Pioneering the Quantum Frontier



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e are on the cusp of a technological revolution – the quantum information revolution – and Canada is poised to become the world's "Quantum Valley."

It's often said that big things come in small packages, but I prefer to rephrase it. The smallest packages – atoms, electrons, and other quantum particles – will bring about the next big thing in scientific innovation. By harnessing the laws of quantum mechanics, we can pioneer incredible new technologies that will forever change the ways we work, communicate, play and live.

The Institute for Quantum Computing (IQC) at the University of Waterloo is the world's largest concentration of quantum information research, and growing every day. Nearly 200 scientists – a multidisciplinary team of faculty, students and postdoctoral fellows spanning physics, computer science, mathematics, chemistry and engineering – pursue research at the highest international level.

Just weeks ago, the institute celebrated the grand opening of its state-of-the-art new headquarters, the Mike & Ophelia Lazaridis Quantum-Nano Centre. This new facility is – quite literally – the next big thing in enabling cutting-edge science. The 285,000-square-foot building, shared between IQC and the Waterloo Institute for Nanotechnology, is unique in the world, from its stringent technical specifications to its collaborative spaces and inspiring architecture. The facility is shielded from even the tiniest disturbances that can disrupt experiments at the quantum scale, and designed to attract top researchers from around the globe. Within a week of the grand opening, more than 5,000 visitors toured the facility, exemplifying IQC's mission to share its discoveries with those who support it and will benefit from it.

Mike and Ophelia Lazaridis, whose visionary philanthropy launched IQC a decade ago and made possible the new Quantum-Nano Centre, foresee Waterloo becoming the world's "Quantum Valley of the 21st Century." At the grand opening of the facility in September, Mike Lazaridis described how the Quantum-Nano Centre will become the future equivalent of Bell Labs (the birthplace of the computing revolution that defined the 20th century). Prof. Stephen Hawking – my former PhD mentor and longtime friend – joined us for the grand opening of the building. He said "what's happening in Waterloo is truly special, from theory to experiment and beyond, (and) such dedication to deep, fundamental science will benefit generations to come."

Quantum information research is about much more than creating the next gadget or "killer app." It is a dramatic transformation of the ways we manipulate, store and transmit information, building upon an entirely different set of physical principles. IQC scientists aim to control phenomena of the quantum world, which often behave in ways contrary to our everyday intuition (even Einstein struggled with the quantum concept called "entanglement," which he described as "spooky").

A century of quantum research has led us to a pivotal point in history. Quantum phenomena that once puzzled us are now within our control, and the technological implications are enormous. Take quantum "superposition," which holds that a particle can be in multiple states simultaneously. If we use such particles as "bits" for computation, those bits could not only be ascribed the conventional binary values of zero or one, but could also be in a "superposition" of both zero *and* one simultaneously. The resulting speed-up to computing power is enormous, and could allow us to solve problems too taxing for even today's most advanced supercomputers.

Beyond computing, quantum information science promises breakthroughs in other important areas, such as information technologies or new sensors of unprecedented precision. These breakthroughs will have applications in medicine, oil exploration, materials design and more. We've only begun to imagine the possibilities.

Just as exciting as the research itself is where it's happening; Canada is already a recognized leader in the quantum race and our research efforts are continually growing. IQC is a shining example of partnerships between the public sector, private philanthropy and academia. Canada's continued position at the forefront of quantum science is the direct result of this teamwork. I can't think of a better place than Waterloo – with its bustling hightech ecosystem, entrepreneurial spirit and history of excellence in computer science and engineering – to have launched this effort.

We're already seeing the first practical technologies and start-up companies emerging from our research – and we're just getting started. The next generation of students will take for granted ideas their professors could only imagine. While we have charted a path toward a full-scale quantum computer, the unexpected breakthroughs and spin-off technologies emerging along that path are equally as exciting. The revolution is well under way. Welcome to the quantum frontier.