiguin, A.M. Tsvelik, F. Demmel, Y. Qiu, J.R.D. Copley, M.S. Kim, M.C. Aronson. *Spinon confinement and a sharp longitudinal mode in Yb₂Pt₂Pb in magnetic fields*. Nat. Commun. **10**, 1123 (2019).

W.J. Gannon, L.S. Wu, I.A. Zaliznyak, W.H. Xu, A.M. Tsvelik, Y. Qiu, J.A. Rodriguez-Rivera, M.C. Aronson. *Local quantum phase transition in YFe₂Al₁₀*. Proc. Natl. Acad. Sci. U.S.A. **115**, 6995 (2018).

L.S. Wu, W.J. Gannon, I.A. Zaliznyak, A.M. Tsvelik, M. Brockmann, J.-S. Caux, M.-S. Kim, Y. Qiu, J.R. Copley, G. Ehlers, A. Podlesnyak, M.C. Aronson. *Orbital-Exchange and fractional quantum number excitations in an f -electron metal, Yb₂Pt₂Pb*. Science **352**, 1206 (2016).



**MONA
BERCIU**

RESEARCH FOCUS

Our main interest is in the development of variational approximations that are quantitatively accurate yet computationally efficient, and can be used to explore the properties of some models of strongly-correlated systems in a wide region of the parameter space. Such studies supplement numerical exact studies, which are usually extremely time consuming and have limitations in terms of system size, temperature range, etc. Our main focus so far has been on few-particle properties in the extremely underdoped limit of insulators at zero temperature. We are now attempting to expand our expertise to cover finite temperatures and finite particle densities.

CURRENT PROJECTS

- Effective magnon-mediated interactions between holes doped in a cuprate parent layer
- Effective phonon-mediated interactions between particles in systems with Peierls-type electron-phonon coupling
- Melting of a bipolaron crystal as a model for insulator-to-metal transition in BaBiO₃ and in rare earth nickelates
- Properties of polarons at finite temperatures

CAREER HIGHLIGHTS

PhD University of Toronto 1995 – 1999
Postdoc. Fellow Princeton University 2000 – 2001
Research Assoc. Princeton University 2001 – 2002
Asst. Professor UBC 2002 – 2007
Assoc. Professor UBC 2007 – 2012
Professor UBC 2012 – present

GRADUATE STUDENTS

Stepan Fomichev, Oliver Yam

POSTDOCTORAL FELLOWS

Krzysztof Bieniasz, Mi Jiang

SELECTED PUBLICATIONS

M.M. Moller, C.P.J. Adolphs, M. Berciu. *Magnon-mediated attraction between two holes doped in a CuO₂ layer*. Phys. Rev. B **100**, 165118 (2019).

K. Bieniasz, M. Berciu, A.M. Oleś. *Spectral properties of spin-orbital polarons as a fingerprint of orbital order*. Phys. Rev. B **100**, 125109 (2019).

J. Sous, M. Chakraborty, R.V. Krems, M. Berciu. *Light bipolarons stabilize by Peierls electron-phonon coupling*. Phys. Rev. Lett. **121**, 247001 (2018).



**CURTIS
BERLINGUETTE**

RESEARCH FOCUS

Our research program specializes in the development and study of advanced materials for use in clean energy conversion and storage schemes, including CO₂ utilization technologies, dynamic windows and next-generation solar cells.

CURRENT PROJECTS

- CO₂ utilization
- Flexible automation and machine learning for accelerating energy materials discovery
- Next-generation solar cells
- Cold fusion

CAREER HIGHLIGHTS

PhD Texas A&M University 2000 – 2004
Postdoc. Fellow Harvard University 2004 – 2006
Asst. Professor UCalgary 2006 – 2011
Assoc. Professor UCalgary 2011 – 2013
Assoc. Professor UBC 2013 – 2017
Professor UBC 2017 – present

GRADUATE STUDENTS

Valerie Chiykowski, Roxanna Delima, Arthur Fink, Rebecka Forward, Ken Hu, Aoxue Huang, Ryan Jansonius, Alec Ji, Dorian Joulie, Cameron Kellett, Yechan Kim, Yohan Ko, Caroline Krzyzskowski, Eric Lees, Nicholas Loo, Ben MacLeod, Thomas Morrissey, Ben Mowbray, Fraser Parlane, Shaoxuan Ren, Angelica Reyes, Danielle Salvatore, Rebecca Sherbo, Danika Wheeler

POSTDOCTORAL FELLOWS

Edward Booker, Yang Cao, Wei Cheng, Saunak Das, Kevan Dettelbach, Maxwell Goldman, Jingfu He, Noah Johnson, Aiko Kurimoto, Changli Li, Tengfei Li, Xin Lu, Raphael Moreira, Marta Moreno, Carolyn Virca, Bill Zhang

SCIENTIFIC STAFF

Jacky Chau, David Dvorak, Ted Haley, Karry Ocean, Phil Schauer, Nina Taherimakhsoosi

SELECTED PUBLICATIONS

C.P. Berlinguette, Y.-M. Chiang, J.N. Munday, T. Schenkel, D.K. Fork, R. Koningstein, M.D. Trevithick. *Revisiting the cold case of cold fusion*. Nature **570**, 45 (2019).

D.M. Weekes, D.A. Salvatore, A. Reyes, A. Huang, C.P. Berlinguette. *Electrolytic CO₂ reduction in a flow cell*. Acc. Chem. Res. **51**, 910 (2018).

R.D.L. Smith, M.S. Prevot, R. Fagan, Z. Zhang, P.A. Sedach, M.K.J. Siu, C.P. Berlinguette. *Photochemical route for accessing amorphous metal-oxide materials for heterogeneous water oxidation catalysis*. Science **340**, 60 (2013).



**DOUG
BONN**

RESEARCH FOCUS

We synthesize ultraclean samples of quantum materials, particularly superconductors, by bulk single crystal and film growth. These samples are then used for microwave spectroscopy, which reveals the low frequency conductivity spectrum, and scanning tunnelling spectroscopy, which provides spectroscopic capabilities at low temperatures with atom-scale spatial resolution.

CURRENT PROJECTS

- Quasiparticle interference in Fe-based superconductors
- Microwave spectroscopy of long-lived quasiparticles in Fe-based superconductors
- Microwave electrodynamics of hydrodynamic electronic materials
- Quasiparticle interference in Weyl semimetal ZrSiTe
- Development of ultra-low temperature STM with in situ MBE
- Vapour-transport growth of chalcogenides

CAREER HIGHLIGHTS

PhD McMaster University 1983 – 1989
Postdoc. Fellow UBC 1989 – 1991
Research Assoc. UBC 1992 – 1994
Asst. Professor UBC 1994 – 1997
Assoc. Professor UBC 1997 – 2000
Professor UBC 2000 – present

GRADUATE STUDENTS

Graham Baker, Jeff Bale, Tim Branch, Dong Chen, Aaron Kraft, Brandon Stuart, Ashley Warner

POSTDOCTORAL FELLOWS

Seokhwan Choi, Giang Nguyen, Mohamed Oudah

SCIENTIFIC STAFF

James Day, Jisun Kim

SELECTED PUBLICATIONS

S. Chi, S. Johnston, G. Levy, S. Grothe, R. Szedlak, B. Ludbrook, R. Liang, P. Dosanjh, S.A. Burke, A. Damascelli, D.A. Bonn, W.N. Hardy, Y. Pennec. *Sign inversion in the superconducting order parameter of LiFeAs inferred from Bogoliubov quasiparticle interference*. Phys. Rev. B **89**, 104522 (2014).

N. Doiron-Leyraud, C. Proust, D. LeBoeuf, J. Levallois, J.B. Bonnemaïson, R. Liang, D.A. Bonn, W.N. Hardy, L. Taillefer. *Quantum oscillations and the Fermi surface in an underdoped high temperature superconductor*. Nature **447**, 565 (2007).

D.A. Bonn, K. Zhang, R. Liang, D.J. Baar, D.C. Morgan, P. Dosanjh, T.L. Duty, A. MacFarlane, G.D. Morris, J.H. Brewer, W.N. Hardy, C. Kallin, A.J. Berlinsky. *Microwave measurements of the quasiparticle scattering time in YBa₂Cu₃O_{6.95}*. Phys. Rev. B **47**, 11314 (1993).



**SARAH
BURKE**

RESEARCH FOCUS

My research interests broadly encompass the study of electronic processes where nanoscale structure influences or reveals the underlying physics. Using scanning probe microscopy (SPM) techniques, my group investigates materials for organic electronics and optoelectronics, graphene and other carbon-based nanomaterials, and materials where a nanoscale view offers the potential for new understanding.

CURRENT PROJECTS

- Energetic landscapes of organic heterojunctions
- Light-matter interactions in organic semiconductors on a single molecule level using SPM
- Quasiparticle interference: understanding interactions with defects and mapping electronic properties of novel 2D materials and electronic states
- Dynamics of charge separation in organic solar cells using time- and angle-resolved photoemission spectroscopy
- Molecular imaging of heterogeneous catalysis in action

CAREER HIGHLIGHTS

PhD McGill University 2005 – 2009
Postdoc. Fellow UC Berkeley 2009 – 2010
Asst. Professor UBC 2010 – 2017
Assoc. Professor UBC 2017 – present

GRADUATE STUDENTS

Graham Baker, Joern Bannies, Miriam DeJong, Rysa Greenwood, Aaron Kraft, Amy Qu, Brandon Stuart, Gary Tom, Alexandra Tully, Ashley Warner, Jiabin Yu

POSTDOCTORAL FELLOWS

Seokhwan Choi, Erik Mårsell, Giang Nguyen

SCIENTIFIC STAFF

James Day, Jisun Kim

SELECTED PUBLICATIONS

P. Nigge, A.C. Qu, É. Lantagne-Hurtubise, E. Mårsell, S. Link, C. Gutiérrez, G. Tom, M. Zonno, M. Michiardi, M. Schneider, S. Zhdanovich, G. Levy, U. Starke, D. Bonn, S.A. Burke, M. Franz, A. Damascelli. *Room temperature strain-induced Landau levels in graphene on a wafer-scale platform*. Sci. Adv. **5**, eaaw5593 (2019).

A. Schiffrin, M. Capsoni, G. Farahi, C.G. Wang, C. Krull, M. Castelli, T. Roussy, K.A. Cochrane, Y. Yin, N.V. Medhekar, M. Fuhrer, A.Q. Shaw, W. Ji, S.A. Burke. *Designing Optoelectronic Properties by On-Surface Synthesis: Formation and Electronic Structure of an Iron-Terpyridine Macromolecular Complex*. ACS Nano **12**, 7 (2018).

S. Chi, R. Aluru, S. Grothe, A. Kreisel, U.R. Singh, B.M. Andersen, W.N. Hardy, R. Liang, D.A. Bonn, S.A. Burke, and P. Wahl. *Imaging the real space structure of the spin fluctuations in an iron-based superconductor*. Nat. Commun. **8**, 15996 (2017).



**LUKAS
CHROSTOWSKI**

RESEARCH FOCUS

Our main research interests are in the applications of silicon photonics, including optical communications, biosensors, and quantum information. Using the relatively mature silicon photonics technology, and very mature CMOS electronics technology, we are developing a quantum information platform.

CURRENT PROJECTS

- Tunable photonic crystal for cavity quantum electrodynamics (with Jeff Young)
- Single photon sources (with Jeff Young)
- Semiconductor laser stabilization using CMOS electronics
- Silicon photonic biosensors

CAREER HIGHLIGHTS

PhD UC Berkeley 1998 – 2004

Postdoc. Fellow UC Berkeley 2004 – 2005

Asst. Professor UBC 2005 – 2010

Assoc. Professor UBC 2010 – 2015

Professor UBC 2015 – present

GRADUATE STUDENTS

Abdelraman Afifi, Adan Azem, Rui Cheng, Adam Darcie, Leanne Dias, Sabastian Gitt, Ya Han, Jaspreet Jhoja, Becky Lin, Stephen Lin, Enxiao Luan, Minglei Ma, Connor Mosquera, Mohammed Shemis, Hossam Shoman, Donald Witt, Xiruo Yan

RESEARCH FOCUS

Our group develops and utilizes angle-resolved photoemission spectroscopy (ARPES) and its time- and spin- resolved variants, as well as resonant x-ray scattering (RXS), to push the limits of these techniques and gain a deeper understanding of quantum materials and new phases of matter. Leveraging facilities established at SBQMI and the Quantum Materials Spectroscopy Centre at the Canadian Light Source, we pursue the engineering of the electronic structures of these materials through in situ adatom deposition, strain, and the optical coherent control of electronic states via pulsed laser excitations.

CURRENT PROJECTS

- Non-equilibrium dynamics of quantum materials
- Coherent control and spectroscopy of quantum materials
- Spin-orbit coupling and unconventional superconductivity
- New avenues in charge and spin manipulation at surfaces
- 2D van der Waals materials and oxide heterostructures

CAREER HIGHLIGHTS

PhD University of Groningen 1994 – 1999

Postdoc. Fellow Stanford University 1999 – 2002

Asst. Professor UBC 2002 – 2007

Assoc. Professor UBC 2007 – 2013

Professor UBC 2013 – present

Scientific Director SBQMI 2015 – present

POSTDOCTORAL FELLOWS

Alireza Samani, Jingda Wu

SCIENTIFIC STAFF

Kashif Awan

SELECTED PUBLICATIONS

L. Chrostowski, H. Shoman, M. Hammood, H. Yun, J. Jhoja, E. Luan, S. Lin, A. Mistry, D. Witt, N.A.E. Jaeger, S. Shekhar, H. Jayatilaka, P. Jean, S.B. Villers, J. Cauchon, W. Shi, C. Horvath, J.N. Westwood-Bachman, K. Setzer, M. Aktary, N.S. Patrick, R.J. Bojko, A. Khavasi, X. Wang, T.F.d. Lima, A.N. Tait, P.R. Prucnal, D.E. Hagan, D. Stevanovic, A.P. Knights. *Silicon Photonic Circuit Design Using Rapid Prototyping Foundry Process Design Kits*. IEEE J. Sel. Top. Quantum Electron. **25**, 8201326 (2019).

A. Afifi, L. Chrostowski, M. Hammood, N.A.F. Jaeger, S. Shekhar, J.F. Young. *Contra-directional couplers as pump rejection and recycling filters for on-chip photon-pair sources* 2019 IEEE 16th International Conference on Group IV Photonics (GFP) **1949** (2019).

J. Wu, X. Yan, R. Watt, M. Nantel, L. Chrostowski, J.F. Young. *Widely Tunable, High-Q Two-Dimensional Photonic Crystal Cavities for cQED Applications*. 2018 IEEE photonics society summer topical meeting series. Summer, **85** (2018).

GRADUATE STUDENTS

Ryan Day, Sydney Dufresne, MengXing Na, Pascal Nigge, Amy Qu, Alexander Sheyerman, Cissy Suen (Joint PhD), Marta Zonno, Berend Zwartsenberg

POSTDOCTORAL FELLOWS

Fabio Boschini, Hao Chu, Christopher Gutiérrez, Danilo Kuhn, Sean Kung, Matteo Michiardi

SCIENTIFIC STAFF

Ilya Elfmov, Giorgio Levy, Arthur Mills, Sergey Zhdanovich

SELECTED PUBLICATIONS

M.X. Na, A. K. Mills, F. Boschini, M. Michiardi, B. Nosarzewski, R.P. Day, E. Razzoli, A. Sheyerman, M. Schneider, G. Levy, S. Zhdanovich, T.P. Devereaux, A.F. Kemper, D.J. Jones, A. Damascelli. *Direct determination of mode-projected electron-phonon coupling in the time-domain*. Science **366**, 1231 (2019).

F. Boschini, E.H. da Silva Neto, E. Razzoli, M. Zonno, S. Peli, R. P. Day, M. Michiardi, M. Schneider, B. Zwartsenberg, P. Nigge, R.D. Zhong, J. Schneeloch, G.D. Gu, S. Zhdanovich, A.K. Mills, G. Levy, D.J. Jones, C. Giannetti, A. Damascelli. *Collapse of high-Tc superconductivity via ultrafast quenching of the phase coherence*. Nat. Mater. **17**, 416 (2018).

R. Comin, A. Frano, M.M. Yee, Y. Yoshida, H. Eisaki, E. Shierle, E. Weschke, R. Sutarto, F. He, A. Soumyanarayanan, Y. He, M. Le Tacon, I.S. Elfimov, J.E. Hoffman, B. Keimer, G.A. Sawatzky, A. Damascelli. *Charge ordering driven by Fermi-arc instability in underdoped cuprates*. Science **343**, 6169 (2014).



**ANDREA
DAMASCELLI**



**STEVE
DIERKER**

RESEARCH FOCUS

Our new Quantum Materials Electron Microscopy Centre will have two state of the art electron microscopes for atomic imaging and characterization of materials and for carrying out electron energy loss measurements as a function of momentum with unprecedented energy resolution. Research with this latter capability may include measurements of the momentum dependence of the dielectric function of quantum materials, studies of collective excitations in inhomogeneous strongly correlated matter, and studies of the spectrum of confined optical modes in polaritonic media. We are also developing a nanospectroscopy laboratory for conducting optical spectroscopy measurements with ~ 10 nm spatial resolution and at temperatures from ~ 2.5K to 450K. This will aid in discovery of new polaritonic materials based on 2D electrides and layered transition metal oxides, and developing means for controlling them by integrating them with quantum materials.

CURRENT PROJECTS

- Development of the Quantum Materials Electron Microscopy Centre
- Development of a Nanospectroscopy Laboratory for studying polaritonic quantum materials
- Raman scattering studies of topological materials
- 2D electride materials and layered transition metal oxides

RESEARCH FOCUS

We perform ultra-low temperature electronic measurements, often at high magnetic fields, of devices defined by micro- and nanolithography, and controlled by various electrostatic gates. Materials used for these devices range from conventional semiconductors, such as GaAs, to 2D materials such as graphene or dichalcogenides, to strongly correlated 2D materials such as strontium vanadate.

CURRENT PROJECTS

- van der Waals heterostructures
- Non-abelian electronic states
- Mesoscopic physics

CAREER HIGHLIGHTS

PhD Stanford University 1998 – 2003
Postdoc. Fellow MIT 2003 – 2004
Postdoc. Researcher Delft Technical University 2005
Asst. Professor UBC 2005 – 2010
Assoc. Professor UBC 2010 – present

CAREER HIGHLIGHTS

PhD University of Illinois 1977 – 1983
Member of Technical Staff, AT&T Bell Laboratories 1983 – 1990
Assoc. Professor University of Michigan 1990 – 1999
Professor University of Michigan 1999 – 2006
Director, National Synchrotron Light Source, BNL 2001 – 2006
Director, National Synchrotron Light Source II Project, BNL 2006 – 2015
Associate Laboratory Director for Photon Sciences, BNL 2003 – 2015
Professor Texas A&M University 2015 – 2018
Professor UBC 2018 – present

SCIENTIFIC STAFF

Alan Maigné

SELECTED PUBLICATIONS

S.B. Dierker, M. C. Aronson. *Reduction of Raman scattering and fluorescence from anvils in high pressure Raman scattering*. Rev. Sci. Instrum. **89**, 053902 (2018).
S.B. Dierker, R. Pindak, R.M. Fleming, I.K. Robinson, L. Berman. *X-Ray Photon Correlation Spectroscopy Study of Brownian Motion of Gold Colloids in Glycerol*. Phys. Rev. Lett. **75**, 449 (1995).
M.V. Klein, S.B. Dierker. *Theory of Raman Scattering in Superconductors*. Phys. Rev. B **29**, 4976 (1984).

GRADUATE STUDENTS

Tim Child, Christian Olsen, Ebrahim Sajadi, Aswin Vishnuradhan

POSTDOCTORAL FELLOWS

Nik Hartman, Manabendra Kuri

SCIENTIFIC STAFF

Silvia Lüscher

SELECTED PUBLICATIONS

E. Sajadi, T. Palomaki, Z. Fei, W. Zhao, P. Bement, C. Olsen, S. Lüscher, X. Xu, J.A. Folk, D.H. Cobden. *Gate-induced superconductivity in a monolayer topological insulator*. Science **362**, 922 (2018).
N. Hartman, C. Olsen, S. Lüscher, M. Samani, S. Fallahi, G.C. Gardner, M. Manfra, J. Folk. *Direct entropy measurement in a mesoscopic quantum system*. Nat. Phys. **14**, 1083 (2018).
M. Kjaergaard, F. Nichele, H.J. Suominen, M.P. Nowak, M. Wimmer, A.R. Akhmerov, J.A. Folk, K. Flensberg, J. Shabani, C.J. Palmstrom, C.M. Marcus. *Quantized conductance doubling and hard gap in a two-dimensional semiconductor-superconductor heterostructure*. Nat. Commun. **7**, 12841 (2016).



**MARCEL
FRANZ**

RESEARCH FOCUS

We formulate and study simple models of solids that are relevant to topological insulators, topological superconductors, Dirac and Weyl semimetals, and other topological or otherwise exotic states of quantum matter. The key criteria driving our research are: (i) cutting edge theoretical developments and (ii) relevance to real systems as studied by our experimental colleagues.

CURRENT PROJECTS

- Quantum holography in a graphene flake with an irregular boundary
- Antichiral edge states in a modified Haldane nanoribbon
- Quantum oscillations and Dirac-Landau levels in Weyl superconductors
- Diagnosing quantum chaos without reversing the flow of time
- Black Hole on a Chip: Proposal for a Physical Realization of the Sachdev-Ye-Kitaev model in a Solid-State System

CAREER HIGHLIGHTS

PhD University of Rochester 1992 – 1994
 Postdoc. Fellow McMaster University 1994 – 1996
 Postdoc. Fellow Johns Hopkins University 1996 – 2000
 Asst. Professor UBC 2000 – 2005
 Assoc. Professor UBC 2005 – 2010
 Professor UBC 2010 – present

GRADUATE STUDENTS

Oguzhan Can, Rafael Haenel, Étienne Lantagne-Hurtubise, Chengshu Li, Alejandro Mercado Tejerina, Vedangi Pathak, Brandon Stuart, Tarun Tummuru

POSTDOCTORAL FELLOWS

Pedro Lopes, Stephan Plugge, Sharmishta Sahoo, Xiao-Xiao Zhang

SCIENTIFIC STAFF

Alberto Nocera

SELECTED PUBLICATIONS

R. Haenel, T. Branch, M. Franz. *Chern insulators for electromagnetic waves in electrical circuit networks*. Phys. Rev. B **99**, 235110 (2019).

É. Lantagne-Hurtubise, M. Franz. *Topology in abundance*. Nat. Rev. Phys. **1**, 183 (2019).

O. Can, E.M. Nica, M. Franz. *Charge transport in graphene-based mesoscopic realizations of Sachdev-Ye-Kitaev models*. Phys. Rev. B **99**, 045419 (2019).



**ALANNAH
HALLAS**

RESEARCH FOCUS

Our group is focused on the design and discovery of new quantum materials using a broad range of crystal growth techniques, including metallic flux, vapour transport, high-pressure synthesis, and floating zone growth. We are particularly interested in establishing structure-function relationships in quantum materials via characterization of their structural, magnetic, and electronic behaviors in order to facilitate the targeted design of materials with novel or useful properties. This research is performed in our state-of-the-art crystal growth laboratories at SBQMI as well as international neutron scattering and muon spin relaxation user facilities.

CURRENT PROJECTS

- Design and crystal growth of new quantum materials
- Structural and magnetic properties of high entropy oxides
- Magnetic frustration in the local to itinerant crossover
- Multipolar interactions in rare earth magnets
- Topological semimetals with strong spin-orbit coupling

CAREER HIGHLIGHTS

PhD McMaster University 2013 – 2017
 Smalley-Curl PDF in Quantum Materials, Rice University 2017 – 2019
 Asst. Professor UBC 2019 – present

UNDERGRADUATE STUDENTS

Sam Mugiraneza

GRADUATE STUDENTS

Graham Johnstone, Samikshya Sahu

POSTDOCTORAL FELLOWS

Dalmau Reig-i-Plessis

SCIENTIFIC STAFF

Oleksandr Foyevtsov

SELECTED PUBLICATIONS

A.M. Hallas, C.L. Huang, B.K. Rai, A. Weiland, G.T. McCandless, J.Y. Chan, J. Beare, G.M. Luke, E. Morosan. *Complex transport and magnetism in inhomogeneous mixed valence Ce₃Ir₄Ge₁₃*. Phys. Rev. Mater. **3**, 114407 (2019).

A.M. Hallas, J. Gaudet, B.D. Gaulin. *Experimental insights into ground-state selection of quantum XY pyrochlores*. Annu. Rev. Condens. Matter Phys. **9**, 105 (2018).

A.M. Hallas, J. Gaudet, N.P. Butch, G. Xu, M. Tachibana, C.R. Wiebe, G.M. Luke, B.D. Gaulin. *Phase Competition in the Palmer-Chalker XY Pyrochlore Er₂Pt₂O₇*. Phys. Rev. Lett. **119**, 187201 (2017).



**DAVID
JONES**

RESEARCH FOCUS

Our research lies at the convergence of condensed matter physics and ultrafast photonics and spectroscopy. It encompasses the development of new and customized femtosecond laser sources and accompanying spectroscopic techniques and employing them in tandem to unravel properties of quantum materials when they are at equilibrium and when they are in excited states. In a long-term scientific goal, we seek to implement photonic manipulation and control of quantum states/phases within solids.

CURRENT PROJECTS

- Femtosecond XUV sources for TR-ARPES over the full Brillouin zone with tunable energy/time resolution
- k-space optical tweezers
- Flexible VUV femtosecond laser sources for time-resolved photoemission
- Spatio-temporal characterization of interfacial charge separation in organic photovoltaics
- Multi-dimensional spectroscopy for studying coherence in solids
- Exciton dynamics in 2D materials

CAREER HIGHLIGHTS

PhD MIT 1994 – 1999
Research Assoc. NIST Boulder Labs 1998 – 2000
Research Assoc. CU Boulder 2001 – 2003
Asst. Professor UBC 2004 – 2010
Assoc. Professor 2010 – present

GRADUATE STUDENTS

Shadab Ahamed, Martin Cross, Rysa Greenwood, Bradley Guislain, MengXing Na, Alexandra Tully, Max Warner

POSTDOCTORAL FELLOWS

Fabio Boschini, Hao Chu, Erik Mårsell

SCIENTIFIC STAFF

Arthur Mills, Evgeny Ostroumov, Sergey Zhdanovich

SELECTED PUBLICATIONS

A.K. Mills, S. Zhdanovich, M.X. Na, F. Boschini, E. Razzoli, M. Michiardi, A. Sheyerman, M. Schneider, T.J. Hammond, V. Suess, C. Felser, A. Damascelli, D. J. Jones. *Cavity-enhanced high harmonic generation for XUV time- and angle-resolved photoemission spectroscopy*. *Rev. Sci. Instrum.* **90**, 083001 (2019).

M.X. Na, A.K. Mills, F. Boschini, M. Michiardi, B. Nosarzewski, R.P. Day, E. Razzoli, A. Sheyerman, M. Schneider, G. Levy, S. Zhdanovich, T.P. Devereaux, A.F. Kemper, D.J. Jones, A. Damascelli. *Direct determination of mode-projected electron-phonon coupling in the time-domain*. *Science* **366**, 1231 (2019).

A.K. Mills, T.J. Hammond, M.H.C. Lam, D.J. Jones. *XUV frequency combs via femtosecond enhancement cavities*. *J. Phys. B* **45**, 14 (2012).

Asst. Professor UBC 1990 – 1992
Assoc. Professor UBC 1992 – 1995
Professor UBC 1995 – present

GRADUATE STUDENTS

Aris Chatzichristos, Martin Dehn, Derek Fujimoto, Victoria Karner, Ryan McFadden, John Ticknor

SELECTED PUBLICATIONS

A. Chatzichristos, R.M.L. McFadden, M.H. Dehn, S.R. Dunsiger, D. Fujimoto, V.L. Karner, I. McKenzie, G.D. Morris, M.R. Pearson, M. Stachura, J. Sugiyama, J.O. Ticknor, W.A. MacFarlane, R.F. Kiefl. *Bi-Arrhenius Diffusion and Surface Trapping of ⁶Li+ in Rutile TiO2*. *Phys. Rev. Lett.* **123**, 095901 (2019).

D.L. Cortie, T. Buck, M.H. Dehn, V.L. Karner, R.F. Kiefl, C.D.P. Levy, R.M.L. McFadden, G.D. Morris, I. McKenzie, M.R. Pearson, X.L. Wang, W.A. MacFarlane. *beta-NMR investigation of the depth dependent magnetic properties of an antiferromagnetic surface*. *Phys. Rev. Lett.* **116**, 106103 (2016).

H. Saadaoui, Z. Salman, H. Luetkens, T. Prokscha, A. Suter, W.A. MacFarlane, Y. Jiang, K. Jin, R.L. Greene, E. Morenzoni, R.F. Kiefl. *The Phase Diagram in Electron-Doped La2-xCexCuO4*. *Nat. Commun.* **6**, 6041 (2015).



**ROB
KIEFL**

RESEARCH FOCUS

Our main objective is to explore the novel magnetic and electronic properties of quantum materials using nuclear methods such as muon spin rotation and beta-detected NMR. In particular we are interested in finding out how their properties change in the bulk compared to the near surface region, near interfaces, and near a point charge such as the positive muon. For example, in some magnetic materials positive muon is expected to mimic a magnetic monopole or form a bound state with a polaron. We are also interested in studying how Li diffuses in battery electrode materials using nuclear tracer methods.

CURRENT PROJECTS

- Magnetic properties of oxide interfaces and their near surface region
- Novel magnetic and chemical properties of nanoparticles
- Lithium diffusion studies in battery electrode materials
- Local magnetoelectric effects studied with beta-NMR and muon spin rotation

CAREER HIGHLIGHTS

PhD UBC 1982
Research Assoc. TRIUMF 1982
Postdoc. Fellow Physics Institute, University of Zurich 1982 – 1984
Research Scientist TRIUMF 1984 – 1987
University Research Fellow UBC 1987 – 1990



**W. ANDREW
MACFARLANE**

RESEARCH FOCUS

Using radioactive beta-detected NMR, we study the electromagnetic properties of single crystals, thin films, and multilayers. Our main probe is the short-lived isotope ^8Li . Using this probe we also study molecular dynamics and lithium ionic mobility in thin films and near interfaces. We develop the techniques and apply them to interesting materials problems, which are difficult or impossible to address with more conventional techniques.

CURRENT PROJECTS

- Metallic and magnetic properties of LaNiO_3 thin films
- Spin relaxation in topological insulators
- Indirect relaxation in magnetic heterostructures
- Spin relaxation as a probe of Li^+ ionic mobility in solids and near interfaces
- ^{31}Mg , a new beta NMR probe

CAREER HIGHLIGHTS

PhD UBC 1997

NSERC Postdoc. Fellow Laboratoire de Physique des Solides,
Université Paris-Sud 1997 – 1999

Postdoc. Fellow University of Toronto 1999 – 2001

Research Assoc. TRIUMF 2001 – 2002

Asst. Professor UBC 2002 – 2008

Assoc. Professor UBC 2008 – present



**MARK
MACLACHLAN**

RESEARCH FOCUS

Our group members synthesize new molecules (especially macrocycles) and study their self-assembly under different conditions. We also develop new photonic materials using liquid crystalline templates, especially derived from cellulose and chitin. Finally, we explore a variety of new nanostructured materials for different applications.

CURRENT PROJECTS

- Flexible photonic materials from cellulose nanocrystals for stimuli-responsive applications (e.g., pressure sensors)
- Stimuli-responsive gelation
- Nanostructured catalysts for low temperature methane oxidation
- Supramolecular compounds for stimuli-driven molecular delivery
- Molecular cluster templating inside shape-persistent macrocycles

CAREER HIGHLIGHTS

PhD University of Toronto 1995 – 1999

Postdoc. Fellow MIT 1999 – 2001

Asst. Professor UBC 2001 – 2007

Assoc. Professor UBC 2007 – 2011

Professor UBC 2011 – present

GRADUATE STUDENTS

Aris Chatzichristos, Martin Dehn, Derek Fujimoto, Victoria Karner,
Ryan McFadden, John Ticknor

SELECTED PUBLICATIONS

V.L. Karner, A. Chatzichristos, D.L. Cortie, M.H. Dehn, O. Foyevstov, K. Foyevstova, D. Fujimoto, R.F. Kiefl, C.D.P. Levy, R.H. Li, R.M.L. McFadden, G.D. Morris, M.R. Pearson, M. Stachura, J.O. Ticknor, G. Cristiani, G. Logvenov, F. Wrobel, B. Keimer, J.J. Zhang, J.F. Mitchell, W.A. MacFarlane. *Local metallic and structural properties of the strongly correlated metal LaNiO_3 using Li-8 beta-NMR*. Phys. Rev. B **100**, 165109 (2019).

R.M.L. McFadden, A. Chatzichristos, K.H. Chow, D.L. Cortie, M.H. Dehn, D. Fujimoto, M.D. Hossain, H. Ji, V.L. Karner, R.F. Kiefl, C.D.P. Levy, R. Li, I. McKenzie, G.D. Morris, O. Ofer, M.R. Pearson, M. Stachura, R.J. Cava, W.A. MacFarlane. *Ionic and electronic properties of the topological insulator $\text{Bi}_2\text{Te}_2\text{Se}$ investigated via β -detected nuclear magnetic relaxation and resonance of ^8Li* . Phys. Rev. B **99**, 125201 (2019).

R.M.L. McFadden, T.J. Buck, A. Chatzichristos, C. Chen, K.H. Chow, D.L. Cortie, M.H. Dehn, V.L. Karner, D. Koumoulis, C.D. Philip Levy, C. Li, I. McKenzie, R. Merkle, G.D. Morris, M.R. Pearson, Z. Salman, D. Samuelis, M. Stachura, J. Xiao, J. Maier, R.F. Kiefl, W.A. MacFarlane. *Microscopic Dynamics of Li^+ in Rutile TiO_2 Revealed by ^8Li β -Detected Nuclear Magnetic Resonance*. Chem. Mater. **29**, 10187 (2017).

GRADUATE STUDENTS

Mohammad Chaudhry, Francesco D'Acierno, Yiling Dai, Madhureeta Das Gupta, Raksha Kandel, Debbie Le, Lev Lewis, Jeanette Loos, Gunwant Matharu, Andy Tran, Chris Walters, Yitao Xu, Shi Yihan

POSTDOCTORAL FELLOWS

Charlotte Boott, Yuanyuan Cao, Michael Duss, Arash Momeni, Miguel Angel Soto Munoz, Peixi Wang, Gosuke Washino

SCIENTIFIC STAFF

Thanh-Dinh Nguyen

SELECTED PUBLICATIONS

Y. Cao, L. Lewis, W.Y. Hamad, M.J. MacLachlan. *Pressure-Responsive Hierarchical Chiral Photonic Aerogels*. Adv. Mater. **31**, 1808186 (2019).

O. Kose, A. Tran, L. Lewis, W.Y. Hamad, M.J. MacLachlan. *Unwinding a Spiral of Cellulose Nanocrystals for Stimuli-Responsive Stretchable Optics*. Nature Commun. **10**, 510 (2019).

K.E. Shopsowitz, H. Qi, W.Y. Hamad, M.J. MacLachlan. *Free-standing mesoporous silica films with tunable chiral nematic structures*. Nature **468**, 422 (2010).



**ALIREZA
NOJEH**

RESEARCH FOCUS

Our research activities centre on the study of the interaction of light with nanostructures leading to highly localized heating and thermal electron emission. Our work involves device design, micro and nanofabrication in the cleanroom, nanostructure growth and deposition, electron and scanning-probe microscopy, building experimental apparatus such as high- or ultra-high vacuum systems, electronic characterization and sensitive instrumentation, and working with lasers and optics. We complement our experimental efforts with theory and simulation using methods ranging from continuum modelling to classical molecular dynamics to first-principles, quantum-mechanical techniques such as the Hartree-Fock theory, configuration-interaction, perturbation theory and the density functional theory.

CURRENT PROJECTS

- Heat localization in carbon nanotubes
- Thermionic energy conversion
- Compact, inexpensive electron microscope

CAREER HIGHLIGHTS

PhD Stanford University 2006
 Asst. Professor UBC 2006 – 2011
 Assoc. Professor UBC 2011 – 2016
 Professor UBC 2016 – present

UNDERGRADUATE STUDENTS

Alexander Dimitrakopoulos, Gabriel Robinson-Leith

GRADUATE STUDENTS

Aashish Bhardwaj, Daniel Bruns, Mike Chang, Mokter Mahmud Chowdhury, Mohab Hassan, Casimir Kuzyk, Robyn McNeil, Ehsanur Rahman, Kevin Voon

POSTDOCTORAL FELLOWS

Shreyas Patankar

SCIENTIFIC STAFF

Harrison Fan

SELECTED PUBLICATIONS

A. Nojeh, G.A. Sawatzky, L.A. Whitehead. *Graphene-based bidirectional radiative thermal transfer method for heat engines*. Appl. Opt. **58**, 2028 (2019).

M. Chang, H.D.E. Fan, M.M. Chowdhury, G.A. Sawatzky, A. Nojeh. *Heat localization through reduced dimensionality*. Phys. Rev. B **98**, 155422 (2018).

P. Yaghoobi, M. Vahdani Moghaddam, A. Nojeh. *“Heat trap”: light- induced localized heating and thermionic electron emission from carbon nanotube arrays*. Solid State Commun. **151**, 1105 (2011).



**ROBERT
RAUSSENDORF**

RESEARCH FOCUS

The work in my group focuses on the theory of quantum computation, such as quantum computer architecture, the relation of quantum computation to foundations of quantum mechanics such as quantum contextuality, and the relation of quantum computation to condensed matter physics, e.g., symmetry-protected topological order.

CURRENT PROJECTS

- Quantum computational phases of matter (measurement-based quantum computation in SPT ordered phases)
- Quantum computer architecture with matter qubits coupled by photons
- The role of contextuality for quantum computation

CAREER HIGHLIGHTS

PhD University of Munich (LMU) 1999 – 2003
 Postdoc. Fellow Caltech 2003 – 2006
 Postdoc. Fellow Perimeter Institute for Theoretical Physics 2006 – 2007
 Asst. professor UBC 2008 – 2013
 Assoc. Professor UBC 2013 – present

GRADUATE STUDENTS

Arnab Adhikary, Poya Hagheghdar, Paul Herringer, Oleg Kabernik, Arman Zaribafiyani, Michael Zurel

POSTDOCTORAL FELLOWS

Cihan Okay, Stephan Plugge

SELECTED PUBLICATIONS

R. Raussendorf, C. Okay, D. Wang, D.T. Stephen, H.P. Nautrup. *Computationally universal phase of quantum matter*. Phys. Rev. Lett. **122**, 090501 (2019).

R. Raussendorf, J. Harrington. *Fault-tolerant quantum computation with high threshold in two dimensions*. Phys. Rev. Lett. **98**, 190504 (2007).

R. Raussendorf, H.J. Briegel. *A one-way quantum computer*. Phys. Rev. Lett. **86**, 5188 (2001).



**JOERG
ROTTLER**

RESEARCH FOCUS

With computational techniques ranging from density functional theory (DFT), molecular dynamics and Monte Carlo simulations on the atomic scale, to field theoretic (phase field) methods on the mesoscale, the group studies a diverse range of materials that include amorphous solids, polymers, and nanomaterials. Computer simulations facilitate the discovery of emergent phenomena, test theories and generic trends, reveal quantities that are difficult or impossible to obtain in experiments, and thus provide essential input into the design of new functional materials. The group maintains close collaborations with several experimental groups at SBQMI.

CURRENT PROJECTS

- Surface relaxation in amorphous polystyrene films via molecular simulations and beta-NMR measurements (collaboration with MacFarlane/Kiefl groups)
- Nanoscale phononics and the origin of the heat-trap effect in carbon nanotubes (collaboration with Nojeh group)
- Statistical physics of driven amorphous materials
- Molecular simulations of polyelectrolyte gel sensors and diodes
- Macromolecular engineering of morphology and thermal transport in organic solids (collaboration with MacLachlan group)
- Memory effects in block copolymer directed self-assembly

CAREER HIGHLIGHTS

PhD Johns Hopkins University 2003
Chercheur Associé E.S.P.C.I. (Paris) 2003
Postdoc. Fellow Princeton University 2003 – 2005
Asst. Professor UBC 2005 – 2010
Assoc. Professor UBC 2010 – 2016
Professor UBC 2016 – present

GRADUATE STUDENTS

Daniel Bruns, Derek Fujimoto, Daniel Korchinski, Vasily Triandafilidi (co-supervised with CHBE)

POSTDOCTORAL FELLOWS

Céline Ruscher

SCIENTIFIC STAFF

Debashish Mukherji

SELECTED PUBLICATIONS

A. Nicolas, J.-L. Barrat, J. Rottler. *Effect of inertia on the steady state shear rheology of amorphous solids*. Phys. Rev. Lett. **116**, 058303 (2016).

M. Greenwood, N. Provatas, J. Rottler. *Free energy functionals for efficient phase field crystal modelling of structural phase transformations*. Phys. Rev. Lett. **105**, 045702 (2010).

J. Rottler, M.O. Robbins. *Shear yielding of amorphous glassy solids: Effect of temperature and strain rate*. Phys. Rev. E **68**, 011507 (2003).



**GEORGE
SAWATZKY**

RESEARCH FOCUS

We use a combination of advanced experimental and theoretical methods in studies of quantum materials exhibiting interesting and not well-understood physical properties. We also develop new experimental spectroscopic methods such as various forms of x-ray spectroscopies that can provide detailed information concerning the electronic, atomic, and magnetic structure of materials and material interfaces. The development of resonant x-ray reflectometry is one of the most recent highly successful developments. On the theory side, we use and develop further density function band theory methods as well as many body exact diagonalization methods to study the electronic structure of materials and material interfaces.

CURRENT PROJECTS

- High oxidation state oxides and negative charge transfer gap materials like BaBiO₃
- Bond disproportionation and dynamical charge fluctuations in the perovskite rare-earth nickelates
- Electron-magnon-phonon coupling and their role in high T_c superconductors and topology
- Resonant soft x-ray reflectometry and the study of buried interfaces in heterostructures
- Controlled physical properties by interface engineering
- Screening of short-range Coulomb interactions in materials with strongly non-uniform polarizability

CAREER HIGHLIGHTS

PhD University of Manitoba 1969
Postdoc. Fellow Groningen University 1969 – 1971
Assoc. Professor Groningen University 1971 – 1979
Professor Groningen University 1979 – 2001
Professor UBC 2002 – present

GRADUATE STUDENTS

Nassim Derriche, Mi Jiang, Kevin Voon, Yau Chuen (Oliver) Yam

SCIENTIFIC STAFF

Ilya Elfimov, Harrison Fan, Oleksandr Foyevstov, Kateryna Foyevtsova, Fengmiao Li, Debashish Mukherji

SELECTED PUBLICATIONS

F. Li, G.A. Sawatzky. *Electron Phonon Coupling versus Photoelectron Energy Loss at the Origin of Replica Bands in Photoemission of FeSe on SrTiO₃*. Phys. Rev. Lett. **120**, 237001 (2018).

V.I. Anisimov, I.V. Solovyev, M.A. Korotin, M.T. Czyzyk, G.A. Sawatzky. *Density-functional theory and NiO photoemission spectra*. Phys. Rev. B **48**, 16929 (1993).

J. Zaanen, G.A. Sawatzky, J.W. Allen. *Band gaps and electronic structure of transition-metal compounds*. Phys. Rev. Lett. **55**, 418 (1985)



**ZILIANG
YE**

RESEARCH FOCUS

We are an optical spectroscopy group studying light matter interaction in low-dimensional materials. We are currently focused on exploring how topology, correlation effects, and other emergent degrees of freedom interact with each other in two-dimensional van der Waals materials such as graphene, phosphorene, transition metal dichalcogenide, hexagonal boron nitride, and their heterostructures. Our expertise includes ultrafast optical spectroscopy with diffraction-limited resolution at low temperatures and strong magnetic fields as well as nearfield optical microscopy, which can reveal nanoscale information beyond the diffraction limit. We are also actively exploring how to utilize strong optical fields to manipulate the phase and electronic structure of quantum materials, known as Floquet engineering.

CURRENT PROJECTS

- High-Tc Bose-Einstein condensate of interlayer excitons in TMD heterostructures
- Topological order in low-dimensional d-wave superconductors
- Shift current and bulk photovoltaic effect at the low-symmetry interface between van der Waals materials
- Developing nearfield optical imaging and spectroscopy techniques

CAREER HIGHLIGHTS

PhD University of California, Berkeley 2013
Postdoc. Fellow University of California, Berkeley 2014
Postdoc. Fellow Columbia and Stanford University 2014 – 2017
Asst. Professor UBC 2017 – present

UNDERGRADUATE STUDENTS

Raghav Chaturvedi, Amritabha Guha, Quentin Guillet, Hirsh Kamakari, Stanley Lim, Huiwen Shen, Vedanshi Vala, Wucheng Zhang

GRADUATE STUDENTS

Eddie Ji, Yunhuan Xiao, Dongyang Yang

SELECTED PUBLICATIONS

Z. Ye, L. Waldecker, E.Y. Ma, D. Rhodes, A. Antony, B. Kim, X. Zhang, M. Deng, Y. Jiang, Z. Lu, D. Smirnov, K. Watanabe, T. Taniguchi, J. Hone, T.F. Heinz. *Efficient generation of neutral and charged biexcitons in encapsulated WSe₂ monolayers*. Nat. Commun. **9**, 3718 (2018).

Z. Ye, D. Sun, T.F. Heinz. *Optical manipulation of valley pseudospin*. Nat. Phys. **13**, 26 (2017).

Z. Ye, T. Cao, K. O'Brien, H. Zhu, X. Yin, Y. Wang, S.G. Louie, X. Zhang. *Probing excitonic dark states in single-layer tungsten disulphide*. Nature **513**, 214 (2014).



**JEFF
YOUNG**

RESEARCH FOCUS

Our group uses electrodynamic models and simulation tools to design compact nanophotonic components in silicon-on-insulator wafers to control the flow of light over a range of infrared wavelengths. Examples include single photon detectors, non-classical light sources, and high quality factor, low mode volume nanophotonic cavities for achieving strong-coupling with dipole transitions within quantum oscillators located in the nanocavities. We also carry out a combination of in-house and external nanofabrication and post-processing (electron beam and optical lithography, plasma etching, metal deposition etc.) tasks to realize our designs in silicon slab waveguides. We then carry out optical spectroscopic characterization of the fabricated circuits.

CURRENT PROJECTS

- Developing a micro electro-mechanical based means of tuning photonic crystal microcavity resonance frequencies while maintaining high quality factors and low mode volumes
- Developing practical single photon sources in the silicon photonic circuit platform
- Designing quantum information processing strategies/architectures that are particularly suited to the photon-mediated coupling of chalcogenide impurities in silicon
- Further developing our integrated single photon superconducting nanowire detectors to work over a broader range of frequencies
- Developing novel coherent light sources for carrying out high resolution spectroscopy in the mid IR

CAREER HIGHLIGHTS

PhD University of Toronto 1983
Research Assoc., Asst., Assoc. Research Officer, NRC 1983 – 1988
Section Head, NRC 1988 – 1990
Senior Research Officer and Group Leader, NRC 1990 – 1992
Assoc. Professor UBC 1992 – 1996
Professor UBC 1996 – present

GRADUATE STUDENTS

Adan Azem, Adam Darcie, Sebastian Gitt, Becky Lin, Donald Witt, Xiruo Yan

POSTDOCTORAL FELLOWS

Alireza Samani, Jingda Wu

SCIENTIFIC STAFF

Kashif Awan

SELECTED PUBLICATIONS

M.K. Akhlaghi, E. Schelew, J.F. Young. *Waveguide integrated superconducting single-photon detectors implemented as near-perfect absorbers of coherent radiation*. Nat. Commun. **6**, 8233 (2015).

C.A. Foell, K.A. Abel, F.C.J.M. van Veggel, J.F. Young. *Kinetic analysis of the temperature dependence of PbSe colloidal quantum dot photoluminescence: Effects of synthesis process and oxygen exposure*. Phys. Rev. B **89**, 045139 (2014).

S. Hughes, L. Ramunno, J.F. Young, J.E. Sipe. *Extrinsic optical scattering loss in photonic crystal waveguides: Role of fabrication disorder and photon group velocity*. Phys. Rev. Lett. **94**, 033903 (2005).



**KE
ZOU**

RESEARCH FOCUS

Our research interests are in the growth and studies of complex oxide and chalcogenide films, and electrical and magnetotransport studies of complex, nanoscale graphene devices by molecular beam epitaxy (MBE) growth. Our research will integrate molecular beam epitaxy synthesis with nanostructure fabrication and characterization techniques for physical and electronic structures, to explore and control the generated properties in new materials and in new forms of materials, such as in heterostructures and gated field effect transistors.

CURRENT PROJECTS

- MBE and device fabrication to create thin films, heterostructures, and transistors of 2D crystals
- Synthesis and characterization of 2D material systems

CAREER HIGHLIGHTS

PhD Pennsylvania State University 2012
Postdoc. Fellow Yale University 2012 – 2018
Asst. Professor UBC 2018 – present

UNDERGRADUATE STUDENTS

Park Chong, Andree Coschizza, Rayan Farid

GRADUATE STUDENTS

Simon Godin, Ryan Roemer, Hyungki Shin

POSTDOCTORAL FELLOWS

Chong Liu

SCIENTIFIC STAFF

Bruce A. Davidson, Fengmiao Li

SELECTED PUBLICATIONS

- F. Li, B.A. Davidson, R. Sutarto, H. Shin, C. Liu, I. Elfimov, K. Foyevtsova, F. He, G.A. Sawatzky, K. Zou. *Epitaxial growth of perovskite SrBiO₃ film on SrTiO₃ (001) by oxide molecular beam epitaxy*. Phys. Rev. Mat. **3**, 100802(R) (2019).
- K. Zou, S. Ismail-Beigi, K. Kisslinger, X. Shen, D. Su, F.J. Walker, C.H. Ahn. *LaTiO₃/KTaO₃ interfaces: a new 2D electron gas system*. APL Mater. **3**, 036104 (2015).
- K. Zou, F. Zhang, C. Clapp, A.H. MacDonald, J. Zhu. *Transport studies of dual-gated ABA- and ABC- trilayer graphene: band gap opening and band structure tuning in very large perpendicular electric field*. Nano Lett. **13**, 369 (2013).

AFFILIATE PRINCIPAL INVESTIGATORS



**ROBERT
GREEN**

RESEARCH FOCUS

Our group studies quantum materials using a combination of synchrotron x-ray spectroscopy and quantum many-body theory. We focus strongly on correlated oxide thin films and heterostructures, aiming to understand and develop control over their functionalities. In alignment with the goals of SBQMI, we strive to pave the way for upcoming generations of electronic and magnetic devices based on the quantum materials we study.

CURRENT PROJECTS

- Orbital and electronic reconstruction at correlated oxide interfaces studied with resonant x-ray reflectometry
- Multi-q, non-collinear magnetic order in SrFeO₃ heterostructures
- The impact of atomic physics on fluctuations in correlated perovskite oxides
- Resistive memories in correlated oxides

CAREER HIGHLIGHTS

PhD University of Saskatchewan 2009 – 2013

Postdoc. Fellow UBC 2013 – 2017

Research Assoc. UBC 2017

Affiliate Asst. Professor SBQMI 2017 – present

Asst. Professor University of Saskatchewan 2017 – present



**KENJI
KOJIMA**

RESEARCH FOCUS

Our group utilizes and develops muon spin rotation/relaxation/resonance (μ SR) and beta-decay detected nuclear magnetic resonance (β -NMR) at the TRIUMF laboratory at UBC, to understand the roles of spin and charge degrees of freedom in various kinds of quantum materials. Muon behaves as a light isotope of hydrogen, and we also utilize μ SR to understand hydrogen's role in quantum materials. Employing the low-energy feature of β -NMR, we characterize spin relaxation phenomena in nanometer-thick thin-films including semiconductor devices.

CURRENT PROJECTS

- Frustrated quantum magnets and their ground states
- Unconventional superconductivity with spin-orbit couplings and strong correlations
- Hydrogen roles in wide gap semiconductors
- Thin-film device characterization under current and light stimulations

CAREER HIGHLIGHTS

PhD University of Tokyo 1991 – 1996

Postdoc. Fellow Columbia University 1996 – 1998

Research Assoc. University of Tokyo 1998 – 2009

Assoc. Professor High Energy Accelerator Research Organization 2009 – 2018

Research Scientist TRIUMF 2018 – present

GRADUATE STUDENTS

Patrick Braun, Jessie Freese, Niyusha Hosseini, Skylar Koroluk

SELECTED PUBLICATIONS

M. Hepting, R.J. Green, Z. Zhong, M. Bluschke, Y.E. Suyolcu, S. Macke, A. Frano, S. Catalano, M. Gibert, R. Sutarto, F. He, G. Cristiani, G. Logvenov, Y. Wang, P.A. van Aken, P. Hansmann, M. Le Tacon, J.-M. Triscone, G.A. Sawatzky, B. Keimer, E. Benckiser. *Complex Magnetic Order in Nickelate Slabs*. Nat. Phys. **14**, 1097 (2018).

Z. Liao, N. Gauquelin, R.J. Green, K. Müller-Caspary, I. Lobato, L. Li, S. Van Aert, J. Verbeeck, M. Huijben, M.N. Grisolia, V. Rouco, R. El Hage, J.E. Villegas, A. Mercy, M. Bibes, P. Ghosez, G.A. Sawatzky, G. Rijnders, G. Koster. *Metal-insulator Transition Engineering by Modulation Tilt-Control in Perovskite Nickelates for Room Temperature Optical Switching*. Proceedings of the National Academy of Sciences of the USA **115**, 9515 (2018).

R.J. Green, M.W. Haverkort, G.A. Sawatzky. *Bond Disproportionation and Dynamical Charge Fluctuations in Perovskite Rare Earth Nickelates*. Phys. Rev. B **94**, 195127 (2016).

POSTDOCTORAL FELLOWS

Yipeng Cai, Sungwon Yoon

SELECTED PUBLICATIONS

K.M. Kojima, M. Hiraishi, H. Okabe, A. Koda, R. Kadono, K. Ide, S. Matsuishi, H. Kumomi, T. Kamiya, H. Hosono. *Electronic structure of interstitial hydrogen in In-Ga-Zn-O semiconductor simulated by muon*. Appl. Phys. Lett. **115**, 122104 (2019).

N. Funamori, K.M. Kojima, D. Wakabayashi, T. Sato, T. Taniguchi, N. Nishiyama, T. Irifune, D. Tomono, T. Matsuzaki, M. Miyazaki, M. Hiraishi, A. Koda, R. Kadono. *Muonium in Stishovite: Implications for the Possible Existence of Neutral Atomic Hydrogen in the Earth's Deep Mantle*. Sci. Rep. **5**, 8437 (2015).

M. Hiraishi, S. Iimura, K.M. Kojima, J. Yamaura, H. Hiraka, K. Ikeda, P. Miao, Y. Ishikawa, S. Torii, M. Miyazaki, I. Yamauchi, A. Koda, K. Ishii, M. Yoshida, J. Mizuki, R. Kadono, R. Kumai, T. Kamiyama, T. Otomo, Y. Murakami, S. Matsuishi, H. Hosono. *Bipartite magnetic parent phases in the iron oxypnictide superconductor*. Nat. Phys. **10**, 300 (2014).

INTERNATIONAL SCIENTIFIC ADVISORY BOARD (ISAB)

We are fortunate to have the support and advice of a group of world-renowned scientists who meet with us annually to review our work, provide us with feedback, and advise us on future directions. The International Scientific Advisory Board complements SBQMI's multidisciplinary approach, with its balance of expertise in theoretical, experimental, and applied research, and representation of different scientific disciplines with strong links to academia and industry.



**DR. LESLEY
COHEN**

CHAIR OF THE BOARD

*Consul for Faculty of Natural Sciences & Education Office
Professor, Department of Physics, Faculty of Natural Sciences,
Imperial College London*

Lesley Cohen is a Professor of Experimental Solid State Physics at Imperial College London and Editor in Chief of Applied Physics Letters. She received the inaugural Imperial College Julia Higgins Award for her contributions to the promotion and support of women in science, and remains committed to equality and diversity within STEM.

Her recent research work focuses on superconducting spintronics, chiral antiferromagnetism, nanostructured honeycomb artificial spin ices and quantum interference effects in organic self-assembled molecules.



**DR. GEORGE
CRABTREE**

*Distinguished Fellow, Argonne National Laboratory
Distinguished Professor of Physics, Electrical and
Mechanical Engineering, University of Illinois at Chicago
Director of the Joint Center for Energy Storage Research (JCESR)*

George Crabtree is Professor of Physics at University of Illinois-Chicago, Distinguished Fellow of Argonne National Laboratory and Director of the Joint Center for Energy Storage Research (JCESR). He has testified before the U.S. Congress on the hydrogen economy, meeting sustainable energy challenges, and energy storage. His research interests include energy storage, materials science, nanoscale superconductors and magnets, superconductivity, and highly correlated electrons in metals.



**DR. J.C. SEAMUS
DAVIS**

*Professor of Physics, Oxford University
Senior Fellow Wadham College, Oxford University
Professor of Quantum Physics, University of College Cork
J.G. White Distinguished Professor Emeritus, Cornell University*

Seamus Davis is a Professor of Physics at Oxford University and a Professor of Quantum Physics at the University of College Cork. He undertakes a wide range of experimental low-temperature research into the fundamental macroscopic quantum physics of superconductors, superfluids, supersolids, heavy-fermions, topological insulators and superconductors, magnetic spin and monopole quantum liquids, as well as developing new techniques for visualization and measurement of complex quantum matter.



**DR. BENJAMIN
EGGLETON**

*Professor of Physics, University of Sydney
Director, The University of Sydney Nano Institute
(Sydney Nano)
Co-Director, NSW Smart Sensing Network (NSSN)*

Benjamin Eggleton is a Professor of Physics at the University of Sydney and the Director of the University of Sydney Nano Institute (Sydney Nano) and the co-Director of the NSW Smart Sensing Network (NSSN). He is a Fellow of the Australian Academy of Science (AA), the Australian Academy of Technology and Engineering (ATSE), the Optical Society of America, IEEE and SPIE. He was previously an ARC Laureate Fellow, and has twice been an ARC Federation Fellow. His research links fundamental science to applied science and spans physics and engineering with pioneering contributions in the areas of nonlinear optics and all-optical signal processing. Eggleton is Editor-in-Chief of APL Photonics.



**DR. ANTOINE
GEORGES**

*Director, Center for Computational Quantum Physics,
Flatiron Institute
Professor of Physics, Collège de France
Chair in Condensed Matter Physics, Collège de France*

Antoine Georges is one of the co-inventors of dynamical mean field theory, for which he shared the 2006 Europhysics Condensed Matter Prize and the 2020 Aneesur Rahman prize of the American Physical Society. This theory has deeply transformed our understanding of quantum materials with strong electronic correlations and our ability to explain, calculate and predict their physical properties. He also received the 2007 Silver Medal of the CNRS, the 2014 Hamburg Prize for Theoretical Physics as well as a major Synergy Grant from the European Research Council. He is a member of the French Academy of Sciences.



**DR. STUART
PARKIN**

*Director at the Max Planck Institute of Microstructure Physics, Halle
Professor at the Institute of Physics of the Martin-Luther-University
Halle-Wittenberg
IBM Fellow (IBM's highest technical honour)
Consulting Professor Dept. of Applied Physics,
Stanford University*

Stuart Parkin is a Professor at the Institute of Physics of the Martin-Luther-University at Halle-Wittenberg where he develops and shapes the field of material sciences, and applied spintronics specifically. Considered a leader in the science and application of spintronic materials, he has made crucial discoveries in the behavior of thin-film magnetic structures leading to the increased data density and capacity of hard drives. More recently, he proposed “Racetrack Memory”—a radically different approach to building a solid-state non-volatile memory device using the current controlled motion of magnetic domain walls in magnetic nanowires.



**DR. R. STANLEY
WILLIAMS**

*Professor and holder of the Hewlett Packard Enterprise
Company Chair
Department of Electrical and Computer Engineering
Texas A&M University*

R. Stanley Williams is the Director of the Hewlett Packard Enterprise Center for Computer Architecture Research at Texas A&M University. For the past 40 years, his primary scientific research has been in the areas of solid-state chemistry and physics, and their applications to technology. This has taken him on a journey that began with surface science; expanded to electronic, photonic and ionic nanotechnologies; and now encompasses computation, chaos, complexity and neuroarchitectonics. In 2008, a team of researchers he led announced that they had built and demonstrated the first intentional memristor, the fourth fundamental nonlinear electronic circuit element predicted by Prof. Leon Chua in 1971. Williams has received recognition for business, scientific and academic achievement, including being named one of the top 10 visionaries in the field of electronics by EETimes, the 2014 IEEE Outstanding Engineering Manager Award, the 2009 EETimes Innovator of the Year ACE Award, the 2007 Glenn T. Seaborg Medal for contributions to Chemistry, the 2004 Herman Bloch Medal for Industrial Research, and the 2000 Julius Springer Award for Applied Physics. He has published over 460 peer reviewed papers and been awarded more than 220 US patents.

2019 PUBLICATIONS

- G.J.W. Aalbers, C.E. Boott, F. D'Acerno, L. Lewis, J. Ho, C.A. Michal, W.Y. Hamad, M.J. MacLachlan. *Post-modification of Cellulose Nanocrystal Aerogels with Thiol Ene Click Chemistry*. *Biomacromolecules* **20**, 2779 (2019).
- S. Ahmed, E. Altieri, T. Andalib, M.J. Barnes, B. Bell, C.P. Bidinosti, Y. Bylinsky, J. Chak, M. Das, C.A. Davis, F. Fischer, B. Franke, M.T.W. Gericke, P. Giampa, M. Hahn, S. Hansen-Romu, K. Hatanaka, T. Hayamizu, B. Jamieson, D.J. Jones, K. Katsika, S. Kawasaki, T. Kikawa, W. Klassen, A. Konaka, E. Korkmaz, F. Kuchler, L. Kurchaninov, M. Lang, L. Lee, T. Lindner, K.W. Madison, J. Mammei, R. Mammei, J.W. Martin, R. Matsumiya, E. Miller, T. Momose, R. Picker, E. Pierre, W.D. Ramsay, Y.-N. Rao, W.R. Rawnsley, L. Rebenitsch, W. Schreyer, S. Sidhu, S. Vanbergen, W.T.H. van Oers, Y.X. Watanabe, D. Yosifov. *Fast-switching magnet serving a spallation-driven ultracold neutron source*. *Phys. Rev. Accel. Beams* **22**, 102401 (2019).
- S. Ahmed, E. Altieri, T. Andalib, B. Bell, C.P. Bidinosti, E. Cudmore, M. Das, C.A. Davis, B. Franke, M. Gericke, P. Giampa, P. Gnyp, S. Hansen-Romu, K. Hatanaka, T. Hayamizu, B. Jamieson, D.J. Jones, S. Kawasaki, T. Kikawa, M. Kitaguchi, W. Klassen, A. Konaka, E. Korkmaz, F. Kuchler, M. Lang, L. Lee, T. Lindner, K.W. Madison, Y. Makida, J. Mammei, R. Mammei, J.W. Martin, R. Matsumiya, E. Miller, K. Mishima, T. Momose, T. Okamura, S. Page, R. Picker, E. Pierre, W.D. Ramsay, L. Rebenitsch, F. Rehm, W. Schreyer, H.M. Shimizu, S. Sidhu, A. Sikora, J. Smith, I. Tanihata, B. Thorsteinson, S. Vanbergen, W.T.H. van Oers, Y.X. Watanabe. *First ultracold neutrons produced at TRIUMF*. *Phys. Rev. C* **99**, 025503 (2019).
- S. Ahmed, T. Andalib, M.J. Barnes, C.B. Bidinosti, Y. Bylinsky, J. Chak, M. Das, C.A. Davis, B. Franke, M.T.W. Gericke, P. Giampa, M. Hahn, S. Hansen-Romu, K. Hatanaka, B. Jamieson, D.J. Jones, K. Katsika, S. Kawasaki, W. Klassen, A. Konaka, E. Korkmaz, F. Kuchler, L. Kurchaninov, M. Lang, L. Lee, T. Lindner, K.W. Madison, J. Mammei, R. Mammei, J.W. Martin, R. Matsumiya, E. Miller, Y.-N. Rao, W.R. Rawnsley, L. Rebenitsch, C.A. Remon, W. Schreyer, A. Sikora, J. Sonier, B. Thorsteinson, S. Vanbergen, W.T.H. van Oers, Y.X. Watanabe, D. Yosifov. *A beamline for fundamental neutron physics at TRIUMF*. *Nucl. Instrum. Methods Phys. Res., Sect. A* **927**, 101 (2019).
- M.W. Altaha, H. Jayatilleka, Z. Lu, J.F. Chung, D. Celso, D. Goodwill, E. Bernier, S. Mirabbasi, L. Chrostowski, S. Shekhar. *Monitoring and automatic tuning and stabilization of a 2x2 MZI optical switch for large-scale WDM switch networks*. *Opt. Express* **27**, 24747 (2019).
- C.P. Berlinguette, Y. Chiang, J.N. Munday, T. Schenkel, D.K. Fork, R. Koningstein, M.D. Trevithick. *Revisiting the cold case of cold fusion*. *Nature* **570**, 45 (2019).
- H. Beygi, S.A. Sajjadi, A. Babakhani, J.F. Young, F.C.J.M.v. Veggel. *Air exposure oxidation and photooxidation of solution-phase treated PbS quantum dot thin films and solar cells*. *Sol. Energy Mater. Sol. Cells* **203**, 110163 (2019).
- K. Bieniasz, M. Berciu, A.M. Oles. *Spectral properties of spin-orbital polarons as a fingerprint of orbital order*. *Phys. Rev. B* **100**, 125109 (2019).
- S.A. Boer, P. Wang, M.J. MacLachlan, N.G. White. *Open Pentiptycene Networks Assembled through Charge-Assisted Hydrogen Bonds*. *Cryst. Growth Des.* **19**, 4829 (2019).
- J. Bonca, S.A. Trugman, M. Berciu. *Spectral function of the Holstein polaron at finite temperature*. *Phys. Rev. B* **100**, 094307 (2019).
- C.E. Boott, A. Tran, W.Y. Hamad, M.J. MacLachlan. *Cellulose Nanocrystal Elastomers with Reversible Visible Color*. *Angew. Chem.-Int. Edit.* (2019).
- D. Bruns, T.E.d. Oliveira, J. Rottler, D. Mukherji. *Tuning Morphology and Thermal Transport of Asymmetric Smart Polymer Blends by Macromolecular Engineering*. *Macromolecules* **52**, 5510 (2019).
- D.J. Campbell, C. Eckberg, P.Y. Zavalij, H. Kung, E. Razzoli, M. Michiardi, C. Jozwiak, A. Bostwick, E. Rotenberg, A. Damascelli, J. Paglione. *Intrinsic insulating ground state in transition metal dichalcogenide TlSe₂*. *Phys. Rev. Mater.* **3**, 053402 (2019).
- O. Can, E.M. Nica, M. Franz. *Charge transport in graphene-based mesoscopic realizations of Sachdev-Ye-Kitaev models*. *Phys. Rev. B* **99**, 045419 (2019).
- O. Can, M. Franz. *Solvable model for quantum criticality between the Sachdev-Ye-Kitaev liquid and a disordered Fermi liquid*. *Phys. Rev. B* **100**, 045124 (2019).
- Y. Cao, Y. Li, T. Morrissey, B. Lam, B.O. Patrick, D.J. Dvorak, Z. Xia, T.L. Kelly, C.P. Berlinguette. *Dopant-free molecular hole transport material that mediates a 20% power conversion efficiency in a perovskite solar cell*. *Energy Environ. Sci.* **12**, 3502 (2019).
- Y. Cao, L. Lewis, W.Y. Hamad, M.J. MacLachlan. *Pressure-Responsive Hierarchical Chiral Photonic Aerogels*. *Adv. Mater.* **31**, 1808186 (2019).
- V. Carta, M.A. Soto, M.J. MacLachlan. *Ligand-modulated ring-expansion*. *Chem. Commun.* **55**, 1245 (2019).
- A. Chatzichristos, R.M.L. McFadden, M.H. Dehn, S.R. Dunsiger, D. Fujimoto, V.L. Karner, I. McKenzie, G.D. Morris, M.R. Pearson, M. Stachura, J. Sugiyama, J.O. Ticknor, W.A. MacFarlane, R.F. Kiefl. *Bi-Arrhenius Diffusion and Surface Trapping of ⁶Li⁺ in Rutile TiO₂*. *Phys. Rev. Lett.* **123**, 095901 (2019).
- R. Cheng, H. Yun, S. Lin, Y. Han, L. Chrostowski. *Apodization profile amplification of silicon integrated Bragg gratings through lateral phase delays*. *Opt. Lett.* **44**, 435 (2019).
- R. Cheng, Y. Han, L. Chrostowski. *Characterization and compensation of apodization phase noise in silicon integrated Bragg gratings*. *Opt. Express* **27**, 9516 (2019).
- L. Chrostowski, H. Shoman, M. Hammood, H. Yun, J. Jhoja, E. Luan, S. Lin, A. Mistry, D. Witt, N.A.E. Jaeger, S. Shekhar, H. Jayatilleka, P. Jean, S.B. Villers, J. Cauchon, W. Shi, C. Horvath, J.N. Westwood-Bachman, M. Setzer, M. Aktary, N.S. Patrick, R.J. Bojko, A. Khavasi, X. Wang, T.F.d. Lima, A.N. Tait, P.R. Prucnal, D.E. Hagan, D. Stevanovic, A.P. Knights. *Silicon Photonic Circuit Design Using Rapid Prototyping Foundry Process Design Kits*. *IEEE J. Sel. Top. Quantum Electron.* **25**, 8201326 (2019).
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SBQMI dogs Hunter (left) and Hobbes (right)

