

FOREWORD – THE INTERNATIONAL YEAR OF QUANTUM SCIENCE AND TECHNOLOGY ACROSS CANADA

John Donohue, Ben Newling and Neil J. Ross, Guest Editors, *Physics in Canada*



The United Nations General Assembly officially declared 2025 to be the International Year of Quantum Science and Technology (IYQ) [1]. The resolution, submitted by the nation of Ghana and co-sponsored by 73 countries, represents more than 5 billion people, which is surely an indication of the breadth of the impact of all things quantum

in everyday lives. More importantly, the resolution is a call for the democratization of quantum science:

“As we press forward with quantum computing, quantum simulation and other applications of quantum technologies to help overcome current constraints and go beyond what is possible today, we should underscore how important it is for the skills in quantum science and technology to be diverse and universal, including from Africa and the developing world, and to mainstream the inclusion of women.” [1]

This special issue of *Physics in Canada* hopes to contribute by “increase[ing] public awareness of the importance of quantum science and applications” [1] and “inspire[ing] young people across the globe... to take an interest in such an exciting field of study” [1].

In 1925, Walter Heisenberg ushered in the “new” quantum mechanics with his paper “On the quantum-theoretical reinterpretation of kinematical and mechanical relationships” [2], in which he sought to establish a basis for the quantum theory using only physical quantities that could be directly observed at the time. Heisenberg drafted his paper in July of 1925 and asked his senior colleague, Max Born, to take a look, before leaving on vacation. While Heisenberg was away, Born realized that some of the mathematics suggested the use of matrices and he enlisted his assistant Pascual Jordan in writing a re-interpretation, which was also published in 1925 [3] and followed by a second part [4] in which the three scientists, together, established key pieces of the understanding upon which quantum technologies are built today [5]. At the same time, Erwin Schrödinger, inspired by an offhand remark by Peter Debye that Louis de Broglie’s matter waves should be governed by some sort of wave equation, had been developing his famous wave mechanics formulation. Schrödinger drew up his wave equation

The contents of this journal, including the views expressed above, do not necessarily represent the views or policies of the Canadian Association of Physicists.

Comments of readers on this Foreword are more than welcome.

in 1925 and published it in 1926 [6]. Shortly afterwards, Schrödinger tied the two threads together by showing that the wave and matrix approaches are equivalent.

Fast forward one hundred years and we find ourselves increasingly reliant upon a host of quantum technologies, such the atomic clocks that underpin GPS, the semiconductor electronics that are the basis for modern computing, magnetic resonance imaging in the clinic, and lasers around every corner. We also find ourselves looking ahead, in the Government of Canada's "National Quantum Strategy" (NQS), to a "quantum-enabled future" [7]. The \$360-million investment described in the NQS is an affirmation of Canada's strategic commitment to quantum science and technology [8], which seems increasingly necessary given optimistic forecasts, for example, of a \$139-billion industry supporting 200,000 Canadian jobs by 2045 [9].

Included in this issue is a tribute to the late Raymond Laflamme, a pioneer of quantum information science in Canada and one of the key guiding figures of the Government of Canada's quantum strategy. A feature article from his group on responsible innovation in quantum technologies highlights the need for thoughtful development of such strategies. To explore how industry needs are accounted for in the NQS, we have included an interview with Photonic Inc founder and co-chair of the Canadian Quantum Advisory Council, Stephanie Simmons.

Exploring the foundations of quantum science led to unexpected fields like quantum computing, and continuing to explore those foundations is a major part of physics research in Canada. In an opinion piece, Gilles Brassard explores what the Nobel-prize winning Bell tests really say about non-locality, challenging the common conception that Bell tests prove nature is nonlocal. In another, Louis Marchildon shares his two major unanswered questions about quantum science.

Quantum information technologies are commonly broken up into a number of categories, which change from place to place but almost always include sensors, communication, and computers. In this issue, we are pleased to include an overview of quantum sensing work in Canada, including the physical systems explored and sectors impacted. For a specific quantum sensor, we have also included a deep dive into atomic gravimeters being developed at the University of New Brunswick. In communication and networking, near-ideal photon sources are essential, as reviewed by Dalhousie University researchers in a feature article on these flying qubits. For computation, you can find a feature article on the history of quantum error correction developments in Canada.

The modern quantum paradigm is one that not only explores how physics intersects with computer science, chemistry, mathematics, and engineering, but also one that breaks down traditional boundaries between fields of physics as its language and tools find homes in new domains. Relativistic quantum information, for example, explores the intersection of relativity, information theory, and quantum mechanics, and has grown rapidly thanks in large part to contributions from Canadian physicists, as detailed in a feature article by Robert Mann's group. More feature articles explore how quantum computing may find uses in healthcare by improving radiotherapy techniques, how quantum phenomena influence biology, and how nanomaterials enabled by quantum mechanics could provide a

path to neuromorphic computing. You can also find a review of how quantum sensors, computation, and materials are applied in particle physics research at TRIUMF.

To realize the promise of quantum information science and technology, a new generation of keen researchers are needed. Those future workers will be educated and trained in schools, colleges, universities, internships and apprenticeships in Canada and outside Canada, in learning situations that may be very different from those we are used to, in order to mentor a diverse, “quantum-ready workforce” [10]. Welcoming new people to a topic with a public-perception problem like quantum science requires presenting the science in new, accessible ways. We have included an article on outreach efforts across Canada aiming to make quantum accessible to pre-university students, as well as an article exploring different models of introducing quantum physics at the undergraduate level. Finally, as IYQ provided a platform to promote the achievements and wonder of quantum mechanics, we have included a yearbook highlighting the numerous celebrations that brought together people across Canada in 2025, as well as the results of the Quantum Arts and IYQ Canada Logo Design competitions organized by the CAP IYQ Task Force with the generous support of NSERC. We have also included a themed crossword puzzle for a quieter sort of celebration.

The future is always (appropriately) uncertain, but we can be confident that fruitful quantum developments will require collaboration between governments, academic institutions, for-profit and not-for-profit organizations and between quantum physicists of all stripes [10]. We hope that you will see some of that variety gathered in this special issue, not as a comprehensive directory of activities across the country, but more as a sample of the diversity of contributions that are absolutely necessary for groundbreaking discovery and innovation.

No less certain is the need for collaboration between quantum scientists and quantum technologists across borders. A national strategy is an essential thing, and provincial collaborations are crucial to leverage the quantum infrastructure and expertise that Canada has nurtured with decades of investment. However, an *international* point of view has been essential in the last one hundred years of ideas freely exchanged and quantum inventions marvelously realized. It is to be hoped that those collaborations may continue to advance quantum science and technology in “its further contribution to addressing the prevailing challenges of our time” [1].

John Donohue, University of Waterloo
Ben Newling, University of New Brunswick
Neil J. Ross, Dalhousie University
Guest Editors, *Physics in Canada*

REFERENCES

- [1] United Nations, Official Records, A/78/PV.88, General Assembly 88th Plenary Meeting, 7th June (2024).
- [2] W. Heisenberg, Über quantentheoretische Umdeutung kinematischer und mechanischer Beziehungen, *Z. Physik* **33** (1), 879–893 (1925).

- [3] M. Born and P. Jordan, Zur Quantenmechanik, *Z. Physik* **34**, 858–888, (1925).
- [4] M. Born, W. Heisenberg, and P. Jordan, Zur Quantenmechanik II, *Z. Physik* **35**, 557–615, (1925).
- [5] B. L. van der Waerden, editor, *Sources of Quantum Mechanics* (Dover Publications, 1968).
- [6] E. Schrödinger, An Undulatory Theory of the Mechanics of Atoms and Molecules, *Phys. Rev.* **28**(6), 1049-1070 (1926).
- [7] Innovation, Science and Economic Development Canada, *Overview of Canada’s National Quantum Strategy*, Government of Canada, <https://ised-isde.canada.ca/site/national-quantum-strategy/en> (2022).
- [8] B. Sussman, P. Corkum, A. Blais, D. Cory, and A. Damascelli, Quantum Canada, *Quantum Sci. Tech.* **4**, 020503 (2019).
- [9] Doyletech Corporation, *Socio-Economic Impact Assessment of Quantum Technologies in Canada*, (Doyletech Corporation, 2020).
- [10] Expert Panel on the Responsible Adoption of Quantum Technologies, “Quantum Potential”, Council of Canadian Academies, <https://cca-reports.ca/reports/quantum-technologies/> (2023).