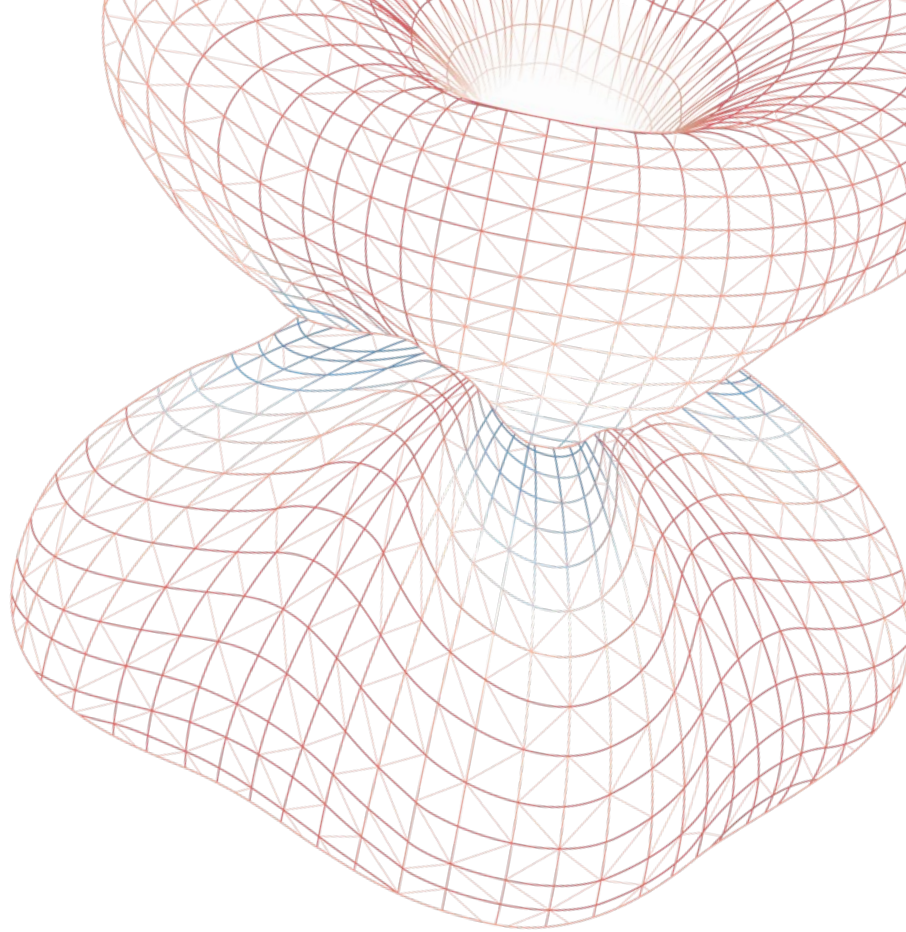
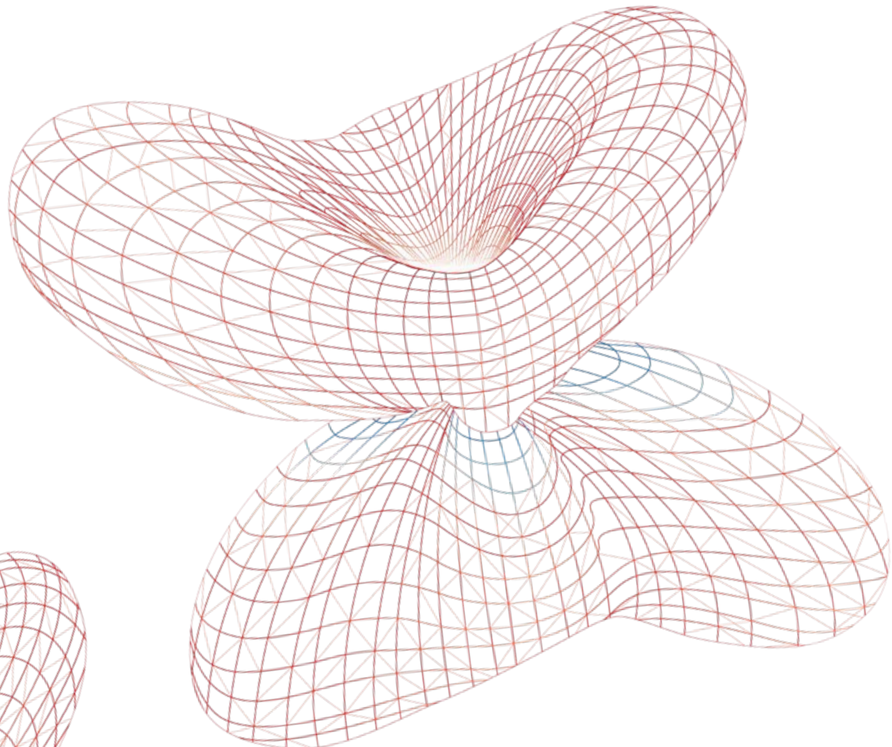
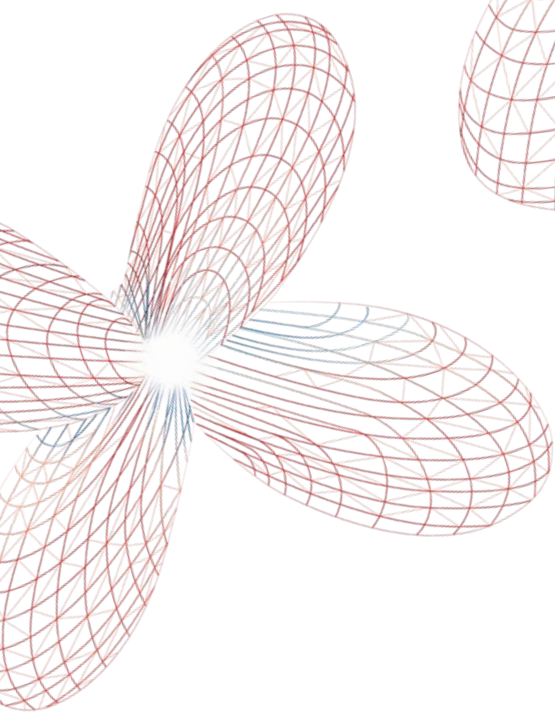






Stewart Blusson
Quantum Matter Institute
THE UNIVERSITY OF BRITISH COLUMBIA

ANNUAL REPORT 2021

MISSION

The Stewart Blusson Quantum Matter Institute (Blusson QMI) 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

Blusson QMI 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

Blusson QMI 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
Pacific Economic Development Canada (PacifiCan)

We wish to express our sincere gratitude and appreciation for their support as their contributions have enabled Blusson QMI to accelerate research productivity and technology translation.

LAND ACKNOWLEDGMENT

We acknowledge that the land on which we work, study and gather is the traditional, ancestral, and unceded territory of the xwməθ–kwəy’əm (Musqueam) people.

TABLE OF CONTENTS

MESSAGE FROM THE SCIENTIFIC DIRECTOR

This past year represented a tipping point for quantum science in Canada, and as we look back on a year of progress, collaboration, and innovation, we also look forward to the next phase in Canada's quantum evolution. With the Government of Canada committing $360 million over seven years to fund a national quantum strategy, Canada is poised to influence the world in quantum science and technology. We are excited to play a leading role, as research and development of quantum materials will underpin the breakthroughs of the quantum era: expectations are high, and we are proud of our researchers' contributions to Canada's quantum readiness.

We celebrated a major milestone in our relationship with the Max Planck Society this year: our partnership, the Max Planck-UBC-UTokyo Centre for Quantum Materials, was extended for a third five-year term, the first time an international Max Planck centre has been renewed beyond 10 years. This renewal speaks to the success and productivity of our partnership: read about some of the outcomes of our collaboration, from novel research to student exchange, that took place in 2021 on page 33.

Our collaborations have in many ways fueled our growth: strong partnerships with industry and with Canadian academic centres have enabled us to expand our capabilities and develop shared infrastructure in order to increase our ability to work together. At the Canadian Light Source, Blusson QMI has led the development of the Quantum Materials Spectroscopy Centre (QMSC) beamline, which opened to users this year, and follows the success of the Resonant Elastic and Inelastic X-ray Scattering (REIXS) beamline also developed under Blusson QMI's leadership. Likewise, working with the University of Waterloo and Université de Sherbrooke, the Quantum Colaboratory has grown considerably since this national facility was launched in 2019. By sharing our resources, we are also working to ensure the sustainability of our operations.

This is a critical time for Blusson QMI: we have leveraged the support of the Canada First Research Excellence Fund and are planning for the next phase in our growth. Our Grand Challenges are now productive research programs reinforcing theoretical and experimental work expected to have far reaching impact over the next decade.

In addition, we have made major progress in connecting with the arts community and the public. Early in the year, we were excited to receive funding for a transdisciplinary partnership with the Morris & Helen Belkin Art Gallery and UBC's Department of Physics & Astronomy: our collaboration—Ars Scientia, jointly co-led with Shelly Rosenblum and Jeremy Heyl—arose from Blusson QMI's long-term quest to close the gap between art and science and foster new modes of knowledge exchange. *The DRIFT: Art and Dark Matter* exhibit that the gallery hosted on campus from September through December was the first official event co-sponsored by Ars Scientia. In October, we were thrilled to host *Dark Matter Day* as an extension of the exhibit. The event took place at the HR MacMillan Space Centre, the first in-person event the Centre had been able to feature since the pandemic began in 2020.

Ars Scientia connected four artists and six physicists in a six-month residency program. The residencies culminated in a symposium in the fall (see page 8) in which the residency partners talked about connecting across art and science, and the ways in which they were able to work together and explore new ideas. Ars Scientia benefited from the commitment and support of James Day, who has lent his considerable talents to the cluster as Program Coordinator, an effort he has taken on in addition to his day-to-day work for Blusson QMI. James continues to be a leader in moving our art program forward, and I am grateful for his creativity and expertise.

I am also pleased to see that *The Frustrated Icosahedron,* a sculpture by artist Pamela Davis Kivelson, is now at home at Blusson QMI; I am grateful to Kim Kiloh and James Day, who worked closely with Pamela to execute the display of the piece, which represents an important connection between art and physics. In addition, scientific display items, images, and artwork are now displayed throughout the Brimacombe Building as a testament to the creativity and beauty that emerges from the work that we do (see page 14).

As for broader quantum community engagement, we were able to deliver 2021 International Conference on Nanoscience and Technology virtually thanks to co-chair Sarah Burke, who led a massive effort as the conference was delayed due to the pandemic before shifting to a virtual format; I am impressed and inspired by Sarah's commitment and work to bring the conference to fruition. Meanwhile, Karl Jessen worked closely with NanoCanada to bring Quantum Days to fruition in early 2021, a substantial effort that enabled the Canadian quantum community, from academia to government to industry, to define its priorities ahead of the Government of Canada's 2021 Federal Budget. I want to thank Karl as well as Gail Murphy, UBC's VP Research and Innovation, for their leadership and support, which ultimately helped launch Canada's National Quantum Strategy this year. Quantum Days 2.0 will take place in early 2022, and I am honoured to have been appointed as Chair of this exciting event.

Finally, I am pleased that we have been able to resume in-person research and training activities. In 2022, we will welcome the world to Vancouver for our first in-person conference in two years as we host the Materials and Mechanisms of Superconductivity (M2S 2022) conference, which had been rescheduled due to COVID-19. Our team, led by Doug Bonn and Mona Berciu, have been working diligently to ensure a successful return to this international in-person event that will bring the superconductivity community together.

Please enjoy this look back at 2021. This is a remarkable period of change; we are emerging from uncertainty into a promising and exciting future. I am immensely proud of what we have been able to accomplish, and am looking forward to what is ahead.

Andrea Damascelli
Scientific Director
Stewart Blusson Quantum Matter Institute

> "… what struck me [at Blusson QMI] was the creative approach to building an agile, supportive team to create the best possible research environment."

Kim Kiloh joined Blusson QMI as Managing Director on February 1, 2021, bringing the collaborative, strengths-based approach she honed over 18 years in student affairs roles with the University of British Columbia. Kiloh has considerable experience running collaborative, interdisciplinary projects and working alongside faculty, previously serving as Director, Centre for Student Involvement & Careers in Brock Hall for eight years; she was recognized for her leadership on behalf of students and staff in 2019 with a President's Service Award for Excellence.

For Kiloh, Blusson QMI is not a radical departure from her work with the Vice-President, Students' portfolio, but an evolution in a career built on challenging established norms. As Managing Director, Kiloh recognizes that faculty, staff and student success are critical to the mission of Blusson QMI, and is eager to support administrative and operations teams in accomplishing their work, and in finding ways for individuals to bring their creativity and ideas to bear on the challenges and opportunities facing the institute as a world-leading research organization.

"Blusson QMI offered an alignment with my own values," said Kiloh. "We have a deep commitment to collaboration and a priority placed on interdisciplinary perspectives."Blusson QMI is—of course—home to leading-edge science and what struck me was the creative approach to building an agile, supportive team to create the best possible research environment. I wanted to be part of it."

Kiloh spent the first months of her role with Blusson QMI navigating the ever-changing climate around the COVID-19 pandemic. Despite the uncertainty of the first months of 2021, Kiloh became an important part of our community.

"Kim's incredible expertise and professionalism, her strategic visionary mind, and her warmth and compassion have brought new life to the Blusson QMI community, especially through the challenges of the pandemic," said Andrea Damascelli. "Despite social distancing, she has in many ways brought us closer together."

For much of her first year, Kiloh has worked to ensure that Blusson QMI truly lives its values. This has meant embedding equity, diversity and inclusion principles into existing systems, from adding regular conversations and learning opportunities around Truth and Reconciliation with Indigenous communities to ensuring that meetings, communications, and projects reflect the diversity of our teams.

She has been deeply involved in sustainability planning: as Blusson QMI moves into its next phase, she is working to ensure that the strong relationships that have been so critical to our success—the Max Planck-UBC-UTokyo Centre for Quantum Materials (page 33), for example, and the International Scientific Advisory Board—continue to thrive and evolve. She has also been working closely with the university administration and QMI faculty to explore sustainability strategies as Blusson QMI's funding model evolves post-CFREF. "Our facilities and infrastructure are rapidly becoming a hub for industry partners, and offer a critical piece in the growth of the nanotechnology, photonics, and quantum computing fields in British Columbia and beyond." With the announcement of funding for a National Quantum Strategy in this year's federal budget, the time is right to strengthen our relationships with our partners and stakeholders in the Canadian quantum ecosystem.

"The opportunities for students and alumni in quantum sciences in Canada are plentiful and increasing, and I'm excited to contribute to the culture of the field by providing a strong training foundation for future leaders in industry, government, and academia" said Kiloh.

> "...we're going to see a lot of progress in our research and collaborations, and I am proud of the Project Management Office's role in driving Blusson QMI forward."

Ken Wong has spent a lot of his career making things—and teams—work better. Wong, who joined Blusson QMI in January 2021, leads the Project Management Office (PMO) in his role as Research Program Manager. As an institute with big goals and Grand Challenges, the PMO plays an important role in the planning, management, and reporting on projects, from individual student research to multi-institute, international collaborations.

Project management was established as a priority for Blusson QMI early on. As a growing centre with ambitious goals, Blusson QMI needed a committed team of experts to provide highly qualified support across key areas including research, reporting, translation, and engagement with industry.

"One of the great things about our team is how embedded they are in Blusson QMI; they are genuine experts in what they do, and in some cases, they have grown into their roles very organically through their relationships with Blusson QMI and its teams," said Wong. "We're in a great position to be able to help Blusson QMI students, staff and faculty with their project planning needs because of the unique perspective of our PMs."

Wong and the PMO team, which includes Jasmine Chipman Koty, Stephen Lin, and Steven Gou (Pedro Lopes departed for a new role at the end of 2021), have been engaging faculty, postdoctoral researchers, graduate students, and staff in discussions around their project management needs. The conversations have informed strategic planning for the group, who anticipates taking an advisory role in supporting the diverse project management needs of the Blusson QMI community.

Over the past year, in addition to planning the future of the PMO, Wong has taken on a greater role in managing the Grand Challenges. With the implementation and installation of new infrastructure and equipment, teams are now building on much of the foundational work that took place in 2019 and 2020, and Wong is working to identify opportunities for cohesion and foster collaboration between researchers.

"At Blusson QMI, there's such a rich tradition of research and innovation," said Wong. "The Grand Challenges are a real effort to nurture that tradition and increase collaboration between labs and PIs, and we're in a position now where we're seeing tangible outcomes from these collaborations."

Wong studied computer science before completing a PhD in Electrical and Computer Engineering at UBC. From there he went to work in the private sector, building a career in industries including aerospace, healthcare, and defense. His experience across a range of scientific and technical fields has enabled him to see the big picture for Blusson QMI, and to leverage the strengths of the PMO to implement the institute's strategic objectives.

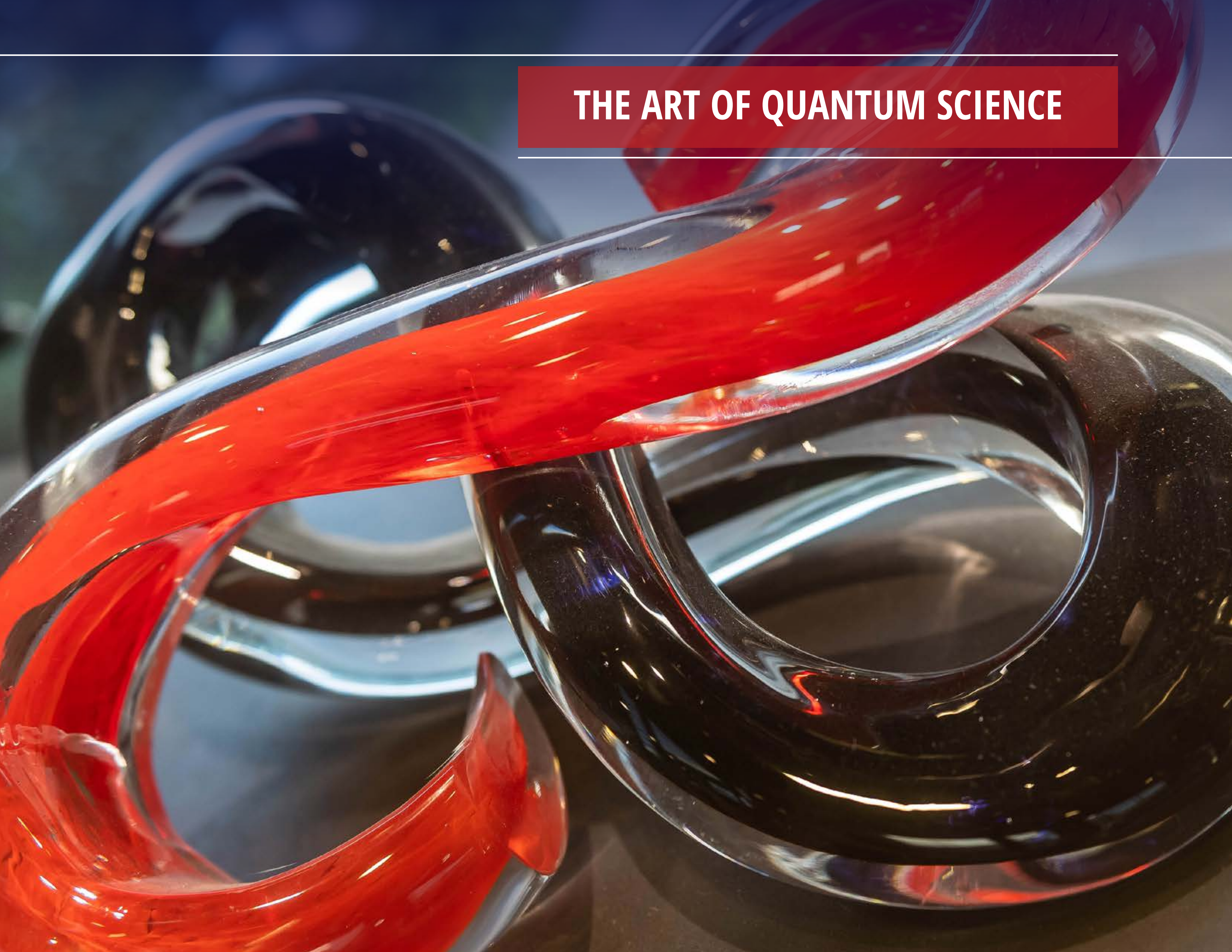
"We're at a very positive moment for Blusson QMI," said Wong. "A lot of the foundational work is there, and now we're looking to build momentum: over the next year, three years, five years—we're going to see a lot of progress in our research and collaborations, and I am proud of the PMO's role in driving Blusson QMI forward."

BY THE NUMBERS

Our goal is to ensure that Blusson QMI 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.

147	Graduate Students
36	QuEST Students
66	Postdoctoral Fellows
3	Affiliate Members
26	Faculty
3	Canada Research Chairs
29	Administrative Staff
39	Scientific & Technical Staff
4	CIFAR Scholars

THE ART OF QUANTUM SCIENCE



ART AND TRANSDISCIPLINARY CONNECTIONS

In 2020, the temporary pause of in-person activities allowed time for building connections with the arts community and the opportunity to think about what we could bring to potential collaborations and their prospective outcomes. In 2021, we were able to secure funding for a UBC Research Excellence Cluster that solidified our partnership with the Morris & Helen Belkin Art Gallery at UBC. In addition, with the support and hands-on efforts of Senior Scientist James Day, we were able to begin featuring original artwork, beautiful scientific imagery, and interesting scientific display items throughout the building.

ARS SCIENTIA

Ars Scientia is a transdisciplinary project that connects physicists and artists in an effort to find shared ways of communicating about science and explaining the world around us. In 2021, Ars Scientia was awarded two years of funding through the UBC Research Excellence Cluster program, an interdisciplinary initiative jointly created by the Vice-President, Research & Innovation and the Provost & Vice-President, Academic, and supported by UBC's Academic Excellence Fund.

Ars Scientia is co-led by Andrea Damascelli, UBC Physics and Astronomy Professor and Blusson QMI Scientific Director; Jeremy Heyl, UBC PHAS Professor; and Shelly Rosenblum, Curator of Academic Programs at the Belkin, and supported by a team of staff including Blusson QMI Senior Scientist and Ars Scientia Program Manager James Day.

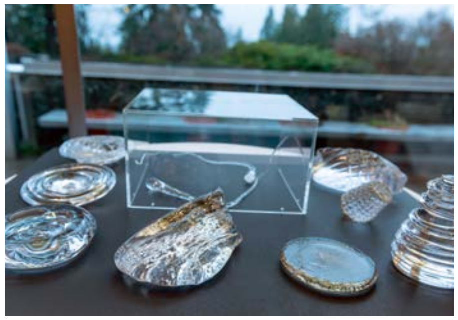
The cluster's early activities centred around an exhibition at the Morris & Helen Belkin Art Gallery called *Drift: Art and Dark Matter* that was generated by Agnes Etherington Art Centre, the Arthur B. McDonald Canadian Astroparticle Physics Research Institute and SNOLAB. While the exhibition was an early connection point, the cluster had begun to pivot toward the end of 2021, with a plan to engage additional disciplines and establish a more formal residency structure in 2022.

Residencies

Ars Scientia partnered UBC physics faculty (Alannah Hallas, Kirk Madison) and graduate students (Rysa Greenwood, Daniel Korchinski, Sarah Morris, and Luke Reynolds) with Vancouver-based artists Justine A. Chambers, Josephine Lee, Khan Lee, and Kelly Lycan over a six-month period. Ars Scientia leads instructed the teams and attended seminars, but generally left the experience open. There was no requirement for a tangible outcome, but they would need to present at a public symposium after those six months.

Paired or grouped together at the beginning of May 2021, the Ars Scientia residencies intended to provide a space of deep contemplation and slow thinking between practicing artists in Vancouver and physicists at the Stewart Blusson Quantum Matter Institute and the UBC Department of Physics and Astronomy. With no expectations or guaranteed deliverables in mind, the trajectory of these partnerships took off in a multitude of directions—manifesting as spending time together in nature, looking through archives and photographs, visiting lab and studio spaces, and even producing art and data collaboratively.





Signals and Apparatuses

On November 25, 2021, the Ars Scientia research cluster hosted a symposium where thoughts and findings on art-science collaborations were shared with the academic community at UBC. As a culmination of Ars Scientia's six-month residency program between artists and physicists, *Signals and Apparatuses* was an opportunity to engage in conversations surrounding points of intersection, expansion, and discovery across two seemingly disparate disciplines that were encouraged to coalesce and collaborate.

While there were no stated deliverables, the symposium was a goal post for these residencies, where the groups could come together in person to present, discuss, and further think through their 6-month partnerships and the impacts they have had on their individual practices.

Justine A. Chambers, Luke Reynolds, and Sarah Morris produced a work titled "Score for a Residency," tracing conversations and time spent together during several trips to the beach while contemplating the oftentimes challenging notion of "no deliverables."

Kelly Lycan and Kirk Madison shared their findings while sifting through hundreds of photographs, as well as drawings made after each group meeting that created a visual web of synchronized ideas.

Khan Lee, Rysa Greenwood, and Alannah Hallas engaged in a conversation about how each of their approaches to research has been challenged by the residency, explaining how vocabulary and terminology can take on a variety of meanings rather than adhere to something absolute or singular.

Josephine Lee and Daniel Korchinski concluded the residency presentations with a mini exhibition of glasswork they produced together on Granville Island, accompanied by an in-depth analysis of its process and subsequent data.

CHAMPIONING ART-SCIENCE CONNECTIONS IN THE BRIMACOMBE BUILDING AND BEYOND

"The biggest breakthroughs in science have always come out of paradigm shifts, or the moment that someone sees something new in what they previously took for granted," said James Day, facilitator of many of the art-related initiatives underway at Blusson QMI.

"For example, in the 1940s, Richard Feynman devised a language of squiggles and shapes—the Feynman diagrams—to simplify equations in physics, forever altering the way that physicists view the world."

In his role as Ars Scientia Program Coordinator, Day spent 2021 guiding a nascent residency program linking local artists with UBC physicists. It has been an experience that has found him enthusiastically outside of his comfort zone, challenging him to think more deeply about how science interacts—and is perceived by—the world outside the lab.

In addition to his Ars Scientia work, Day has been creating displays of art (including original material from Research Operations Facilitator Alex Anees, see page 17) and scientific imagery throughout Blusson QMI.

Pictured, left to right: Tatiana Mellema, Andrea Damascelli, James Day, Shelly Rosenblum, and Marcus Day.

What's in a word?

There is often a lot of meaning packed into the language of physics. Words we use frequently in the lab or in our publications convey complex ideas and are useful in communicating to other scientists about our research. However, to non-scientists, these words have little meaning and are often essentially jargon. The result is that the language that serves physicists can also be an obstacle to those outside of science.

This disconnect between how physicists speak and what artists and others who work outside of science understand of that language became apparent throughout the residencies.

"Finding a common ground in language was sometimes difficult, but it was also fun," said Day. "You can't presume that you share an understanding of key terms; I found that when we were using words that physicists commonly understand one way, the artists understood those words differently."

Being forced to consider how some words have other meanings in different disciplines and having to explain their meaning in unfamiliar contexts caused researchers to think about how well they understand certain concepts. Artists and scientists observe the world from divergent but not necessarily opposing perspectives, and if they are able to talk about what they see, the effect is very powerful.

"I appreciated how the artists pushed us to contemplate topics we thought we understood pretty well; they led me to consider more deeply what I mean, what I intend, and where I am coming from," said Day. "Working with the artists took us outside of our science bubble and made us consider analogies we had been using, that we had assumed were functional, and seeing where those broke down for people outside of science. Working with people from other disciplines forces us as scientists to find effective ways to communicate about our work."

Beyond “multidisciplinary”

Opportunities like the Ars Scientia residencies program and other art-science initiatives are especially important to students and early career researchers, who can benefit from the breadth of perspective interdisciplinary experiences can offer.

In his 1995 paper Fruits, Salads, and Smoothies, Wayne State University researcher Moti Nissani proposed that “multidisciplinary” is a bowl of fruit; “interdisciplinary” is a fruit salad. “Transdisciplinary” is a smoothie, a transformation that takes what we understand to be fruit and makes something completely new: this, according to Day, is what we need to be doing more of in academia.

“When scientists work with artists, they are exposing themselves to questions they might never be asked by another scientist in their field,” said Day. “We don’t always question if we truly understand what we have learned. Sometimes an artist will ask a question that is so fundamental, it forces a researcher to look at their area of expertise in a completely new light. That is so beneficial, especially early on.”

Much depends on a broader understanding of what scientists do and why, from funding of research projects to the public perception of the value of fundamental science. Inter- and transdisciplinary partnerships invite participation from excluded groups.

This exchange is beneficial for artists as well, who benefit from access to scientific spaces not generally accessible to the public. With opportunities to peer into otherwise restricted spaces, artists can find meaning in research before it becomes public knowledge; this enables them to shape the conversation in interesting and potentially meaningful ways.

“Someone who thinks differently than you do offers you a chance to see a little more of the world than you might otherwise,” said Day. “It’s impossible to imagine where the next paradigm shift might come from but by partnering artists and physicists, we create the potential for a clash of views that leads to creative ideas we may not have generated otherwise.”

“Transdisciplinary” is a smoothie, a transformation that takes what we understand to be fruit and makes something completely new: this, according to Day, is what we need to be doing more of in academia.

Finding beauty in the lab

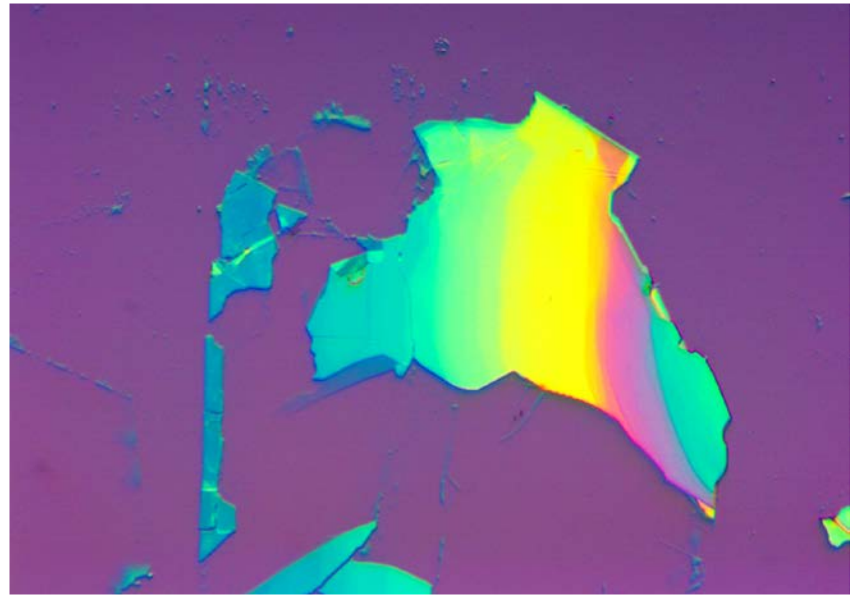
Romina Mahinpei spent her first year as an undergraduate student at The University of British Columbia taking classes online, and until her first days as a participant in the Quantum Pathways program at Blusson QMI, she had not set foot on campus. For Romina, a summer in Josh Folk's lab was formative: "It was nice to get a sense of what real research looks like, but having the experience in the lab and at the Institute has given me a clearer perspective on what's possible in quantum fields," she said.

Mahinpei spent the summer learning about quantum materials, focusing on the fabrication of hexagonal boron nitride (h-BN) and graphene stocks and exfoliating flakes using scotch tape, a process Romina notes is identical to the one used by the two researchers who won the 2010 Nobel prize for discovering graphene.

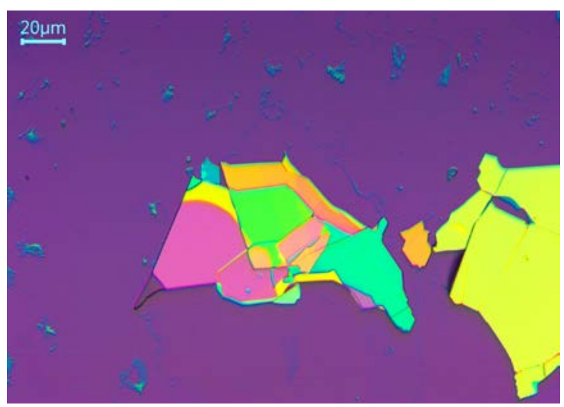
"I wondered, why are we doing it this way? But it gives us the best quality of flakes," Mahinpei says. After exfoliating the flakes, Mahinpei uses an optical microscope to identify and catalogue the flakes, which are then stored for future research needs.

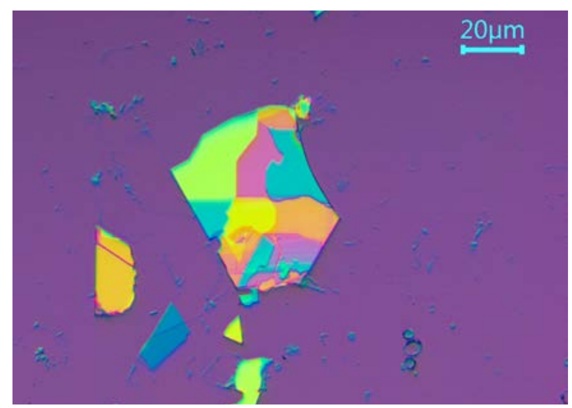
"When we're using the optical microscope to classify the flakes, we're looking for shades of blue," Mahinpei explains. She generated the images here during her Quantum Pathways work this summer. "I was looking for samples that were about 60 microns by 60 microns, and in h-BN, a certain shade of blue that indicated an ideal thinness. In graphene, we were looking for purple."

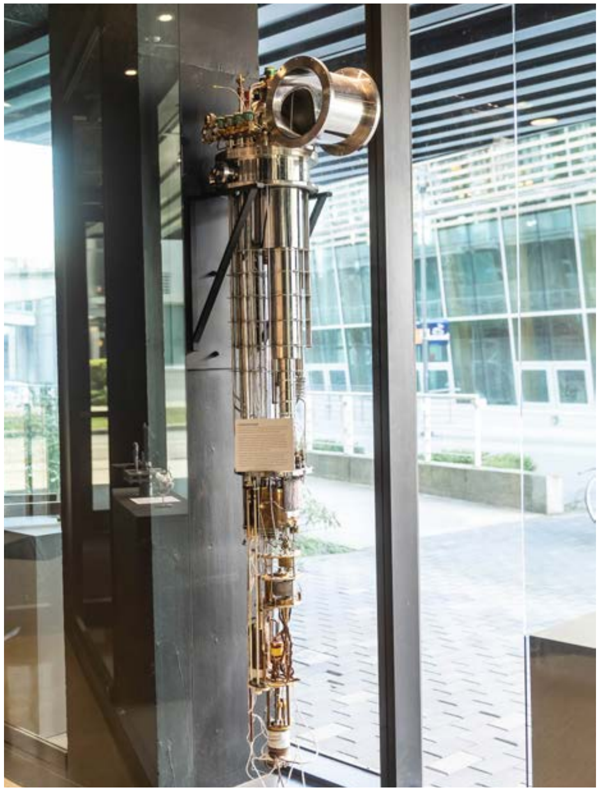
Mahinpei's images are currently on display in the third-floor atrium at Blusson QMI.



Samples of hexagonal boron-nitride under an optical microscope. While these do not reflect the shade of blue researchers are seeking when preparing samples, their colours do represent varying degrees of sample thickness. Image credit: Romina Mahinpei.





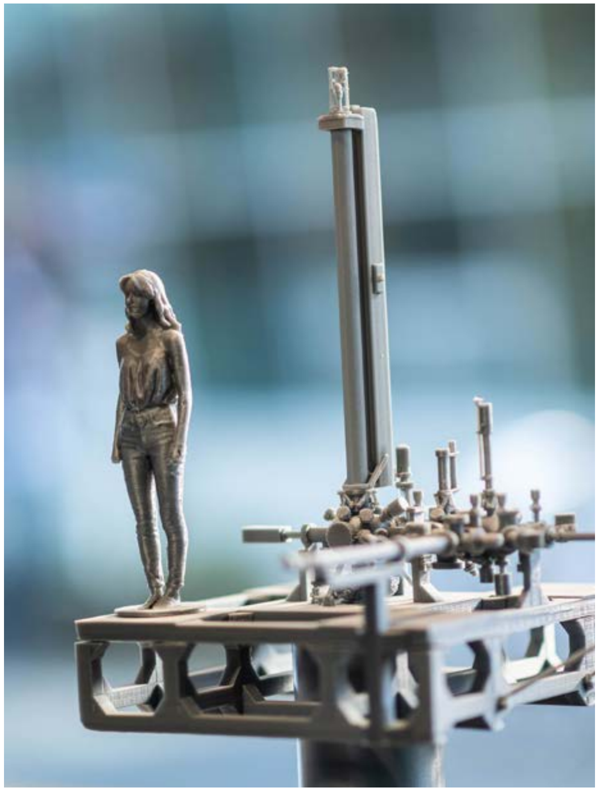


Hydrogen Maser

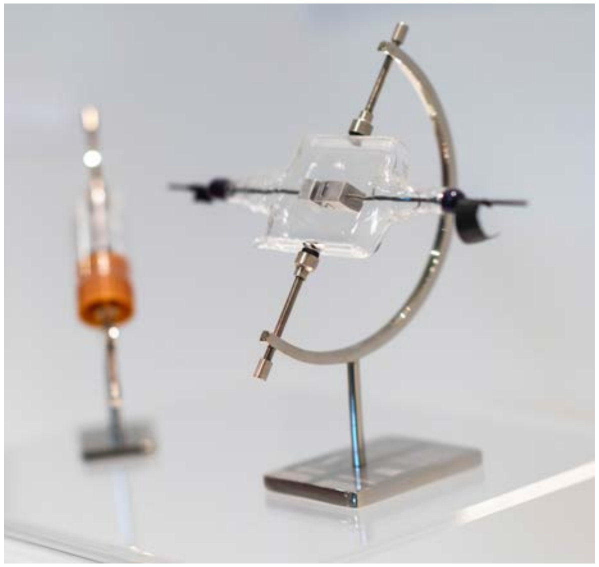
A *maser* is a device that uses stimulated emission to produce coherent electromagnetic waves through amplification. (Maser is an acronym for *M*icrowave *A*mplification by *S*timulated *E*mission of *R*adiation.)

The hydrogen maser is a specific type of maser that uses the intrinsic properties of the hydrogen atom to serve as a precision frequency reference. It is among the most stable atomic frequency standards available today.

This hydrogen maser was a prototype constructed by Walter Hardy and colleagues in the mid-1980s, with the initial goal of observing Bose-Einstein condensation in atomic hydrogen. For a short while, this instrument was the most precise time-keeping piece on the planet.

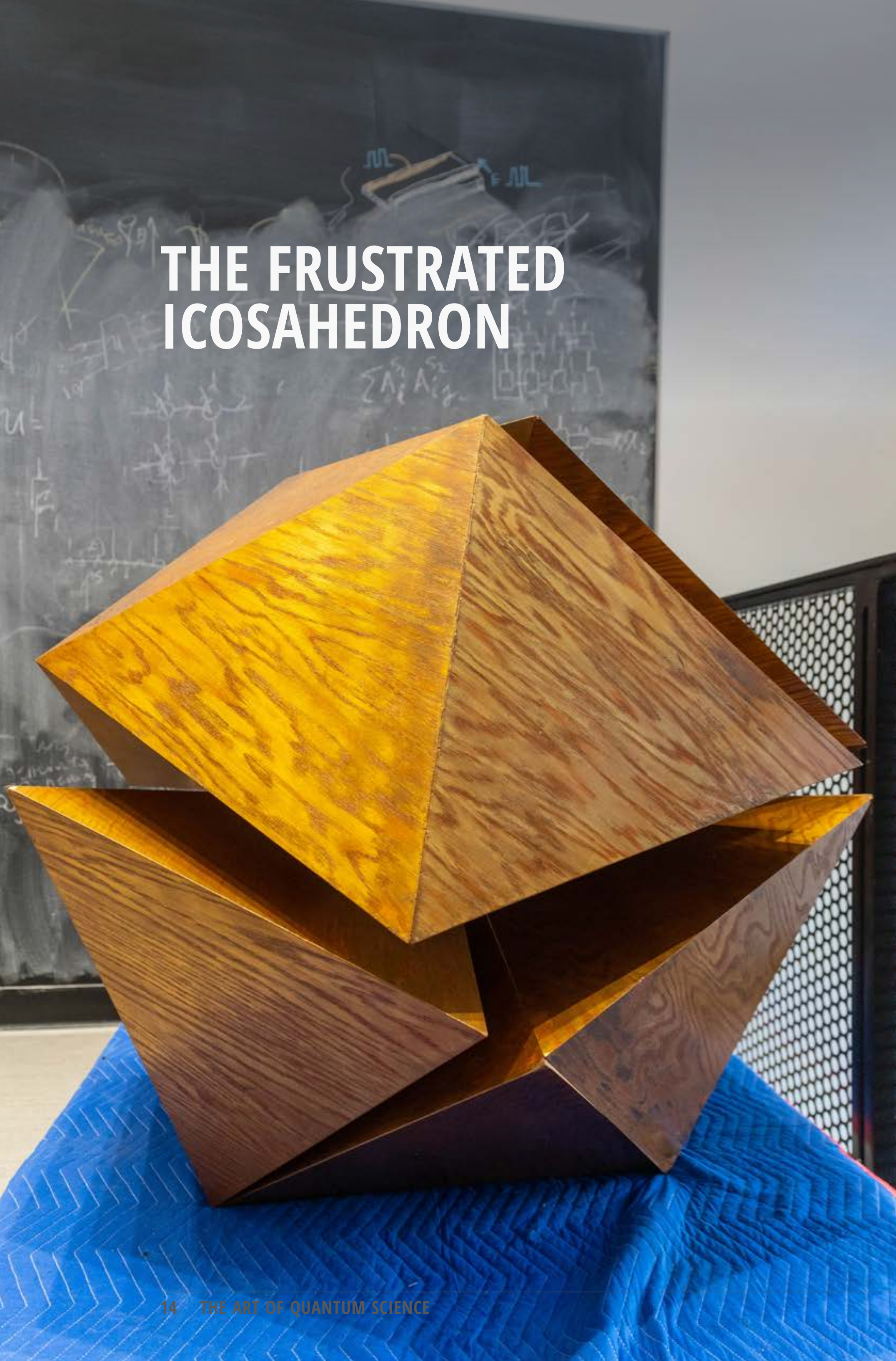


Pictured: An 11:1 scale model of the "The Beast," a milliKelvin Scanning Tunneling Microscope (STM) in the basement at Blusson QMI. This STM operates at temperatures near absolute zero, and can image surfaces at the atomic level.



Pictured: A solar thermionic converter. Thermionic emission is the thermally induced flow of particles carrying an electric charge from a surface or over a potential-energy barrier. One of the conceptually simplest ways of conversion of solar energy to electricity is based on thermionic emission. This process can be implemented in carbon nanotube forests through the Heat Trap effect, whereby a small amount of focused light results in unusually localized and thus extremely efficient heating. Alireza Nojeh's group has exploited this phenomenon to build a new generation of simple and compact solar thermionic converters.

THE FRUSTRATED ICOSAHEDRON



"One of the important purposes of art is to transform spaces by making novel phenomena visible," said Pamela Davis Kivelson, the artist behind the sculpture *The Frustrated Icosahedron*. "That, and to face uncertainty and then turn that uncertainty into creative exploration."

The Frustrated Icosahedron is currently situated at the Stewart Blusson Quantum Matter Institute (Blusson QMI). The piece, a structure comprised of 20 gilded tetrahedra, was assembled to form an icosahedron that doesn't quite fit together; seams where the tetrahedra do not quite align reflect geometric constraints, rather than flaws in the assembly.

Kivelson is interested in art that inspires awe, and that drives prosocial behaviour: art should create opportunities for connection and conversation, and a sense of wellbeing that extends beyond the individual for the benefit of the community.

"When the Icosahedron is packed, it's pretty compact and small, but there's something about the experience of putting it together that's very beautiful, and it cannot be done alone," said Kivelson.

"When you put it together, it takes up a lot of space; I think about how when you're working on something together, it's bigger than one idea. You're all sharing in creation. You're co-creating an experience. When the viewer encounters *The Frustrated Icosahedron,* they need to puzzle it out, and that can be a connecting and hopefully joyful experience," said Kivelson.

The Frustrated Icosahedron came to Blusson QMI in 2016. In late 2015, Andrea Damascelli met Pam Kivelson at a CIFAR meeting in Paris: Kivelson's spouse, Steven Kivelson, is a Professor in the Department of Physics at Stanford University and an international Associate Fellow with CIFAR. Over dinner near the Arc de Triomphe, Damascelli recalls discussing his vision for the Institute—at that point, Blusson QMI didn't have a completed building, and had only just been awarded funding through the Canada First Research Excellence Fund (CFREF).

"It was the beginning of Blusson QMI as we know it today," said Damascelli.

At Blusson QMI, James Day, Pinder Dosanjh, Doug Wong, Tim Warkentin, and Andrea Damascelli worked to unpack and assemble the sculpture. As the team worked to assemble the tetrahedra at first, and the icosahedron days later, the effort resembled a dance as people joined in to help and as curious passersby stopped to ask questions or make suggestions, and as the pieces moved as the sculpture came together.

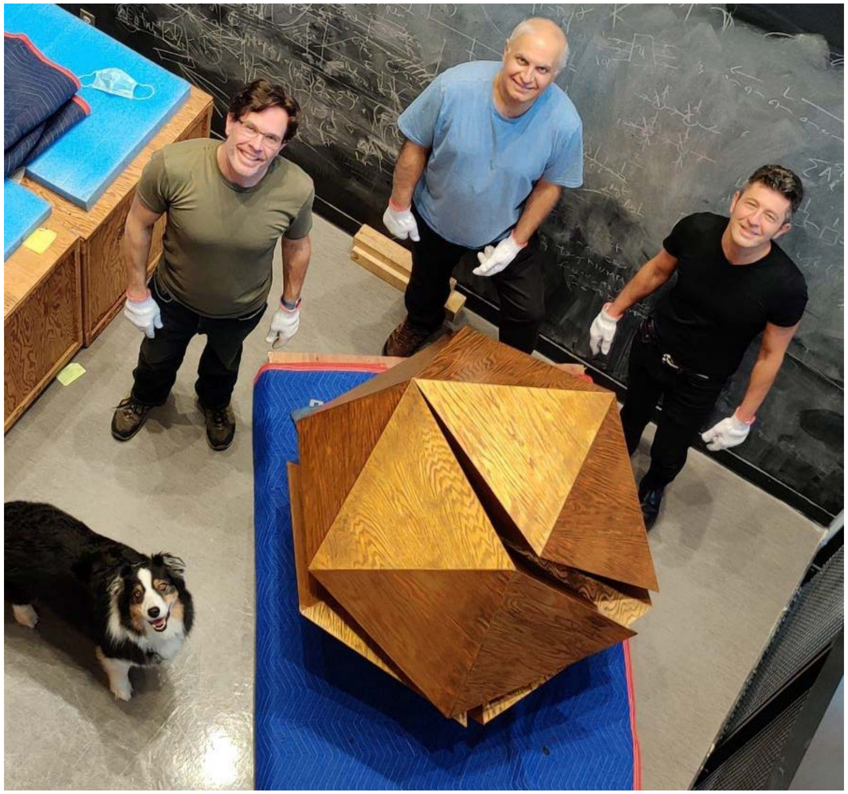
"The act of working together, of assembling the sculpture, becomes this sort of singular moment that can't be recreated," said Kivelson. "But the memory can be very, very impactful—like an 'art shadow' that extends out from the work, personalizing it."

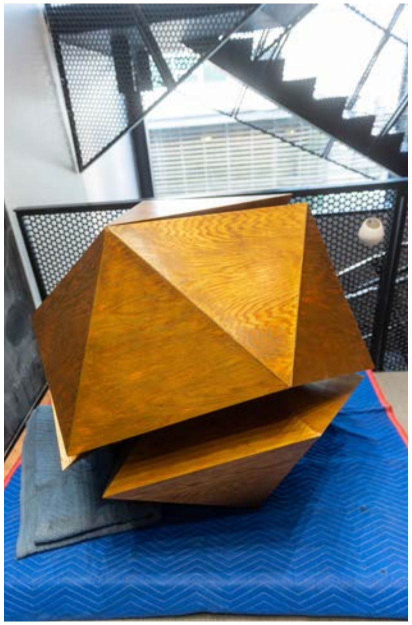
An icosahedron is a shape with twenty triangular plane faces, and while there is little in the macroscopic world that takes this shape in nature, it is not uncommon in miniature; some crystals, molecules, and viruses appear as icosahedra. By enlarging the piece, Kivelson has created something almost other-worldly and mechanically complex: it isn't intuitive, and that's the point.

In physics, frustration refers to conflicting forces that individually favor different arrangements of constituents (e.g. magnetic moments), and hence that result in complex structures. In the book *Statistical Mechanics: Entropy, Order Parameters, and Complexity*[1], author James Sethna describes a kind of frustration in relation to *The Frustrated Icosahedron* and another of Kivelson's works, *The Orange Peel Carpet*, as a type that "arises when the energetically favourable local packing of atoms or molecules is incompatible with the demands of building large structures."

"Frustration can lead to energetic instability, and eventually to a phase transition," said Damascelli. "And this is how new and exotic states of matter can be discovered and established."

Frustration can feel like an individual barrier to progress, but Kivelson's work aims to build connection, both between art and science and through collaborative works, including *The Frustrated Icosahedron*. Perhaps frustration is a catalyst: we spark creativity when we work together. If we look differently at what we think of as flawed, we can find beauty to admire.





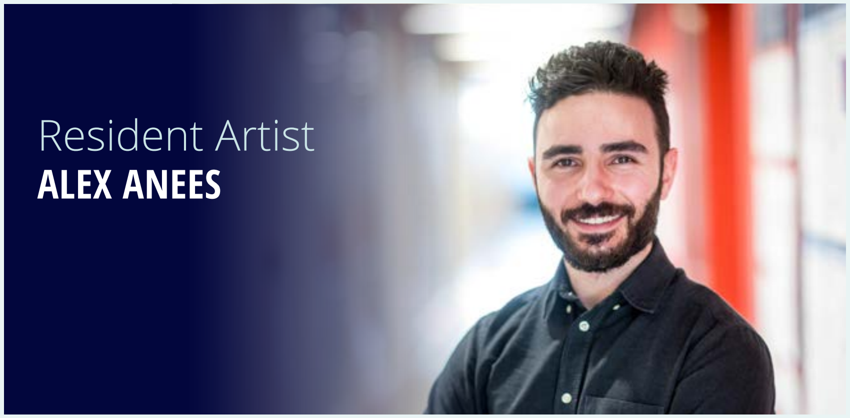
"What I like about this piece, with its cracks and seeming imperfection, is that it connects to the experience of being a researcher, the desire to understand the universe and our place within it, a process that comes with a full range of emotions—from stress, frustration, and pain, to excitement, liberation, and hope," said Damascelli. "And, after all, 'there is a crack in everything,' as Leonard Cohen wrote, 'that's how the light gets in.'"

"When you're trying to figure out how these pieces fit together, you reach into your subconscious to come up with associations and recollections and images," said Kivelson. "I think there's something really wonderful about the fact that this object has such a rich history, and so many intersections with different physicists and publics. *The Frustrated Icosahedron* is, in a way, a symbol of working together to solve problems that we cannot fix on our own."

[1] Sethna, J., Sethna, L. o. A. a. S. S. P. J. P. (2006). Statistical Mechanics: Entropy, Order Parameters, and Complexity. United Kingdom: OUP Oxford.

> One of the important purposes of art is to transform spaces by making novel phenomena visible."
>
> — Pamela Davis Kivelson

Resident Artist
ALEX ANEES



"You know, the world is your oyster," said Alex Anees, Research Operations Facilitator (ROF). "And that's true, but it can also be overwhelming."

Since joining the Stewart Blusson Quantum Matter Institute in 2017, Anees has become an essential part of the organization; in his role as a ROF, he supports several faculty members and operations needs, including working with Pinder Dosanjh on some projects, reports, and billing and invoicing for the cleanroom and the helium recovery plant.

In order to learn more about his new role, he began drawing. An artist at heart, Anees felt a need to connect with Blusson QMI in a creative way. The complexity of the research taking place at the institute is only part of the story; for people to connect with this place, Anees thought, it was important to get to the core of what Blusson QMI is about. His drawings, originally meant to support event-related communications, have become a feature of the institute.

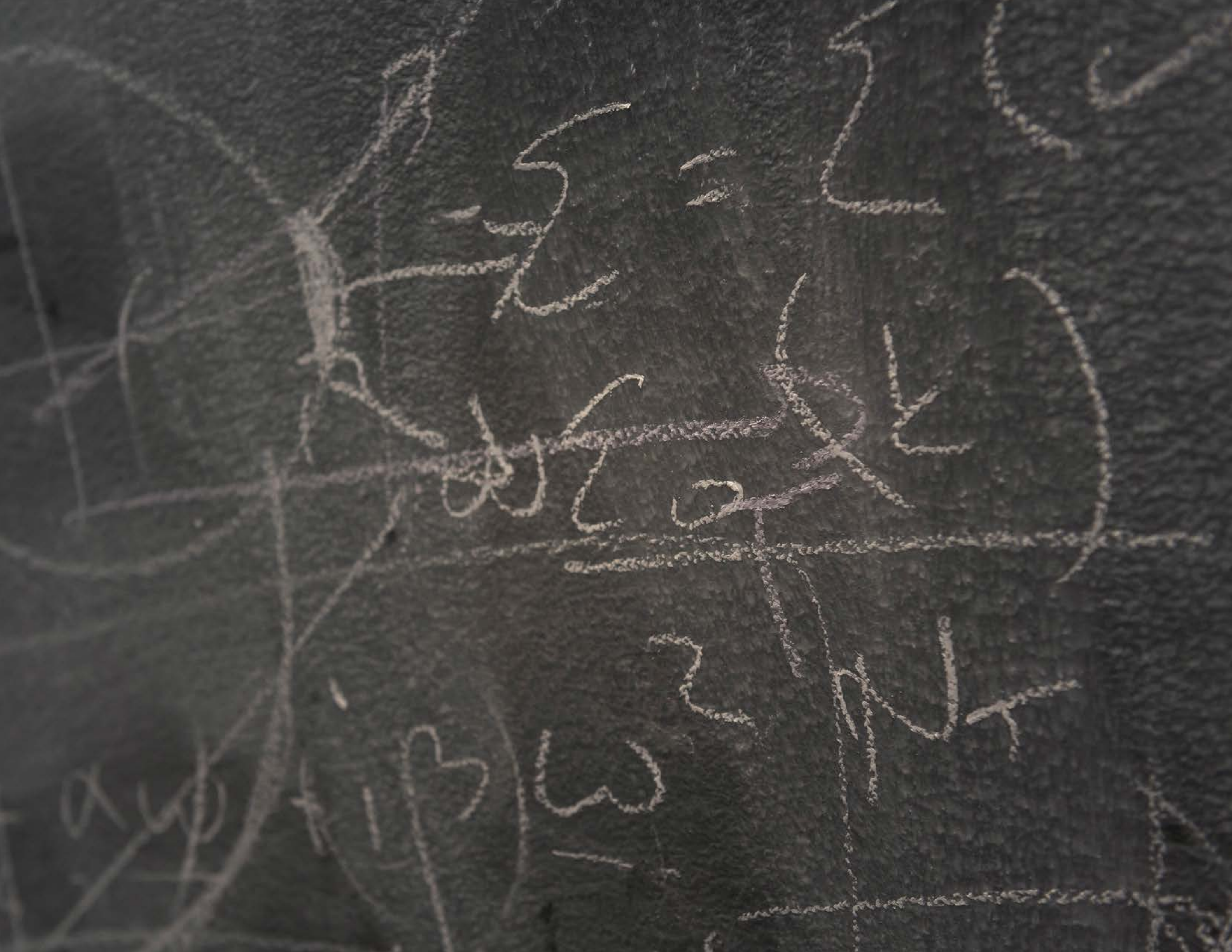
"I wanted to better understand research at Blusson QMI, even when aspects of it feel abstract; drawing came from a need interpret it in meaningful way, to define its personality," he said. "I wanted people to feel connected with this place."

Anees wants people to feel spoken to, and to feel like the things taking place at the centre—whether that's events, workshops, or even something as simple as Doughnut Day—are for them.

"I don't want this to sound like a cliché, but the thing that I am most interested in is learning," he said. "As an introvert, I spend a lot of time just listening and thinking. Sometimes, I connect with an idea, and then I like to spend my time figuring out how to make it happen; art is often the medium, but it's not about a particular tool; it's learning how to make something a reality, in the form that best suits the idea."

It's this keen ear and desire to make things happen that has helped Alex find his place at Blusson QMI.

"When I started in 2017, I wasn't sure what I wanted to do, and I was just happy to be working at UBC. Working as a ROF has been a completely surprising opportunity," he said.




RESEARCH

GRAND CHALLENGE | 2D MATERIALS

Our Grand Challenge: ***Engineering exotic phases in two-dimensional (2D) materials*** matured in 2021, with progress in several key areas, including equipment and publications. In particular, we built on some key experimental-theoretical collaborations. In addition to the projects highlighted in this section, we have also discussed related work from Ke Zou in our Research Highlights section (page 21) and Ziliang Ye in our section on our collaboration under the Max Planck-UBC-UTokyo Centre for Quantum Materials (page 34).

TUNING MAGNETISM IN TWISTED DOUBLE BILAYER GRAPHENE

A 2D material stacking facility opened at Blusson QMI in 2019; the facility enables exfoliating and stacking of 2D materials and offers capabilities for high-yield and large-flake exfoliation of various van der Waals materials, automated searching for microscopic flakes, and techniques for making twisted heterosamples. Manabendra Kuiri, a Research Associate in Joshua Folk's lab, has worked to develop the ultra-precise stacking capabilities necessary to make cutting-edge twisted 2D materials. Such twisted electronic devices are sometimes referred to as "twistronic" systems. Kuiri has focused on twisted double bilayer graphene, an engineered material formed by taking two bilayers of graphene and stacking them on top of each other with a small-angle twist between them. Twisted double bilayer graphene offers a powerful experimental platform for studying twistronic materials because most of its properties can be controlled using gate voltages, which can easily be tuned in situ during an experiment.

Building off the twistronics stacking capability he helped to implement, Kuiri and colleagues have discovered that, for the right set of gate voltage applied to the sample, spontaneously broken time-reversal symmetry (that is, magnetism) and anomalous Hall effect emerge in twisted double bilayer graphene. In other words, just by setting some voltages a certain way, Kuiri can generate a magnetic state where there wasn't one before.

"Other researchers have observed broken time-reversal symmetry in other twisted materials, but it's not yet clear if our observations share a similar origin," said Kuiri. "It's not the first time we have seen these properties in graphene structures, but there is a lot of excitement around twisted double bilayer graphene because there are still a lot of questions about what the essential ingredients are that make something magnetic."

"The unifying feature between graphene in various compositions seems to be that magnetism occurs when the bands are flat," said Folk. "The appearance of correlated states, like magnetism or superconductivity, in twisted 2D materials with flat bands is connected with a wider set of work in Blusson QMI's 2D Grand Challenge; what's especially helpful with this material is that we can tune the bands by adjusting the gate voltage, giving us more flexibility in the samples we measure as we can tune them even when they're in the cryostat."

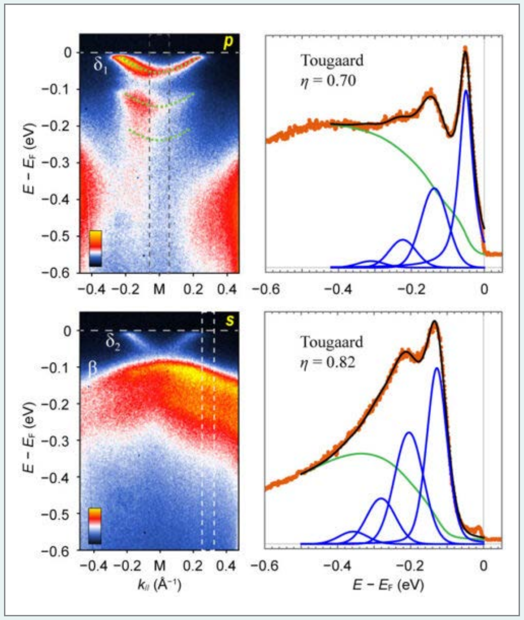
This work is important because it informs the ultimate question of how exotic electronic states emerge out of interactions between particles in bands where topology plays an important role. For example, twisted double bilayer graphene and twisted bilayer graphene share many similarities in their band structures—like flat bands—but some important differences as well. Understanding, in detail, which properties of the two materials are the same and which are different helps the community understand the driving mechanisms behind each of these properties.

Joshua Folk

M. Kuiri, C. Coleman, Z. Gao, A. Vishnuradhan, K. Watanabe, T. Taniguchi, J. Zhu, A.H. MacDonald, J. Folk. *Spontaneous time-reversal symmetry breaking in twisted double bilayer graphene.* arXiv:2204.03442 (2022).

NEW INSIGHTS ACHIEVED ON THE THINNEST HIGH-TC SUPERCONDUCTOR — MONOLAYER FeSe

Ke Zou



Pictured: Multiple replica bands of monolayer FeSe/SrTiO3 measured with linearly polarized light.

Two works from Ke Zou's team uncovered the mechanisms of the enhanced superconductivity in monolayer superconductor FeSe—the thinnest high-temperature superconductor. The papers, published in *npj Quantum Materials,* provided new insights into the electronic structure of the material, the physical origin of its photoemission replica band, and its behavior when it is placed next to strong magnetic moments.

The first work, led by first-author and Zou lab postdoctoral fellow Chong Liu, used a novel experimental approach to examine a pair of existing theories for this thin film's specific behaviors. The experiments were conducted at the CFI- and BCKDF-funded Quantum Materials Spectroscopy Centre (see page 38), a state-of-the-art beamline facility developed at the Canadian Light Source (CLS) under the leadership of Andrea Damascelli, where Liu and colleagues were able to employ polarization-dependent angle-resolved photoemission spectroscopy (ARPES) to examine the intensity of the replica bands.

"Energy bands" describe the energy and momentum distribution of electrons in a given material. Replica bands are shaken off from the original bands by passing energy from electrons to phonons. This phenomenon is unique among superconducting films, in that it has only been observed on monolayer FeSe on oxide substrates.

Polarization-dependent ARPES gives a much clearer perspective on individual energy bands, reducing background "noise" and enabling researchers to observe the true intensity of the replica bands in the photoemission spectrum.

"This is the first time we were able to demonstrate experimentally in this material how an electron can excite multiple phonons, losing energy multiple times," said Liu.

However, this observation has also resulted in new questions. The results Liu and colleagues were able to achieve now cast doubt on some earlier held conclusions. The intensity of the replica band is much higher than researchers originally thought, and higher than the previously predicted value, and so existing theories may need to be revisited. Regardless of the background the researchers chose, the replica intensities they extracted were higher by at least a factor of two.

This paper builds on a theory proposed by Sawatzky and Li that the replica band process could be extrinsic, occurring after the electron has been excited by a photon.

"Using the synchrotron light source at CLS, we were able to choose different polarizations of the photons, which gave us a big improvement on the data, which is the key to getting the clear replica bands," said Liu. "Now we can see that the puzzle still lingers: the intensity of the replica bands cannot be fully explained by the either intrinsic or extrinsic scenarios, so it's too early to draw a conclusion. We may need more theories to explain what is going on."

In the second work, published in *npj Quantum Materials,* the team explores the superconductivity in FeSe, when FeSe is placed right next to strong magnetic moments. In certain materials, when electrons spin they create a magnetic field that can be harnessed to develop spintronic devices, a type of technology that derives its power from the spin of an electron rather than the charge used in conventional electronics. However, spin polarization and superconductivity often compete with each other. Research uncovered an interfacial structure that can enhance the superconductivity of FeSe by a magnetic oxide. This new material could be a possible spintronics platform useful in the development of future spintronic applications.

The findings offer a new look at the origin of superconductivity in monolayer FeSe/titanate materials and their viability as a platform for spin-charge devices, and build on previous Zou lab studies on the mechanism underlying the enhanced superconductivity in monolayer FeSe grown on SrTiO3, a material that is in the same perovskite family as EuTiO3. This discovery affirms that this material is a viable platform for understanding the interplay between the spin and charge in monolayer titanite materials.

The researchers combined two-dimensional (2D) FeSe layers with europium titanate (EuTiO3) in order to bring the magnetic order into the interface and examine its effect on superconductivity. Using Zou's Canada Foundation for Innovation-funded molecular beam epitaxy (MBE) laboratory—the Quantum Materials and Devices Foundry—Liu and colleagues grew the sample in an ultrahigh vacuum environment, and then studied its properties using X-ray absorption spectroscopy (XAS), transport measurements, and angle-resolved photoemission spectroscopy (ARPES).

"This technique helps us see the magnetization of the EuTiO3 film," said Liu. "When we change the external magnetic field, we can confirm that the material can be switched from antiferromagnetic to ferromagnetic."

"The film is just a few nanometers thick," said Liu. "But we are able to achieve high-temperature superconductivity at a transition temperature of 30 degrees Kelvin, together with a magnetic state that can be tuned by an external magnetic field, making this potentially useful for spintronics applications."

The team confirmed their findings using ARPES, in collaboration with Damascelli and Blusson QMI colleagues.

"Using ARPES, we could see large electron pockets, meaning that the film is electron doped," said Liu, describing a process by which charge carriers are added to the film in order to modify their electronic properties. "These electrons come from the EuTiO3 layers, similar to what we saw happen in FeSe/SrTiO3."

C. Liu, R.P. Day, F. Li, R.L. Roemer, S. Zhdanovich, S. Gorovikov, T.M. Pedersen, J. Jiang, S. Lee, M. Schneider, D. Wong, P. Dosanjh, F.J. Walker, C.H. Ahn, G. Levy, A. Damascelli, G.A. Sawatzky, and K. Zou. *High-order replica bands in monolayer FeSe/SrTiO3 revealed by polarization-dependent photoemission spectroscopy.* Nat. Commun. **12**, 4573 (2021).

C. Liu, H. Shin, A. Doll, H.H. Kung, R.P. Day, B.A. Davidson, J. Dreiser, G. Levy, A. Damascelli, C. Piamonteze, and K. Zou. *High-temperature superconductivity and its robustness against magnetic polarization in monolayer FeSe on EuTiO3.* npj Quantum Materials **6**, 1 (2021).

TITANIUM OXIDE—A SUPERCONDUCTOR—DISTINGUISHED FROM OTHER TRANSITION METAL MONOXIDES

Quantum materials are the basis for many emerging quantum technologies, but the extent to which individual elements are understood depends on scientists' ability to produce these materials in the laboratory and study them. 3d transition metal monoxides, a class of compounds, represent a well-studied family of quantum materials, and most are insulators; one exception is titanium monoxide (TiO), which had not been examined in its single-crystal state.

A collaboration between George Sawatzky, Ke Zou, and teams at the Canadian Light Source (CLS) in Saskatchewan has resulted in new clarity around the intrinsic properties of TiO. Published in *Science Advances,* these results resolve a lingering uncertainty around the behaviour of TiO, revealing that it behaves similarly to its metal counterpart, distinguishing it from other transition-metal monoxides.

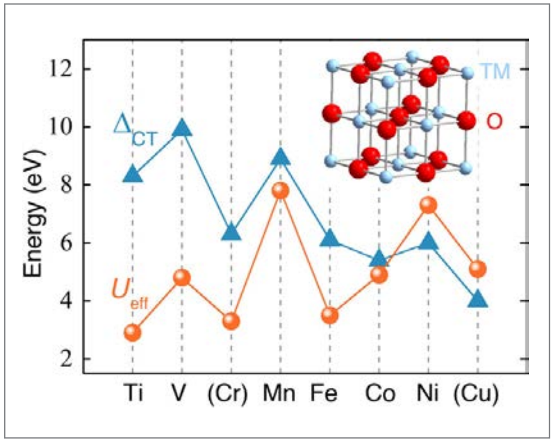
"Prior to our work, it was not clear whether TiO is a metal or an insulator," explained Fengmiao Li, a Research Associate who works closely with Sawatzky and Zou, and first author on the paper. "We demonstrate with this new publication that TiO is both a metal and, below 0.5 degrees Kelvin, transitions to a superconducting state, similar to Ti in its metal state; it is the only superconductor in a family of compounds that are otherwise insulators at low temperatures."

It has been difficult to develop a pure TiO crystalline sample for study; atomic titanium favors a bond with two oxygen atoms forming titanium dioxide (TiO2). Using a technique called molecular beam epitaxy, Li and colleagues were able to stabilize the compound and generate the cleanest TiO thin film to date.

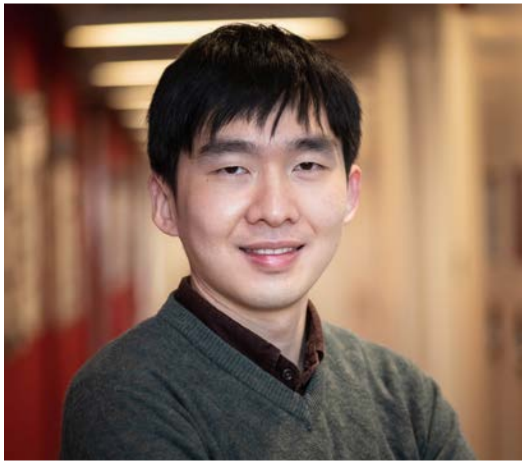
"This recipe for growth was established at CLS, where they have the capacity to do the kind of in situ spectroscopy necessary to examine the cultivated films, guiding crystal growth in order to produce clean samples for research," said Li.

Now that the team has a recipe for the thin film, they can grow pure crystals in the lab at Blusson QMI, and work to further understand the material and its potential applications. A theoretical understanding of the superconductivity has also been presented in their manuscript.

F. Li, Y. Zou, M.G. Han, K. Foyevtsova, H. Shin, S. Lee, C. Liu, K. Shin, S.D. Albright, R. Sutarto, F. He, B.A. Davidson, F.J. Walker, C.H. Ahn, Y. Zhu, Z.G. Cheng, I. Elfimov, G.A. Sawatzky, K. Zou. *Single-crystalline epitaxial TiO film: A metal and superconductor, similar to Ti metal.* Sci. Adv. 7, eabd4248 (2021).



Pictured: The value of the effective d electron Coulomb repulsion and the charge-transfer energy in 3d transition-metal monoxides. The inset image shows the rock salt structure of 3d transition metal monoxides.



Left to right: Marcel Franz, Oguzhan Can, Ziliang Ye

NEW TWIST CREATES EXPERIMENTAL FRAMEWORK FOR UNCOVERING TOPOLOGICAL SUPERCONDUCTIVITY

Last year, Marcel Franz published new theoretical work that proposed combining two monolayer-thin sheets of copper-based superconductors in a twisted configuration would lead to topological superconductivity. Superconductivity is a quantum state of matter that occurs at very low temperatures. The state enables frictionless motion of electrons, meaning that electrical current does not lose energy in the form of heat and can persist indefinitely. Topological superconductors are a special class of superconductors with interesting and unusual properties that could be useful in future quantum computing technologies.

“We are interested in topological phases since they are novel phases of matter with potential device applications,” said Oguzhan Can, PhD student in the Franz lab and co-first author on the paper. “Our calculations show that when two layers are twisted and stacked in a certain way, a new phase of matter called topological superconductivity emerges.”

This new work from Franz, Can and colleagues proposes an experiment to verify their theory that combining two monolayer-thin sheets of copper-based materials (such as Bi2Sr2CaCu2O8+δ, or “BSCCO”) in a twisted configuration will lead to topological superconductivity at potentially higher temperatures than in previously established superconducting materials, making the study of these materials more accessible for researchers and industry scientists.

Ziliang Ye and colleagues are currently working on the twistronics experiment Franz and colleagues proposed, also using the new van der Waals (2D materials) facility.

“We are measuring so-called optical Kerr effect in the light reflected off the twisted BSSCO structure,” explained Ye. “It’s a complex experiment, with many technical aspects pushing the limits of instruments, and the work is underway.”

“The idea is that when we shine light onto a two-dimensional sample, we can compare the relative rotation of the polarization of the light upon its reflection off of the surface of the sample. This is called the Kerr rotation and it is observed when there is an effect called ‘time reversal symmetry breaking’ which is not present in the isolated BSCCO monolayers,” explained Can. “However, if we consider stacking two monolayers in the twisted configuration, our earlier theory work predicts this effect, resulting in finite Kerr rotation, as the mechanism that drives topological superconductivity.”

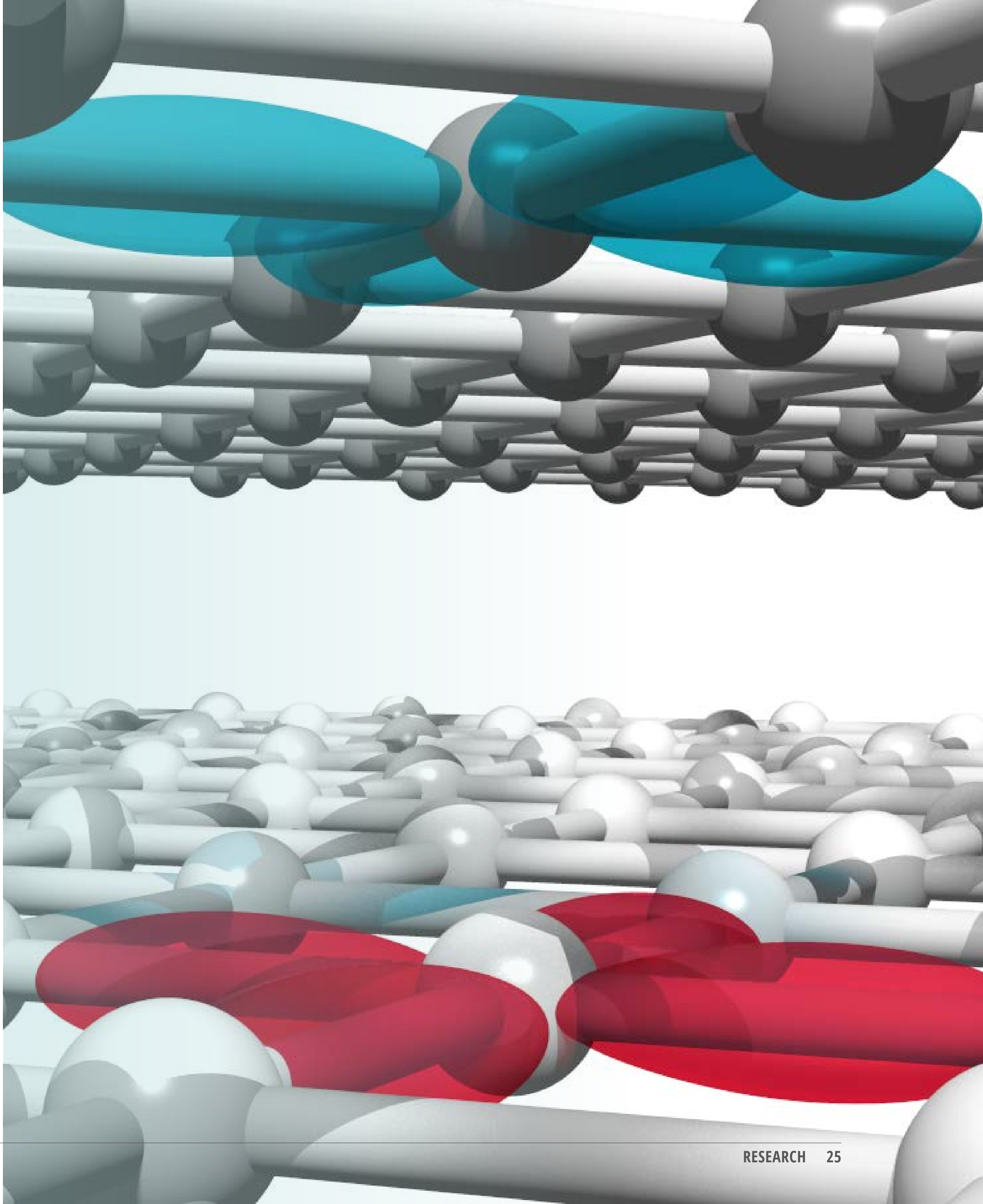
“In this recent work, we estimate the magnitude of Kerr rotation in twisted BSCCO samples, which turns out to be quite large compared to what is expected of other topological superconductor candidates. If Ziliang’s group measures a Kerr rotation, it will be experimental evidence towards topological superconductivity in twisted BSCCO,” said Can.

O. Can, X.X. Zhang, C. Kallin, and M. Franz. Probing Time Reversal Symmetry Breaking Topological Superconductivity in Twisted Double Layer Copper Oxides with Polar Kerr Effect. Phys. Rev. Lett. **127**, 157001 (2021).

OTHER HIGHLIGHTS

- Ye received Research Tools and Instruments funding from the Natural Sciences and Engineering Research Council in 2021 to construct a Zero-loop Sagnac Interferometer for probing the optical Kerr effect theorized by Franz and Can.

- A new Multi-Dimensional Coherent Spectrometer is now operational under the direction of David Jones. Multi-Dimensional Coherent Spectroscopy enables simultaneous measurement of optical response in both time and frequency domain, and unwrapping it in two (or more) dimensions enables the study of correlated behaviour of excitons and is also a perfect tool for studying Bose-Einstein Condensation excitons in 2D systems.



GRAND CHALLENGE | DISORDERED MATERIALS

The goal of the Grand Challenge: ***Atomistic approach to emergent properties of disordered materials*** is to examine the atomic-scale mechanisms and conditions under which different forms of entropy can lead to new behavior in materials. From Alannah Hallas' work on high chemical disorder within high-entropy oxides, to structural disorder and the LIGO team, to thermal disorder and Alireza Nojeh's team's focus on improving the efficiency of solar energy conversion, this challenge has implications ranging from cleaner ways to power our world, to better detection of the gravitational waves produced by black holes in our galaxy.

ATOMISTIC APPROACH TO EMERGENT PROPERTIES OF DISORDERED MATERIALS

In 2021, Alannah Hallas and colleagues produced the first phase-pure samples of magnetic high-entropy oxides.

"The reason we are interested in high-entropy materials is that they have an aspect of disorder that contributes to the stabilization of these materials: if there are five different elements within a single crystal, for example, we can arrange these in specific ways that give a material properties that it wouldn't normally have," said Alannah Hallas.

The atoms in naturally occurring crystals form a predictable pattern within a given material. In Hallas' lab, researchers combine those naturally occurring elements within a single crystal in order to generate specific properties, such as magnetism, that would not necessarily exist within a conventional material.

Hallas and colleagues designed a material that is magnetic, with five magnetic elements that are randomly distributed throughout a material—not the neat arrangement one might find in nature—with a goal to control the overall magnetism of the crystal by replacing the magnetic elements with non-magnetic ones. This way, they can see how the magnetism changes and how different elements contribute, and whether they work together or independently.

"In these materials, you can have so much disorder that the entropy itself becomes the most important property," said Hallas.

To understand these properties, Hallas has been collaborating with Robert Green, a Blusson QMI Affiliate Investigator at the University of Saskatchewan and the Canadian Light Source (CLS) to use x-ray technology to probe individual elements and understand each one in isolation. At CLS, Green took Hallas lab samples and collected x-ray data; back at Blusson QMI, PhD student Mario Ulises González Rivas has been analysing that data.

In many ways, the *Atomistic approach to emergent properties of disordered materials* challenge is symbolic of the mission and vision of Blusson QMI as a whole, with projects like Hallas' linking UBC researchers with teams across Canada, while also relying on the historical context provided by trailblazing researchers like George Sawatzky.

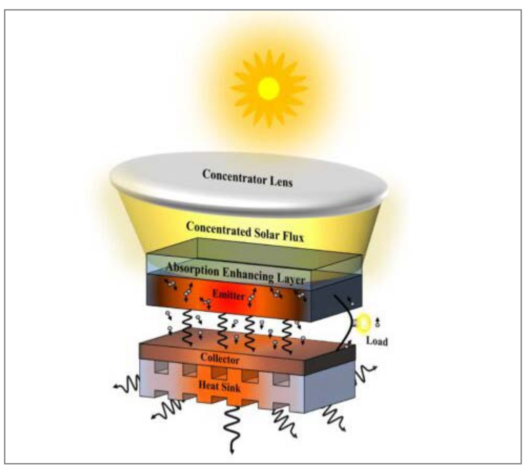
"Interestingly, George did his PhD work on crystal formations not unlike the ones we're studying, and so he's been helping us with this project at a very high level and guiding us toward questions and results we may not have known to look for," said Hallas.

In addition to Hallas' work, Ke Zou and colleagues are looking at other approaches to producing high-entropy oxides using molecular beam epitaxy and the newly refurbished pulse laser deposition device. For more on Zou's research, see page 21.

Alannah Hallas

SCALING UP SOLAR ENERGY CONVERSION TO GENERATE CLEANER ELECTRICITY

Ehsanur Rahman



The amount of radiation the sun delivers to the earth's surface in a single hour could supply the entire world with electricity for a year. To harness the full potential of solar energy, however, scientists must first overcome some critical performance gaps to convert sunlight into useful electricity. Research from investigators at the Blusson QMI, published in *Nature Communications,* offers a theoretical framework for—and insight into how— semiconductors can be used for efficient energy conversion using the mechanism of thermionic emission.

Global energy demand is increasing at a time when deriving energy from fossil fuel sources continues to harm the environment. For decades, researchers have pursued cleaner, more renewable forms of energy, and for a long time photovoltaic (PV) solar cells—like those used in solar panels—have been at the forefront of capturing solar energy. PV devices are effective, but commercially established solar panels offer only around 20% efficiency, losing significant energy in the form of heat. Loss of heat means that the device does not produce as much electricity; heat also causes the performance of the device to degrade more quickly.

The ability to transition to clean, renewable forms of energy at a global level is more urgent than ever, and researchers have been attempting for decades to increase the efficiency of existing solar harvesting technologies, including PVs. An alternative approach, thermionic energy conversion, a mechanism complementary to photovoltaics that is capable of exploiting heat, has been known to researchers for over a century.

Thermionic emission relies on heating a material to very high temperatures so that it emits electrons. In 2010, a research group from Stanford University proposed an interesting method to use optical excitation by solar photons to enhance thermionic energy conversion: their idea was to exploit both the quantum and thermal nature of solar photons, turning a problem into a benefit to maximize the energy captured by solar cells.

Like in a PV solar cell, a photon-enhanced thermionic energy converter can generate electricity, but crucially, it uses the energy of the solar photons that would be lost as heat in a PV device. Despite the promising nature of this approach, it has not yet surpassed the existing PV solar cells in terms of performance in experimental studies.

The Blusson QMI study, led by Ehsanur Rahman, Vanier scholar and PhD candidate in the Department of Electrical and Computer Engineering (ECE), demonstrated that while the idea of photon enhanced thermionic emission shows promise, there are still critical limitations to this approach to energy conversion.

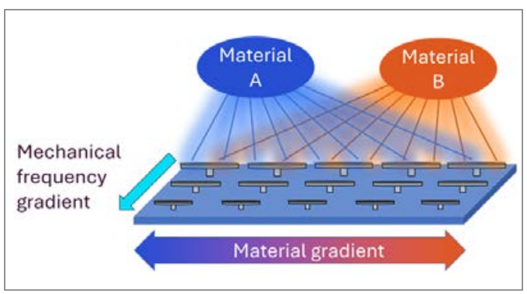
Apart from the engineering challenges, this new research demonstrates that there is a gap in our fundamental understanding of this new solar cell's operational mechanism. Up until now, researchers had assumed that the photon enhancement effect (which can improve the efficiency of thermionic emission by further reducing the vacuum barrier for electrons) can be taken for granted in this type of solar cell; Rahman and Alireza Nojeh, Principal Investigator at Blusson QMI and Professor in the Department of Electrical and Computer Engineering, demonstrate that the photon enhancement effect may not always occur as expected.

"The realistic potential of this new solar cell concept is limited by several fundamental loss mechanisms," said Rahman. "We believe our findings have the potential to elucidate the workings of this solar conversion approach and facilitate the design of an efficient thermionic solar cell that could one day surpass its PV counterpart."

E. Rahman, A. Nojeh. *Semiconductor thermionics for next generation solar cells: photon enhanced or pure thermionic?* Nat. Commun.**12**, 4622 (2021).

LIGO COATINGS TEAM NOW BUILDING CAPACITY

Kirsty Gardner



Pictured: Diagram of microdisk array with geometry that varies along one axis, and material composition along the other.

The Laser Interferometer Gravitational-Wave Observatory (LIGO) is a US-based gravitational-wave research and detector development, observation, and data analysis facility. The Grand Challenge team at Blusson QMI is working with colleagues at UBC to develop better amorphous materials for coating films that suppress mechanical vibrations while keeping efficient desirable properties like reflectivity for current Advanced LIGO detectors and future ground-based gravitational-wave observatories.

The team, which includes Joerg Rottler, Jeff Young, and Ke Zou, as well as Jess McIver, who leads the UBC arm of the LIGO collaboration, has been working to devise experimental set-ups in which to test potential materials. Kirsty Gardner, a postdoctoral fellow who joined the team in May 2021, is working on the microfabrication of vibrating microdiscs that will enable the characterization of new materials.

Gardner and Matthew Mitchell, both supervised by Jeff Young, are focused on the experimental characterization of thin films created using Molecular Beam Epitaxy in the Zou lab to compare against theoretical models from Rottler. However, current methods of measuring potential materials are time-consuming: existing tools enable researchers to take high-quality measurements, but the process is slow.

“We’re focused right now on devising the experimental infrastructure for this project,” said Gardner. “We’re currently building a high-throughput system that will increase the Grand Challenge team’s capacity to measure a larger number of samples at once, partially automating the process so we can characterize candidate materials more efficiently.”

Gardner, Mitchell, and colleagues are currently building vacuum chambers and testing techniques on single devices to inform the construction of the high-throughput system. The devices are microscale mechanical resonators onto which thin films are applied; these are tested using a vacuum chamber system developed in-house.

“We’re just about ready to do our first in-vacuum measurements, which lead to much cleaner measurements that tell us a lot more about a material’s properties,” said Gardner. Much of what the team needs to properly characterize prospective materials has to be created at Blusson QMI.

In addition to Gardner and Mitchell’s work, a team of undergraduate Engineering Physics students has been working on a project titled *High Throughput Testing of Coating Mechanical Loss for Advanced LIGO*. The students—Alexi Garbuz, Bridget Meyboom, Dora Yang, and Ray Su—have been working on data analysis and designing tools to measure the vibration of the materials on the microdisks and separate the material’s signal from the background noise caused by the vibration.

“The vibrating signal that we’re looking for is quite small, and it can be somewhat tricky to filter it from the background,” said Gardner. The signal occurs at a specific frequency, and over time, it weakens and can become lost in the noise of the measurement equipment.

Currently, the team is primarily focused on proof-of-concept work to ensure that the tools are effective before moving on to potentially more exotic materials in the future.

THE FUTURE OF RESEARCH WILL BE AUTOMATED

B.P. MacLeod, F.G.L. Parlane, A.K. Brown, J.E. Hein, C.P. Berlinguette. *Flexible automation accelerates materials discovery.* Nat. Mater.(2021).

Automation is under-used in materials research and could accelerate the discovery of quantum materials. Flexible, robotics-driven automation enables the rapid creation of new automated experiments and empowers researchers to solve problems faster and with greater agility.

Flexible automation capitalizes on synergistic advances in robotics, rapid prototyping, computer vision, and open-source software ecosystems. Its major benefit is that it is customizable across a range of inorganic and organic materials and applications, reducing manual steps in even the most intricate experiments.

Materials discovery is foundational for new technologies, particularly in the clean energy sector. But while the need for clean energy technologies is urgent, the process of discovering and engineering these prospective materials can take decades using conventional approaches. According to Curtis Berlinguette, Professor in UBC's Departments of Chemistry and Chemical & Biological Engineering, automation could realize more efficient technologies sooner, and at a lower cost.

"Flexible automation makes robotics accessible to materials researchers," said Berlinguette. "The diverse experimental workflows used in materials science often require highly customized automation that is not commercially available. 'Flexible automation' is changing this situation because of the recent emergence of safer, cheaper, and more user-friendly robotics."

Berlinguette and colleagues have refined an automation process that originated with Ada, an artificially intelligent, self-driving laboratory able to explore formulations for a type of thin-film material common to advanced solar cells and consumer electronics. While it is inherently challenging to automate materials experiments, Ada can process around 50 consecutive samples without error, with other robotic platforms showing similar promise.

Canada currently leads the world in applying flexible automation to materials science due to an $8 million investment from Natural Resources Canada in Project Ada.

"This project has taught researchers around the world how to automate diverse workflows in the laboratory," said Berlinguette. "Flexible automation also enables the materials science community to realize the full potential of machine learning algorithms. We used flexible automation to build the world's first 'self-driving lab' for clean energy materials."

With substantial investment from the Government of Canada in a National Quantum Strategy, and leadership in quantum materials and technology at several leading institutes including Blusson QMI at The University of British Columbia, advances in flexible automation and self-driving laboratories will further cement Canada's leadership role in advanced materials innovation.

Berlinguette and his team will establish their hub, the Flexible Automation Lab, in Blusson QMI in 2022. Their move to this newly renovated, larger space will bring them closer to other Blusson QMI researchers, including those working on thin films and coatings under the *Atomistic approach to emergent properties of disordered materials* Grand Challenge.

GRAND CHALLENGE — QUANTUM COMPUTING

Pushing the boundaries of Noisy Intermediate Scale Quantum (NISQ) computing by Focusing on Quantum Materials

Researchers with the ***Pushing the boundaries of Noisy Intermediate Scale Quantum (NISQ) computing by Focusing on Quantum Materials Problems*** Grand Challenge (QCGC) made considerable progress and established clear priorities and milestones for the road ahead in 2021. In particular, the machine learning collaboration linking Joseph Salfi and Roman Krems progressed, building on a 2019 pilot study that investigated the capabilities of hypergraph states for entanglement distribution. Efforts continued to meet key targets related to the primary goals of the Challenge's three main pillars: Machine learning, Hardware Quantum Simulator, and Fundamental analysis of quantum computer programming approaches (Theory).

REFINING THE ROADMAP

Jeff Young, Lukas Chrostowski, and Robert Raussendorf are partners with a team from Simon Fraser University (SFU) on a CFI-funded project titled 'Silicon Quantum Leap' that aims to use photons to interrogate and manipulate the spin of electrons in isotopically pure silicon (Si). The project lead, Stephanie Simmons from SFU, has identified a class of atoms and defects that have a long spin-coherence time, which makes this system an attractive platform for a potentially scalable quantum computer.

Long spin-coherence time offers stability and longer processing for quantum information stored in the electron spin state of the defects. The ability of photons to interact with those spins enables the manipulation of that stored quantum information using optical rather than electrical "wires", which offers engineering advantages as photons are by their nature ideal transporters of (quantum) information.

The question of how to use these long-lived spin coherence times and quantum memories on a commercially-scalable platform is one that researchers at Blusson QMI are uniquely positioned to address:

- Chrostowski brings expertise in silicon photonic components,
- Young is a leader in the area of photonic crystals and silicon quantum photonic information technology;
- Raussendorf is well-known for his ground-breaking work in the field of measurement-based quantum computing.

Jeff Young and Chrostowski's teams, PhD student Xiruo Yan and postdoctoral fellow Andreas Pfenning, have offered a bird's-eye view of the road ahead for quantum computing research based on a silicon photonic platform. The paper based on their work was published this year in the journal APL Photonics, and served as the foundation as researchers came together in September to establish some critical milestones in the QCGC.

In 2020, Young and Raussendorf, with first author Xiruo Yan, proposed a universal and scalable fault-tolerant circuit architecture and a protocol for realizing 3D cluster states through photonic-measurement-based donor-spin-qubit entanglement and readout.

The paper, published in the journal *Advanced Quantum Technologies,* described a theoretical framework for quantum computing in which single photons are used to interrogate, manipulate and entangle said donor spin qubits.

Building on that work, Young, Yan and Pfenning's road mapping paper took Raussendorf et al's framework and tested the ideas with one question in mind: "What kind of device properties do we need to achieve in order to actually realize this architecture on a silicon chip?"

"We're piecing together a puzzle, and it is exciting because we have world-leading expertise in silicon devices with Lukas Chrostowski and Jeff Young, and we have one of the most renowned theoreticians in quantum computing theory with Robert Raussendorf," said Pfenning.

X. Yan, S. Gitt, B. Lin, D. Witt, M. Abdolahi, A. Afifi, A. Azem, A. Darcie, J. Wu, K. Awan, M. Mitchell1, A. Pfenning, L. Chrostowski, J.F. Young. *Silicon photonic quantum computing with spin qubits.* APL Photonics **6**, 070901 (2021).

X. Yan, W. Asavanant, H. Kamakari, J. Wu, J.F. Young, R. Raussendorf. *A Quantum Computer Architecture Based on Silicon Donor Qubits Coupled by Photons.* Adv. Quantum Technol. **3**, 2000011 (2020).

QUIETING QUANTUM NOISE

Leon Ruocco, a postdoctoral fellow who works with Mona Berciu, has been developing a theoretical framework for the hardware aspect of the QCGC challenge.

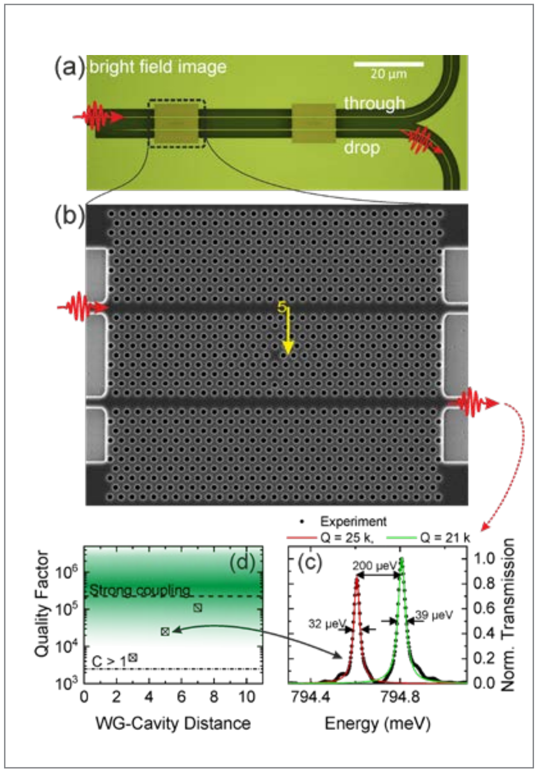
“Intelligent architectures are important, but for them to function you need the hardware to work properly,” said Ruocco. “Noisy intermediate-scale quantum computing is inhibited by decoherence, with ‘noisy’ being the operative word.”

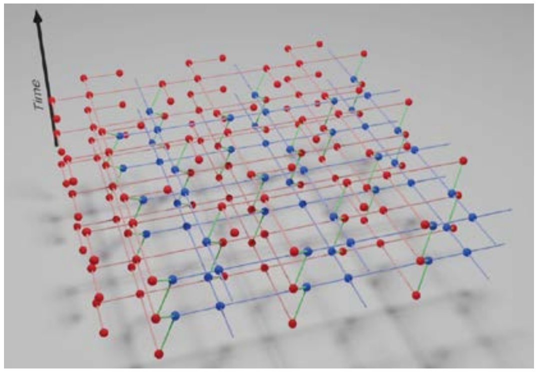
Ruocco has been particularly interested in the SFU work that looked at a particular manifestation of silicon qubit devices. The experimental results from Simmons’ team have been of interest to the quantum computing community of late, but certain features in the optical transition that connects the photons to the spin are not currently understood.

Young, Berciu and Ruocco have been conducting a theoretical modelling study of these processes to potentially unravel the physics underlying these anomalous results in the hope that by understanding these processes, they can propose an experimental process to improve functionality of silicon-based qubit devices.

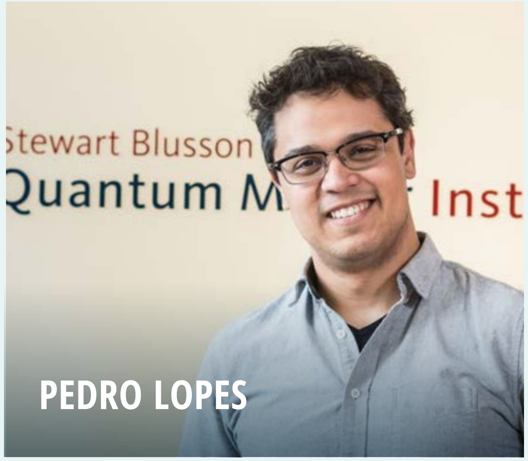
QUANTUM SIMULATION AND DEVICES

Joseph Salfi has been working to develop networks for a quantum dot-based device to simulate Fermionic particles and characterize the ability to control Fermi-Hubbard parameters in the simulator. In 2021, he developed a working formula, and the stability of the device exceeded expectations. Working with Roman Krems, Salfi and colleagues have been deploying machine-learning techniques to create a suite of artificially intelligent design tools that will enable targeted design of device parameters. The team is in the early stages of developing the hardware that will be used to explore the phenomenology of fermions related to unconventional superconductivity in a small simulator.





Pictured: A visual representation of the creation of 3D cluster states over time.



PEDRO LOPES

“With respect to the Grand Challenges, building these teams and making the structure function is a collective effort,” said Pedro Lopes. “But I miss Blusson QMI, where work gave as much to me as I gave to the Grand Challenges program.”

After completing his PhD at Universidade Estadual de Campinas in Brazil, Lopes was looking for something different, and so he traded the tropics for Canadian winter, arriving in Quebec for a postdoctoral role at L’Université de Sherbrooke. It was serendipitous timing to arrive in 2016, just after the Institut Quantique received Canada First Research Excellence Funding (CFREF): in many ways, the CFREF launched Lopes’ career. At the Institut Quantique, Lopes met and worked with Ion Garate who had previously been in an appointment as a postdoctoral fellow at UBC, where he had been supervised by Marcel Franz and Ian Affleck.

With CFREF funds to support some travel, and a strong bridge for networking from his then-supervisor at Sherbrooke, Lopes came to UBC to talk to Affleck and present his work. Their interests aligned.

“And I guess that’s how I ended up at the Stewart Blusson Quantum Matter Institute,” said Lopes, who arrived at UBC in 2018 to take on a postdoctoral research position.

In early 2020, Lopes moved into a staff position at Blusson QMI, taking on a project management role with the Project Management Office in support of the Grand Challenges program.

“When I was first thinking about making the change, I mentioned the idea to Robert Raussendorf, who expressed surprise—I was an active member of the research team, so I guess in some ways it was unusual,” said Lopes.

But the move came after some important lessons, which Lopes learned after living and working in Canada.

“I spent about a decade with the goal of being a professional scientist,” said Lopes. “In Brazil, careers in science can be limited—there are academic roles, but the type of work a scientist can do is not as wide-ranging as in other places.”

“When I came to Canada I started to see that there were opportunities beyond a professorship; a person could do work in science that wasn’t specifically academic research, and this is something I acknowledge about the Canadian system—you can absolutely do impactful, meaningful work as a scientist, beyond academia,” Lopes said.

As his career at Blusson QMI began to change and he grew into his role as Project Manager, Lopes realized that his goal was to do work that enabled him to connect more with people.

“Taking on a project management role was a matter of seizing an opportunity: if you don’t take opportunities as they come, eventually your life kind of gets decided for you. I think that’s why I decided not to pursue an academic role: I want to have the flexibility to be able to take things as they come.”

Lopes left Blusson QMI in late 2021 for a role with QuEra, a full-stack quantum computing company located in Boston, MA. Lopes now manages business development for the company, which he notes has parallels to Blusson QMI: it’s a lively, diverse environment where many different personalities and skill-sets work together to achieve big things.

“In everything you do, you bring your own dreams and your history and your life story: I think this is a positive step for me,” said Lopes. “As a student, you are blind to the system, and you don’t necessarily see how many people are involved in making a company or a department or an institute run. Doing science is a privilege, and I want to use my skills to make sure that the systems work for the next generations of researchers: I want to help people realize their goals.”

“Doing science is a privilege, and I want to use my skills to make sure that the systems work for the next generations of researchers.”

MAX PLANCK-UBC-UTOKYO CENTRE FOR QUANTUM MATERIALS

The Max Planck-UBC-UTokyo Centre for Quantum Materials (CQM) was formed in 2017 as an expansion of the original Max Planck-UBC Centre for Quantum Materials that was established in 2012. Now, all three organizations have committed to the extension of the Max Planck-UBC-UTokyo partnership into 2027. An important milestone for a Max Planck Society-partnered collaboration, this is the first time an international Max Planck centre has been extended beyond a ten-year period.

This Max Planck-UBC-UTokyo partnership combines internationally recognized scientists with extensive infrastructure for research in quantum materials. The CQM supports collaborative projects, scholarly exchanges, annual workshops, the International PhD Program in Quantum Materials, training for graduate students and postdoctoral fellows, and provides a platform for interdisciplinary exchange and cooperation.

The partnership has been fruitful, with about 250 joint publications since 2012. The citation impact of papers published under the CQM banner is well above average, many of them field-leading. All of these projects have benefited from complementary expertise in experimental and theoretical methods established at the partner institutions, with the sharing of critical infrastructure, such as the synchrotron facilities at the Canadian Light Source in Saskatchewan, or at Bessy in Berlin.

The CQM renewal is a testament to the commitment of the partners and the strength of the collaboration; reflecting the viability of the partnership, the CQM will continue to be funded at the same level as it was in its first decade. In addition, the CQM has attracted major investments from the Moore Foundation and MITACS, who have committed to funding that will support graduate student training and internship opportunities. In 2021, Hao Tjeng (Director, Max Planck Institute for Chemical Physics of Solids, Dresden) and Bernhard Keimer (Director, Max Planck Institute for Solid State Research, Stuttgart) were appointed adjunct professors at UBC; similarly, Andrea Damascelli was appointed a Fellow at the Max Planck Graduate Centre for Quantum Materials in Germany.

For graduate students, postdoctoral fellows and junior faculty associated with the CQM, participation in partnership activities provides the opportunity to access critical research infrastructure and equipment, and build an international network of collaborators among leading experts in quantum material research. The CQM will also retain its leadership; it will continue to be led by co-directors Bernhard Keimer, Andrea Damascelli, and Ryo Shimano (University of Tokyo, Japan).

> **“Our partnership with the Max Planck Society and the University of Tokyo has been a very fruitful one for UBC and for quantum research in Canada at large. I'm looking forward to the continued progress in this partnership and continued breakthroughs in quantum research in the years ahead.”**
>
> — Santa Ono
> UBC President and Vice-Chancellor

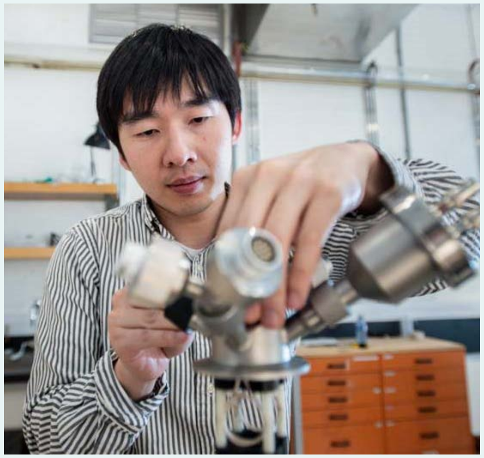
> **“When we initiated this partnership, we were aiming to become a world-leading research and training centre in the area of quantum materials, and I am pleased to see that we have achieved this goal. The research infrastructure and expertise at these institutes is complementary, and we've been able to support students and postdoctoral fellows to develop a very deep understanding of their research areas, and redefine the field in ways they could not without access to this Centre.”**
>
> — Bernhard Keimer
> Director, Max Planck Institute
> for Solid State Research, Stuttgart

> **“At the inception of the Max Planck-UBC-UTokyo partnership, we made the strategic decision to invest in people rather than projects. Apart from costs associated with scientific meetings and personnel exchanges, most of the Centre funding is allocated to fellowship support for junior scientists. This ensures the CQM will have meaningful, long-term influence over the culture and community of quantum materials research at a global scale.”**
>
> — Andrea Damascelli
> Scientific Director, Stewart Blusson
> Quantum Matter Institute

> **“The partnership between our institutions has enabled us to develop research ideas we might not have the resources to pursue independently. By working together, we are united in a common goal to train the next generation of leaders in this field, and to probe the biggest questions in quantum materials research.”**
>
> — Ryo Shimano
> Professor, Department of Physics,
> The University of Tokyo

RESEARCH HIGHLIGHT

CQM collaboration finds novel photovoltaic effect in 2D materials



Ziliang Ye

A photovoltaic (or solar) cell turns light from the sun into electricity. New research from Ziliang Ye and graduate student Dongyang Yang, and a team from University of Tokyo led by Yoshihiro Iwasa and Toshiya Ideue, has uncovered a new type of photovoltaic effect that occurs in specific configurations of certain van der Waals, or two-dimensional (2D) materials. The team's discovery, published in *Science,* shows promise as a portable complement to conventional silicon-based solar energy-harvesting technology.

The effect Ye and colleagues describe is unusual, as the individual materials' crystal symmetry does not allow for a bulk photovoltaic effect; together, however, a photovoltage emerges parallel to the interface due to the symmetry hybridization, making this novel 2D material combination, comprised of tungsten diselenide (WSe2) and black phosphorus (BP), more than the sum of its parts.

Van der Waals materials are comprised of layers that are weakly bonded to one another; this enables researchers to easily exfoliate a single layer of atoms using regular adhesive tape, the kind used in any home or office. 2D materials are of particular interest to Ye, Assistant Professor in UBC's Department of Physics and Astronomy. These materials offer unique opportunities for engineering via a third spatial dimension; by stacking these atomically thin layers, new physics emerge.

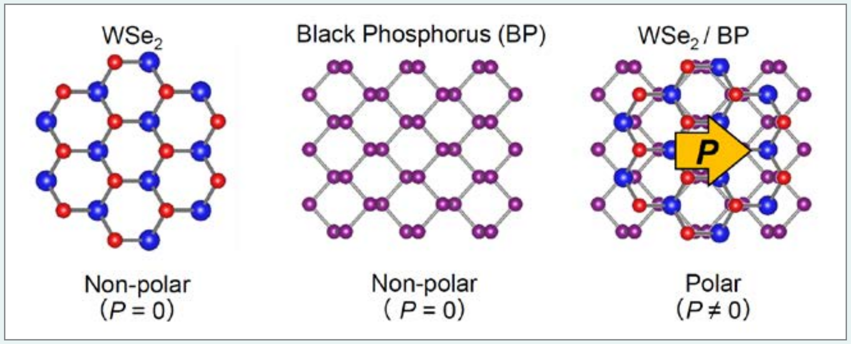
The team chose WSe2 and BP for this experiment because of their unique symmetries, but the symmetry engineering proposed in this new work is applicable to a variety of 2D materials. The paper establishes "symmetry engineering" as a concept, an important contribution to the field of 2D materials that will serve as a milestone in the *Engineering exotic phases in two dimensions* Grand Challenge.

The research partnership between Ye and UTokyo's team fructified in late 2019 at a meeting of the Max Planck-UBC-UTokyo Centre for Quantum Materials (CQM) hosted at Blusson QMI. Ye first learned about Iwasa's work at the 2018 CQM meeting, shortly after joining the institute as a new Principal Investigator.

"In the second year's meeting, as soon as I learned about the discovery of this new photovoltaic effect, I took the initiative to characterize the spectrum of the responsivity," said Ye. "Toshiya was in Vancouver for a week. During the day, we attended the CQM meeting, and at night, we were working on the experiment in the lab. It was a fun time."

Inspired by their collaboration and its ongoing success, Ye and Iwasa are now working on a new device that takes advantage of their novel photovoltaic effect.

"This paper, for us, is a comma, not a period," says Ye. "We will continue to work together to explore other aspects of this phenomenon."



Pictured: Tungsten selenide (WSe2) and black phosphorus (BP) do not exhibit polarized electronic behavior until combined such that their structures overlap. ©2021 Ideue et al.

T. Akamatsu, T. Ideue, L. Zhou, Y. Dong, S. Kitamura, M. Yoshii, D. Yang, M. Onga, Y. Nakagawa, K. Watanabe, T. Taniguchi, J. Laurienzo, J. Huang, Z. Ye, T. Morimoto, H. Yuan, Y. Iwasa. *A van der Waals interface that creates in-plane polarization and a spontaneous photovoltaic effect.* Science 372, **68** (2021).

Xiao-Xiao Zhang forges a path under the Max Planck-UBC-UTokyo Centre for Quantum Materials

Xiao-Xiao Zhang

New theoretical work conducted under the banner of the Max Planck-UBC-UTokyo Centre for Quantum Materials (CQM) demonstrates that a material known for its broken continuous symmetry changes its physics under pulsing light, and in its new form offers potential as a novel type of material with nontrivial topology in the nonequilibrium regime. Put simply, researchers have proposed an approach to materials design that offers the flexibility to re-engineer materials between states in order to incorporate new and desirable properties.

The research, published in *Phys. Rev. B*, emerged from an international collaboration between researchers at the Max Planck Institute for Solid State Research (Max Planck), The University of British Columbia (UBC), and The University of Tokyo (UTokyo).

Xiao-Xiao Zhang, first author, was a postdoctoral fellow at the Stewart Blusson Quantum Matter Institute under the supervision of Marcel Franz, Professor in UBC's Department of Physics and Astronomy, when he met Dirk Manske (Max Planck) in 2019. Zhang had been nurturing an interest in nonequilibrium states, currently a hot topic in condensed matter physics, and was looking for his next steps when he connected with researchers at Max Planck and UTokyo.

"These are places with a high degree of expertise in the area of nonequilibrium, and the work they are doing is of broad interest," said Zhang.

A major goal of the CQM is to facilitate opportunities for career growth for graduate students, postdoctoral fellows, and early career researchers.

"There is a lot of expertise in nonequilibrium physics in Max Planck and UTokyo," said Zhang, who is now a postdoctoral fellow at the RIKEN Center for Emergent Matter Science (CEMS) in Wakō, Japan.

The most common and effective way that researchers probe quantum materials is using light. With light, researchers are able to observe how a material behaves and changes. Sometimes, researchers shine light, and then take it away to see how a material responds. In the case of Zhang's new work, the researchers propose using a pump-probe-like spectroscopy approach, in which a pulse of light is used to excite the electrons in a charge density wave system where the electron density is periodically modulated in space due to interaction effects.

The researchers theorize that in such a system, targeted pulses of light will induce a nonequilibrium topological phase transition due to the formation of unconventional solitons. This ultrafast light-induced state is considerably different from equilibrium, where physical quantities are essentially at rest. Topological soliton, a robust excitation connecting neighboring but distinct structures, is a subject of intense interest that governs many types of novel physical phenomena, but it is relatively less addressed in the nonequilibrium.

"We see that light can turn a well-known conventional system into a nontrivial system with topological features," said Zhang. "This was the goal of our study, and this paper points out a possible route toward experimental detection."

"We were able to develop really good collaborations and the resultant discussions intrigued me; it was different from the topics I have worked on, but this experience spurred my interest in nonequilibrium systems," said Zhang. "The benefit of the CQM is that it enables young researchers to learn from and be challenged by more established researchers. I would not have explored this research area without the connections I made through the CQM."

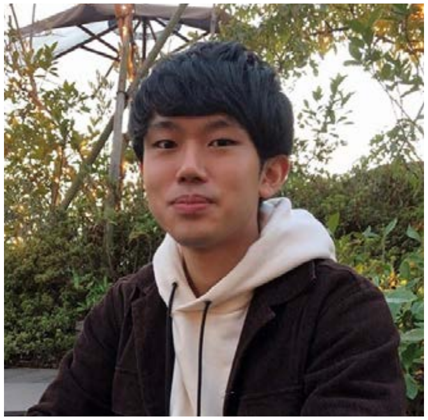
X.X. Zhang, D. Manske, N. Nagaosa. *Ultrafast excitation and topological soliton formation in incommensurate charge density wave states.* Phys. Rev. B **104**, 125132 (2021).

BRIEF RESEARCH HIGHLIGHTS

A team of researchers from Max Planck, Blusson QMI, the University of Tokyo, and the University of Saskatchewan has presented a comprehensive study on the silver bismuthate Ag2BIO3 synthesized under high-pressure high-temperature conditions. This research builds on recent theoretical work on topologically complex electronic states. The work demonstrates that Ag2BIO3 is topologically nontrivial and push forward the group of monovalent bismuthates as a class of bismuthates with interesting topological properties. Next, the team plans to perform in situ high-pressure experiments predicting a metallic state and perhaps even superconductivity in this class of materials. [*Phys Rev Mat* **5**, 064203 (2021)]

Performing resonant x-ray scattering on prototypical cuprate superconductor Bi2Sr2CaCu2O8+δ to probe the CuO_2 plane, researchers have discovered a dynamic quasi-circular pattern in the x-y scattering plane with a radius that matches the wave vector magnitude of the well-known static charge order. The team reveals a picture of charge order competing with superconductivity where short-range domains along x and y can dynamically rotate into any other in-plane direction. This quasi-circular spectrum, a hallmark of Brazovskii-type fluctuations, has immediate consequences to our understanding of rotational and translational symmetry breaking in the cuprates, and provides a centrally connected piece to the cuprate puzzle. [*Nat Commun* **12**, 597 (2021)]

VISITING STUDENT



Hiroki Takahashi
University of Tokyo

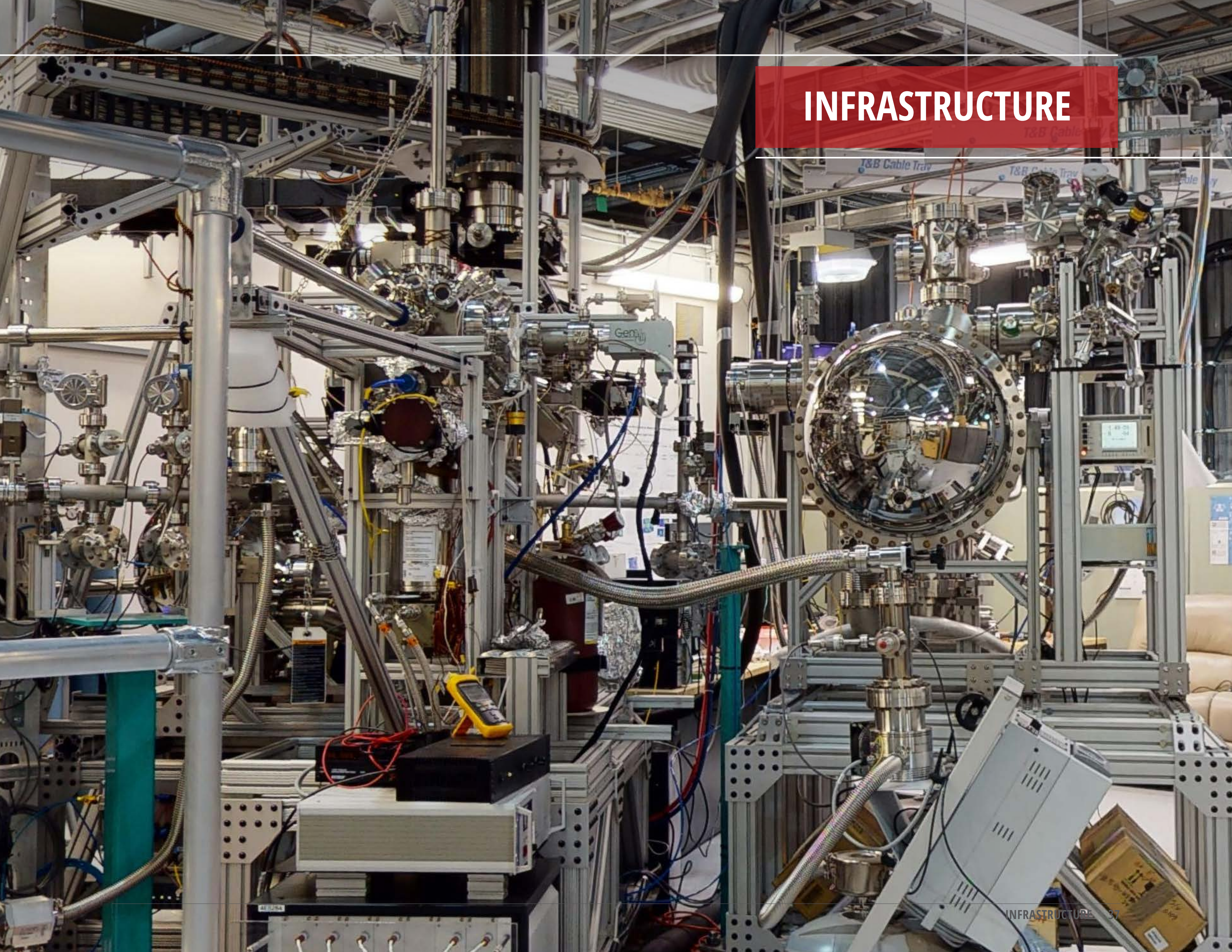
Hiroki Takahashi is moved by beauty, from the mystery of dark matter to the math underlying quantum mechanics, to the vivid memory of reading Haruki Murakami's *Kafka on the Shore* as a teenager one cold winter in Hokkaido. Though he came to physics perhaps later than his peers, discovering his passion in his sophomore year at the University of Tokyo, he recalls being taken by the elegance of Einstein's theory of special relativity.

"The theory was constructed in such a beautiful way—through a radically different observation of reality, and in just a few assumptions, he derived this incredible theory with huge implications for the universe," said Takahashi. "Little by little, I became taken with these ideas, and that's when I decided to major in physics."

Takahashi is a fourth-year undergraduate student at the University of Tokyo, and he is spending the last credits of his degree program studying condensed matter physics with Andrea Damascelli at Blusson QMI. Through an exchange program hosted by the Max Planck-UBC-UTokyo Centre for Quantum Materials, Takahashi is taking the opportunity to explore a new culture and try out new topics in physics. While at Blusson QMI, he will work with graduate student Sydney Dufresne to develop optics simulations.

"One of the big reasons I am here is to learn experimental skills," said Takahashi, who is currently thinking ahead to graduate school, and the opportunity to further explore the intersection of particle physics and condensed matter. "I'm also interested in how condensed matter can contribute to our understanding of dark matter—there is something almost romantic about how unexplainable it is. There is so much we don't know, and so the possibilities in this area of research are very broad and exciting."

INFRASTRUCTURE



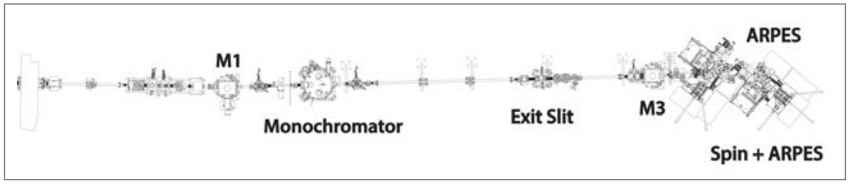
THE QUANTUM MATERIALS SPECTROSCOPY CENTRE (QMSC) AT THE CANADIAN LIGHT SOURCE (CLS)

The QMSC beamline, led by Andrea Damascelli, was commissioned this year. The state-of-the-art QMSC is Canada's premier facility for Spin + Angle-resolved Photoemission spectroscopy (Spin+ARPES) and enables the study of many interesting questions in condensed matter physics. Researchers can request access to the QMSC either by purchasing direct access time or via a peer-reviewed process.

QMSC's key capabilities are rare on an international level. The expertise of the scientists who built and now run the infrastructure spans not only advanced Spin+ARPES techniques and their associated hardware, but also materials preparation and condensed matter theory. This cross-disciplinary involvement ensures that the facility's capabilities—wide photon energy range, circular and elliptically polarized light, high resolution endstations, access to new materials, and theoretical predictions—are all tailored coherently to form a bespoke instrument suite. The approach ensures that facility's highest performance level, and offers the most user friendly and accessible Spin+ARPES platform available anywhere in the world to serve a large community of Canadian and international users.

QMSC at CLS: New Developments in Fe-based Superconductivity Workshop

The QMSC at CLS Workshop, co-organized by the Canadian Light Source Inc. and Blusson QMI, was held virtually on December 13 and 14, 2021. The workshop offered an overview of the QMSC at CLS, a beamline facility dedicated to performing spin- and angle-resolved photoemission spectroscopy (Spin+ARPES). It also showcased QMSC's capabilities, and reviewed a number of case studies performed on Fe-based superconductors in both thin-film and single crystalline form.



Pictured: a diagram of the QMSC.

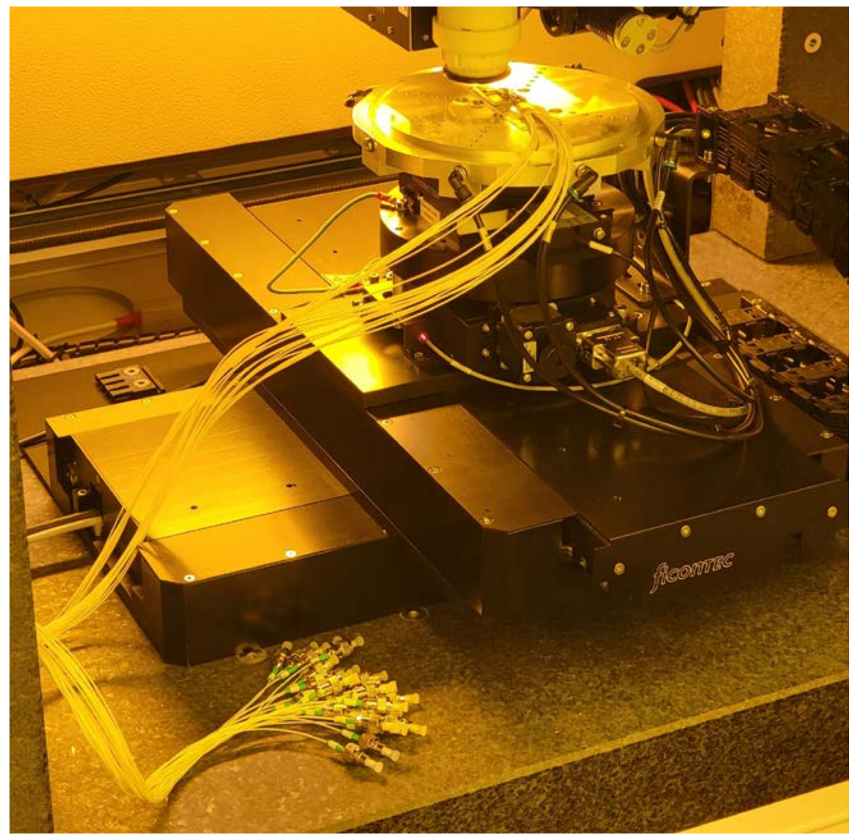
QUANTUM MATERIALS ELECTRON MICROSCOPY CENTRE (QMEMC)

In 2021, work began to build up two of Blusson QMI's next-generation vibration isolated vaults. One vault will house the new Focused Ion Beam system (FIB) integrated with a Scanning Electron Microscope (SEM), which will be shared between QMEMC and Blusson QMI's Nanofabrication Facility. The system uses a focused beam of ions to precisely image thin samples for use with our Scanning Transmission Electron Microscope (STEM), or for patterning devices. It's an extremely useful technique in materials science and the semiconductor industry. Blusson QMI's new dual function SEM/FIB system patterns and characterizes samples or devices from crystals, films, and heterostructure, as well as other types of nanoscale devices and structures. This instrument is also being operated with the framework of a user facility for the wider community.

The other vault will house a fully customized NION STEM—this instrument is a highly customized instrument to perform a very specialized measurement needed to advance our research program in quantum materials. It will directly probe the dielectric matrix of a material with high energy and momentum resolution. Combined with the REIXS beamline at the Canadian Light Source, we will be able to, for the first time, characterize the polarizability of oxide material at the level of individual atoms. The space renovations are expected to be completed by early 2023.

PHOTONIC WIRE BONDING

The Advanced Nanofabrication Facility recently acquired a Vanguard Sonata 1000 photonic wire bonder for the challenging task of integrating micro-optical components with traditional semiconductor devices. This system uses a proprietary photonic wire bonding technology that exploits two-photon laser technology for in-situ fabrication of freeform waveguides that connect photonic chips on a package level. This capability will be critical in Blusson QMI's ambitious qubit development activities for the realization of a quantum computer that will integrate photonics based read/write circuitry as a part of its design.



BUILDING A FUTURE FOR CANADIAN NEUTRON SCATTERING

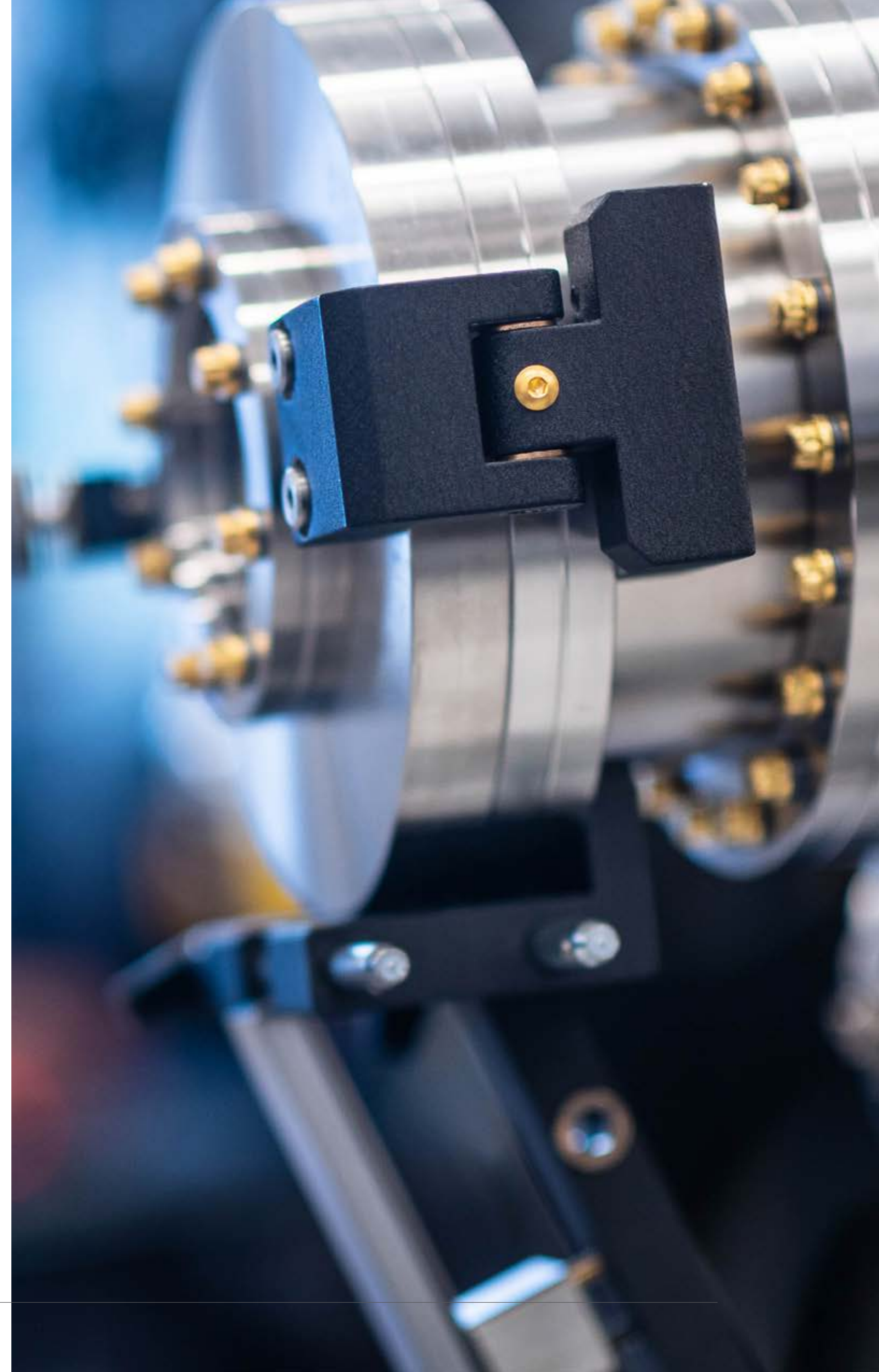
This CFI-funded national project led by McMaster University includes 17 other academic institutions, including Professors Aronson and Hallas from UBC. The project will enable research and innovation in areas such as materials for clean energy technology, materials for structural integrity of reliability-critical components of vehicles or nuclear power plants, biomaterials for understanding and combating disease, and materials for information technology.

Since the recent closure of the Canadian Neutron Beam Centre and the expiry of Canada's only agreement for access to a foreign neutron beam facility, the McMaster Nuclear Reactor (MNR) is Canada's only major neutron source right now. This project will complete its neutron beam lab by adding three neutron beamlines, and builds partnerships with two US-based, world-leading neutron beam facilities—National Institute of Standards and Technology's Centre for Neutron Research and the Spallation Neutron Source at the Oak Ridge National Laboratory — that will enable experiments requiring high neutron brightness.

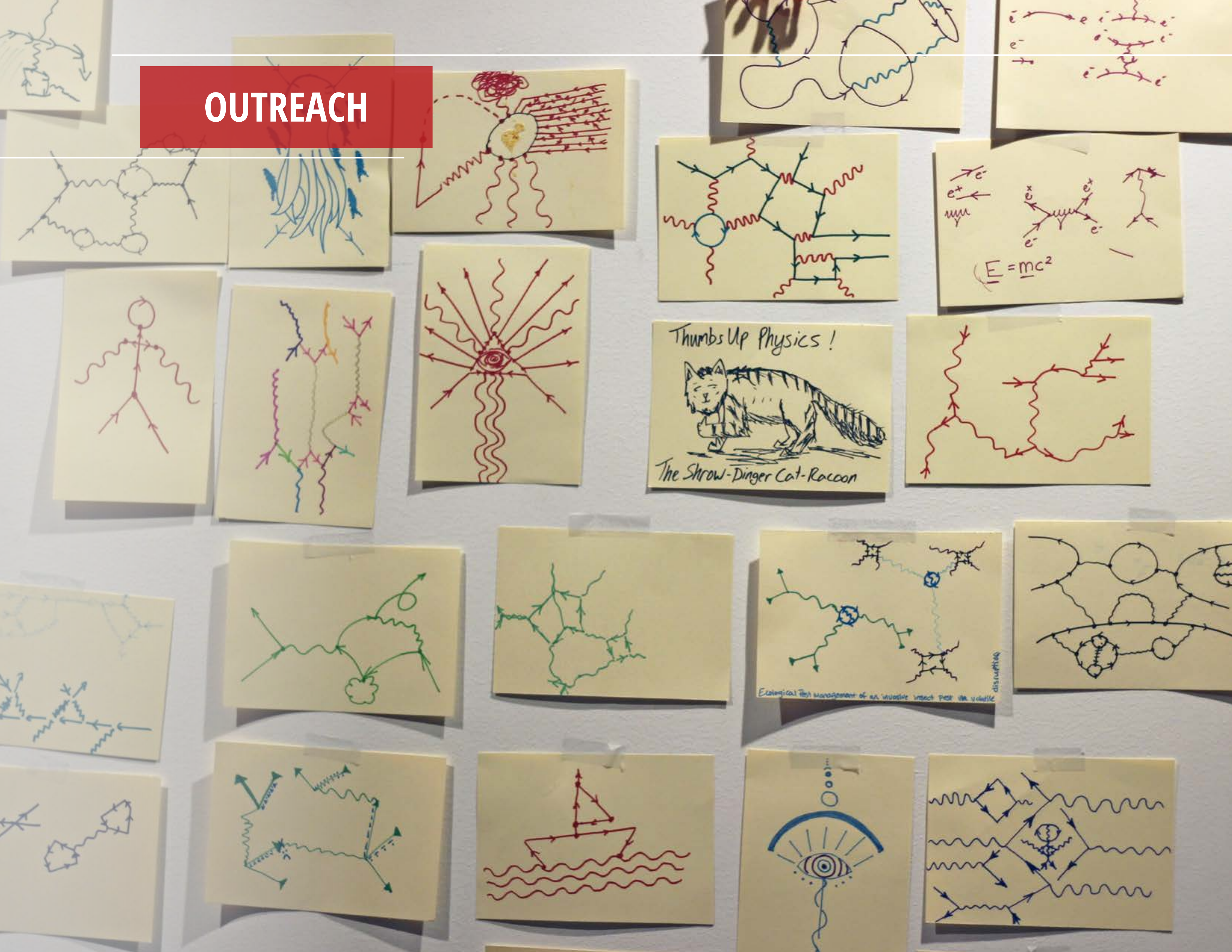
COINCIDENCE TWO-ELECTRON ANGLE-RESOLVED PHOTOEMISSION SPECTROSCOPY (2E-ARPES)

Thanks to funding from CFI and BCKDF, QMI is building a new instrument that will directly probe the electron correlations using a novel technique: coincidence two-electron angle-resolved photoemission spectroscopy (2e-ARPES). The system will be the first of its kind anywhere in the world, and will uniquely combine coincidence electron pair detection with high momentum-, energy-, and dynamic time-resolution. No existing photoemission system that can separately detect two coincidental electrons has any of its key attributes—angular resolution, high angular coverage, energy resolution sufficient to study the Fermi surface, or time-resolved capability to study nonequilibrium phenomena—let alone all of them.

Once built, it will provide unprecedented insights into the physics of quantum materials. The project, co-led by Damascelli and Jones, will provide quantum materials knowledge likely to form the foundation for transformative future technologies in areas as diverse as clean energy, transportation, medicine, computation, and communications.



OUTREACH



NEW PROGRAMMING PUTS QUANTUM INTO THE CURRICULUM

Ontario high school students are learning about quantum computing through a unique program developed by Quantum BC's Diversifying Talent in Quantum Computing and UBC Geering Up. The class, supported by the University of Ottawa, builds on a framework structured by graduate student Parham Pashaei (PI: Lukas Chrostowski) in 2020.

Students in Ontario can enroll in the course and earn credit toward their science requirement through the University of Ottawa's Faculty of Engineering Secondary School. The course was designed by the UBC Geering Up team, who worked with teachers and subject matter experts in curriculum design to develop lessons that are both educationally stimulating and fit within existing learning modules. For the program to be successful and meaningful to students, the team has ensured that the curriculum integrates existing content in physics, math, and computer science, making the introduction of key concepts in quantum computing organic within existing programs.

The program introduces students to topics that include the fundamentals of classical and quantum computing, circuit design, and programming. It is currently running as a pilot project, and Ella Meyer, Quantum Computing Outreach Program Coordinator, hopes that it will become part of the Ontario high school curriculum—and eventually, part of British Columbia's (BC's) as well.

"Our long-term goal is to take the successes and learning experiences of this pilot and adapt them so that they fit within Ontario and BC high school curricula," said Meyer.

Making quantum education work for teachers

"It's important that we make quantum computing curriculum work for teachers," said Meyer, who is working with Diversifying Talent in Quantum Computing to develop training for teachers. "We don't want to ask them to try to fit in anything new—we're really looking to find ways to add these lessons to existing modules in related subject areas."

For now, the class is offering a first look at how quantum computing education could work for Canadian students.

"We're working closely with teachers in Ottawa to make these lessons applicable to other topics students are learning," said Meyer. "Quantum computing is going to impact many different areas of science and technology, so building these ideas into existing lesson plans will not require teachers to design new course content, and it will also make the concepts meaningful for students."

Quantum education will be critical for this generation of students

According to Cissy Suen, a graduate student in the International PhD in Quantum Materials Program, we're at a moment in the development of quantum technology where there is an "understanding gap" between the scientists engaged in research and the business community looking to move from research to commercialization.

"As this sector grows, a fundamental issue known as the 'quantum bottleneck' looms large over progress," Suen wrote in a 2021 Toronto Star editorial. "On one side, there are researchers who have related degrees and vast amounts of technical knowledge, but lack business experience. On the other side, there are investors and interested parties who lack the academic knowledge. This creates the perfect recipe for miscommunication, misinformation and missed opportunities."

Creating opportunities for kids to develop literacy in quantum science will only help them as the technology evolves faster than school curricula.

"Quantum technologies are established as one of the primary emerging technologies of our time. That means there's still a lot we don't understand about what quantum tech can do or where it can go," said Suen. "Educating our children early (in the same way that we should have incorporated programming into our curriculum years ago) will be key to ensuring that Canada remains competitive in the field and that Canadians continue to be well-informed about potentially society-changing technologies."

"Incorporating quantum is not too difficult—quantum is about thinking in a different way, not necessarily a new way and many of the foundations of quantum mechanics are already taught in high school," said Suen.

C. Suen. *We've finally changed the math curriculum to accommodate programming. Why wait to include quantum computing as well?* Toronto Star. July 30, 2021.

QUANTUM NAVIGATOR GAMIFIES QUANTUM CONCEPTS

A new video game designed to teach quantum computing to kids aged 11 and older launched this fall. The game, Quantum Navigator, is designed to provide a foundation, offering an introduction to key terms and concepts, such as superposition, so that kids can develop a basic understanding of the guiding principles of this emerging technology.

“The game introduces topics in quantum science that users have to learn in order to solve problems and advance through the levels,” said Meyer. “We believe video games are an underrated tool for learning, and an accessible way to teach quantum computing to kids.”

One of the goals of Quantum Navigator, and the larger effort behind introducing quantum computing themes to children and young adults, is to “hide” the education.

“Think of it a bit like making a smoothie for kids,” said Meyer. “You want it to include vegetables, but don’t want it to taste like vegetables. It’s the same with making an educational videogame: we’re masking the challenging parts, and packaging an idea that can seem a bit cold or inaccessible to the average person in something fun. Engaging with tough concepts in a game makes the lessons more palatable; it’s essential that we make learning about quantum computing fun.”

“Video games can help us engage with learning material,” said Dr. Amori Mikami, Professor in UBC’s Department of Psychology. “Video games are a great way to introduce educational content or learn new skills.”

“In addition, many video games have reinforcements built into them, where after we do certain tasks or achieve milestones we are rewarded with points, stars, or some other method of tracking our achievements; this can help us stay motivated,” said Mikami, who was not involved in the project but who conducts research on learning and forming social relationships in digital spaces.

The idea for the game came from Haris Amiri, who previously held the role of Project Manager with this initiative. Amiri led the K-12 quantum computing program in its inception, leading the development of STEM and quantum education curriculum and software, workshops and high school courses used by thousands of Canadian youth and educators.

“For a video game to be successful, the players must be constantly challenged but only up to their skill levels. As they advance, they must pick up new skills and tools that they can use to take on greater challenges,” said Amiri. “You can use a similar model in education. Equip youth with the fundamentals and as you help them ‘upgrade’ their toolkit through experiential learning, they are better adapted to taking on more challenges.”

At present, most of those who work in the quantum computing space are in research and development, working in academic or technical roles that require a background in computer engineering, physics, or other highly specialized STEM fields.

To expand the scope of who has access to quantum computing, and to develop the future of quantum computing, the team behind Quantum Navigator has worked to ensure that people of diverse skill-sets and interests can engage with the game and learn its core lessons: the future of quantum tech will need artists, writers, user-experience developers, and expertise from the liberal and creative arts, the same way that classical computing and gaming do today.

“It’s critical that we introduce quantum computing education to those with a variety of interests,” said Meyer. “For quantum computing to truly advance, the field of experts involved needs to be very interdisciplinary; the field will only thrive with diverse perspectives to drive the technology and its related applications forward.”

Quantum Navigator was developed by UBC Geering Up and Quantum BC’s Diversifying Talent in Quantum Computing effort, with Lukas Chrostowski, Professor in UBC’s Department of Electrical and Computer Engineering serving as a champion for the initiative. The game is part of a bundle of quantum computing educational tools, including the soon-to-be-launched Quantum Arcade and Quantum Hub, that are designed to make quantum computing concepts accessible to a wide range of potential users.

MEASURING SUCCESS: EVALUATING STEM OUTREACH PROGRAMS

Postsecondary institutions regularly host or lead STEM outreach programs tailored to elementary and secondary school-aged children with a goal of inspiring students to consider STEM education and careers. Natalia Bussard, Manager, Programs and Careers, authored a paper in the *Journal of Higher Education Theory and Practice* that sought to establish metrics for the success of these programs.

Consulting with five experts in STEM outreach from not-for-profit science centers, industry, research institutes, and universities, Bussard determined that success metrics vary by audience: for younger kids, for example, qualitative data such as “did the activity spark enjoyment or interest?” are sufficient to gauge the success of an individual program. For older kids, outcomes may include imparting new problem-solving skills, or successfully enrolling participants in subsequent STEM programming.

While it is possible to survey or gain other quantitative measures in older adolescents and young adults, in younger kids the success of outreach programs is harder to evaluate, and so ideally outreach programs are targeted to specific audiences with established learning outcomes. In addition, to improve diversity and inclusion in STEM, programs should be tailored to groups who are underrepresented in science fields and be led by those with diverse backgrounds and lived experiences. Bussard recommends establishing networks that connect elementary and secondary schools with industry, research, and not-for-profit organizations with shared information and complementary activities in order to ensure STEM outreach is impactful and meaningful.

N. Bussard. *How Can Outreach Foster Further Interest in Stem and Eventually Lead to Careers in STEM?*. Journal of Higher Education Theory and Practice **21**, (2021).

QUANTUM COMPUTING OUTREACH STATS

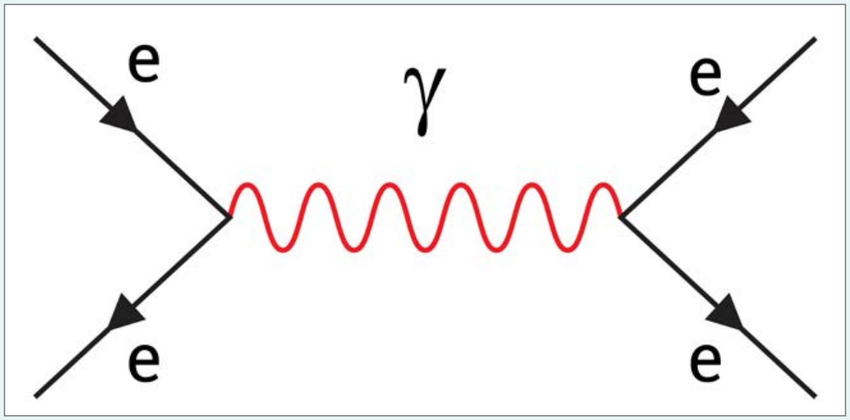
23 EVENTS INCLUDING

14 week-long summer camps

558 youth reached, including

298 girls (53% of program participants)

JAMES DAY WANTS YOU TO THINK DIFFERENTLY



Pictured: a Feynman diagram

Sometimes the shortest distance between a concept and understanding is a squiggly line. It was Richard Feynman, the Nobel prize-winning American theoretical physicist, who famously proposed cartoon models as a way to communicate complex physical equations more simply; in doing so, he fundamentally altered how physicists think and show their work. In a paper published in the journal *The Physics Teacher*, James Day and colleagues detail their approach to learning to think like a physicist, offering exercises for how to teach complex math problems using cartoons, or “toy models.”

A toy model is a purposely simple image used to convey complex information efficiently. Theoretical physicists often use Feynman diagrams, a variation on toy models, to explain complex mathematical expressions to describe the behaviour of quantum particles.

“Before Feynman, theoretical physicists used these very complex mathematical equations to describe quantum electrodynamics,” said Day. “Feynman realized that drawings could simplify things, getting us to the same place with the same integrity, but much faster.”

“Feynman tells us that if you take the right lateral step, you can make a major breakthrough,” said Day. “Quantum mechanics, or theoretical physics in general, are topics that anyone can understand; it might not seem that way if you don’t know the language, but you can learn.”

By creating a visual language for complex ideas, these ideas become more accessible to those who do not speak the language of quantum mechanics. Even when they seem simple, Feynman diagrams are useful across a range of experiences.

“The experts are drawing these squiggles and discovering new things about the universe,” said Day.

Lateral thinking is less about thinking a problem through to its logical conclusion than it is about approaching it from a completely different angle. It requires creativity, and the ability to see solutions outside of logical steps: it is thinking outside the box, or, more accurately, not paying much attention to the box in the first place.

“Lateral thinking is about looking at a concept in a new way, or finding a connection that had been there all along, but that no one has noticed yet,” said Day. “Sometimes it’s about putting the solution first, and finding a way there.”

At the Blusson QMI, lateral thinking and creative problem solving underpin much of the work that takes place.

“None of these big, complex ideas we’re thinking about are truly inaccessible,” said Day. “And anyone can learn to think like a physicist.”

“One great thing about Blusson QMI is that we’re all colleagues, but we’re not doing the same thing,” said Day. “We’re able to dig deeply, but we’re not all digging in the same spot. Some of the biggest breakthroughs have come not from digging the deepest holes, but from those who combined their efforts and determined the best spot to dig holes together.”

J. Day, E. Lantagne-Hurtubise, A. Sheyerman, Y.H.T. Liao, C. Hoyt, *Quantum Matter on the Table: A Pretty, Simple Hands-on Activity.* The Physics Teacher **59**, (34) (2021).

PARTNERSHIPS

Our partnerships allow us to collaborate, share resources, and provide enrichment opportunities for our students. In 2021, our partnerships grew stronger with the renewal of the Max Planck-UBC-UTokyo Centre for Quantum Materials. Together with the University of Waterloo and the University of Sherbrooke, we launched the Quantum Colaboratory, making our shared infrastructure more broadly accessible to Canadian researchers. Our researchers looked outside their disciplines to form new research partnerships, establishing exciting new research directions. As we look ahead, we are seeing the future of quantum research in Canada take shape as uncertainty dissipates and details emerge: it's clear to us that when we go together, we can go much farther.

Max Planck-UBC-UTokyo Centre for Quantum Materials

The Max Planck-UBC-UTokyo Centre for Quantum Materials (CQM) was formed in 2017 as an expansion of the original Max Planck-UBC Centre for Quantum Materials that was established in 2012. Now, all three organizations have committed to the extension of the Max Planck-UBC-UTokyo partnership into 2027. An important milestone for a Max Planck Society-partnered collaboration, this is the first time an international Max Planck centre has been extended beyond a ten-year period. Read more about this partnership on page 33.

Our partnership with the Max Planck Society was recently highlighted in a Government of Canada feature celebrating 50 years of science and technology cooperation between Canada and Germany following the 1971 Canada-Germany Science and Technology (S&T) Agreement.

ICORD and the Blusson Spinal Cord Centre

Ziliang Ye has partnered with John Madden, Professor in UBC's Department of Electrical and Computer Engineering and the School of Biomedical Engineering (Faculty of Applied Science), and Babak Shadgan, Assistant Professor in UBC's Department of Orthopaedics (Faculty of Medicine) and Director of the ICORD Clinical Biophotonics Laboratory on a fundamental materials discovery project with the goal of developing functional nanomaterials to support implantable biosensors to aid in spinal cord injury recovery. The collaboration began at a 2019 joint workshop between Blusson QMI and ICORD researchers co-organized by Andrea Damascelli and Madden.

German–Canadian Materials Acceleration Centre

Natural Resources Canada and the National Research Council of Canada have partnered with Forschungszentrum Jülich and the Karlsruhe Institute of Technology in Germany in the formation of the German–Canadian Materials Acceleration Centre (GC-MAC). This new Centre, co-located in both Germany and Canada, will be a joint hub for advanced energy materials development and represents an important milestone for Canadian and German research collaborators in a year where Canada and Germany are celebrating 50 years of science and technology co-operation.

GC-MAC-affiliated researchers will include Curtis Berlinguette, Professor, UBC Department of Chemistry, who will serve as an "Associated Expert" with the project. Berlinguette will bring his leadership and expertise with "Ada", an artificially intelligent, self-contained, and self-driving laboratory which has given rise to new, complementary initiatives to fast-track thin-film materials research, and which will have direct ties to the GC-MAC.

The primary goal of the GC-MAC is to expedite the development and deployment of new energy technologies, with an aim to meet or exceed Canada's and Germany's clean energy targets through the development of efficient, carbon neutral applications. But the development and optimization of new materials for industry can be a lengthy process, and the urgency of finding clean alternatives to existing fuel sources is increasing. Researchers including Berlinguette have been working to accelerate research in thin-film materials through automation (see Grand Challenges, page 29).

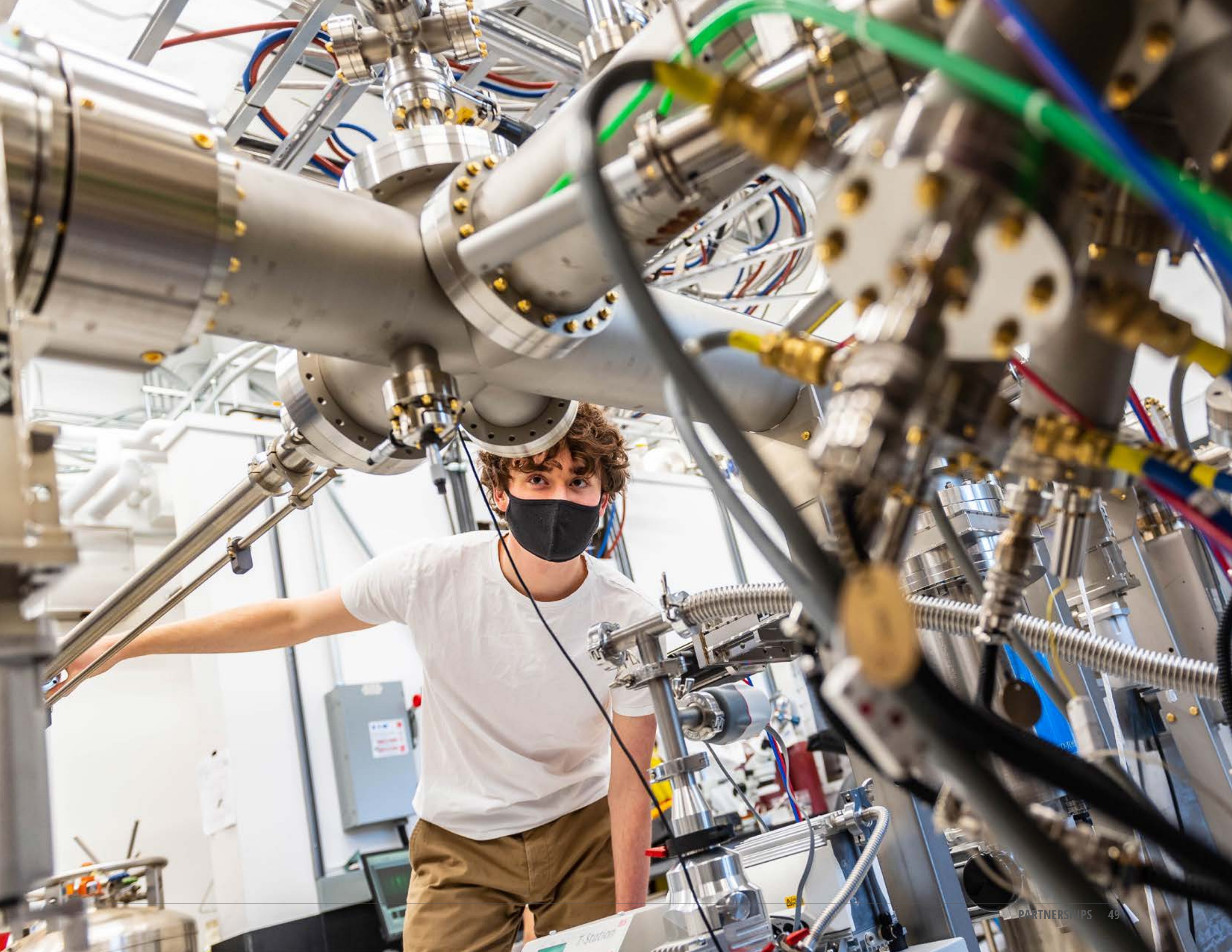
"Using flexible automation, we are able to readily adapt and expand our platforms for different types of materials and workflows," said Berlinguette. "This is in contrast to other approaches that use expensive, highly-customized commercial robotic platforms that are rigidly designed for particular tasks. Project Ada is a home-grown example for other materials research projects; the effort to help build self-driving lab capacity began here in Canada with Ada."

The Quantum Colaboratory (QCoLab)

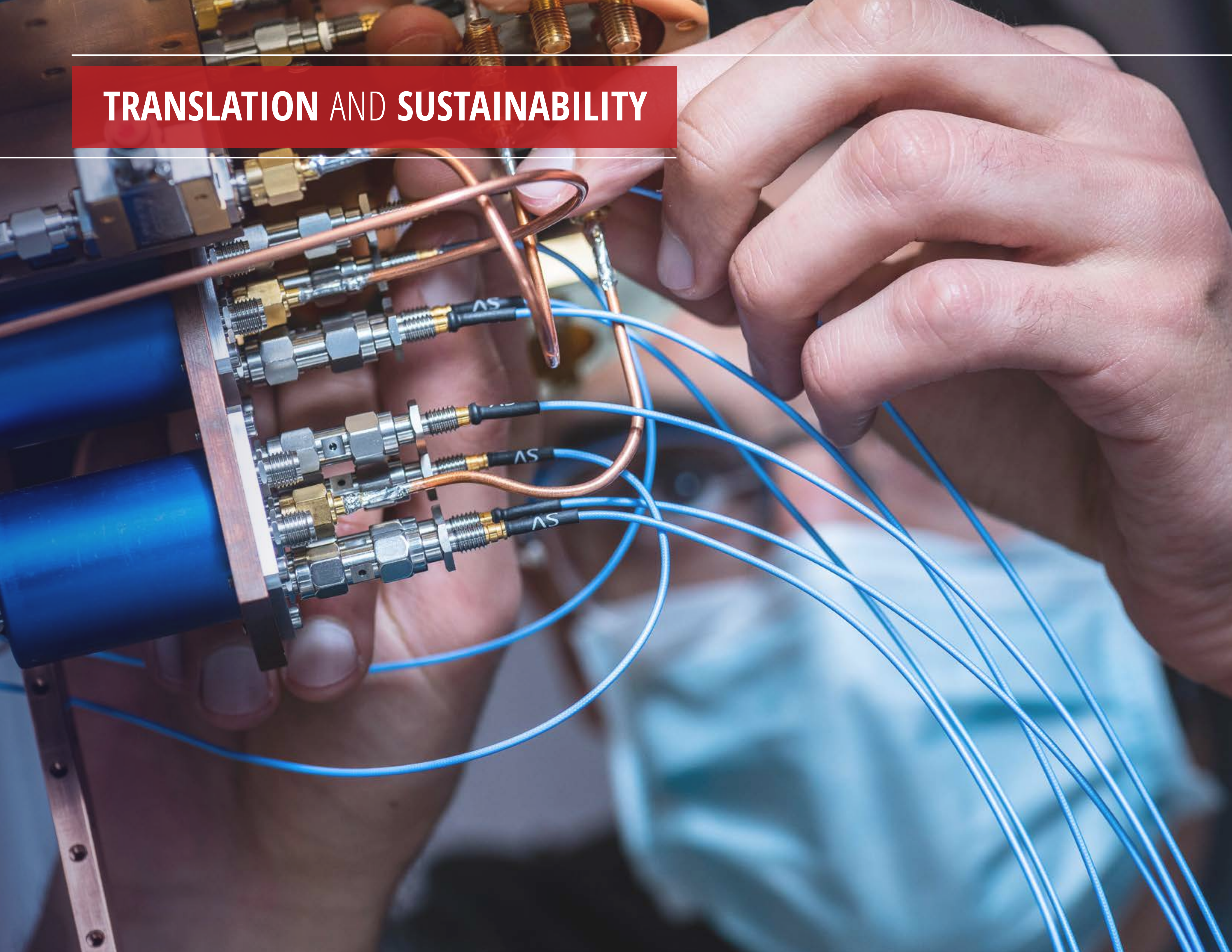
The QCoLab network links the University of Waterloo, Université de Sherbrooke, and the Stewart Blusson Quantum Matter Institute at The University of British Columbia in an effort to make the Canadian infrastructure and resources needed to support the broad quantum community, enable new research and development, and commercialization accessible to our partners across the country.

A key objective of QCoLab is to connect quantum technologies to novel applications. To achieve this, QCoLab is organized around a Quantum Innovation Cycle supporting five essential capabilities to enable the development of the tools and processes to grow the field of quantum technologies: growing and characterizing quantum materials, device fabrication, integration of devices into processors, and simulation of new quantum materials.

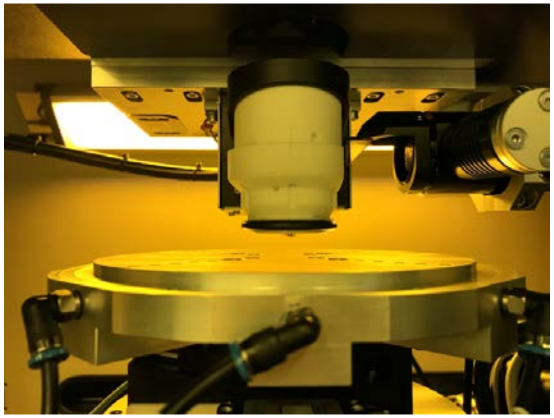
The QCoLab partnership is enabling academic, non-profit and industry users to access and benefit from our highly specialized capabilities, empowering them to engage in world-class research and technology development. QCoLab is open to all quantum researchers and engineers from academia and industry who stand to benefit from the resources and opportunities the QCoLab partnership provides. Together, we offer renovated laboratory space; reliable, state-of-the-art equipment; reproducible processes; professional advice and technical support; free training on all available equipment and services; and affordable user fees.



TRANSLATION AND SUSTAINABILITY



Lukas Chrostowski



Pictured: Photonic Wirebonder

Silicon Electronic Photonic Integrated Circuits Fabrication (SiEPICfab)

The SiEPICfab consortium led by Lukas Chrostowski scaled up its fabrication activities in the Nanofabrication Facility at the Stewart Blusson Quantum Matter Institute (Blusson QMI), and expanded its partnerships from 11 companies and four universities in 2019 to 17 companies and six universities in 2021.

Chrostowski has been a leader in bringing silicon photonics capability to Canada. His influence and expertise are widely appreciated throughout the industry.

“We’ve seen 15 years of success in training graduate students in silicon photonics, with our annual workshops drawing students from many Canadian universities,” said Chrostowski.

In November, SiEPICfab hosted a workshop on laser integration with ePIXfab, the European Silicon Photonics Alliance. The workshop enabled SiEPICfab to showcase their photonic wirebonding technique, a new process made possible using the SONATA1000, a precise multi-photon lithography tool from Vanguard Automation, for which SiEPICfab received funds from the Canada Foundation for Innovation.

Typically, the process for packaging silicon photonic chips has been expensive and complex. The chips process information using photons (light), but silicon cannot produce light; typically, this has meant that technicians must align tiny optical fibres with silicon chips to make them functional. The new process, known as photonic wirebonding, enables integration of lasers onto silicon chips; on-chip laser integration is a process that the silicon photonics industry has been working toward for a long time.

Silicon photonic devices are used in consumer electronics, automobiles, computers, and biosensors, such as the COVID-19 biosensor biosensor Chrostowski has been developing with ECE colleagues Karen Cheung and Sudip Shekhar. Silicon photonic devices use less energy than those made with materials including copper, commonly found in electronic devices and cables, which uses electrons to conduct electricity.

By partnering with ePIXfab, SiEPICfab gained a new audience with which to share its photonic wirebonding technique, expanding its potential customer base. Participants in the SiEPICfab-ePIXfab course were able to purchase and design a laser-integrated chip following the course.

In addition, the partnership is enabling both groups to access a wider variety of potential speakers, expanding access to critical knowledge in silicon photonics on two continents. SiEPICfab’s objective is to help research progress from rapid prototyping towards commercialization, with the overarching goal of providing large-scale silicon photonic research fabrication within Canada. The new equipment and cleanroom in Blusson QMI’s Nanofabrication Facility have increased SiEPICfab’s capacity for prototyping and fabrication. Ultimately, SiEPICfab and its partners are working to establish Canadian leadership in a fast-growing global industry.

“Over the past 15 years, I have been very privileged to be part of this growing community of silicon photonics researchers, engineers and scientists,” said Chrostowski. “I have seen the field transition from a curiosity, to training 500 students, and finally seeing widespread industry adoption where now most data centres employ silicon photonic chips.”

Quantum Days 2021

In January 2021, more than 1000 people from across Canada participated in the inaugural Quantum Days conference, a national effort to link academic research centres, industry partners, prospective students, and investors. Canada has a strong, growing, coast-to-coast quantum community spanning from academia to government laboratories and industry, and Quantum Days represented an opportunity to bring Canadian quantum science and technology leaders together to align priorities in the push for a unified national quantum strategy. Karl Jessen, formerly Executive Director at Blusson QMI, was influential in the planning as he worked closely with the Vice-President, Research Office in partnership with the organizer, NanoCanada.

Andrea Damascelli will be Conference Chair for Quantum Days 2022, cementing Blusson QMI and UBC involvement in this critical effort to ensure the sustainability of the Canadian quantum community.

National Quantum Strategy for Canada

The Government of Canada announced a significant investment to launch a National Quantum Strategy, committing $360 million over seven years and signaling its intention to grow the interconnected Canadian quantum industry into a global leader. Announced on April 19 as part of the 2021 federal budget, this commitment will support research into quantum science and technologies and bolster an emerging quantum industry, helping to unite research institutes and industry partners from coast to coast. The announcement follows years of concerted effort. At UBC, Andrea Damascelli and Karl Jessen have worked closely with Gail Murphy, Vice-President, Research and Innovation, and her team to keep the Canadian quantum sector competitive on the global stage.

For Blusson QMI, this represents an opportunity for us to further develop our key priorities, including our Grand Challenges. Basic science is an important investment for Canada, as the discoveries made at the fundamental level will be impactful for decades to come, especially related to quantum materials and quantum devices. We are grateful for this significant commitment from the Government of Canada, and we look forward to working with our colleagues at UBC, in government and Innovation, Science and Economic Development Canada, and across the country to develop and implement the strategy.

Quantum Devices to Improve the Scalability of Commercial Annealing Quantum Computers

Joseph Salfi received funding from NSERC through its Alliance Grants program to partner with Canadian quantum computing company D-Wave Systems Inc. The goal of the project is to experimentally investigate non-linear quantum devices that Salfi and colleagues anticipate will assist D-Wave in the fundamental and engineering challenges of their core commercial activity: making quantum annealing based quantum computers that are faster and can solver larger and more varied problems. The project encompasses device design, micro-fabrication using an industry-compatible planar process, and measurement in low-noise cryogenic environment. Success of the project will give D-Wave a competitive advantage over competitors, create more jobs in the Canadian quantum sector at D-Wave and closely related companies like 1QBit, better positioning Canada to reap the economic benefits of quantum computing technology.

CREATE and Mitacs partner in new training program

The NSERC Collaborative Research and Training Experience (CREATE) Quantum Computing Program and Mitacs launched a partnership to assist in training the next generation of graduate students who will power Canada's growing quantum computing sector. The international race to build quantum computers has attracted $20 billion in R&D investment worldwide and the National Research Council of Canada predicts that by 2030, the Canadian quantum computing sector could generate revenues of $4.1 billion to $8.2 billion per year, and support 8,000 to 16,000 jobs. The partnership between Mitacs and the CREATE Quantum Computing program supports this growth by providing over 100 students with industrial internships at quantum computing companies over the next seven years.

The partnership with NSERC will streamline the Mitacs internship application process for graduate students at the UBC, UVic, and SFU, the three partner universities involved in the CREATE Quantum Computing program. This will provide students with highly relevant, hands-on work experience with some of the world's leading quantum computing companies and ensure that businesses have access to the talent they need to make it in a competitive global marketplace and that graduates have the skills they need to succeed in the job market.

Pictured: Parham Pashaei leads a demonstration in a quantum science lecture in a Department of Electrical and Computer Engineering course. Image credit: Peyman Servati.

Quantum computing education has become Parham Pashaei's niche, and his work toward developing as a teacher and his commitment to improving the learning experience and outcomes for students in Applied Science courses earned him a Killam Graduate Teaching Assistant award. The award is given each year to just a few graduate students who have made outstanding contributions to teaching and learning at UBC, particularly those who are to solve teaching challenges or initiate new principles to improve the learning environment for UBC students.

Pashaei is an emerging leader in quantum computing education, having worked as a Teaching Assistant, initiating quantum computing lectures through UBC's Department of Electrical and Computer Engineering, and most recently as the Curriculum Development Lead for the Diversifying Talent in Quantum Computing project. The project, led by Lukas Chrostowski at UBC, brings quantum computing themed workshops, local events, summer camps, and public outreach to youth in the K-12 grade range.

"I realized that bringing topics in quantum computing and quantum electronics to undergraduate students in engineering would be valuable for them, and so I started teaching in a few courses, which over time expanded to more courses as people became more interested in these topics," said Pashaei.

Recently, Pashaei has led a series of Master Classes in Quantum Computing through Quantum BC, in partnership with Microsoft, D-Wave, UBC Geering Up, and Canada's Digital Technology Supercluster. The classes are aimed at high school students, and have proven popular.

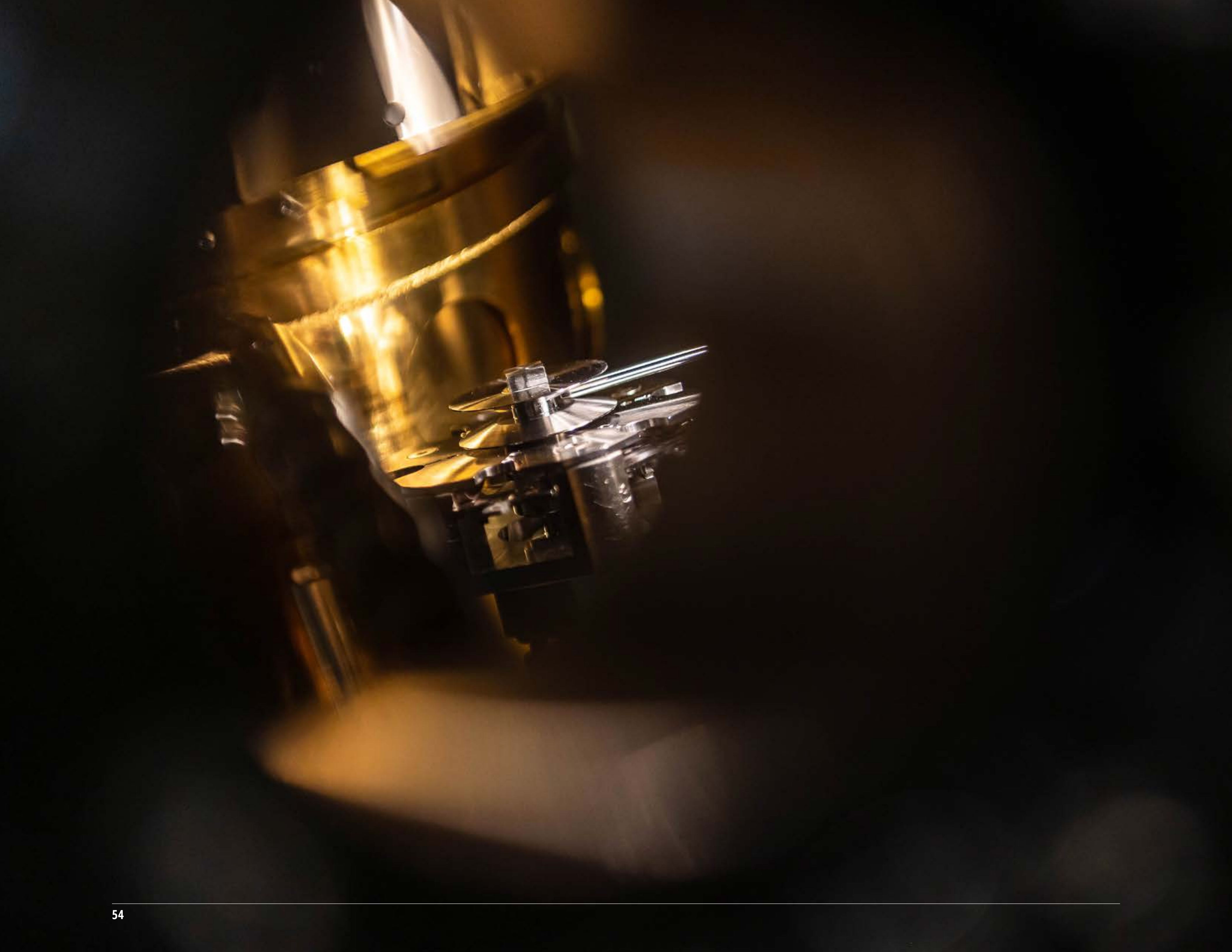
"When we launched, we expected maybe 10 people to sign up—we had 110 kids in Level 1, and half of them were girls," said Pashaei. The courses are designed to teach theory and practical quantum computing basics, including how to write code for a quantum computer. Level 2 concluded recently, with a smaller cohort due to the more complex material; more than 50% of the students were girls.

"Our master class is a unique program, one of the first of its kind in Canada, but with the popularity of quantum computing as a topic and enthusiastic support from industry, classes like these are important in developing a culture of people who are passionate about learning to use quantum tools; we're essentially training a generation of kids from a variety of backgrounds to be comfortable with quantum computing," said Pashaei.

As Pashaei looks forward, he expects to always be teaching in some capacity.

"I love research, and I want to continue my research, but I think I will always teach; teaching is an investment, and it's an enjoyable process and working with the students has been a great way to understand the topic in new ways," said Pashaei.

> "We're essentially training a generation of kids from a variety of backgrounds to be comfortable with quantum computing."



EQUITY, DIVERSITY, AND INCLUSION

EARLY CAREER INVITED LECTURE: ALINE RAMIRES

In February 2021, we welcomed Aline Ramires from the Paul Scherrer Institute to deliver an Early Career Award Lecture, sponsored by the Faculty of Science. The Early Career Invited Lecture initiative gives units within UBC's Faculty of Science a unique opportunity to introduce promising researchers from around the world to the inclusive, top-tier community of scholars already working within the Faculty.

An Ambizione Fellow at the Paul Scherrer Institute, Switzerland, Dr. Aline Ramires investigates unconventional phases of matter in complex quantum materials. She completed her PhD at Rutgers University, was a junior fellow at the Institute for Theoretical Studies at ETH Zurich, and a distinguished postdoctoral fellow at the Max Planck Institute for the Physics of Complex Systems in Germany.

"It was a pleasure to deliver the invited lecture and to engage in discussions with the faculty members from the Stewart Blusson Quantum Matter Institute. This award is certainly going to boost my profile as a scientist and bring more visibility to my research through new contacts at UBC," said Ramires.

WOMEN IN SCIENCE

A recent panel entitled "Women in Science: Equity, Diversity and Inclusion" including Aline Ramires, Mona Berciu and Sarah Burke, gave researchers an opportunity to come together and discuss challenges for women in science. The panel, which took place virtually on April 6, was an effort to build allyship among Blusson QMI colleagues and discuss ways to address inequities, which have increased in the shadow of the pandemic.

"Barriers women in science face add up over time," explained Natalia Bussard, Manager, Programs and Careers and organizer of the panel discussion. "Many of the challenges are systemic, which means they can be hard to recognize and identify. Systemic barriers can be reinforced through day-to-day interactions often taking the form of subtle micro-aggressions. Groups with elevated power, such as male academics in our context, can play an important role in changing these dynamics. Men can share the burden of educating colleagues and pointing out these moments as they happen. While it is positive that conversations around gender inequality in science are now being welcomed, we need to begin taking things from discussion to action."

"It's that idea of death by a thousand paper cuts," said Burke, Associate Professor in the Departments of Chemistry and Physics and Astronomy at UBC, and Chair of Blusson QMI's Equity, Diversity and Inclusion (EDI) committee. "Over time these things add up, and they make people feel 'othered.' A comment one person may find innocuous will have a whole different meaning to another group of people, and we have to work on reducing unconscious biases among majority groups in science."

Since March 2020, women have disproportionately been affected by job losses, childcare facility closures, and gendered expectations around caregiving and household duties. For female-identifying scientists, the impacts have often included increased workload as courses were quickly transitioned to online delivery, and fewer publications as labs closed with other academic responsibilities stretching workdays into evenings.

"It's been a very challenging time for women, and women of colour in particular," said Burke. "We've lost that sense of community we get from seeing people who look like us every day, and while some of those communities re-emerged online, it has been an isolating time for a lot of people."

"The effect of that loss is a lack of visibility; we're not seeing that other people are struggling too, and our female-identifying colleagues are juggling a lot of responsibilities that are often out of sight," said Burke. "It's great if people are able to find their people online, but we need to have those in-person interactions."

Bussard concurs. "Women need other women, as allies and as mentors."

MENTORSHIP PROGRAMS

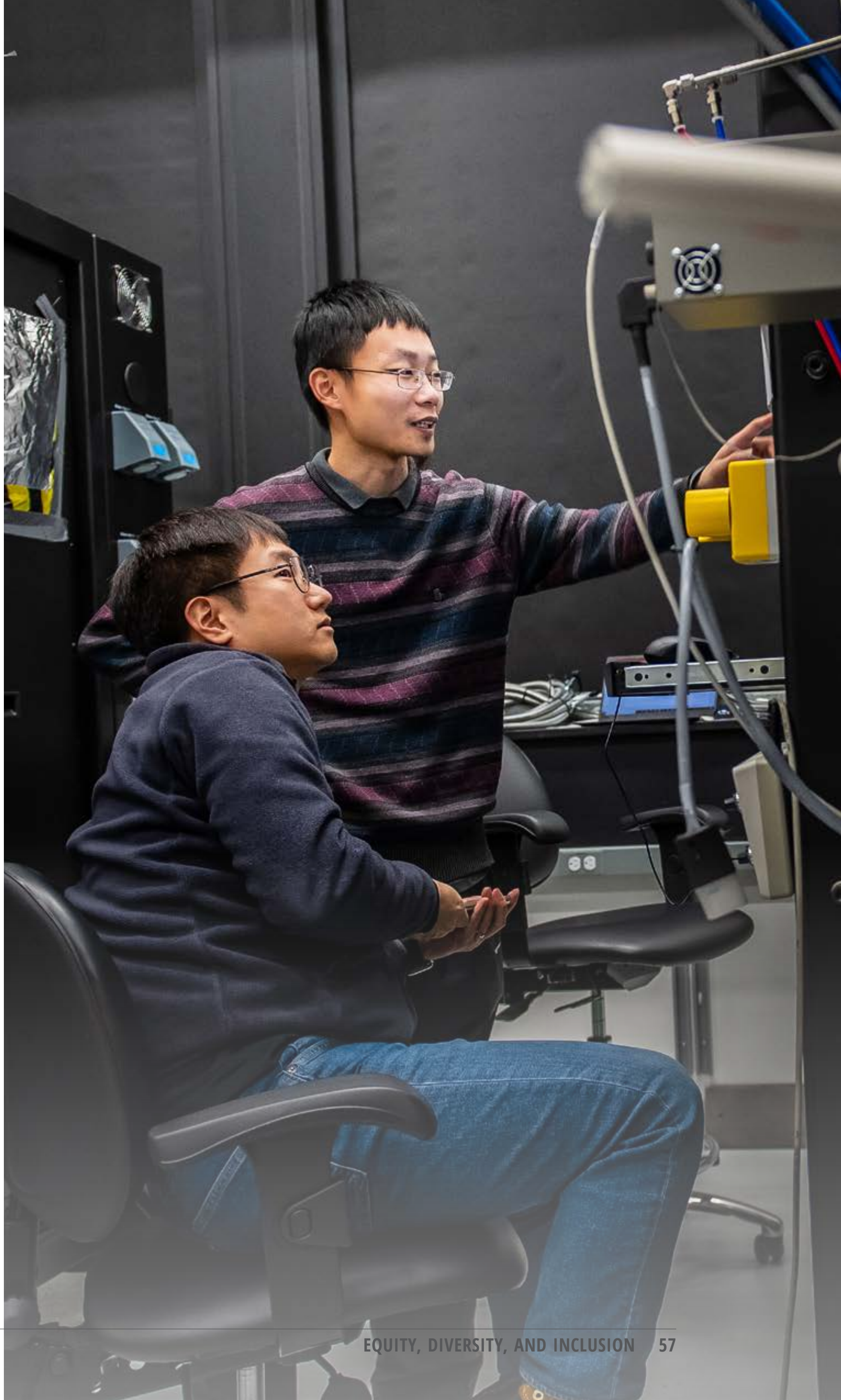
Mentorship programs at Blusson QMI provide students and postdoctoral fellows opportunities for networking, career planning, and growth. Over the past four years, the Blusson QMI Graduate Student and Postdoctoral Fellow Mentoring Program, designed and led by Natalia Bussard, has connected 32 students and postdocs with 32 mentors.

“The intention of the program is to create a bridge connecting students’ research knowledge and expectations with the realities of a career in industry, academia or entrepreneurship,” said Bussard. “Mentoring goes both ways: mentors can provide a platform to share their insights, as well as inspire and motivate students on their career journeys; mentees offer a fresh perspective, including connection with laboratories, current research and the latest publications.”

“Our goal is to equip mentees with the right knowledge to start a career in their desired field and be able to determine the tools they need to get there,” said Bussard.

In 2021, Andreas Pfenning, a postdoctoral fellow working on the Silicon Quantum Leap project with Lukas Chrostowski (Professor, Department of Electrical and Computer Engineering) and Jeff Young (Professor, Department of Physics and Astronomy), was matched with Gordon Harling, the CEO of CMC Microsystems.

“Gordon is a great mentor. My personal highlight was to meet him in person during his visit to Vancouver in September,” said Pfenning, who was able to help Harling resolve a scientific problem that CMC Microsystems was facing. In addition to talks about science and career development, Pfenning and Harling have discussed a range of topics, from where in the world to go after Pfenning finishes his postdoctoral studies, to the pros and cons of working in industry versus remaining in academia.



Ana Ciocoiu realized quantum computing was for her when she was ten years old.

"I had a little book on quantum physics that I was obsessed with," she recalls. As an only child reading through long Edmonton winters, she found the ideas in the book exciting. "At ten, I'd get a bit bogged down with the math, but I remember that I spent a lot of time making a chart that listed all the quarks and their interactions and strengths."

For a kid who took pleasure in reading the dictionary, physics offered unlimited potential for discovery and fun. In a way, she has waited her whole life to be where she's at right now as a QuEST student and part of the first cohort of the NSERC CREATE Program in Quantum Computing.

"By the time I started university, I finally had the skills to pursue quantum physics, so I kept doing that and tried to find opportunities to explore and develop that knowledge," said Ciocoiu.

As an undergraduate student, Ciocoiu studied electrical engineering at UBC Okanagan, where she also gained research experience working in the Integrated Optics Laboratory under the supervision of Jonathan Holzman, a Professor in the Department of Electrical Engineering.

"Dr. Holzman generously let me work in his lab and fiddle around with stuff for a couple of years," said Ciocoiu, who built her skills in optics and photonics research, which she has been further developing with her graduate supervisor, Joseph Salfi.

With Salfi, she is now in her first year as a Master's student and has been developing scientific code for spin qubits, which are realized when electronic spin in a semiconductor creates qubit states.

"There's been a renewed interest in the idea of doing this with holes instead of electrons, using materials such as germanium," said Ciocoiu. "There's this novel way of creating qubits and it's promising because their properties are much better than what we can see in the current systems that exist."

A qubit is the quantum version of the classical bit, the unit of information that in conventional computers can either be a one or a zero. The difference between a qubit and a classical bit is that a qubit can exist in a state that is simultaneously one and zero at the same time.

A "hole" is not a physical particle, but rather the absence of an electron in an atom, and while an electron has a negative charge, a hole's charge is positive. Holes offer greater electric control over qubit spin frequencies, a property that may be beneficial in quantum devices.

Over the summer, she participated in a first-of-its-kind workshop hosted by CMC Microsystems and NSERC CREATE programs Quantum BC and QSciTech (see page 60). The workshop focused on the design, fabrication and testing of superconducting circuits like those used in quantum computing hardware. She also worked with *Geering Up* to deliver programming for STEM Teachers NYC, and provided curriculum and graphic design support for the *Geering Up* summer camps in quantum computing for kids aged 10 and up (see Outreach section for more on *Geering Up* activities, page 42).

In the fall, Ciocoiu spent much of her time in the cleanroom at the Stewart Blusson Quantum Matter Institute, trying to fabricate the devices and see what their properties are.

"I'm looking forward to working on the fabrication of the devices we have simulated so far, trying to develop fabrication processes for these systems and then testing them," said Ciocoiu. As part of the CREATE Program in Quantum Computing, she will also be seeking internship opportunities, and is eager to explore opportunities in quantum computing outside of academia.

"I really enjoyed teaching math and science teachers about quantum computing, getting them to code a little bit, and designing materials to get kids into the idea of quantum science," said Ciocoiu. "It's so rewarding to see people getting excited about physics. It's hard to explain, but, I mean, physics kind of just calls to you sometimes."

SIGNATURE EVENTS

We were pleased to welcome Dr. Stewart Blusson and colleagues for a visit to the Brimacombe Building and a tour of Blusson QMI labs on September 24, 2021.

Image credit: [illegible]/UBC

ICNT 2021

The International Conference on Nanoscience and Technology had been planned as an in-person event, but due to challenges related to the COVID-19 pandemic, the conference had to run virtually from July 11 – 16, 2021, instead. Co-chaired by Sarah Burke, the conference connected participants around the world with content tailored to individual time zones, a monumental effort that was well-received by the nanoscience community.

QSciTech-Quantum BC Virtual Workshop: Superconducting Circuits and Qubits

NSERC CREATE-funded programs Quantum BC and Quebec's QSciTech partnered with CMC Microsystems to offer a first-of-its-kind workshop on the design, fabrication and testing of superconducting circuits like those used in quantum computing hardware.

The workshop, which ran from July 19 – 30, connected investigators and graduate students across Canada as they learned to use models to predict the behavior of superconducting devices and circuits, design those devices and circuits, translate them to a foundry-compatible process, and devise and execute low-temperature experiments for superconducting circuits and devices.

"This is the first workshop in the world to put these together, giving access to education and know-how that would normally only be available to members of very well-funded research teams," said Assistant Professor Joseph Salfi, one of the three organizers together with Prof. Rogério de Sousa (University of Victoria) and Prof. Yves Bérubé-Lauzière (Université de Sherbrooke), who leads several quantum computing-focused sessions as part of the overall workshop. "The true value of this workshop is that it is exposing many more people to this set of learning outcomes, positioning these students to be successful in the thriving local ecosystem and beyond."

Cornerstone Models of Quantum Computing Virtual Summer School

The Cornerstone Models of Quantum Computing Summer School / TRIUMF Summer Institute 2021 took place from August 2 – 13, 2021. It was hosted by partners TRIUMF, Stewart Blusson Quantum Matter Institute at the University of British Columbia, Quantum Algorithms Institute, Simon Fraser University, University of Victoria, Université de Sherbrooke, DESY from the Helmholtz Association, with industry partners Xanadu and D-Wave. The school provides an in-depth introduction to the seminal models of quantum computing.

Quantum BC Roadmapping Workshop

On Thursday, September 2, 2021, The University of British Columbia, University of Victoria and Simon Fraser University, under the banner of Quantum BC, offered a unique online Roadmapping Workshop that brought together students, faculty, and industry members across the quantum computing ecosystem in order to brainstorm the outlook for quantum technology development in BC over the next decade, and shed some light on the prevailing uncertainties in the field.

The 75 workshop attendees included students, faculty and staff from the province's three major universities, representatives from our partners at Institut Quantique (Sherbrooke, Quebec), and industry leaders in BC and beyond. Attendees discussed state-of-the-art quantum hardware, including gate-based, photonic, annealing and trapped ion quantum computers, as well as the potential for future development and strategies to maximize the societal and industrial impact of these emerging technologies.

2021 Undergraduate Summer Talks

On August 23, 2021, undergraduate student scientists who spent their summer learning experimental skills and gaining laboratory experience at Blusson QMI presented talks about the research projects they completed during their summer undergraduate research experience. Participants included Quantum Pathways students, who returned to in-person learning experiences in Summer 2021 after the program ran virtually in 2020, and NSERC Undergraduate Student Research Award students. Students participating in summer research programs were supported in their experimental projects by Pinder Dosanjh and James Day as they completed Summer Skills Workshops and related training, including technical laboratory skills modules, scientific writing, and communication skills; they also received access to career panels and mentoring.

Dark Matter Day

On Saturday, October 30, the H.R. MacMillan Space Centre in Vancouver hosted a public event celebrating Dark Matter Day. Speakers including Ars Scientia's Jeremy Heyl and residency partner Alannah Hallas gave presentations that explored matter on Earth and across time and the universe, giving a comprehensive picture of everything we do and do not know about matter, especially dark matter. In addition to discussion of different types of matter, this event was linked with our Grand Challenge, *Atomistic approach to emergent properties of disordered materials,* which Jess McIver, as the lead of the UBC arm of the LIGO project, is a member of. Though COVID restrictions meant that capacity in the planetarium dome was decreased, the event ran as a hybrid, nearly selling out in person while also running simultaneously via live-stream, engaging listeners from across British Columbia. This was an incredible opportunity to get together and talk about science, *Drift: Art and Dark Matter*, and our experience of knowing about something that exists outside of our human senses to a public audience, and we were grateful to participate.

Pictured, left to right: Emanuele Michielin, Ludovic van Waerbeke, Alannah Hallas, Jeremy Heyl, and Jess McIver.

Canadian Undergraduate Physics Conference 2021

Blusson QMI was a platinum sponsor of the 2021 Canadian Undergraduate Physics Conference (CUPC 2021), which ran from November 4 – 7, 2021. We are proud of the support we were able to offer to his important effort to amplify and engage with the work of undergraduate physics students and connect them with pathways to graduate studies in quantum materials. We are also grateful for the support of Ken Wong, Jisun Kim, Bruce Davidson, Giorgio Levy, and graduate student Rafael Haenel, who represented Blusson QMI at the conference.

Congratulations to Julie Belleville (PI: Jeff Young and Lukas Chrostowski), who won an award for best student presentation in the Solid State/Quantum Physics category, and to Stephen Cashen (PI: Lukas Chrostowski and Jeff Young), who won an award for best student presentation in the Applied/Engineering Physics category.

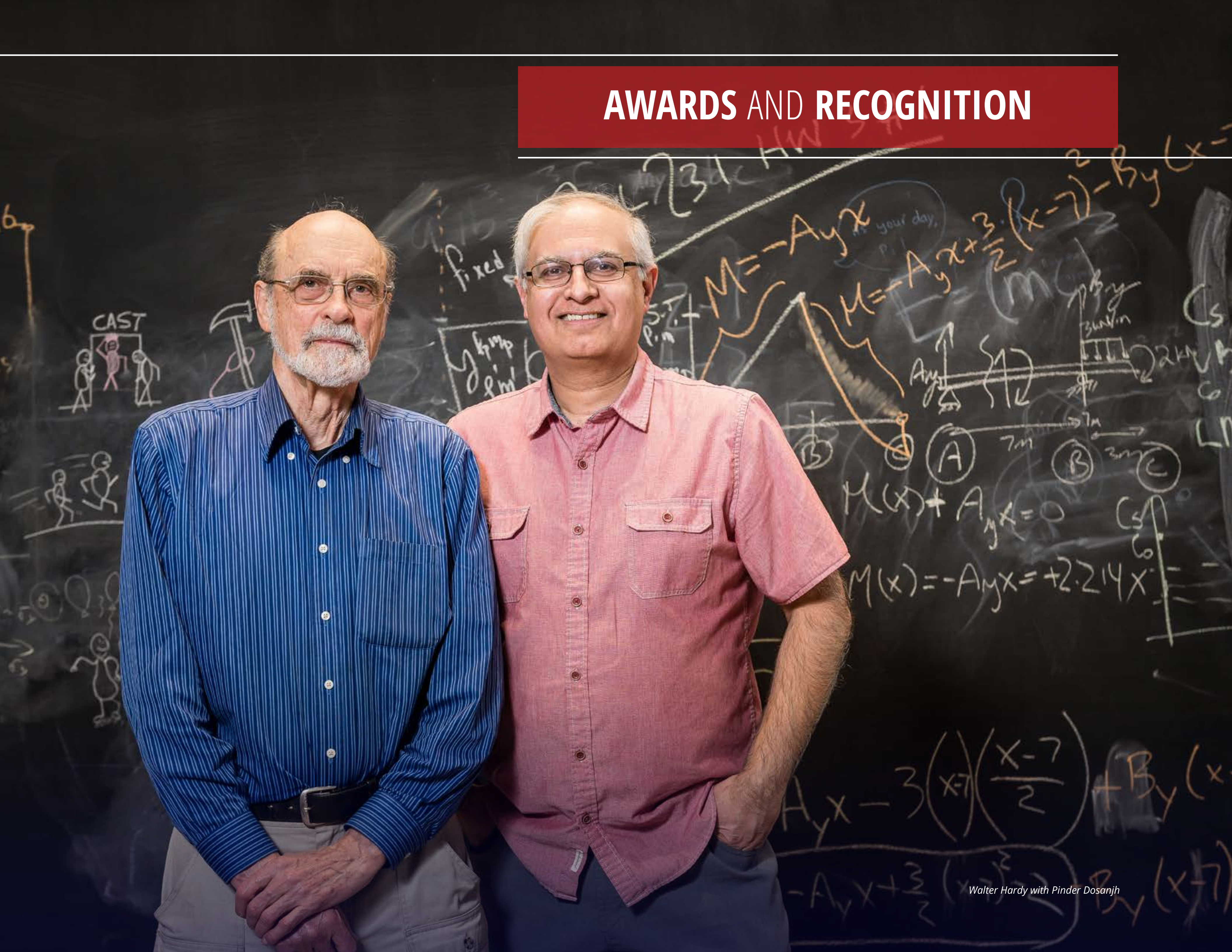
New Frontiers in Quantum Materials Research 2021

On December 9 and 10, we hosted a virtual workshop with our colleagues at Rice University's Centre for 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:

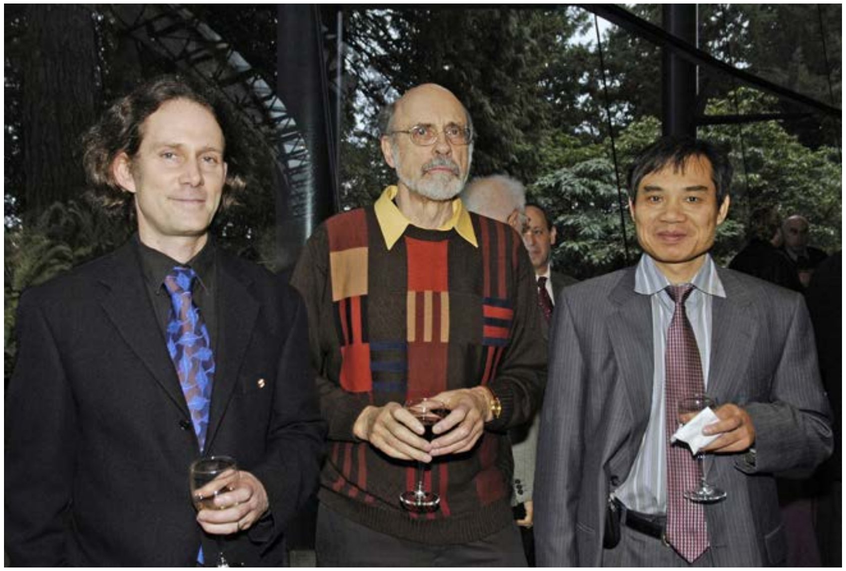
1. quantum dynamics and structures;
2. new materials and emergent phenomena;
3. topological materials by design; and
4. topology in bulk materials.

This year, workshop sessions were held virtually, and discussions took place over Zoom.

AWARDS AND **RECOGNITION**



Walter Hardy with Pinder Dosanjh



Left to right: Doug Bonn, Walter Hardy, Ruixing Liang (image circa 1993).

> Working with Walter is always as fun as it is insightful... if it can be measured, Walter will figure out the very best way forward.
>
> —Michael Hayden

LEGENDARY CANADIAN PHYSICIST WALTER HARDY APPOINTED TO ORDER OF CANADA

Walter Hardy was appointed a Member of the Order of Canada for "his pioneering contributions to the fields of particle physics, materials science and high-temperature superconductivity, as a distinguished theorist and experimentalist." Hardy, now Professor Emeritus in the University of British Columbia's (UBC) Department of Physics & Astronomy, is known worldwide for his work across multiple branches of physics, ranging from ground-breaking work on high-temperature superconductivity at UBC, to the first trapping and spectroscopy of antihydrogen at CERN. He has had enormous influence on the development of research in quantum matter in Canada, fueling the development of nation-wide expertise and the start of UBC's Stewart Blusson Quantum Matter Institute.

Hardy's great talent has been his imaginative ability to conceive of wholly new ways of doing experiments, coupled to tremendous technical knowledge and skill.

"Working with Walter is always as fun as it is insightful," said former student Michael Hayden, now a Distinguished Professor in the Department of Physics at Simon Fraser University. "Some of the very best physics discussions I've ever had have been with Walter over a cup of coffee and his pad of paper. It is deeply rewarding to think through complex problems with him; if it can be measured, Walter will figure out the very best way forward."

A pivotal force in physics

Hardy studied at UBC, earning his PhD from the University in 1965. He then spent two years as an NRC Postdoctoral Fellow in France, and five years working at the North American Rockwell Science Centre in California, before returning to UBC for a faculty position in 1971. In his academic role, he quickly emerged as a pivotal force in shaping the future of physics at UBC.

Most of his early work focused on the unusual properties of atomic hydrogen at ultra-low temperatures, research that ultimately led to the development of a cryogenic hydrogen maser. Room temperature masers are like lasers, but instead of light, masers shoot micro-waves; they are used in applications where ultra-precise timing is necessary, such as in atomic clocks used on global positioning satellites. For a while, Hardy and his group, including then-student Michael Hayden (with whom he continues to collaborate with as part of the ALPHA antihydrogen project), held the world record for the most stable frequency reference over short time intervals. To this day, that maser hangs in the foyer at the Stewart Blusson Quantum Matter Institute (Blusson QMI).

When high-temperature superconductivity was discovered, Hardy pivoted in his field of research. The cuprates, as a class of high-temperature copper-based superconductors, were discovered in 1986; by 1987, physics had crossed a boundary in the discovery of the first superconductor to exceed the boiling point of liquid nitrogen (77 Kelvin, or nearly -200 Celsius). This was an incredibly important discovery; it opened new opportunities for applications based on a superconductor's ability to conduct electricity with zero resistance. It also drove researchers around the world to develop new techniques to unravel the origins of this superconductivity.

Changing the field of superconductivity at UBC and beyond

Hardy's entry into the field of superconductivity had a modest goal at the beginning.

In addition to having zero resistance, superconductors have an ability to shield out magnetic fields; this led to the origin of a well-known demonstration where a superconductor can levitate a magnet indefinitely.

"Walter thought he should hold a demo at a departmental open house, using the new superconductor," said Douglas Bonn, Professor in UBC's Department of Physics and Astronomy. "But the tools and expertise to make the materials did not exist at UBC yet. They had to build everything from scratch."

In order to build the demo, (a version is still used as an educational tool at Blusson QMI today), Hardy worked with colleagues including Jim Carolan at UBC Physics and Jess Brewer at TRIUMF to make poly-crystalline samples, ceramic superconductors that were, in essence, a lot of tiny crystal bits all stuck together, resembling a clump of dirt.

Hardy had more than a demo in mind, however. He wanted to build a team that could make state-of-the-art superconducting materials and develop experiments to unravel the mystery of the new superconductors. With no background in either materials or superconductivity, he nonetheless drew together a group, centred around his own singular talents as an experimental innovator.

When Bonn came to UBC as a postdoctoral fellow to work with Hardy in 1987, the collaborative potential between physicists and solid-state chemists had yet to be realized at UBC, so Hardy also brought in solid-state chemists, eventually bringing Ruixing Liang (now retired) to the team, a move he would later describe as his "most important contribution to the field." In tandem with researchers at McMaster University, University of Toronto, Université de Sherbrooke, and other universities, the stage was set for a collaborative and interdisciplinary effort that drove major contributions to the field by Canadian researchers. The collaborative spirit grew further when the team joined researchers at AMPEL, a multi-department, multi-faculty materials facility.

From 1989 to 1993, Hardy, Bonn, and Liang collaborated on a series of experiments that completely changed the direction of the field. They became influential in the field of high-temperature superconductors through the discovery of D-wave superconductivity, showing that the cuprates were a truly new phase of matter, a very different kind of superconductor. Until Hardy and Bonn, much of the field had based their understanding of HTC materials on what we now know to be unsuitable samples. A paper Bonn and Hardy published in the journal Physical Review Letters in 1993, *Precision measurements of the temperature dependence of λ in YBa2Cu3O6.95: Strong evidence for nodes in the gap function,* has more than 1000 published citations and has influenced generations of researchers.

This discovery, and many subsequent experiments over the next two decades were rooted in a combination of growing the best crystals in the world, together with novel ideas for experiments.

> “Walter is just an extraordinary experimental designer; almost everything he designs, he builds himself so that his experiments were always exquisitely informed and inventive.
>
> —Douglas Bonn

“Making your own samples gives you a huge edge,” said Bonn. “If you can become a material-maker, you tighten the feedback loop between the chemistry and the experimentation; enough success, and you become a global player in your field.” Hardy’s success in the field is largely attributable to his unwavering do-it-yourself work ethic.

The wandering physicist

Hardy, Bonn, Liang, and their materials experiments in the 1980s and 1990s, would draw researchers including George Sawatzky, and later, Andrea Damascelli, to roles at UBC. Their efforts laid the groundwork for what would eventually become Blusson QMI.

Despite this, Hardy didn’t maintain exclusive focus on the field of high-temperature superconductors, preferring to reinvent himself and move from field to field. Over his career, his research interests took him from the quantum mechanics of solid molecular hydrogen to the study of gaseous atomic hydrogen involving precision measurements and hard-core low-temperature physics. Ultimately, his expertise in hydrogen and microwave spectroscopy led him to be recruited to join the ALPHA Collaboration at CERN in his 70s. The Canadian arm of the ALPHA team, including Hardy, received the 2013 NSERC John C. Polanyi Award for their contributions to our understanding of antimatter.

In another side-trip, for a brief period in the late 1980s, Hardy worked with Hayden and other graduate students to determine whether cold fusion, a reaction in which two atoms of hydrogen merge to form helium, was possible after an announcement from a team at the University of Utah.

“Walter’s scientific passion lives in the first element of the periodic table, and the potential cold fusion of hydrogen atoms was one of many topics that sparked his curiosity,” said Bonn. “Walter is a traveler, moving across different areas of physics, and he has this almost moral obligation to figure out the science behind things. Cold fusion was a side-trip, but he was excited—if skeptical—and if it could be done, he was going to figure it out.”

For fusion to occur, hydrogen must be heated to nearly 100 million degrees Celsius. It requires enormous pressure; the sun’s core is one such environment. Controlled fusion as a source of energy here on earth is pursued with large, complex instruments that try to mimic this environment. Which is why when Utah researchers announced that fusion could be replicated at room temperature in a basement laboratory, the news shook the scientific community. If fusion could be achieved at terrestrial temperatures, it would represent a scalable opportunity for unlimited renewable energy.

“It was a short but intense period,” said Hayden. By year-end, the team had debunked the cold fusion claims. “Within a year, we produced three publications and then it was over.”

Hardy continued to contribute to physics decades after retirement, which is no surprise to Bonn, who remains in touch with Hardy and his family.

“I think Walter felt a little uncomfortable if he didn’t make a major switch in his direction every decade or so,” said Bonn. “He’s just an extraordinary experimental designer; almost everything he designs, he builds himself so that his experiments were always exquisitely informed and inventive.”

FACULTY

Walter Hardy

Order of Canada
Walter Hardy was appointed a Member of the Order of Canada for "his pioneering contributions to the fields of particle physics, materials science and high-temperature superconductivity, as a distinguished theorist and experimentalist." For more on Hardy and his work, see page 64.

Curtis Berlinguette

Fellow of the Royal Society of Canada
The Royal Society of Canada recognizes Canadians from all branches of learning who have made remarkable contributions in the arts, humanities and sciences. Prof. Berlinguette is recognized for a collective body of work that incudes designing carbon dioxide utilization technologies, building self-driving labs, and advancing fusion sciences.

UBC 2021 Distinguished University Scholar
The Distinguished University Scholar program at the University of British Columbia recognizes exceptional faculty members who have distinguished themselves as scholars in research and/or teaching and learning.

Lukas Chrostowski

IEEE J.M. Ham Outstanding Engineering Educator Award
The Institute of Electrical and Electronics Engineers (IEEE) Canada recognizes outstanding Canadian engineers who have shared their technical and professional abilities through teaching making an outstanding contribution to engineering education. Prof. Chrostowski is recognized for "exceptional training and education leadership in the design of silicon photonic devices and systems for applications in optical communications, biosensors and quantum information."

IEEE Technical Skills Educator Award
This award recognizes effective, impactful, and innovative educators who bring specialized training to communities for whom photonics is not typically viewed as a common educational and career path, and educators who bring technician and technical skills training to traditionally underserved communities. Prof. Chrostowski received this award in recognition of "the creation of innovative training and education programs in silicon photonic device and systems design with global reach".

Andrea Damascelli

Fellow of the Max Planck Graduate Centre for Quantum Materials
The Max Planck (MP) Graduate Centre for Quantum Materials builds on the complementary activities of the MP-UBC-Utokyo Centre for Quantum Materials. The MP Graduate Centre brings together world leading lecturers and partner institutions to provide talented doctoral students innovative research-oriented training.

Andrew Potter

Sloan Research Fellowship in Physics
The Alfred P. Sloan Foundation established these fellowships for early career researchers in recognition of "distinguished performance and a unique potential to make contributions to their field." Fellows represent the very best of the next generation of scientific leaders in the US and Canada.

IUPAP Young Scientist Prize in Structure and Dynamics of Condensed Matter
The International Union of Pure and Applied Physics (IUPAP) recognizes emerging leaders for their outstanding contributions to the structure and dynamics of condensed matter physics. Prof. Potter received this recognition for his "fundamental contributions to the theory of many-body-localization and non-equilibrium states of quantum matter".

Robert Raussendorf

CAP-CRM Prize in Theoretical and Mathematical Physics
The Canadian Association of Physicists (CAP) and the Centre de recherches mathématiques (CRM) and the Canadian Association of Physicists (CAP) jointly award this annual prize in recognition of exceptional achievements in theoretical and mathematical physics. The prize recognizes Professor Raussendorf's "eminent contributions to the theory of quantum computing, including groundbreaking work on measurement-based or "one way" quantum computing, fault-tolerant quantum computing, and computationally universal quantum phases of matter".

STUDENTS AND POSTDOCTORAL FELLOWS

Julie Belleville

Best Student Presentation (Solid State/ Quantum Physics) at the Canadian Undergraduate Physics Conference (CUPC)
Co-supervised by Lukas Chrostowski and Jeff Young
Held annually since 1965, CUPC brings together students from across Canada to engage and share their work in physics and astronomy.

Ben Brown

Best Undergraduate Poster at the Pacific Centre for Advanced Materials and Microstructures (PCAMM) conference
Supervised by Jeff Young
PCAMM is a collaborative venture between UBC, Simon Fraser University, and the University of Victoria, which brings together resources and experts in materials growth, fabrication, and characterization. Ben received the Best Undergraduate Poster award for "Off-the-shelf electronics facilitate superconducting nanowire single-photon detector readout and characterization".

Stephen Cashen

Best Student Presentation (Applied/ Engineering Physics) at the Canadian Undergraduate Physics Conference (CUPC)
Co-supervised by Lukas Chrostowski and Jeff Young
Held annually since 1965, CUPC brings together students from across Canada to engage and share their work in physics and astronomy.

Alexander Dimitrakopoulos

TECHNATION Career Ready BC Rising Star Award
Alireza Nojeh Group
Alexander received the Career Ready Regional Rising Star Award (BC) for participating in the 2021 cohort of TECHNATION's Career Ready Program, where he worked on AweSEM, a project that aims to bring high resolution imaging to the masses by developing a low-cost scanning electron microscope (SEM). The project is a collaboration between Nojeh's group and Fabian Pease's group at Stanford.

Kirsty Gardner

Best Poster at the Pacific Centre for Advanced Materials and Microstructures (PCAMM) conference
Jeff Young Group
PCAMM is a collaborative venture between UBC, Simon Fraser University, and the University of Victoria, which brings together resources and experts in materials growth, fabrication, and characterization. Kirsty's "Microdisks can be used to rapidly test different low-mechanical loss coating materials" poster was selected as the overall winner.

Ryan Jansonius

Young Chemist Award
Curtis Berlinguette Group
Ryan was awarded the Young Chemist award from Metrohm USA for his work "Carbon Neutral Chemical Manufacturing with an Electrochemical Membrane Reactor". The award recognizes outstanding research performed by the brightest minds in Canada and the United States.

Daniel Korchinski

2nd place in the 6th Annual McGill Physics Hackathon
Joerg Rottler Group
For the second year in a row, Daniel and teammates Adam Dong and Raelyn Sullivan placed second in this annual event where teams put together a project—involving scientific computing and physics—over a 24-hour period. This year they participated with "Frost Spreading with Cellular Automata".

Valentina Mazzotti

Erich Vogt First Year Summer Research Experience (FYSRE)
Supervised by Andrea Damascelli
FYSRE offers research opportunities to emerging academic undergraduate stars after their first year. Valentina worked on the hardware and software required to track the position of micrometre size samples inside the ARPES spectrometer during laser-based photoemission experiments on cuprates and other quantum materials.

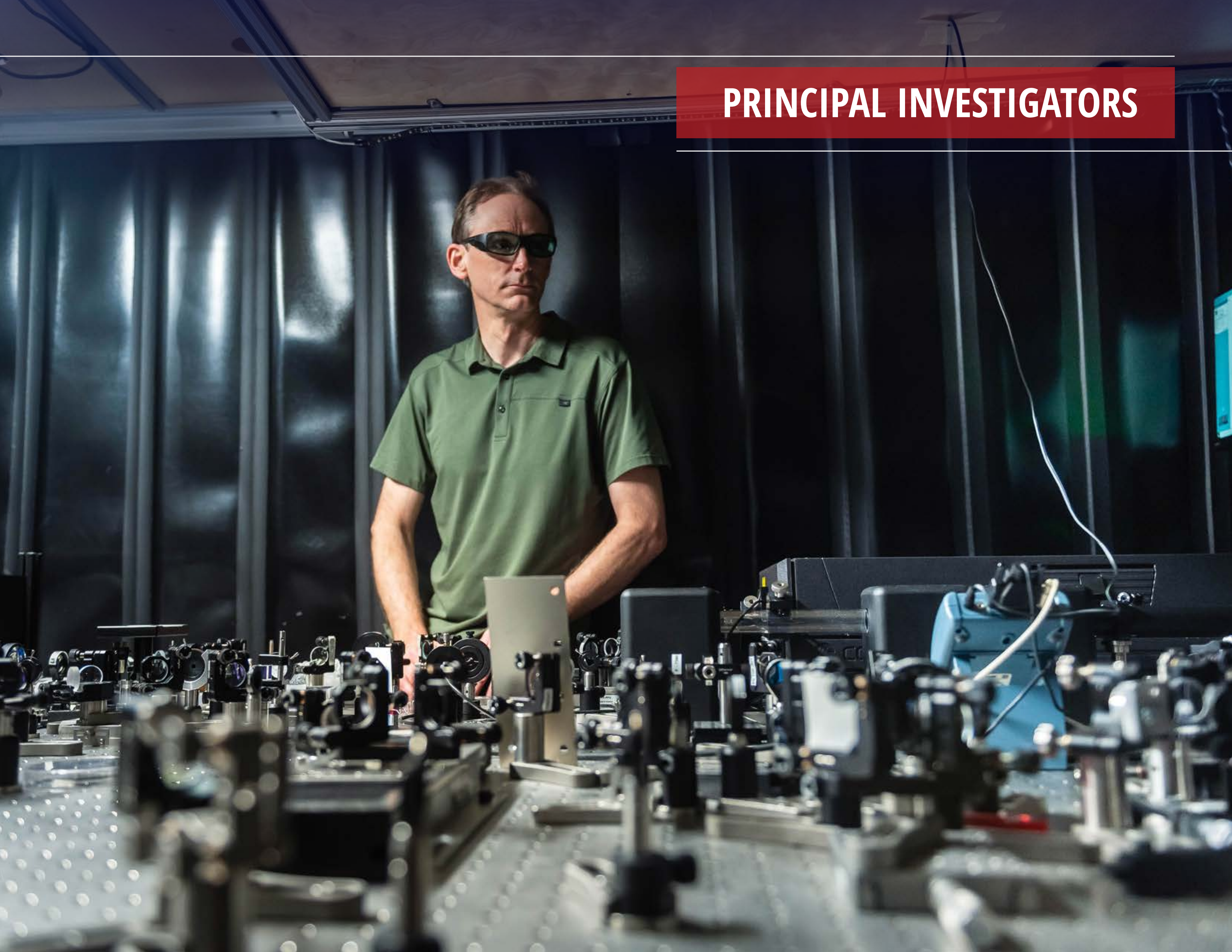
Matthew Mitchell

Best Poster "Peoples' Choice" at the Pacific Centre for Advanced Materials and Microstructures (PCAMM) conference
Co-supervised by Lukas Chrostowski and Jeff Young
PCAMM is a collaborative venture between UBC, Simon Fraser University, and the University of Victoria, which brings together resources and experts in materials growth, fabrication, and characterization. Matthew was the clear Peoples' Choice winner with the poster titled "Hybrid integration via photonic wire bonds".

Cissy Suen

NSERC Canada Graduate Scholarship
Co-supervised by Andrea Damascelli and Bernhard Keimer
This highly competitive federal program promotes excellence in Canadian research by "rewarding and retaining high-calibre doctoral students", and strives to nurture impact beyond the research realm. The award will support Cissy's research into strongly correlated quantum materials.

PRINCIPAL INVESTIGATORS



NEW INVESTIGATOR
ANDREW POTTER

Andrew (Drew) Potter joined the Department of Physics and Astronomy at UBC as an Assistant Professor and the Stewart Blusson Quantum Matter Institute (Blusson QMI) as a Principal Investigator in August 2021. Previously, he was Assistant Professor in the Department of Physics at the College of Natural Sciences at the University of Texas in Austin. He completed his PhD at the Massachusetts Institute of Technology and a Gordon and Betty Moore Foundation postdoctoral fellowship at the University of California (Berkeley).

His interest, on the fundamental science side, is in the types of phases of matter that are possible in nature, and in trying to come up with mathematical frameworks to understand new phases of matter. He is also interested in how to change the properties of a given material, or create artificial materials. His work spans several research areas, with implications across a range of projects including *Pushing the boundaries of Noisy Intermediate Scale Quantum (NISQ) computing by Focusing on Quantum Materials Problems,* the Blusson QMI quantum computing Grand Challenge.

“One of the big questions for my team is: if you are able to control matter in a time-dependent way, can you create phenomena that are stable like a phase of matter, but which have properties that would be forbidden in thermodynamic equilibrium?”

To answer these questions, Potter is exploiting the power of quantum computing to understand materials. “Even if you know the structure of the material and try to predict how it’s going to behave when you pass current through it or shine light on it, it’s a really challenging computational problem, and not one a conventional computer can solve,” said Potter. “Quantum computers behave like the materials we are trying to simulate, but the quantum computers that we have now are very small scale and error prone.”

To solve the problem, Potter has been working to leverage what researchers currently know about materials and create simulation algorithms that will be able to solve problems on these smaller scale quantum computers. He has already begun engaging with the quantum computing researchers including Joseph Salfi about how to connect Potter’s quantum algorithms work with his spin-qubit hardware; he’s also working with Robert Raussendorf to pursue connections between his measurement-based quantum computing work and Potter’s theory of tensor networks and topological phases.

“I’m really excited to be part of this network of researchers, and I appreciate that Blusson QMI really has a full stack of people, from theorists to people who grow materials through to experimentalists measuring their properties, it seems like they all work very closely together,” said Potter. “I think it will be beneficial—but also fun—to have that kind of tight knit experimental community to work with.”

> “I appreciate that Blusson QMI really has a full stack of people, from theorists to people who grow materials through to experimentalists measuring their properties”

IAN AFFLECK

RESEARCH FOCUS

One method which 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, Kyle Wamer

SCIENTIFIC STAFF

Alberto Nocera

SELECTED PUBLICATIONS

I. Affleck, A.W.W. Ludwig. *Universal Non-Integer `Groundstate Degeneracy' in Critical Quantum Systems.* Phys. Rev. Lett. **67**, 161 (1991).

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

I. Affleck, T. Kennedy, E. Lieb, H. Tasaki. *Rigorous Results on Valence-Bond Ground States in Antiferromagnets.* Phys. Rev. Lett. **59**, 799 (1987).

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 Blusson 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 1982 – 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

UNDERGRADUATE STUDENTS

Divya Chari, Satyam Priyadarshi

GRADUATE STUDENTS

Joern Bannies

POSTDOCTORAL FELLOWS

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

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

My current interests focus on developing accurate variational approximations for answering key questions that arise in the study of strongly correlated systems: (i) what are the characteristics of the quasiparticle (polaron) that forms when a charge carrier becomes “dressed” by a cloud of excitations such as phonons, magnons, etc.; (ii) what effective interactions arise between such quasiparticles through exchange of excitations between their clouds; and (iii) what is their combined influence on the properties of the host material. We use these methods to study effective models of materials such as the high-temperature cuprates and iron pnictides, rare-earth nickelates, bismuthates, etc., in a wide region of the parameter space. Such studies supplement numerical exact studies, which are usually rather 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

- Developing a variational method to calculate one-particle propagators in metals with strong electron-phonon coupling
- New mechanism for high-temperature superconductivity in models with Peierls-type electron-phonon couplings
- Cuprate critical temperatures calculated microscopically with a strongly-correlated three-band model
- Exciton dissociation driven by electron-phonon coupling
- Effects of electron-phonon coupling on RIXS spectra

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

UNDERGRADUATE STUDENTS

Paul Froese, James Wu

GRADUATE STUDENTS

Stepan Fomichev, Oliver Yam

POSTDOCTORAL FELLOWS

Leon Ruocco

SELECTED PUBLICATIONS

K. Bieniasz, S. Johnston, M. Berciu. *Beyond the single-site approximation modeling of electron-phonon coupling effects on resonant inelastic X-ray scattering spectra.* SciPost Phys. **11**, 062 (2021).

M. Jiang, M. Berciu, G.A. Sawatzky. *Critical Nature of the Ni Spin State in Doped* $NdNiO_2$. Phys. Rev. Lett. **124**, 207004 (2020).

H. Ebrahimnejad, G.A. Sawatzky, M. Berciu. *The dynamics of a doped hole in cuprates is not controlled by spin fluctuations.* Nat. Phys. **10**, 951 (2014).

CURTIS BERLINGUETTE

RESEARCH FOCUS

The Berlinguette Group designs and builds advanced electrochemical reactors to power the planet.

CURRENT PROJECTS

- Reactive CO_2 capture
- Electrification of the chemicals industry
- Advanced nuclear fusion
- Flexible automation and self-driving labs
- Carbon-neutral building materials

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

UNDERGRADUATE STUDENTS

Mohamad Abbas, Julian Black, Matheus Cassol, Alisa Da Silva, Elija De Hoog, Komal Fatima, Tor (Oliver) Horner, Alyssa Liu, Lukas Nering, Ryan Oldford, Grace Simpson, Tyler Wong

GRADUATE STUDENTS

Roxanna Delima, Arthur Fink, Aoxue Huang, Ryan Jansonius, Andrew Jewlal, Tengxiao (Alec) Ji, Cameron Kellett, Eric Lees, Natalie LeSage, Benjamin MacLeod, Thomas Morrissey, Benjamin Mowbray, Fraser Parlane, Douglas Pimlott, Shaoxuan Ren, Alexandra Rousseau, Connor Rupnow, Mia Stankovic, Danika Wheeler, Aubry Williams

POSTDOCTORAL FELLOWS

Yang Cao, Kevan Dettelbach, Faezeh Habib-Zadeh, Camden Hunt, Yong Wook Kim, Aiko Kurimoto, Xin Lu, Ben Luginbuhl, Siwei Ma, Madeline Peterson, Danielle Salvatore, Zishuai (Bill) Zhang

SCIENTIFIC STAFF

Nathan Chiu, David Dvorak, Daniel Lin, Karry Ocean, Mike Rooney, Phil Schauer, Nina Taherimakhsousi, Chris Waizenegger

ADMINISTRATION TEAM

Amanda Brown, Amber Herbert, Kate Vasilchenko

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).

T. Li, E.W. Lees, M. Goldman, D.A. Salvatore, D.M. Weekes, C.P. Berlinguette. *Electrolytic Conversion of Bicarbonate into CO in a Flow Cell.* Joule **3**, 1487 (2019).

R.S. Sherbo, R.S. Delima, V.A. Chiykowski, B.P. MacLeod, C.P. Berlinguette. *Complete Electron Economy by Pairing Electrolysis with Hydrogenation.* Nat. Catal. **1**, 501 (2018).

DOUG BONN

RESEARCH FOCUS

We synthesize ultraclean samples of quantum materials, particularly superconductors and topological materials, 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 of unconventional superconducting state in Fe-based superconductors
- Microwave spectroscopy of long-lived quasiparticles in Fe-based superconductors
- Microwave electrodynamics due to ballistic and hydrodynamic flow in high mobility materials including $PdCoO_2$ and WP_2
- Quasiparticle interference in Weyl semimetal ZrSiTe: drumhead states and floating bands
- Development of ultra-low temperature STM with in situ MBE

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

UNDERGRADUATE STUDENTS

Jocelyn Baker

GRADUATE STUDENTS

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

POSTDOCTORAL FELLOWS

Seokhwan Choi, Giang Nguyen

SCIENTIFIC STAFF

James Day, Jisun Kim, Mohamed Oudah

SELECTED PUBLICATIONS

J. Chang, E. Blackburn, A.T. Holmes, N.B. Christensen, J. Larsen, J. Mesot, R. Liang, D.A. Bonn, W.N. Hardy, A. Watenphul, M.v. Zimmermann, E.M. Forgan, S.M. Hayden. *Direct observation of competition between superconductivity and charge density wave order in* $YBa_2Cu_3O_{6:67}$. Nat. Phys. **8**, 871 (2012).

N. Doiron-Leyraud, C. Proust, D. LeBoeuf, J. Levallois, J.B. Bonnemaison, 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).

W.N. Hardy, D.A. Bonn, D.C. Morgan, R. Liang, K. Zhang. *Precision Measurements of the Temperature Dependence of* λ *in* $YBa_2Cu_3O_{6.95}$*: Strong Evidence for Nodes in the Gap Function*. Phys. Rev. Lett. **70**, 3999 (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 2-dimensional materials, 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
- Development of a 4-probe STM for Quantum Materials characterization

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, Jörn Bannies, Rysa Greenwood, Vanessa King, Amy Qu, Brandon Stuart, Alexandra Tully, Ashley Warner, Jiabin Yu

POSTDOCTORAL FELLOWS

Seokhwan Choi, 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).

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, P. Wahl. *Imaging the real space structure of the spin fluctuations in an iron-based superconductor.* Nat. Commun. **8**, 15996 (2017).

K.A. Cochrane, A. Schiffrin, T.S. Roussy, M. Capsoni, S.A. Burke. *Pronounced polarization-induced energy level shifts at boundaries of organic semiconductor nanostructures.* Nat. Commun. **6**, 8312 (2015).

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
- SiEPICfab consortium on chip prototyping and integration

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, Mohammed Al-Qadasi, Ahmed Atef, Adan Azem, Adam Darcie, Leanne Dias, Joshua Fabian, Sabastian Gitt, Sheri Jahan Chowdhury, Daniel Francis Julien-Neitzert, Sean Lam, Becky Lin, Jake Osborne, Sayantani Podder, Mohammed Shemis, Hossam Shoman, Jingxiang Song, Iman Taghavi, Alexander Tofini, Jing Wang, Kithmin Wickremasinghe, Donald Witt, Shangxuan Yu

POSTDOCTORAL FELLOWS
Samantha Grist, Ata Khorami, Zhongjin Lin, Matthew Mitchell, Andreas Pfenning, Reza Sanadgol Nezami

SCIENTIFIC STAFF
Mahssa Abdolahi, Kashif Awan, Malcolm Haynes, Jaspreet Jhoja

PROJECT MANAGERS
Steven Gou, Stephen Lin

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. Jayatilleka, 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).

L. Chrostowski, M. Hochberg. *Silicon photonics design: from devices to systems.* Cambridge University Press (2015).

X. Wang, W. Shi, H. Yun, S. Grist, N.A.F. Jaeger, L. Chrostowski. *Narrow-band waveguide Bragg gratings on SOI wafers with CMOS-compatible fabrication process.* Opt. Express. **20**, 15547 (2012).

ANDREA DAMASCELLI

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 Blusson QMI in the UBC-Moore Centre for Ultrafast Quantum Matter 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, Blusson QMI 2015 – present
Co-Director, MP-UBC-UTokyo CQM 2015 – present

GRADUATE STUDENTS
Christine Au-Yeung, Sydney Dufresne, MengXing Na, Brian Pang, Amy Qu, Cissy Suen (Joint PhD)

POSTDOCTORAL FELLOWS
Martin Bluschke, Hao Chu, Ryan Day, Sean Kung, Igor Marković, Dan Sun, Marta Zonno, Berend Zwartsenberg

SCIENTIFIC STAFF
Ilya Elfimov, Giorgio Levy, Matteo Michiardi, Arthur Mills, Sergey Zhdanovich

SELECTED PUBLICATIONS
B. Zwartsenberg, R.P. Day, E. Razzoli, M. Michiardi, N. Xu, M. Shi, J.D. Denlinger, G. Cao, S. Calder, K. Ueda, J. Bertinshaw, H. Takagi, B.J. Kim, I.S. Elfimov, A. Damascelli. *Spin-orbit-controlled metal-insulator transition in Sr2IrO4.* Nat. Phys. **16**, 290 (2020).

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).

STEVE DIERKER

RESEARCH FOCUS

Our new Quantum Materials Electron Microscopy Centre will have a state-of-the-art electron microscope for atomic imaging and characterization of materials and for carrying out electron energy loss measurements as a function of momentum with ultra-high 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. 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

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

POSTDOCTORAL FELLOWS

Ali Abdullah Husain, Hsiang-His (Sean) Kung

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).

E.M. Dufresne, T. Nurushev, R. Clarke, S.B. Dierker. *Concentration Fluctuations in the Binary Mixture Hexane-Nitrobenzene with Static and Dynamic X-ray Scattering.* Physical Review E **65**, 061507 (2002).

S.B. Dierker. *X-ray Photon Correlation Spectroscopy, in Light Scattering and Photon Correlation Spectroscopy*. Proc. NATO Adv. Res. Workshop (1997).

JOSHUA FOLK

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.

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

UNDERGRADUATE STUDENTS

Anton Cecic, Johann Drayne, Sean Ghaeli, Romina Mahinpei, Owen Sheekey, Ray Su

GRADUATE STUDENTS

Tim Child, Zhenxiang Gao, Christian Olsen

POSTDOCTORAL FELLOWS

Christopher Coleman, Manabendra Kuirii

SCIENTIFIC STAFF

Silvia Lüscher

SELECTED PUBLICATIONS

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).

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).

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).

MARCEL FRANZ

RESEARCH FOCUS

We formulate and study simple models of solids that are relevant to topological states of quantum matter, including topological insulators, superconductors and semimetals as well as models of strongly interacting many-body systems. The key criteria driving our research are: (i) cutting-edge theoretical developments and (ii) relevance to real physical systems as studied by our experimental colleagues.

CURRENT PROJECTS

- Topological superconductivity in twisted double layer cuprates
- Quantum models of traversable wormholes
- Magic angle physics in dichalcogenides and nodal superconductors
- Majorana fermions for topological quantum computation

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

UNDERGRADUATE STUDENTS

Amrit Guha

GRADUATE STUDENTS

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

POSTDOCTORAL FELLOWS

Sayak Dasgupta, Stephan Plugge, Sharmishta Sahoo, Tong Zhou

SCIENTIFIC STAFF

Alberto Nocera

SELECTED PUBLICATIONS

O. Can, T. Tummuru, R.P. Day, I. Elfimov, A. Damascelli, M. Franz. *High-temperature topological superconductivity in twisted double-layer copper oxides.* Nat. Phys. **17**, 519 (2021).

M. Lu, X.-X. Zhang, M. Franz. *Magnetic suppression of non-Hermitian skin effects.* Phys. Rev. Lett. **127**, 256402 (2021).

É. Lantagne-Hurtubise, V. Pathak, S. Sahoo, M. Franz. *Superconducting instabilities in a spinful Sachdev-Ye-Kitaev model.* Phys. Rev. B **104**, L020509 (2021).

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 Blusson QMI 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 (Vanier Scholar) McMaster University 2013 – 2017
Smalley-Curl Postdoc. Fellow, Rice University 2017 – 2019
Asst. Professor UBC 2019 – present
CIFAR Azrieli Global Scholar 2020 – 2022

UNDERGRADUATE STUDENTS

Sam Mugiraneza, Gurleen Sandhu

GRADUATE STUDENTS

Mario Gonzalez-Rivas, Graham Johnstone, Megan Rutherford, Samikshya Sahu

POSTDOCTORAL FELLOWS

Dalmau Reig-i-Plessis, Solveig Stubmo Aamlid

SCIENTIFIC STAFF

Mohamed Oudah

SELECTED PUBLICATIONS

D. Reig-i-Plessis, A.M. Hallas. *Frustrated Magnetism in Fluoride and Chalcogenide Pyrochlore Lattice Materials.* Phys. Rev. Mater. **5**, 030301 (2021).

C.L. Huang, A.M. Hallas, K. Grube, S. Kuntz, B. Spiess, K. Bayliff, T. Besara, T. Siegrist, Y. Cai, J. Beare, G.M. Luke, E. Morosan. *Quantum critical point in the itinerant ferromagnet Ni1-xRhx.* Phys. Rev. Lett. **124**, 117203 (2020).

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).

DAVID JONES

RESEARCH FOCUS

Our research lies at the convergence of condensed matter physics, 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

- Next Generation Femtosecond XUV sources for TR-ARPES
- Flexible VUV femtosecond lasers 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 2-D materials
- Frequency combs for mine sensing

CAREER HIGHLIGHTS

PhD MIT 1994 – 1999
NRC Research Assoc. NIST Boulder Labs 1998 – 2000
Senior Optical Engineer Photonex Corp. 2000 – 2001
Senior Research Assoc. CU Boulder 2001 – 2003
Asst. Professor UBC 2004 – 2010
Assoc. Professor UBC 2010 – 2020
Professor UBC 2020 – present

UNDERGRADUATE STUDENTS

Matan Guttmann, Fiona Lang, Jiayi Tang, Josh Zindler

GRADUATE STUDENTS

Rysa Greenwood, Bradley Guislain, Mike Hemsworth, Alexandra Tully, Max Werner

POSTDOCTORAL FELLOWS

Hao Chu, Philipp Sulzer

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).

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
- Neutral charge state of the muon in magnetic materails

CAREER HIGHLIGHTS

PhD UBC 1978 – 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
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

M.H. Dehn, J.K. Shenton, S. Holenstein, Q.N. Meier, D.J. Arseneau, D.L. Cortie, B. Hitti, A.C.Y. Fang, W.A. MacFarlane, R.M.L. McFadden, G.D. Morris, Z. Salman, H. Luetkens, N.A. Spaldin, M. Fechner, R.F. Kiefl. *Observation of charge-neutral Muon-Polaron Complex in Antiferromagnetic Cr_2O_3.* Phys. Rev. X **10**, 011036 (2020).

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 ^{8}Li+ in Rutile TiO_2.* 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. Letts. **116**, 106103 (2016).

ROMAN KREMS

RESEARCH FOCUS

Our work is at the intersection of quantum physics, machine learning and chemistry on problems of relevance to quantum materials and quantum technologies, including quantum computing, quantum sensing and quantum algorithms. We are particularly excited about applications of machine learning for solving complex quantum problems and applications of quantum hardware for machine learning.

CURRENT PROJECTS

- Exploring ways to accelerate quantum dynamics calculations with machine learning and combine quantum computing with machine learning for interesting applications

CAREER HIGHLIGHTS

PhD Goteborg University 1999 – 2002
SAO Predoc. Fellow Harvard-Smithsonian Centre for Astrophysics 2001 – 2002
Postdoc. Fellow Harvard University 2003 – 2005
Asst. Professor UBC 2005 – 2009
Assoc. Professor UBC 2009 – 2013
Professor UBC 2013 – Present

UNDERGRADUATE STUDENTS

Tom Hao, Mark Long, Wucheng Zhang

GRADUATE STUDENTS

Kasra Asnaashari, Jun Dai, Katherine Herperger, Pranav Kairon, Dawn Mao, Elham Torabian

POSTDOCTORAL FELLOWS

Ludmila Szulakowska

SELECTED PUBLICATIONS

R.A. Vargas-Hernández, J. Sous, M. Berciu, R.V. Krems. *Extrapolating Quantum Observables with Machine Learning: Inferring Multiple Phase Transitions from Properties of a Single Phase.* Phys. Rev. Lett. **121**, 255702 (2018).

J. Sous, M. Chakraborty, R.V. Krems, M. Berciu. *Light Bipolarons Stabilized by Peierls Electron-Phonon Coupling.* Phys. Rev. Lett. **121**, 247001 (2018).

J. Huang, S. Liu, D.H. Zhang, R.V. Krems. *Time-Dependent Wave Packet Dynamics Calculations of Cross Sections for Ultracold Scattering of Molecules.* Phys. Rev. Lett. **120**, 143401 (2018).

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 ^{8}Li. 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 1992 – 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

GRADUATE STUDENTS

Martin Dehn, Luca Egoriti, Derek Fujimoto, Victoria Karner, Edward Thoeng, John Ticknor

SELECTED PUBLICATIONS

V.L. Karner, A. Chatzichristos, D.L. Cortie, M.H. Dehn, O. Foyevstov, K. Foyevtsova, 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 LaNiO3 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 Bi2Te2Se investigated via β-detected nuclear magnetic relaxation and resonance of ^{8}Li.* 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 TiO2 Revealed by ^{8}Li β-Detected Nuclear Magnetic Resonance.* Chem. Mater. **29**, 10187 (2017).

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
- Photonic liquids based on graphene oxide
- Supramolecular compounds for stimuli-driven molecular delivery
- Self-assembly of cellulose nanocrystals in confined spaces

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

UNDERGRADUATE STUDENTS
Gagan Daliaho, Shine Huang, Joyce Li, Dorien Peng, Kacy Wang

GRADUATE STUDENTS
Amanda Ackroyd, Lucas Andrew, Mohammad Chaudhry, Francesco D'Acierno, Madhureeta Das Gupta, Raksha Kandel, Zongzhe Li, Jeanette Loos, Gunwant Matharu, Yihan Shi, Chris Walters, Yitao Xu

POSTDOCTORAL FELLOWS
Charlotte Boott, Kyoungil Cho, Michael Duss, David Ester, Arash Momeni, Miguel Angel Soto Munoz, Joanna Szymkowiak, Chris Walters, Gosuke Washino, Allen (Zhen) Xu

SELECTED PUBLICATIONS
Y. Cao, P.-X. Wang, F. D'Acierno, W.Y. Hamad, C.A. Michal, M.J. MacLachlan. *Tunable Diffraction Gratings from Biosourced Lyotropic Liquid Crystals*. Adv. Mater. **32**, 1907376 (2020).

C.E. Boott, A. Tran, W.Y. Hamad, M.J. MacLachlan. *Cellulose Nanocrystal Elastomers with Reversible Visible Color.* Angew. Chem. Int. Ed. **59**, 226 (2020).

M.A. Soto, V. Carta, R.J. Andrews, M.T. Chaudhry, M.J. MacLachlan. *Structural Elucidation of Selective Solvatochromism in a Responsive-at-metal Cyclometalated Platinum(II) Complex.* Angew. Chem. Int. Ed. **59**, 10348 (2020).

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 and photon emission. Our work involves device design, micro/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, low-cost scanning electron microscope

CAREER HIGHLIGHTS
PhD Stanford University 2000 – 2006
Asst. Professor UBC 2006 – 2011
Assoc. Professor UBC 2011 – 2016
Professor UBC 2016 – present

UNDERGRADUATE STUDENTS
Alexander Dimitrakopoulos, Maryam Rahbaran

GRADUATE STUDENTS
Daniel Bruns, Mike Chang, Mokter Mahmud Chowdhury, Mohab Hassan, Robyn McNeil, Ehsanur Rahman, Kevin Voon

POSTDOCTORAL FELLOWS
Céline Ruscher

SCIENTIFIC STAFF
Casimir Kuzyk

SELECTED PUBLICATIONS
E. Rahman, A. Nojeh. *Semiconductor thermionics for next generation solar cells: photon enhanced or pure thermionic?.* Nat. Commun. **12**, 4622 (2021).

M.V. Moghaddam, P. Yaghoobi, G.A. Sawatzky, A. Nojeh. *Photon-impenetrable, electron-permeable: the carbon nanotube forest as a medium for multi-photon thermal-photoemission.* ACS Nano **9**, 4064 (2015).

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 – 2021
Professor UBC 2021 – present

GRADUATE STUDENTS
Arnab Adhikary, Luis Mantilla Calderon, Paul Herringer, Michael Zurel

POSTDOCTORAL FELLOWS
Dmytro Bondarenko, Polina Feldmann, Wang Yang

SCIENTIFIC STAFF
Daniel Huerga

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).

X.-C. Yao, T.-X. Wang, H.-Z. Chen, W.-B. Gao, A.G. Fowler, R. Raussendorf, Z.-B. Chen, N.-L. Liu, C.-Y. Lu, Y.-J. Deng, Y.-A. Chen, J.-W. Pan. *Experimental demonstration of topological error correction*. Nature **482**, 489 (2012).

T.-C. Wei, I. Affleck, R. Raussendorf. *The 2D AKLT state is a universal quantum computational resource.* Phys. Rev. Lett. **106**, 070501 (2011).

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 Blusson QMI.

CURRENT PROJECTS
- Statistical physics of driven amorphous materials
- Thermodynamics, morphology, mechanics and thermal transport in entropy stabilized polymer blends
- Nanoscale phononics and thermal transport in carbon nanotubes (collaboration with Nojeh group)
- Computational exploration of multiple principal component oxides (GC project, collaboration with Hallas group)
- Amorphous metal oxide coatings with low mechanical loss (GC project, collaboration with Young/Zou groups)

CAREER HIGHLIGHTS
PhD Johns Hopkins University 1999 – 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

UNDERGRADUATE STUDENTS
Genevieve Ke, James We

GRADUATE STUDENTS
Daniel Bruns, Derek Fujimoto, Daniel Korchinski, Jared Popowski, Daniel Wong

POSTDOCTORAL FELLOWS
Solveig Aamlid

SCIENTIFIC STAFF
Debashish Mukherji

SELECTED PUBLICATIONS
D. Bruns, A. Nojeh, A.S. Phani, J. Rottler. *Nanotube heat conductors under tensile strain: Reducing the three-phonon scattering strength of acoustic phonons.* Phys. Rev. B **104**, 075440 (2021).

J. Rottler, M. Müller. *Kinetic Pathways of Block Copolymer Directed 2 Self-Assembly: Insights from Efficient Continuum Modeling.* ACS Nano **14**, 13986 (2020).

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).

JOESEPH SALFI

RESEARCH FOCUS

My group's main research interest is the physical implementation of quantum computers and quantum simulators. Our research expertise is in spin physics and quantum devices with a growing interest in superconducting devices. We work with spin-based qubits to investigate and build prototypes of future large-scale quantum computers based on silicon materials that underpin classical computer technologies, of very high industrial relevance. We employ similar techniques to build quantum simulators, which are anticipated to be one of the first technological applications of quantum information science, to help design materials. Quantum simulators are also anticipated to enable real laboratory tests of exotic aspects of many-body quantum theory, beyond that which can be tested by traditional experiments in, e.g., of relevance to e.g. condensed matter physics.

CURRENT PROJECTS

- Physical implementation of quantum computers
- Quantum simulation using spin qubits

CAREER HIGHLIGHTS

PhD University of Toronto 2005 – 2011
Postdoc. Fellow CQC2T University of New South Wales 2011 – 2015
ARC DECRA Fellow and Lecturer CQC2T University of New South Wales 2016 – 2018
Asst. Professor UBC 2019 – present

UNDERGRADUATE STUDENTS

Ashutosh Bhudia, Ryan Payne, Victor Sira, Noa Tajwar

GRADUATE STUDENTS

Hanieh Aghaee, Ana Ciocoiu, Karim Elkholy, Daniel Francis Julien-Neitzert, Mohammad Khalifa, Mukhlasur Rahman Tanvir

POSTDOCTORAL FELLOWS

Ebrahim Sajadi

SELECTED PUBLICATIONS

T. Kobayashi, J. Salfi, J. van der Heijden, C. Chua, M.G. House, D. Culcer, W.D. Hutchison, B.C. Johnson, J.C. McCallum, H. Riemann, N.V. Abrosimov, P. Becker, H.-J. Pohl, M.Y. Simmons, S. Rogge. *Engineering long spin coherence times of spin-orbit qubits in silicon.* Nat. Mater. **20**, 38 (2021).

J. Salfi, J.A. Mol, D. Culcer, S. Rogge. *Charge-insensitive single-atom spin-orbit qubit in silicon.* Phys. Rev. Lett. **116**, 246801 (2016).

J. Salfi, J.A. Mol, R. Rahman, G. Klimeck, M.Y. Simmons, L.C.L. Hollenberg, S. Rogge. *Quantum simulation of the Hubbard model with dopant atoms in silicon.* Nat. Commun. **7**, 11342 (2016).

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 are particularly interested in using inelastic electron scattering, also known as electron energy-loss spectroscopy, to probe the static and dynamic interactions between charge degrees of freedom in solids, especially at short wavelengths. 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

- Q-resolved electron energy-loss spectroscopy of charge excitations in strongly-correlated systems
- Screening of short-range Coulomb interactions in materials with strongly non-uniform polarizability
- Dynamical charge fluctuations, bond disproportionation, and negative charge transfer gap in systems such as $BaBiO^3$ and the perovskite rare-earth nickelates
- Electron-magnon-phonon coupling and their role in high Tc superconductors and topology
- Resonant soft x-ray reflectometry and the study of buried interfaces in heterostructures

CAREER HIGHLIGHTS

PhD University of Manitoba 1965 – 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, Yau Chuen (Oliver) Yam

POSTDOCTORAL FELLOWS

Oliver Dicks, Ali A. Husain, Mi Jiang, Dan Sun, Srinivas Vanka

SCIENTIFIC STAFF

Oleksandr Foyevstov, Fengmiao Li, Debashish Mukherji

SELECTED PUBLICATIONS

S. Johnston, A. Mukherjee, I. Elfimov, M. Berciu, G.A. Sawatzky. *Charge Disproportionation without Charge Transfer in the Rare-Earth-Element Nickelates as a Possible Mechanism for the Metal-Insulator Transition.* Phys. Rev. Lett. **112**, 106404 (2014).

M.T. Czyżyk, G.A. Sawatzky. *Local-density functional and on-site correlations: The electronic structure of La_2CuO_4 and $LaCuO_3$.* Phys. Rev. B **49**, 14211 (1994).

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. In the past, we have utilized ultrafast nonlinear optical spectroscopies to reveal the crystal and electronic structure of TMDCs. We are currently interested in developing novel scanning near-field optical microscopy techniques to interrogate the material's intrinsic response with subdiffractional resolution. We hope to leverage the extreme thickness of 2D materials and the ultra-strong field within the laser light to coherently control the material's electronic band structure. Novel devices such as photodetectors with bulk photovoltaic effect and topological superconductors are also under investigation within our group.

CURRENT PROJECTS

- Shift current and bulk photovoltaic effect at low-symmetry interfaces
- Topological superconductivity in van der Waals heterostructures
- Bose-Einstein condensate of interlayer excitons
- Sliding ferroelectricy in twisted 2D semiconductors
- Multidimensional coherent spectroscopy of correlated materials

CAREER HIGHLIGHTS

PhD University of California, Berkeley 2008 – 2013
Postdoc. Fellow University of California, Berkeley 2014
Postdoc. Fellow Columbia and Stanford University 2014 – 2017
Asst. Professor UBC 2017 – present

UNDERGRADUATE STUDENTS

Sean Chen, Sukhman Claire, Luna Liu, Edmond Ng, Teri Siu, Vedanshi Vala, Zhengbang Zhou

GRADUATE STUDENTS

Eddie Ji, Sean Raglow, Yunhuan Xiao, Dongyang Yang

POSTDOCTORAL FELLOWS

Jing Liang, Jingda Wu

SCIENTIFIC STAFF

Jerry Dadap

SELECTED PUBLICATIONS

T. Akamatsu, T. Ideue, L. Zhou, Y. Dong, S. Kitamura, M. Yoshii, D. Yang, M. Onga, Y. Nakagawa, K. Watanabe, T. Taniguchi, J. Laurienzo, J. Huang, Z. Ye, T. Morimoto, H. Yuan, Y. Iwasa. *A van der Waals interface that creates in-plane polarization and a spontaneous photovoltaic effect.* Science **372**, 68 (2021).

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).

JEFF YOUNG

RESEARCH FOCUS

Our group develops new optical materials and devices by controlling composition on lengthscales from 5 nm–500 nm. Electron-beam, atomic-force-microscopy (AFM), and optical lithographies are used in conjunction with a variety of etching and deposition technologies to produce 3D-textured structures in which the electronic and photonic eigen states can be "designed" by judicious choice of patterns, lengthscales, and material combinations. The motivation is to offer optical device engineers a more diverse range of material options when developing next and next-next generation technologies.

CURRENT PROJECTS

- Nonlinear properties of high-Q SOI-based photonic microcavities
- Integrated non-classical light sources in SOI based on parametric down conversion
- Integrated superconducting single photon detectors on silicon waveguides in SOI
- Scalable architectures for fault-tolerant photon-spin enabled quantum computing

CAREER HIGHLIGHTS

PhD University of Toronto 1979 – 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

UNDERGRADUATE STUDENTS

Julie Belleville, Ben Brown, Stephen Cashen, Baldeep Grewal

GRADUATE STUDENTS

Abdelrahman E. Afifi, Adan Azem, Adam Darcie, Sebastian Gitt, Becky Lin, David Roberts, Donald Witt, Xiruo Yan

POSTDOCTORAL FELLOWS

Kirsty Gardner, Matthew Mitchell, Andreas Pfenning

SCIENTIFIC STAFF

Kashif Awan

SELECTED PUBLICATIONS

X. Yan, W. Asavanant, H. Kamakari, J. Wu, J.F. Young, R. Raussendorf. *A quantum computer architecture based on silicon donor qubits coupled by photons.* Adv. Quantum Technol. **3**, 2000011 (2020).

H. Beygi, S.A. Sajjadi, A. Babakhani, J. Young, F. Veggel. *Surface chemistry of as-synthesized and air-oxidized PbS quantum dots.* App. Surf. Sci. **457**, 1 (2018).

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).

KE ZOU

RESEARCH FOCUS
Our research interests are in the growth of complex oxide and chalcogenide films by molecular beam epitaxy and the studies of their properties and functions. We aim to achieve scientific and technological breakthroughs in new materials and new functional devices. We 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
- Superconducting oxide thin films and heterostructures
- Emergent magnetism in oxide thin films and heterostructures
- 2D monolayer and multilayer ferromagnetic chalcogenide films
- Fe-based high temperature superconductors

CAREER HIGHLIGHTS
PhD Pennsylvania State University 2006 – 2012
Postdoc. Fellow Yale University 2012 – 2018
Asst. Professor UBC 2018 – present

UNDERGRADUATE STUDENTS
Henry Mullock

GRADUATE STUDENTS
Simon Godin, Rebecca Pons, Ryan Roemer, Hyungki Shin

POSTDOCTORAL FELLOWS
Chong Liu, Srinivas Vanka

SCIENTIFIC STAFF
Bruce A. Davidson, Fengmiao Li

SELECTED PUBLICATIONS
C. Liu, H. Shin, A. Doll, H.H. Kung, R.P. Day, B.A. Davidson, J. Dreser, G. Levy, A. Damascelli, C. Piamonteze, K. Zou. *High-temperature superconductivity and robustness against magnetic polarization in monolayer FeSe on EuTiO3.* npj Quantum Materials **6**, 85 (2021).

C. Liu, R.P. Day, F. Li, R.L. Roemer, S. Zhdanovich, S. Gorovikov, T.M. Pedersen, J. Jiang, S. Lee, M. Schneider, D. Wong, P. Dosanjh, F.J. Walker, C.H. Ahn, G. Levy, A. Damascelli, G.A. Sawatzky, K. Zou. *High-order replica bands in monolayer FeSe/SrTiO3 revealed by polarization-dependent photoemission spectroscopy.* Nat. Commun. **12**, 4573 (2021).

F. Li, Y. Zou, M.G. Han, K. Foyevtsova, H. Shin, S. Lee, C. Liu, K. Shin, S.D. Albright, R. Sutarto, F. He, B.A. Davidson, F.J. Walker, C.H. Ahn, Y. Zhu, Z.G. Cheng, I. Elfimov, G.A. Sawatzky, K. Zou. *Single-crystalline epitaxial TiO film: A metal and superconductor, similar to Ti metal.* Sci. Adv. **7**, eabd4248 (2021).

AFFILIATE INVESTIGATORS

FABIO BOSCHINI

RESEARCH FOCUS
We will take advantage of high-intensity long-wavelength light excitations to selectively explore and drive novel quantum phases of matter with no equilibrium counterpart. This research will be accomplished by accessing the dynamical properties of complex systems via state-of-the-art time- and angle-resolved photoemission spectroscopy (TR-ARPES) at INRS-EMT and Blusson QMI, as well as large-scale international user facilities, such as synchrotrons and free-electron lasers.

CURRENT PROJECTS
- Exploration of dynamic charge correlations in high-temperature superconductors via equilibrium and out-of-equilibrium x-ray scattering
- Probe Floquet-Bloch states in Dirac-like systems via time-resolved photoemission spectroscopy
- Mapping resonant phonon pumping effects in complex materials via TR-ARPES Imaging

CAREER HIGHLIGHTS
PhD Politecnico di Milano 2012 – 2014
Postdoc. Fellow 2015 – 2020
Asst. Professor INRS-EMT 2020 – present
Affiliate Asst. Professor Blusson QMI 2021 – present

GRADUATE STUDENTS
Sydney Dufresne at UBC (co-supervised with A. Damascelli at UBC)
Benson Kwaku Frimpong (INRS)
Jean-Michel Parent at INRS (co-supervised with F. Légaré at INRS)

POSTDOCTORAL FELLOWS
Gaetan Jargot at INRS (co-supervised with F. Légaré at INRS)

SELECTED PUBLICATIONS
F. Boschini, M. Minola, R. Suarto, E. Schierle, M. Bluschke, S. Das, Y. Yang, M. Michiardi, Y.C. Shao, X. Feng, S. Ono, R.D. Zhong, J.A. Schneeloch, G.D. Gu, E. Weschke, F. He, Y.D. Chuang, B. Keimer, A. Damascelli, A. Frano, E.H. Da Silva Neto. *Dynamic electron correlations with charge order wavelength along all directions in the copper oxide plane.* Nat. Commun. **12**, 597 (2021).

F. Boschini, M. Zonno, E. Razzoli, M. Michiardi, R.P. Day, B. Zwartsenberg, P. Nigge, M. Schneider, E.H. da Silva Neto, A. Erb, S. Zhdanovich, A.K. Mills, G. Levy, C. Giannetti, D.J. Jones, A. Damascelli. *Emergence of pseudogap from short-range spin-correlations in electron-doped cuprates.* npj Quantum Mater. **5**, 6 (2020).

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 superconductivity in cuprates via ultrafast quenching of phase coherence.* Nat. Mater. **17**, 416 (2018).

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 Blusson QMI, 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 heavy fermion systems and correlated oxides
- Orbital imaging in multipolar-ordered compounds
- 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 Blusson QMI 2017 – present
Asst. Professor University of Saskatchewan 2017 – present

GRADUATE STUDENTS

Patrick Braun, Jessie Freese, Grant Harris, Niyusha Hosseini, Lucas Korol, Skylar Koroluk

SELECTED PUBLICATIONS

R.J. Green, V. Zabolotnyy, M. Zwiebler, Z. Liao, S. Macke, R. Sutarto, F. He, M. Huijben, G. Rijnders, G. Koster, J. Geck, V. Hinkov, G.A. Sawatzky. *Intrinsic versus extrinsic orbital and electronic reconstructions at complex oxide interfaces.* Phys. Rev. Mater. **5**, 065004 (2021).

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KENJI KOJIMA

RESEARCH FOCUS

Our group utilizes and develops muon spin rotation/relaxation/resonance (μSR) and beta-decay detected nuclear magnetic resonance (β-NMR) at the TRIUMF laboratory on UBC campus, to understand the roles of spin and charge degrees of freedom in various kinds of quantum matter. They are sensitive magnetic probes; we utilize μSR and Li-NMR to probe and characterize magnetism and superconductivity. Muon is a light isotope of hydrogen, so the role of hydrogen is also investigated in quantum materials.

CURRENT PROJECTS

- Frustrated quantum magnets and their ground states
- Unconventional superconductivity with spin-orbit couplings and strong correlations
- Hydrogen roles in wide gap semiconductors
- Characterization of carrier motion and density via the Li β-NMR in semiconductors

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
Affiliate Assoc. Professor Blusson QMI 2018 – present

UNDERGRADUATE STUDENTS

Marta-Villa de Toro Sanchez (Edinburgh)

POSTDOCTORAL FELLOWS

Yipeng Cai, Sungwon Yoon

SELECTED PUBLICATIONS

R. Okuma, M. Kofu, S. Asai, M. Avdeev, A. Koda, H. Okabe, M. Hiraishi, S. Takeshita, K. Kojima, R. Kadono, T. Masuda, K. Nakajima, Z. Hiroi. *Dimensional reduction by geometrical frustration in a cubic antiferromagnet composed of tetrahedral clusters.* Nat. Commun. **12**, 4382 (2021).

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K. Koshino, K.M. Kojima, I. McKenzie, S. Ito. *Muonium Addition to a peri-Trifluoromethylated 9-Phosphaanthracene Producing a High-Energy Paramagnetic p-Conjugated Fused Heterocycle.* Angew. Chem. Int. Ed. **60**, 24034 (2021).

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 Blusson QMI'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.

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.

J.C. SÉAMUS 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

Séamus Davis is a Professor of Physics at Oxford University, Professor of Quantum Physics at the University of College Cork, and Emeritus Professor of Physics at Cornell University. 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, and space-time; as well as developing new techniques for visualization and measurement of complex quantum matter.

GEORGE CRABTREE

Distinguished Fellow, Argonne National Laboratory
Distinguished Professor of Physics, Electrical and Mechanical Engineering, University of Illinois at Chicago
Director of the Joint Centre 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 Centre 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.

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.

ANTOINE GEORGES

Director, Centre for Computational Quantum Physics,
Flatiron Institute (New York)
Professor, Collège de France (Paris)

Antoine Georges is a theoretical physicist with expertise in condensed matter and quantum physics. He 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.

STUART PARKIN

Max Planck Institute for Microstructure Physics, Halle (Saale), Germany

Stuart Parkin is a Director of the Max Planck Institute for Microstructure Physics, Halle, Germany, and an Alexander von Humboldt Professor, Martin Luther University, Halle-Wittenberg. His research interests include spintronic materials and devices for advanced sensor, memory, and logic applications, oxide thin-film heterostructures, topological metals, exotic superconductors, and cognitive devices. Parkin's discoveries in spintronics enabled a more than 10000-fold increase in the storage capacity of magnetic disk drives. For his work that thereby enabled the "big data" world of today, Parkin was awarded the Millennium Technology Award from the Technology Academy Finland in 2014 (worth 1,000,000 Euro) and, most recently the King Faisal Prize for Science 2021 for his research into three distinct classes of spintronic memories. Parkin is a Fellow/ Member of: Royal Society (London), Royal Academy of Engineering, National Academy of Sciences, National Academy of Engineering, German National Academy of Science—Leopoldina, Royal Society of Edinburgh, Indian Academy of Sciences, and TWAS—academy of sciences for the developing world and has received numerous awards from around the world.

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 Centre 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.

2021 PUBLICATIONS

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M.R. Benam, K. Foyevtsova, A. Khazraie, I.S. Elfimov, G.A. Sawatzky. *Bond versus charge disproportionation and nature of the holes in s-p* ABX_3 *perovskites*. Phys. Rev. B **104**, 195141 (2021).

D. Betto, R. Fumagalli, L. Martinelli, M. Rossi, R. Piombo, K. Yoshimi, D. Di Castro, E. Di Gennaro, A. Sambri, D.A. Bonn, G.A. Sawatzky, L. Braicovich, N.B. Brookes, J. Lorenzana, G. Ghiringhelli. *Multiple-magnon excitations shape the spin spectrum of cuprate parent compounds*. Phys. Rev. B **103**, L140409 (2021).

A. Bhardwaj, A.S. Phani, A. Nojeh, D. Mukherji. *Thermal Transport in Molecular Forests*. ACS Nano **15**, 1826 (2021).

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M.T. Chaudhry, S. Akine, M.J. MacLachlan. *Contemporary macrocycles for discrete polymetallic complexes: Precise control over structure and function*. Chem. Soc. Rev. **50**, 10713 (2021).

M.T. Chaudhry, S. Ota, F. Lelj, M.J. MacLachlan. *Breathing Room: Restoring Free Rotation in a Schiff-Base Macrocycle through Endoperoxide Formation*. Org. Lett. **23**, 9538 (2021).

R. Chavez Zavaleta, S. Fomichev, G. Khaliullin, M. Berciu. *Effects of reduced dimensionality, crystal field, electron-lattice coupling, and strain on the ground state of a rare-earth nickelate monolayer.* Phys. Rev. B **104**, 205111 (2021).

R. Cheng, L. Chrostowski. *Spectral Design of Silicon Integrated Bragg Gratings: A Tutorial*. J Lightwave Technol **39**, 9247140 (2021).

L. Chrostowski, L. Dias, M. Mitchell, C. Mosquera, E. Luan, M. Al-Qadasi, A. Randhawa, H.R. Mojaver, E. Lyall, A. Gervais, R. Dubé-Demers, K. Awan, S. Gou, O. Liboiron-Ladouceur, W. Shi, S. Shekhar, K.C. Cheung. *A silicon photonic evanescent-field sensor architecture using a fixed-wavelength laser.* Proc SPIE Int Soc Opt Eng **11692**, 116920W (2021).

L. Chrostowski, H. Shoman. *Online Training in the Design-Fabricate-Test of Silicon Photonic Circuits*. Opt. InfoBase Conf. Papers F2B.3 (2021).

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F. D'Acierno, W.Y. Hamad, C.A. Michal, M.J. MacLachlan. *Sustainable biochars from carbonization of cellulose filaments and nanocrystals*. Bioresour. Technol. Rep. **16**, 100838 (2021).

A. Darcie, M. Mitchell, K. Awan, M. Abdolahi, M. Hammood, A. Pfenning, X. Yan, A. Afifi, D. Witt, B. Lin, S. Gou, J. Jhoja, J. Wu, I. Taghavi, D.M. Weekes, N.A.F. Jaeger, J.F. Young, L. Chrostowski. *SiEPICfab: The Canadian silicon photonics rapid-prototyping foundry for integrated optics and quantum computing*. Proc SPIE Int Soc Opt Eng **11691**, 116910C (2021).

M.H. Dehn, J.K. Shenton, D.J. Arseneau, W.A. MacFarlane, G.D. Morris, A. Maigné, N.A. Spaldin, R.F. Kiefl. *Local Electronic Structure and Dynamics of Muon-Polaron Complexes in* Fe_2O_3. Phys Rev Lett **126**, 037202 (2021).

M.H. Dehn, R. Scheuermann, P.X. Wang, Y. Cao, M.J. MacLachlan, V.M. Zamarion, D.G. Fleming, R.F. Kiefl. *Precision measurement of the muonium hyperfine interaction in mesoporous silica and aerogel*. Phys. Rev. Res. **3**, 013029 (2021).

G. Farinelli, A. Di Luca, V.R.I. Kaila, M.J. MacLachlan, A. Tiraferri. *Fe-chitosan complexes for oxidative degradation of emerging contaminants in water: Structure, activity, and reaction mechanism*. J. Hazard. Mater. **408**, 124662 (2021).

A.G. Fink, E.W. Lees, Z. Zhang, S. Ren, R.S. Delima, C.P. Berlinguette. *Impact of Alkali Cation Identity on the Conversion of* HCO_3^- *to CO in Bicarbonate Electrolyzers*. ChemElectroChem **8**, 2094 (2021).

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M. Goldman, E.W. Lees, P.L. Prieto, B.A.W. Mowbray, D.M. Weekes, A. Reyes, T. Li, D.A. Salvatore, W.A. Smith, C.P. Berlinguette. *Chapter 10: Electrochemical Reactors*. RSC Energy Environ. Ser. **2021-January**, 408 (2021).

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B.H. Goodge, D. Li, K. Lee, M. Osada, B.Y. Wang, G.A. Sawatzky, H.Y. Hwang, L.F. Kourkoutis. *Doping evolution of the Mott-Hubbard landscape in infinite-layer nickelates*. Proc. Natl. Acad. Sci. U. S. A. **118**, e2007683118 (2021).

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B. Hou, R.V. Krems. *Quantum transfer through small networks coupled to phonons: Effects of topology versus phonons*. Phys. Rev. E **104**, 045302 (2021).

A. Huang, Y. Cao, R.S. Delima, T. Ji, R.P. Jansonius, N.J.J. Johnson, C. Hunt, J. He, A. Kurimoto, Z. Zhang, C.P. Berlinguette. *Electrolysis Can Be Used to Resolve Hydrogenation Pathways at Palladium Surfaces in a Membrane Reactor.* JACS Au **1**, 336 (2021).

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M. Jiang, G.A. Sawatzky, M. Berciu, S. Johnston. *Polaron and bipolaron tendencies in a semiclassical model for hole-doped bismuthates*. Phys. Rev. B **103**, 115129 (2021).

V.L. Karner, A. Chatzichristos, D.L. Cortie, D. Fujimoto, R.F. Kiefl, C.D.P. Levy, R. Li, R.M.L. McFadden, G.D. Morris, M.R. Pearson, E. Benckiser, A.V. Boris, G. Cristiani, G. Logvenov, B. Keimer, W.A. MacFarlane. *Evolution of the metallic state in $LaNiO_3/LaAlO_3$ superlattices measured by Li 8 β -detected NMR*. Phys. Rev. B **104**, 205114 (2021).

T. Kobayashi, J. Salfi, C. Chua, J. van der Heijden, M.G. House, D. Culcer, W.D. Hutchison, B.C. Johnson, J.C. McCallum, H. Riemann, N.V. Abrosimov, P. Becker, H.J. Pohl, M.Y. Simmons, S. Rogge. *Engineering long spin coherence times of spin–orbit qubits in silicon*. Nat. Mater. **20**, 38 (2021).

D. Korchinski, C. Ruscher, J. Rottler. *Signatures of the spatial extent of plastic events in the yielding transition in amorphous solids*. Phys. Rev. E **104**, 034603 (2021).

A. Kurimoto, R.P. Jansonius, A. Huang, A.M. Marelli, D.J. Dvorak, C. Hunt, C.P. Berlinguette. *Physical Separation of H_2 Activation from Hydrogenation Chemistry Reveals the Specific Role of Secondary Metal Catalysts*. Angew. Chem. Int. Ed. **60**, 11937 (2021).

É. Lantagne-Hurtubise, V. Pathak, S. Sahoo, M. Franz. *Superconducting instabilities in a spinful Sachdev-Ye-Kitaev model*. Phys. Rev. B **104**, L020509 (2021).

A. Laucht, F. Hohls, N. Ubbelohde, M.F. Gonzalez-Zalba, D.J. Reilly, S. Stobbe, T. Schröder, P. Scarlino, J.V. Koski, A. Dzurak, C.H. Yang, J. Yoneda, F. Kuemmeth, H. Bluhm, J. Pla, C. Hill, J. Salfi, A. Oiwa, J.T. Muhonen, E. Verhagen, M.D. LaHaye, H.H. Kim, A.W. Tsen, D. Culcer, A. Geresdi, J.A. Mol, V. Mohan, P.K. Jain, J. Baugh. *Roadmap on quantum nanotechnologies*. Nanotechnology **32**, 162003 (2021).

F. Li, Y. Zou, M.G. Han, K. Foyevtsova, H. Shin, S. Lee, C. Liu, K. Shin, S.D. Albright, R. Sutarto, F. He, B.A. Davidson, F.J. Walker, C.H. Ahn, Y. Zhu, Z.G. Cheng, I.S. Elfimov, G.A. Sawatzky, K. Zou. *Single-crystalline epitaxial TiO film: A metal and superconductor, similar to Ti metal*. Sci. Adv. **7**, eabd4248 (2021).

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Blusson QMI dogs Hunter (left) and Hobbes (right)

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