# Commercialising Quantum Technologies in New Zealand

## A Report on the Current State and Opportunities

Murray Early, Anne French, Nick Long, Jevon Longdell, Scott Parkins, Harald Schwefel and Frédérique Vanholsbeeck

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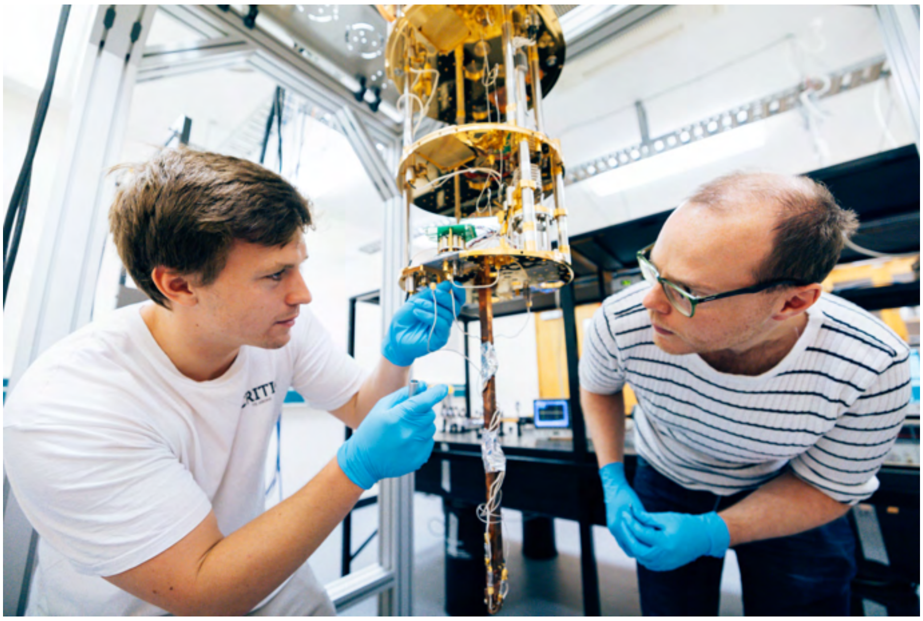

**Figure 1:** Otago based researchers preparing an experiment for cooling to milli-Kelvin temperatures. These ultra-low temperatures are where many quantum computers operate.

# Contents

# Executive Summary

## Global momentum, local opportunity

NZ stands at a pivotal moment as a global shift toward the development and adoption of quantum technologies is underway. Major economies such as the US, UK, EU, China and Singapore have already invested heavily in quantum technologies. Countries like Korea have acknowledged they are behind and are rapidly scaling, committing billions to catch up.

New Zealand investment has been modest in comparison but the country has built a **globally respected research base** in the relevant areas, photonics, atomic physics, quantum optics, materials science and cryogenics. This capability is the result of a very long-term focus on these areas.

In the last couple of decades, this work has been supported by New Zealand's Centres of Research Excellence (CoRE) Scheme. Most notably, Te Whai Ao — The Dodd-Walls Centre for Photonic and Quantum Technologies and The MacDiarmid Institute for Advanced Materials and Nanotechnology. These CoREs have also trained a generation of researchers involved in the development of quantum technologies around the world. More recently, the Quantum Technologies Aotearoa research program has accelerated investment with a stronger focus on technologies (as opposed to science) and on maintaining strong international links.

*This foundation positions New Zealand to participate in global supply chains with timely investment.*

If New Zealand chooses not to invest in quantum technologies, it does not simply delay participation — it likely forfeits it. Quantum capability is path dependent, relying on early accumulation of skills, infrastructure, and international positioning that cannot be rapidly rebuilt later. In a counterfactual of no investment, NZ becomes structurally dependent on foreign quantum infrastructure, misses spillovers into climate, health, and primary industries, exports its talent, and loses influence over emerging global standards. Given the asymmetric risk – where modest early investment preserves strategic options while no investment creates irreversible lock-in – the dominant risk lies not in acting too early, but in waiting too long.

## Why Quantum matters for NZ

Quantum technologies, in addition to providing new computational capabilities, are expected to underpin new industries in secure communications, advanced sensing, and precision navigation. Like all technology areas, these will be enabled by diverse supply chains, which NZ can be a part of.

Quantum technologies have particular relevance for national security and NZ's sovereign capabilities. Quantum sensing and communication directly support:

- Resilient position, navigation and timing (PNT) capabilities that can be used in the absence of GPS.

- Secure financial and government communications.
- Environmental and hazard monitoring. Including seismic, volcanic and tsunami monitoring.
- Biomedical sensing and imaging.

### Existing strengths

New Zealand has a broad range of relevant research strengths:

- **Quantum sensing** including Rydberg electrometers, atomic magnetometers, gravimeters, and atomic clocks.
- **Quantum communication** including quantum memories, entangled light sources, and free space optical links.
- **Quantum computing components** including microwave to optical transducers, memories, microcombs, and quantum simulation software.
- **Quantum-adjacent hardware** including photonic technologies, materials science, cryogenics and cryogenic memory.

### Quantum adjacent technologies

NZ should not take a narrowly defined approach to quantum investment. This report makes it clear that quantum technologies do not stand alone. They rely on a broad ecosystem of enabling technologies, many of which are already research strengths in New Zealand. NZ should also be ready to commercialise non-quantum technologies that come out of quantum research.

### Recommendations

The report's recommendations include:

1. **Establish a New Zealand Quantum Technologies Hub**. Modelled on the UK quantum hubs, the goal would be adoption and commercialisation of quantum technologies. This would be enabled by industry (including Māori enterprises), researchers, and policy makers working closely together. After a decade of investment in quantum hubs, the UK now ranks in the top three in the world in terms of the number of quantum startups, and first in Europe.
2. **Flagship quantum programmes**. The investment should include support for one or more nationwide, pan-institutional, quantum flagship programmes.
3. **Create a Masters-level quantum engineering programme** to build a skilled workforce.

# 1 Quantum technology and its benefits

> "Quantum technologies represent a new paradigm with potentially groundbreaking applications for digital economies and society. Quantum sensing, computing and communication are significantly expanding technological capabilities to gather, process and transmit information."
>
> *OECD, A Quantum Technologies Policy Primer, 2025, No 371, p3*[1]

## 1.1 What is quantum technology?

Quantum technologies are applications of the principles of quantum mechanics. Quantum mechanics is a covering term for the laws of nature governing a range of physical systems from elementary particles, atoms, and light through to molecules and solids. Its beginnings date to Einstein's description of the photoelectric effect and Max Planck's explanation for the spectrum of black body radiation in the early 1900s. The major revolution occurred in the 1920s with Schrödinger's equation and other formulations for calculating the frequencies for the absorption and emission of light by atoms.

The underlying physical laws by which matter and light operate were found to be very strange. They required introducing a mysterious 'wave function' of unclear physical status, which could be used to calculate the probabilities of experimental outcomes. Uncertainty was found to be an irreducible property of physical systems, not just an experimental limitation. Through popular science writing, many aspects of quantum physics and interpretative controversies are familiar to the general reader, such as the Uncertainty Principle, Schrödinger's cat, and Einstein's dictum that 'God doesn't play dice'.

What is completely certain is the technological impact of what we will call Quantum Technology 1.0. The first wave of quantum applications included the development of the transistor, of integrated circuits, lasers, and MRI machines– to name only a few examples. The new quantum science enabled a technology revolution in the twentieth century that used the electromagnetic spectrum (this includes x-ray, visible light, radio and microwaves, etc.), atoms, molecules and solids to transform energy, sense the world around us and within us, and to process and communicate information.

In this report, we assess the potential of what is being called Quantum Technology 2.0. In this second technological wave, the 'spooky' properties of quantum systems are used directly to sense, compute, and communicate. Our existing computers at the material level of transistors rely on quantum phenomena to operate; however, at the level of information processing, they operate with Boolean algebra - 'classical' zeroes and ones. We know at each point of an executing algorithm whether a bit (a unit of information) is 0 or 1. In quantum computing, the foundational computing unit becomes a 'quantum bit' or qubit.

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[1] A quantum technologies policy primer: OECD digital economy papers, January 2025, No. 371, `https://www.oecd.org/en/publications/a-quantum-technologies-policy-primer_fd1153c3-en.html`

**Quantum sensing**

Precise measurement for applications including:

- Resource monitoring, infrastructure management and environmental monitoring
- Navigation without GPS
- Biomedical imaging

**Quantum computing**

Solving:

- Complex problems beyond the capabilities of classical computers
- Optimisation
- Simulating natural or synthetic biology, chemistry, physics

**Quantum communication**

Enabling:

- Advanced cryptography
- Scaling quantum computers
- Linking sensors for enhanced performance

**Figure 2:** Quantum technologies are usefully grouped into three classes.

This unit can only be described by a quantum wavefunction. The properties of the qubit can be controlled and usefully manipulated – but they must be described using quantum physics.

## 1.2 Quantum sensing and metrology

Quantum sensors measure many of the same things we measure now: magnetic fields, properties of light, time, mass, and gravity. However, they do this with unprecedented sensitivity and precision, opening up new application areas.

Often, the key advantage of quantum sensors is low signal drift, especially if using atoms. Atoms are all identical, and their properties do not change with time. A quantum gravimeter, for example, is particularly useful for long-term monitoring of geothermal fields or petroleum resources.

Examples:

- Magnetometers, which can measure fields that are more than a trillion times weaker than the Earth's magnetic field.
- Electrometers, measuring electric fields in frequency ranges from DC to THz; classical spectrum analysers can typically only measure kHz to GHz.
- Gravimeters that exploit the fall of cold atoms already compete with the best conventional instruments (10 $\mu$gal) and have promise for even more detailed information.
- Atomic clocks, already in wide use; further developments of higher frequency optical clocks will make them accurate to 1 second in $10^{13}$ years

(the age of the Universe is only $14 \times 10^9$ yrs). Nuclear clock concepts are starting to emerge at even higher frequencies.

- Photon detectors, which can detect single photons of light. Quantum imaging may also detect objects that are not in direct view (ghost imaging) and may counter stealth technology.

Health applications are a high-priority for investment. Quantum sensors can be used as a diagnostic tool, monitoring temperature, electric and magnetic fields, and chemical changes at the cellular level. Quantum magnetometers can detect magnetic fields generated by biological systems such as the brain or other organs. Magnetic fields of certain proteins at low concentration can indicate biomarkers for disease. Advanced spectroscopy systems, which use entangled photons, can detect cancer cells at low concentration.

Quantum sensing also has the potential for providing high-precision navigation without relying on GPS. Quantum sensors can measure the Earth's gravitational and magnetic fields to high accuracy and then compare the results to existing maps to allow precise navigation without the need for satellite communications. Combined with high precision inertial sensors and atomic clocks, Positioning Navigation and Timing (PNT) is possible with a local autonomous system. Enhancements to PNT and alternatives to satellite GNSS are of interest for military applications. The ability to enhance radar or create alternate technologies for sensing at a distance (and hence defeat stealth technologies) is also of defence interest.

Civilian applications of quantum sensing include surveying of underground resources. The global mining industry has already gained billions of dollars in value by applying quantum technology in magnetic surveys. The use of atomic clocks underpins the global GPS system and national power systems through the synchronisation of power generation.

Metrology is often the first user of new advances in quantum science and technology, and the International System of Units (the SI) has now gone quantum. With Annette Koo, formerly New Zealand's Chief Metrologist, taking up the directorship of the International Bureau of Weights and Measures in Paris, New Zealand is well represented internationally. Originally based on artefacts, the SI system is now based on having agreed fixed values for seven fundamental constants. The constants, like the speed of light and the charge on an electron, were once measured in experiments. Now, these experiments are used instead to provide a calibration basis for all other measurements. An increasing number of units are now realised via quantum phenomena, such as the Josephson effect for voltage and the quantum Hall effect for resistance. Single electron and single photon techniques are also being investigated as standards of electrical current and light intensity and improving towards the required accuracy ($\approx 10^{-8}$ for current).

## 1.3 Quantum computing

Quantum computing promises to solve some very hard problems that can't be solved with current computers. They are most applicable to problems where classical computers scale very badly. Their ability to more efficiently explore a broad range of possible inputs to a problem will make them useful for problems as diverse as optimising the allocation of resources and breaking codes.

Quantum computers are also uniquely well-suited to simulating complex physical quantum systems, a task notoriously difficult with classical computers. Increased understanding of such systems will potentially impact the optimisation of solid state devices, lead to better materials for the energy transition, and improve drug design, to name a few examples.

Different approaches to quantum computing are in development globally.

- **Universal Quantum Computing**

  This mode is analogous to how conventional classical computers work. In this technology, qubits replace the bits of classical computers and new structures are used to create the 'gates' that process the qubits, just as there are gates (such as AND, NOR and XOR) in classical computers to perform algebraic functions. In quantum computing, these become quantum logic gates (such as Pauli, Hadamard, phase (S and T), and rotation gates). The quantum computer can then execute, in principle, any algorithm through a series of operations on the set of qubits.

  There are numerous physical implementations of universal quantum computing being pursued:

  - The systems from Google, IBM, and Microsoft use **superconducting circuits** (the basis for which was awarded the Nobel Prize in Physics in 2025) to create and manipulate microwave-frequency qubits.
  - In the optical-frequency domain, PsiQuantum and Xanadu are large startups pursuing a **purely photonic** approach, in which all storage and manipulation of quantum information is done with light.
  - **Trapped ion** quantum computers confine charged atoms (ions) using electromagnetic fields and qubits are stored in internal electronic states of the atoms. The qubits are manipulated via lasers and direct forces between ions. Companies including IonQ and Honeywell are leaders in this approach.
  - **Neutral atom** quantum computing employs neutral atoms, also held in place by electromagnetic fields, and qubits are stored and manipulated in a similar fashion to trapped ion quantum computing, only the atom-atom interactions involve laser excitation to high-energy Rydberg atomic states. Leading companies in this space are QuEra and Atom Computing.

- **Quantum annealers**

  These systems are suitable for solving certain classes of optimisation problems. In these systems, the qubits are physically linked, and the system evolves from an initial state where all solutions are represented equally to the desired solution encoded in the final state. D-Wave systems is the company most associated with this computing approach.

- **Quantum emulators**

  These can be thought of as a 'virtual' quantum computer created by code running on a conventional computer. Emulators allow quantum algorithms to be tested without the limitations imposed by currently existing quantum computers. The limitation is that the complexity of the calculations grows as a power law with the number of qubits being emulated. A classical computer, therefore, will never be able to manage calculations employing more than the order of 50 qubits. Emulators are useful in the early evolution of quantum computing, but will be superseded by actual quantum computers as the technology evolves.

- **Ising machines**

  This approach stands somewhere between an actual quantum computer and a classical computer as it is based on quantum and probabilistic concepts but can be realised by entirely classical means. It uses artificial binary elements (referred to as spins) that are physically coupled together to represent a certain combinatorial optimisation problem, with the optimal solution corresponding to the lowest energy state. With Nature's tendency to always spontaneously evolve towards the lowest energy state, the Ising machine is then left to evolve by itself, and the solution is read out once the system reaches thermal equilibrium, letting "physics do the computing". Many important problems fall into what computer scientists call the NP-hard category. As such problems get bigger, they very rapidly become too hard to solve with classical computers, whilst an Ising machine holds promise for efficient solution.

All quantum computers are susceptible to noise that disturbs the qubits and causes errors in calculations. Decreasing noise and increasing the system's resilience to noise through error correction or other means is therefore a large topic in quantum computing.

There is considerable divergence in opinion about the short- and long-term value of quantum computing. At present, quantum computers have too few qubits and are too primitive in operation to demonstrate significant advantages over classical supercomputers. Quantum computing is, however, fundamentally different from classical computing. The potential upside in the type of computing problems that can be solved and the speed (and energy efficiency) is yet unproven but potentially enormous.

## 1.4 Quantum communication

The advent of quantum technology has already had a major impact on classical communications. Secure communications, such as public key cryptography, rely on the existence of so-called one-way functions which are easy to compute but hard to invert, where 'easy' and 'hard' are used in the sense of mathematical complexity theory. In simple terms, they require solving mathematical problems that are beyond the capability of current supercomputers. However, in theory at least, they are not beyond the power of quantum computers.

Further, hostile actors are already undertaking 'record now, decrypt later' activities to use the power of quantum computers when they are operational to break encrypted data from the present to use for criminal or hostile purposes. The data being copied includes financial and personal health data, as well as state secrets.

The threatened existence of practical quantum computers has already led to post-quantum cryptography (PQC); classical cryptographic algorithms that we currently do not know how to crack with a quantum computer. Moving to PQC is unsurprisingly a priority for governments and militaries around the world. The U.S. National Institute of Standards and Technology (NIST) released final versions of its first three Post-Quantum Cryptography Standards in 2024. (Section 4.4, Dependencies, provides more details.)

Another way to ensure communication security is to use quantum properties directly in the communication process. So-called Quantum Key Distribution (QKD) allows the creation of encryption keys transmitted as qubits, making them impossible to intercept without signalling the presence of an eavesdropper. Demonstrations of QKD have been made via fibre optic cable and satellite transmissions. Whether transmitting qubits will ultimately be technically and economically superior to other methods for securing communications is still an open question.

High-level security is not the only reason to transmit qubits. Much of the value of computing lies in its networking and memory capabilities. If networking and memory can also be quantum, then one can envisage a much more powerful system where computing can be distributed, scaled to solve relevant problems, and secure. It is also possible, via quantum communication systems, for distributed quantum sensors to share entangled states leading to more precise and efficient measurements.

## 1.5 About this report

This report was prepared by the Quantum Technologies Aotearoa steering group, augmented by Anne French and resourced by a small sub-grant. It was informed by a workshop and interviews with relevant industry, investment, and research subject matter experts to canvas the state of quantum technology development in New Zealand and opportunities for commercial and social impact. While 86% of those individuals made themselves available, not all relevant researchers and potential industry stakeholders were available for interviews, and the opportunity for feedback and iteration on the document were somewhat time-constrained. In making our recommendations, we acknowledge these limitations.

The report was shared with QTA investigators and other interviewees as it was developed. The last version shared was very close to the final version released. This was done to ensure that, as much as possible, it represents a consensus view from the NZ quantum research community.

Quantum technologies are emerging globally and are incredibly diverse. The knowledge base in New Zealand is limited, particularly in relation to commercialisation. Given the time frame and budget available, the opportunity for international input into the document and deeper analysis of individual technologies was minimal.

The QTA steering group consists of: Jevon Longdell (University of Otago, Science Lead), Frédérique Vanholsbeeck and Scott Parkins (University of Auckland), Nick Long (Robinson Research Institute), Murray Early (Measurement Standards Laboratory NZ (MSL)), Harald Schwefel and David Hutchinson (University of Otago)

**Figure 3:** Checking the operation of an ultra-high vacuum chamber for magnetic thin film growth at VUW.

## Further reading

Lewis, J. and G. Wood (2023), Quantum Technology: Applications and Implications, Center for Strategic and International Studies, https://csis-website-prod.s3.amazonaws.com/s3fs-public/2023-05/230526_Lewis_Quantum_Technology.pdf?VersionId=iCOWm7k02Ms846I0Eb5DLeyD6dZN8K5F (accessed on 28 June 2025).

# 2 New Zealand's present capability

This is a brief survey of existing research topics and research capability directly related to, or adjacent to quantum technology. Enough detail is provided to distinguish between different research groups and to show how the research connects to the bigger picture of the development of quantum technology.

Almost all of the *quantum* research mentioned here has been carried out by investigators of Quantum Technologies Aotearoa (QTA). However, we believe that we achieve very good coverage of quantum research in New Zealand. The QTA programme was set up as an open shop, with the aim of encompassing all relevant research in New Zealand. Everyone was welcome but all funding was allocated following rigorous processes.

The vast majority of this work has been supported in some way by the QTA, building on what has been built by long-term support of quantum research by the Dodd-Walls Centre.

The categories of *quantum adjacent* research and *quantum relevant capabilities* are much broader. For quantum adjacent research and quantum relevant capabilities, there is a focus in what is presented here on work that is close to other QTA activities.

## 2.1 Quantum hardware

### Rydberg atom radio frequency antennae

In this technology, lasers excite an electron in an atom to a highly excited "Rydberg" state, in which the atom is very sensitive to electromagnetic fields. In particular, the transmission spectrum of probe light then changes when electric or magnetic fields are present. These techniques have been demonstrated in the laboratory. The group led by Professor Niels Kjærgaard at the University of Otago is working to show they can be miniaturised and packaged to become a commercial product. The technology may cover a wide frequency range of the electromagnetic spectrum, including the terahertz (THz) regime.

### Modelling of devices for quantum computing

Dr. Waltraut Wustmann (University of Otago) models and simulates the behaviour of Josephson Junction-based devices for quantum computing. Superconducting-based quantum computing relies on Josephson Junctions as the primary circuit element. Wustmann's models and simulations explore how the arrangement of Josephson Junctions operates as a circuit; for example, how the capacitance and inductance of the circuit elements affect the speed and fidelity of reading and writing qubits. This work is also necessary to understand the efficiency of different logic schemes deployed in these circuits and how circuits can be scaled up.

## Quantum memory and transduction with rare earths

The University of Otago group, led by Associate Professor Jevon Longdell, builds quantum memories for light. Professors Mike Reid and Jon-Paul Wells from the University of Canberbury contribute to the effort by improving our understanding of the relevant material systems.

Quantum memories store and recall light in a way that preserves its precise quantum state. The quantum state is preserved in the excitation state of rare-earth ions embedded in a host crystal. These memories are at the heart of the quantum repeaters needed for long-distance quantum networks and have the potential to significantly reduce overheads in purely photonic quantum computers. Work has started with Youngik Sohn at KAIST in Korea to integrate these quantum memories with photonic integrated circuits.

These rare-earth ions can also be used for the coherent conversion of microwave photons to optical photons. This is useful for quantum systems as one of the dominant approaches to quantum computing uses superconducting qubits. The superconducting systems operate at microwave frequencies. This has many advantages at the computing level, but microwave photons encoding quantum information are impractical for transmission at room temperature. Converting to photons that can be carried using fibre optic networks is a step towards quantum networks. The rare earth ion technology for memory and transduction has been demonstrated in laboratory experiments, and the theoretical basis has been well established.

## Optical nanofibres for atom-light quantum interfaces

Efficient sources of single photons are central to emerging, optics-based quantum communication and quantum computing technologies. For long-distance communication, photons with wavelengths in telecom bands of the electromagnetic spectrum (approximately 1.3 to 1.6 microns) are highly desirable. Also very desirable is the ability to efficiently interface these photons with quantum memories based on qubit states stored in individual atoms. A single platform that offers all these features simultaneously is an alkali atom (e.g., caesium) coupled to the evanescent field of an optical nanofibre – a fibre with a diameter of just 100's of nanometres. Associate Professor Scott Parkins works on the theoretical modelling of these systems. The group of Associate Professor Maarten Hoogerland at the University of Auckland employs this platform in experiments. They are both working with collaborators in Japan towards applications in quantum technology.

## Superposition and entanglement in atoms for quantum-enhanced magnetometry

A very tightly focussed laser beam can be used to trap a small number of atoms within a confined space in vacuum. These atoms, maybe even a single atom, can then be manipulated, investigated, and exploited for their fundamental quantum properties. For example, a pair of rubidium atoms can be made to undergo a controlled "collision" that leaves them in a quantum entangled state that is more sensitive to magnetic fields than the state of two unentangled atoms. Alternatively, a single dysprosium atom (the most magnetic atom in nature) can be prepared in a quantum superposition of spin states that is maximally sensitive to magnetic fields. These scenarios are being pursued in experimental work led by Associate Professor Mikkel Andersen at the University of Otago, with the goal of precision measurement of magnetic fields and their variation over microscopic distances.

### Electro-optic microwave to optical transduction

Superconducting quantum computers and other leading quantum computing technologies have characteristic frequencies in the microwave range. Being able to convert quantum signals from microwave to optical frequencies would allow simple networking using known telecom techniques such as fibre optic cable. This project uses resonant structures fabricated from nonlinear electro-optic materials (called whispering gallery mode resonators) to develop an efficient transduction platform to convert quantum signals between frequencies. This will allow quantum devices operating in a cryogenic environment to communicate over long distances using telecom techniques. This work is led by Dr. Nicholas Lambert (University of Otago), with support from Professor Harald Schwefel, Dr. Florian Sedlmeir, and Dr. Mallika Suresh. Work has started with the Quantum Materials Global Research Center at Kyung Hee University (Seoul, Korea) to study the electro-optic upconversion of Korean-made, on-demand, electrically-triggered, microwave bursts into telecom-ready single photon pulses. With Whitika Ltd. Suresh, Sedlmeir and Schwefel are in the process of spinning out a quantum tech hardware company to enable quantum networking through microwave-to-optical transduction.

### Optical microcombs

A minuscule ring made of special glass, with a diameter on the order of 100 microns (about the right size to wrap around a human hair), can transform a single-frequency laser beam into a beam with a mix of thousands of different frequencies. The resultant “micro-resonator optical frequency combs” or "microcombs” are an emerging technology with massive potential. They can be applied in high-capacity optical communications and LiDAR systems as well as for precision measurements such as optical clocks and spectroscopy. Of relevance here, they can generate photons in known quantum states for quantum communication and sensing. Due to the small size, they are a key component in bringing laboratory-scale optical systems onto chip scale devices. The nonlinear optics group at the University of Auckland, led by Professor Miro Erkintalo, Professor Stéphane Coen, and Associate Professor Stuart Murdoch, have made important discoveries in microcombs, e.g., with regards to their theoretical underpinning and to experimental control of the breadth and frequency regime of the spectrum generated. The group, with collaborators from Europe and the USA, is exploring the quantum optical properties of these microcombs.

### Quantum-enhanced probabilistic computing in fibre-ring resonators

Quantum random number generators are a much sought-after technology, offering true randomness rooted in the unpredictability of quantum mechanics. They are therefore intimately related to security applications such as quantum cryptography, as well as probabilistic computing and optimisation problems. The nonlinear optics group of Professor Coen, Professor Erkintalo, and Associate Professor Murdoch at Auckland has also pioneered the manipulation of short optical pulses via topology and optical nonlinearity in much larger, fibre-loop resonators to achieve intrinsically bias-free "coin toss" dynamics in the detected light intensity. With this capability, they plan to deliver a unified photonic platform capable of true quantum randomness, programmable probabilistic computing, and scalable photonic Ising optimisation, with immediate applicability to cryptography, machine learning, and hard-combinatorial problem solving. A proof-of-principle demonstration of a photonic Ising machine has now been demonstrated by the Auckland group. While it is currently limited to solving trivial near-neighbour problems, its capabilities are being extended to be able to solve general problems, using a measurement and feedback approach based on FPGAs.

### Chip-integrated squeezed light sources for secure quantum communication

This work, led out of the University of Auckland by Associate Professor Stuart Murdoch and Dr. Mark Hogg, and in collaboration with researchers from Korea, aims to develop a fully integrated Quantum Key Distribution (QKD) laser source, with all critical components monolithically fabricated on a single 1-cm$^2$ silicon-nitride chip. Central to the design is an on-chip optical parametric oscillator 'squeezer' circuit, engineered to transform the input laser light into the correct quantum state required for a high performance QKD protocol known as continuous-variable (CV) QKD. This project lays the foundations for future wafer-scale mass fabrication of QKD sources, an essential step toward low-cost, large-scale deployment of quantum communication networks.

## 2.2 Quantum-adjacent hardware

### Cryogenic memory for quantum computers

This project explores the integration of memory components using rare-earth nitride (REN) materials with quantum computing circuits, particularly those using superconducting qubits. These materials are both magnetic and semiconducting, and can function at extremely low temperatures, where many quantum computing technologies operate. The research is being led by Dr. Simon Granville and Professor Ben Ruck (Victoria University of Wellington). Quantum computers will require classical computers to control them. At the low temperatures at which many quantum technologies operate, there is no memory technology analogous to the RAM used in conventional computing. This project aims to develop energy-efficient, fast memory that operates at these extremely low temperatures. The VUW project team is also exploring how the

REN materials can be used for devices that allow control gates for the microwave signals within superconducting quantum computing circuits.

### Seismic monitoring of the ocean using the Southern Cross Cable

This is an innovative development using optical interferometry and the lasers developed for atomic clocks for seismic monitoring of the ocean floor. A collaboration with researchers at the UK's National Physical Laboratory (NPL)(who pioneered the technology) is being led by Dr. Johan Grand of the Measurement Standards Laboratory, ESNZ. The method uses the submarine telecommunication cable infrastructure as an array of sensors for earthquake and tsunami detection. The current project is taking place in the Tasman Sea, an ideal testing ground due to its high seismic activity. This technique could transform environmental monitoring of the ocean, providing unprecedented insights into Earth's dynamic processes and advancing research in earthquake detection and ocean circulation. Early results have shown the soundness of the technique and yielded valuable seismic data.

### Cryogenic technology

Many quantum technologies require cooling to very low temperatures (sub 1 K). New Zealand has substantial expertise in cryogenics through the Christchurch company Fabrum and the CryoLab research team at the University of Canterbury, led by Dr. Alan Caughley. The Paihau - Robinson Research Institute has expertise in cryogenic systems for superconducting magnets and is applying its expertise in a research project in Adiabatic Demagnetisation Refrigeration with application to quantum systems.

## 2.3 Quantum-relevant capability

### Modelling quantum systems

New Zealand has a strong history and expertise in theoretical quantum physics and, specifically, the modelling of quantum systems relevant to quantum technologies, including atomic, optical, and solid-state platforms.

It is this theoretical work that has provided the foundation on which NZ's quantum technology efforts have been built. Historically, the efforts towards experimental development of quantum technology were nurtured by the theory community, which achieved international prominence earlier. In addition to directly contributing to the development of technologies, they are a crucial part of the intellectual environment that allows the experimental work to flourish.

- Massey University: Joachim Brand (condensed matter physics and ultracold quantum gases)
- University of Auckland: Elke Pahl (solid-state physics), Scott Parkins (quantum optics)

- Measurement Standards Laboratory: Vladimir Bubanja (quantum metrology and condensed matter physics)
- Victoria University: Uli Zülicke (condensed matter physics and ultracold quantum gases), Michele Governale (condensed matter physics)
- University of Canterbury: Mike Reid (impurity sites in crystals)
- University of Otago: Blair Blakie, David Hutchinson, Ashton Bradley, Danny Baillie (ultracold quantum gases), Waltraut Wustmann (superconducting quantum devices)

### Ion beam engineering

A key manufacturing technique for advanced electronic devices is ion beam engineering. This can involve the addition of dopants to materials, such as the creation of p-n junctions by adding phosphorus or boron to silicon, or it can involve etching and micromachining to create precise 2D or 3D structures, such as for micro-electromechanical systems. The technique also encompasses several analytical techniques, such as Rutherford backscattering (RBS) and nuclear reaction analysis (NRA), which can be used for analysing chemical compositions and ion distributions in micro-materials. (The Auckland magnet company Buckley Systems Ltd supplies precision electromagnets and other associated systems for ion beam engineering.) New Zealand's scientific capability in ion beam engineering is held in the Ion Beam group at Earth Sciences New Zealand, led by Dr. John Kennedy. The team has worked previously on quantum systems in collaboration with the University of Melbourne; in particular, on focussed $P^+$ ion implantation in silicon for qubit construction. This team has the capability for precision ion implantation and analytical techniques such as RBS and NRA.

## 2.4 Quantum Software

### Quantum simulation software

Quantum simulation is the use of a controllable quantum system to simulate, model, and analyse other, often inaccessible, complex quantum systems. Applications are found in quantum chemistry (e.g., for the purpose of drug design), the design of quantum materials (e.g., novel superconductors), or in fundamental science. Quantum simulation is likely the first genuinely useful application of quantum computing hardware as it may not require fully fault-tolerant digital quantum computers. Instead, useful results can be expected from noisy digital quantum computers or from analogue quantum devices that manipulate quantum states with high precision. Professor Joachim Brand (Massey University) and Dr. Elke Pahl (University of Auckland) are developing an open-source software package (Rimu.jl) for simulating quantum many-body problems that can be used to benchmark and calibrate hardware quantum simulators. Professor Brand is collaborating with the University of Oxford (Professor Andrew Daley) on improving quantum simulation algorithms that run on classical computers with the aim of benchmarking ultracold Rydberg-atom-based analogue quantum simulators.

### Quantum network protocols

Networked computers rely on protocols such as those that manage the world wide web. Some of these protocols, like HTML and FTP, are common parlance among anyone technically savvy. For quantum networks, no such protocols exist yet. A network implies that multiple computers can share computational tasks and exchange information, even if they are not physically connected. Professor Winston Seah (Victoria University of Wellington) is working with colleagues in Taiwan, Korea, and China on quantum network protocols. It is early-stage research because the physical layer for quantum networks is not yet mature. Having the capability to understand and contribute to this important software layer in the system is important in understanding the requirements for hardware and how New Zealand can interact with emerging quantum networks for maximum benefit.

### Quantum and cybersecurity

Professor Steven Galbraith (University of Auckland) works on theoretical cryptography, including the implications of quantum technologies for cyber defence and the application of so-called post-quantum cryptography. He is part of an MBIE-funded NZ and Australia collaboration in post-quantum cryptography.

### Quantum computing capability

Earth Sciences New Zealand has highly complex computing needs related to weather forecasting and atmospheric chemistry. They have built links to UK high-performance computing and quantum computing groups and, through these, have begun exploring the use of quantum computing for solving problems in atmospheric chemistry as a first step towards applying quantum computing more generally to increase computational efficiency.

Within the VUW School of Chemical and Physical Sciences, Professors Michele Governale and Uli Zülicke train students to solve quantum problems using quantum computers via Amazon WebServices. There may be other university physics courses giving students experience with quantum computing via web services. This is a useful first step in creating a generation of graduates familiar with quantum computing, but falls short of the dedicated course offering necessary to prepare students to be quantum software developers.

NZ computer scientists are also increasingly interested in quantum computing. Léa Cassé, Bernhard Pfahringer and Albert Bifet from the University of Waikato, who are specialists in AI, have recently published work looking at quantum circuits for machine learning and time series data. Shahrokh Heidari, Michael Dinneen and Patrice Delmas from the University of Auckland are investigating the application of quantum annealers to computer vision problems

Bupper,[2] a start-up company based in Wellington, has the goal of solving logistics problems using quantum computing. It is early days for the company and with the limited capacity of quantum computers available today, the capa-

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[2] https://www.bupper.nz

bility of the company to solve problems using quantum computing is not yet clear.

## 2.5 Quantum Metrology

### Physical Measurement Standards

The Measurement Standards Laboratory of NZ (MSL) maintains and is developing several quantum standards for voltage and resistance with the expectation that new technology developments (e.g., quantum anomalous Hall effect, graphene, etc.) will broaden the application (e.g., impedance and power) and use of such standards for the benefit of NZ industry.

The use of single electrons and single photons also presents promising improvements to our measurement capabilities. Dr. Vladimir Bubanja has carried out significant theoretical analysis to improve the accuracy of single electronic devices that allow currents to be determined by counting electrons.

Dr. Ana Rakonjac is collaborating with NIST researchers in exploiting the quantum properties of an optical-mechanical device to measure thermodynamic temperature.

Random numbers play a crucial role in (classical, quantum, and post-quantum) cryptography, with their quality directly determining the security strength of the system. Generating random numbers by a process that is based entirely on quantum mechanics provides a way to generate truly random numbers. Currently, MSL is working on statistical evaluation of randomness of the output of two commercial random number generators. As a National Metrology Institute, MSL can provide a comprehensive and internationally accepted evaluation of random number generators.

This experience of performing high-accuracy measurement in cryogenic environments means that MSL is well-suited to develop calibration, testing and validation processes for NZ's quantum industry. This has been the practice of many major National Measurement Institutes (NMIs) such as NPL (UK), NIST (US) and PTB (Germany), etc. These labs have formed a consortium (NMI-Q) consisting of members of G7 economies and Australia to facilitate collaboration in the practical, metrological use of quantum technologies. MSL has a good relationship with most of these members.

### Standardisation

Standardisation "promotes the legitimacy of emerging quantum technologies" (Tim Prior, Physics World, Nov 2025). The IEC/ISO JTC 3: Quantum Technologies committee and the IMEKO TC25 - Quantum Measurement and Quantum Information committee are supported by researchers from DWC/QTA and MSL. MSL plays a critical role in ensuring calibration facilities in NZ produce internationally recognised certificates via ISO 17025, and it is anticipated that this will play a role in any future supply chain for quantum devices. There are also broader consortia like QED-C that address industry challenges in the uptake of quantum technologies, where NZ membership would be beneficial.

# 3 A survey of opportunities for New Zealand

In this section, we discuss the opportunities, with an emphasis on expanding NZ's present capability, in quantum communication and computation, optical sources, cryogenic memory for quantum computing, and sensing technologies. We also discuss the possibility of quantum missions for NZ (infrastructure, space, health, hazards, agriculture), and engagement with international research and capability.

China, the US, the UK, the EU, and Singapore were swift to recognise the potential of quantum technologies. Other countries, such as Korea, have recognised that they are running behind their competitors, and have recently invested large amounts of money into quantum technologies. In 2023, Korea announced combined public and private-sector investments of 3 trillion Won (about USD 2 billion) from 2023-2035.

It is time to ramp-up New Zealand's investment in quantum science and technologies. Our foundation is solid, with over 30 years of research excellence in photonics, quantum optics, atomic physics, magnetics, cryogenics, and more, contributing to a stellar international reputation. We have a solid core of excellent research in quantum sensing, communications, and computing technologies. As one interviewee put it: 'NZ is at a really good stage for photonics and quantum. It's a small country ... so it needs to focus on areas of strength.'[3] There is a new awareness of the need for sovereign technologies in today's overheated geopolitical environment. 'Defence Science and Technology is interested in PNT [Positioning, Navigation, and Timing], resilience of timing, inertial sensors, sensors in general, and microwave to optical transduction.'[4] However, as the OECD puts it, 'Considerations around dual-use applications, digital security and privacy, research security, and technology leadership are creating important frictions for international co-operation.'[5]

Some 25 years ago, New Zealand recognised the opportunity to invest in ICT and digitally enabled content. We developed various national strategies (The Knowledge Economy, Digital Strategy, Digital Strategy 2.0), which have borne fruit in the decades since. According to Tech New Zealand, the industry body,

> the New Zealand technology sector is one of the country's largest and fastest-growing industries, driving innovation, jobs, exports, and economic growth. In 2024, the sector contributed \$23.8 billion to GDP (8% of the economy), employed more than 119,000 people (4.8% of the workforce), and generated \$11.4 billion in exports, making tech New Zealand's third-largest export earner after dairy and tourism.[6]

Further, New Zealand's ICT firms were big investors in R&D, spending \$1.15 billion NZD in 2024, outstripping the \$204 million spent by the primary sector

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[3] Interview with Harald Schwefel, 19 September 2025.

[4] Interview with David Galligan and Clinton Barnes, DST, 19 November 2025.

[5] OECD, ibid, p. 5

[6] https://nztech.org.nz/reports/new-zealand-tech-sector-key-metrics-report-2024/

**Figure 4:** Combined optical-THz resonator made of silicon. THz frequency modes are guided by the petal structure of air holes; these holes were cut by femtosecond laser machining.

on R&D.[7]

We are now at a similar inflection point in 2026 for quantum technologies. In 2000, policymakers were convinced that New Zealand should invest in ICT. They had an instinct that software and games might become significant. By 2024, software as a service and games development were the fastest-growing segments of the digital industry. Software exports have grown at 22% CAGR for over a decade. As the OECD puts it, 'Quantum sensing, computing, and communication harness the unique behaviours of tiny particles to create and extend technological capabilities, heralding a second quantum revolution.'[8]

We have identified numerous opportunities in quantum computing (especially quantum memory), quantum sensing, and quantum communications, based on specialist expertise, proprietary technology, and the potential to create local jobs and companies. Further, cold atom physics and cryogenic memory can build on our existing industrial expertise in cryogenics. As Professor Miro Erkintalo put it, 'New Zealand is strong in microwave to optical. We have niche

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[7] `https://nztech.org.nz/wp-content/uploads/sites/8/2025/09/Tech-Sector-Key-Metrics-2024_web.pdf`

[8] OECD, ibid, p. 5

capabilities where we could provide hardware to the broader ecosystem.'[9]

There is broad agreement that, as far as NZ's research is concerned, it is the work on quantum sensing technologies that is the most mature. Professor Niels Kjærgaard described quantum sensing as 'the only area of quantum that has enough maturity.'[10] The investors we interviewed expressed more interest in quantum sensing than in other areas, suggesting that it is closer to commercialisation.

### Seismic sensing in the ocean

Dr Johan Grand from the Measurement Standards Laboratory (MSL) has a project underway in partnership with the National Physical Laboratory (NPL) in the UK to use interferometric sensors on the Southern Cross Cable to detect seismic activity in the ocean. Phase 1 of the project took place in the Tasman Sea, an ideal testing ground due to its high seismic activity. This technique could transform environmental monitoring of the ocean, providing unprecedented insights into Earth's dynamic processes and advancing research in earthquake detection and ocean circulation. Early results have shown the soundness of the technique and already yielded valuable seismic data. But the cable station is unmanned, so the equipment needs to be stable. The data is relayed directly from the racks in Auckland to NPL.

The laser used in Phase 1 lacks the stability to detect lower-frequency events such as tsunamis, which appear as noise in the data. The solution is an optical frequency comb to convert the laser from 1542nm to the correct frequency (1550 nm, as used in the cable station). A key goal for Phase 2 is to upgrade the laser (operating at a lower frequency over a longer time period) to enable tsunami detection, which would provide valuable data for predicting landfall time and impact. Southern Cross Cables Ltd has given permission to use the trans-Tasman section of the cable until the end of 2026.

A company building a data centre in Invercargill, which will have its own fibre optic cable connection across the Tasman, has contacted the team about installing sensors to monitor its cable for seismic activity.

## 3.1 Quantum sensing

Quantum sensors detect and measure physical quantities, such as mass, time, gravitational fields, and luminous intensity, with unprecedented sensitivity and precision. Table 1 lists relevant sensor technologies, who in NZ is working on them, and the existing and potential end users.

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[9] Interview with Miro Erkintalo, 20 October 2025.

[10] Interview with Niels Kjærgaard, 18 November 2025.

| **Quantum Sensors** | **NZ research expertise** | **End Users** |
|---|---|---|
| Atomic clocks | Measurement Standards Laboratory (MSL) | MSL for standards; DST has an interest for PNT applications; telecoms networks; power networks; emerging uses are possible, e.g., earth science and seismic monitoring with synchronised arrays |
| Quantum inertial sensors and gravimeters. | Prof David Hutchinson; A/Prof Mikkel Andersen; Prof Niels Kjærgaard (UoO); Alexei Veryaskin (adjunct, Robinson) | CAA and DST have an interest for PNT. MSL interested. Minerals, oil and gas exploration and resource monitoring. Monitoring geothermal and volcanic fields. |
| Quantum electrometers | Quantum electrical metrology – MSL Electrical Standards, Dr Ana Rakonjac, Dr Vladimir Bubanja, MSL; Prof Uli Zuelicke (VUW); Prof Niels Kjaergaard (UoO) | MSL for realisation of new standards for the electrical units of ac and dc voltage, current, and resistance and potentially impedance and electrical power. Wide range of quantum device applications e.g., optomechanical thermometers that directly relate the measured oscillations of a mechanical nanoresonator to the thermal energy of its environment; biosensors; read out of qubit states in quantum computing and communications |
| Fibre optic interferometry | Dr Johan Grand (MSL) (seismic and tsunami sensing using Southern Cross Cable) | Telecommunications operators, e.g., Chorus; data centre operators; Earth Sciences NZ; NEMA |
| Electromagnetic sensing (Rydberg Atom RF antennae) | Prof Niels Kjaergaard (UoO) | (RF antennae using cold Rydberg atoms; high sensitivity and wide frequency range) Transpower; Buckley Systems; WSP; other network operators |
| Quantum magnetometers | A/Prof Mikkel Andersen (UoO)(precision measurement of fields and change of fields) | DST has an interest |

**Table 1:** Quantum sensing opportunities for New Zealand.

## 3.2 Quantum communication

Quantum communication involves the transfer of quantum states from one place to another. This effort is almost exclusively focused on using light. Optical photons have enough energy that there is no thermal background noise and the same very low-loss optical fibers used in classical networks can be used.

Enabling distributed quantum sensing and computation would greatly increase their performance, as the advantages of both grow rapidly as the system size is increased. Furthermore, the quantum key distribution enabled by quantum networks offers secure communications.

An area of focus for some of the NZ community has been developing the technology to connect quantum systems to quantum networks. NZ also has an emerging capability in free space optical communications (FSOC), particularly in ground-to-space links.

Associate Professor Scott Parkins (University of Auckland) describes quantum communication as being practical – 'it's being implemented now' - and very much less challenging than building a quantum computer.[11] Opportunities in quantum communication for New Zealand are listed in Table 2

## 3.3 Quantum computing

Most of the international research on quantum computing is taking place in the US, China, and Europe, although the Chinese work is not widely publicized. In the US, the race is on to build the first fullscale quantum computers, but numerous technological challenges must be overcome first. New Zealand's research addresses several of those challenges, from software to hardware. In particular, the research on scalable memory for quantum computers, quantum transduction, and the on-chip microwave circulator have the potential to put New Zealand in a position to participate in the international supply chain for quantum computing. The quantum computing market is estimated to exceed US$12 billion over the next decade and will continue to grow strongly into the future. 'Quantum networks also have the potential to support distributed quantum computing, where interconnected quantum processors work collectively to solve complex computations that are far beyond the capabilities of individual processors (Cuomo, Caleffi and Cacciapuoti, 2020[22]).'[12] Opportunities for New Zealand quantum computing are listed in Table 3.

## 3.4 National quantum missions

National missions focus research and investment and accelerate technology development. Some countries have established national quantum missions to focus research and investment and accelerate technology development. These missions

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[11] Interview with Scott Parkins, 15 December 2025.

[12] OECD, ibid, p. 5

| **Quantum Communication** | **NZ research expertise** | **End Users** |
|---|---|---|
| Quantum memories, repeaters, and entanglement sources | A/Prof Jevon Longdell (UoO) | Secure communications; Future quantum networks |
| Chip-integrated quantum light sources | A/Prof Stuart Murdoch and Dr Mark Hogg (UoA) | End Users: Secure communications; Future quantum networks |
| Free space optical communication | A/Prof Nick Rattenbury (UoA) and Prof John Cater (AUT): free-space optical communication (FSOC), quantum optics, and ground-space networked experimentation | Space companies (in NZ and elsewhere); Defence |
| Quantum microcombs | Prof Miro Erkintalo (Auckland) (parametrically driven microcombs) | Applications in Metrology and communication; MSL, Defence. |
| Optical nanofibres and cold atoms | A/Profs Scott Parkins and Maarten Hoogerland (UoA) | Neutral atom quantum computer companies |
| Quantum random number generators characterisation. | Dr. Vladimir Bubanja (MSL) | Cryptography and communication networks. |

**Table 2:** Quantum communication opportunities for New Zealand.

| **Quantum Computing** | **NZ research expertise** | **End Users** |
|---|---|---|
| Quantum simulation software | Prof Joachim Brand (Massey), Dr Elke Pahl (UoA) | Quantum computing companies, analogue quantum simulators |
| Distributed quantum computing protocols | Dr Winston Seah (VUW) (quantum networking protocols) | Software developers for quantum computers. |
| Quantum algorithms, post-quantum cryptography | Prof Steven Galbraith (Auckland) | NIST, everyone who uses the internet for communication. |
| Transducers for quantum networks | A/Prof Jevon Longdell (UoO), Professor Harald Schwefel (UoO), Dr Nicholas Lambert (UoO) (microwave to optical transducers that allow room temperature connectivity between cryogenic quantum computers) | Companies developing quantum computer networks, e.g., Cisco, HP-E and companies that work on superconducting microwave qubits, e.g., IBM, Google, Rigetti |
| Quantum microcombs | Prof Miro Erkintalo (UoA) (parametrically driven microcombs) | Unknown (scalable multimode entanglement, applicable to QC) |
| Cryogenic memory (novel materials) | Dr Simon Granville, Prof Ben Ruck, Dr William Holmes-Hewitt (VUW) | SEEQC; potentially overseas companies building quantum computers or NZ suppliers of components |
| Quantum memories for light | A/Prof Jevon Longdell (UoO) (application of rare-earth-ion doped solids to quantum information, quantum computing and signal processing optics) | Overseas companies building quantum computers or NZ suppliers of components |
| Microwave circulator (on chip) | Dr Jackson Miller (VUW) (scalable memory for quantum computers), Dr Nicholas Lambert (UoO) | Google Quantum AI have provided letter of support. Other companies building superconducting qubit based devices. NZ suppliers of components. |

**Table 3:** Quantum computing opportunities for New Zealand.

### How to connect quantum computers

Dr Nick Lambert has a project underway to build a microwave-to-optical transducer, enabling the connection of separate quantum computers via standard optical fibre. This project addresses a key challenge in scaling quantum computing: transmitting delicate quantum information between cryogenic units without it being destroyed by thermal noise at room temperature, inherent at microwave frequencies.

The proposed transducer will convert microwave frequencies to the 1550 nm optical band, which is compatible with the existing low-loss telecom fibre infrastructure. Using the 1550 nm standard allows the project to leverage the existing infrastructure and investment of the global telecommunications industry. The 1550 nm wavelength was chosen, as it represents the point of minimum signal loss in optical fibres, which is why it was chosen by the telecommunications industry many decades ago.

Whispering Gallery Mode resonators developed by Professor Harald Schwefel will be used to enhance the weak non-linear effect required for frequency conversion by increasing light interaction time. Success would enable the creation of larger, distributed quantum systems by linking multiple, physically separate quantum computing nodes.

Without this technology, the scale and complexity of quantum computations are limited to what can be housed within a single dilution refrigerator.

Defence Science and Technology has expressed an interest in the microwave-to-optical transducer, and may be willing to support further development once the prototype is built and tested.

have time-bound, specific, ambitious, and achievable goals, and the realisation of these goals will have spillover benefits in related technology areas.

The UK has five such Quantum Missions[13] To give a flavour, one mission is: *By 2035, the UK will have deployed the world's most advanced quantum network at scale, pioneering the future quantum internet.* Another mission is: *By 2030, every NHS Trust will benefit from quantum sensing-enabled solutions, helping those with chronic illness live healthier, longer lives through early diagnosis and treatment.* There are also missions regarding navigation systems, sensor networks, and quantum computers.

At the Quantum Meets events organised by Te Whai Ao – Dodd-Walls Centre and Quantum Technologies Aotearoa in August 2025, the potential of quantum technologies to transform infrastructure, space and environmental monitoring, health, and agriculture were explored with stakeholders. Creating national missions in such sectors would create momentum, focus research, and attract investment.

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[13] `https://www.gov.uk/government/publications/national-quantum-strategy/national-quantum-strategy-missions`

## 3.5 International engagement

New Zealand quantum researchers are well-connected internationally and outward-looking. It has been this way historically due to the leadership of the likes of Dan Walls and Crispin Gardiner. In recent years, this has been supported by the Dodd-Walls Centre and most recently boosted by the formation of QTA.

The Quantum Technologies Aotearoa (QTA) Catalyst has funded 14 projects, with collaborations concentrated in, but not exclusive to, the target countries: US, UK, Singapore, Germany, and Japan. QTA is also managing 3 additional projects funded separately with the Republic of Korea. The engagement is strong and broad within academia (e.g., Oxford, Ulm, Strathclyde, Birmingham, NUS, ANU, University of Manchester, Ngoya and Yokohama) and government research institutions (e.g., NPL, NIST, A*Star, CNRS, Fraunhofer and KAIST).

These connections have come through the personal or institutional connections held by the New Zealand researchers. Institutions such as the UK Quantum Hubs have been particularly welcoming of New Zealand involvement and offer connections to start-up and established companies, as well as academic connections.

The connections with international companies are weaker, with only a few links (examples are NTT in Japan and SEEQC in the US and Italy). This reflects the low TRL of many of the domestic technologies and the barriers to attracting international commercial interest in technologies developed within New Zealand.

New Zealand can build on the excellent academic and research links and move from a largely academic science focus to commercial engagement. For example, through building the capacity and networks to engage with Horizon EU programmes, which directly involve end users or leveraging academic relationships to gain introductions to programme leaders in industry.

The likelihood of a successful scientific or commercial quantum New Zealand programme without international academic and commercial engagement is low. Commercial success requires understanding market structures, barriers to entry, competition, and customers, in addition to solving the technical problems. This knowledge comes most easily through international networks.

# 4 Dependencies

What else must happen to enable success? In this section, we consider the research infrastructure, IP management and commercialisation support, standards, institutional arrangements, and partnerships.

## 4.1 Research infrastructure

It is notable that the TEC-funded centres of research excellence have brought together leading researchers working in connected fields, such as Te Whai Ao – Dodd-Walls Centre for Photonic and Quantum Technologies (founded in 2015) and the MacDiarmid Institute for Advanced Materials and Nanotechnology (founded in 2002). The CoREs accelerated New Zealand's research effort and developed the next generation of talented young researchers. Prior to and in parallel with the CoREs, quantum research has had significant support from basic science funding mechanisms such as the Marsden fund. Without this foundational support, NZ's capability would not be nearly as strong. How do we best build on the scientific platform that we have?

### A national quantum hub

One of the successes of the UK's investment in quantum has been the development of national quantum hubs to bring industry, policymakers and researchers closer together. The UK initially funded four such hubs and has since increased the number to five. For example, in April 2025 the UK founded the Integrated Quantum Networks Hub, hosted at Heriot-Watt University, 'to develop scalable, secure quantum communications infrastructure' as part of the UK's 2035 quantum strategy. This new hub brings together 12 universities, two national laboratories, and 40 industry partners, backed by £42 million from the UK government. The purpose of this new hub is to 'tackle key challenges in quantum networking, including interoperability, security protocols, and integration with current fibre infrastructure' so as to 'accelerate the deployment of secure and scalable quantum communications infrastructure' in the UK.[14] The total UK government investment in quantum hubs under the UKRI is £106 million. The hubs are national innovation clusters, 'where cross-sector collaboration can support workforce development and drive commercial impact'.[15][16]

The innovation hub model is different from national science challenges or centres of research excellence, which were more tightly focused on research and capability development within an academic context. The National Science Challenge 'Science for Technological Innovation' worked closely with industry, as does the Riddet Institute, which builds capability and provides thought leadership

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[14] https://thequantuminsider.com/2025/04/10/uk-launches-54m-integrated-quantum-networks-hub-to-develop-advanced-quantum-network-infrastructure/

[15] https://thequantuminsider.com/2022/04/18/the-worlds-top-12-quantum-computing-research-universities/

[16] As this report was being finalised a further investment of up to £2 billion was announced. https://www.gov.uk/government/news/uks-quantum-leap-tohelp-beat-diseasedeliver-high-paid-jobs-and-strengthen-national-security-as-first-country-in-the-world-to-roll-out-quantum

to the food technology sector. A National Quantum Hub must incorporate NZ companies from the start, to ensure that they are prepared to adopt quantum technologies and participate in global supply chains for New Zealand's benefit.

The Canadians have put considerable effort into the Institute for Quantum Computing at the University of Waterloo, which is now home to 300 researchers in quantum computing, sensing, communication, and quantum materials. What distinguishes it from other institutes is its combination of research excellence with a drive to commercialise. Commercialisation is supported by the University's Creator-Owned IP Policy, which means that the inventor owns their IP and can determine how it is commercialised. University start-ups attract investment from local and national investors. The IQC has been named as one of the '12 best quantum universities', just ahead of Oxford.[17] For New Zealand, a stand-alone national quantum hub may be the better approach, to prevent capture by any one entity.

## From physics to engineering

Several stakeholders identified a gap in the New Zealand quantum ecosystem. At present, most of the research is conducted in science laboratories. But if the new technologies are to see the light of day, they need multidisciplinary teams doing the development. For example, to create a product that end users can operate, the optical table in the physics lab must be turned into a smaller, modular component that can be incorporated into a device, or a compact cryogenic module may be needed to keep the system cold.

Turning quantum science into technologies that create value is a multidisciplinary enterprise. None of our engineering schools is currently educating our future quantum engineers. We suggest that a master's programme in quantum engineering is needed, to create the engineers who can take technologies that have reached proof of concept forward to the TRL, so they can be commercialised. Ideally the Master's students in the programme would connect with industry, and may already be working in industry, with special projects co-supervised by industry. In addition, we think it would be helpful to bring computer scientists, data scientists, and mathematicians in to offer specific modules and attract students from those disciplines.

A model for the masters in quantum engineering is the MSc in Quantum Technologies offered by Oxford University. It is a taught interdisciplinary course covering quantum computing, sensing, and communications. It incorporates practical training and a four-month research project that bridges academia and industry. It is taught by the Department of Physics in collaboration with the Departments of Engineering, Materials, Mathematics, Computer Science, and Chemistry, and is 'designed to be accessible to students with a strong background in any of these areas of study'. [18]

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[17] https://thequantuminsider.com/2022/04/18/the-worlds-top-12-quantum-computing-research-universities/

[18] https://www.ox.ac.uk/admissions/graduate/courses/msc-quantum-technologies

**Figure 5:** Preparing for a process in the fabrication of a cryogenic memory device.

## 4.2 IP management and commercialisation support

There is a need for inventors to be trained in the basics of commercialisation if New Zealand wants greater impact from research investments. Inventors need more support to turn their ideas into value through licensing or venture formation. The support could be provided by the proposed national quantum hub, by existing technology transfer offices, or by a new mechanism, such as mentoring by venture builders. Other countries offer useful models. In Singapore, A*STAR's Innovation and Enterprise Group fosters those connections, enabling companies to 'move faster from lab to market' by:

- Partnering with industry, investors, and researchers to co-develop solutions for real business challenges.
- Licensing and commercialisation of breakthrough technologies and intellectual property into market-ready products and services.
- Venture building that nurtures deep-tech start-ups from early concepts to global growth.[19]

Efforts are already underway, led by the CoREs in partnerships with universities, to carry out this work, which provides a platform for these efforts to be expanded. For New Zealand to benefit from Quantum technologies, better connections with industry and a greater understanding of the realities of turning ideas into value will be needed.

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[19] `https://www.a-star.edu.sg/enterprise`

A challenge for IP management in the quantum sector (although not unique to quantum) is the early-stage nature of the research. Patenting ideas that are at the TRL 1-3 has the advantage that they may turn out to be foundational to large areas of application. The disadvantage is the potentially long lead time before there is significant revenue generation from the IP. Maintaining a comprehensive IP portfolio for long time periods is beyond the resources of many of our TTOs. Throwing ownership of the IP to inventors would not solve this problem and may make funding of a portfolio even more difficult.

Commercialisation in the quantum sector likewise has challenges. The markets and customers are international, so market exploration and development is more time-consuming and expensive than with a local market. Knowledge of these market sectors within the NZ business community is limited and a hesitancy to invest in the unknown is to be expected. This is where institutional co-ordination and building of teams around commercialisation opportunities is important.

## 4.3 Standards, and standardisation readiness level

In 2012, the Nobel Prize for Physics was awarded to David Wineland and Serge Haroche for their work that ‘enables measuring and manipulation of individual quantum systems’ of matter and light as ‘the first steps towards the quantum computer, and the development of extremely accurate optical clocks.’[20] Metrology and the second quantum revolution are now inextricably linked.

> Metrology has often been both the motivation and the direct beneficiary of ground-breaking discoveries. The Josephson and quantum Hall effects provide the basis for the realisation of electrical units. Rabi and Ramsey spectroscopy methods are essential to the operation of hydrogen maser and other atomic clocks. The invention of lasers led to even more accurate length metrology. Frequency standards now rely on ion and cold-atom trapping techniques, frequency combs, and methods to manipulate the quantum state of matter.[21]

In 2019, the International System of Units (SI) was redefined in terms of fundamental constants, not via a measurement chain that goes back to unique physical artefacts, such as the kilogram, a chunk of metal kept in a safe in Paris. That means quantum is at the heart of measurement. Quantum key distribution relies on the ability to generate and detect photons one at a time. ‘Other less mature technologies, such as quantum computing, also require characterization, benchmarking and evaluation — both platform-specific and agnostic — to inform development and prioritize investment.’

Documentary standards to define quantum computing terms are being developed. In June 2020, the CEN-CENELEC Focus Group on Quantum Technologies (FGQT) was established to coordinate and support the development

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[20] https://www.nobelprize.org/uploads/2018/06/advanced-physicsprize2012_02.pdf

[21] Tzalenchuk et al., *‘The Expanding Role of National Metrology Institutes in the Quantum Era’*, Nature Physics, 12 July 2022. https://www.nature.com/articles/s41567-022-01659-z

of standards relevant for the European industry and research.[22] New Zealand participates in the international standards setting process via the Measurement Standards Laboratory. For quantum technologies, MSL is supported by Dodd Walls Centre researchers' involvement in IEC/ISO JTC 3: Quantum Technologies.

Quantum technology is of particular relevance to cybersecurty. NIST, the National Institute of Standards and Technology in the US, has been working on various quantum-related communications standards matters. In 2014, it started work on the Cybersecurity Framework, a voluntary system of guidance to help US organisations manage and reduce cybersecurity risk. In 2018, the Framework became mandatory for US government organisations. The Cybersecurity Maturity Model, an extension of the Framework, was introduced in 2019 and finally published in September 2025. In 2024, NIST released a final set of encryption tools designed to withstand the attack of a quantum computer. These post-quantum encryption standards secure a wide range of electronic information, from email to e-commerce.

Can New Zealand outsource its cybersecurity standards and practices to organisations such as NIST? Not according to Professor Steven Galbraith, who contributed to NIST's work on cryptography algorithms. He said: 'Safe implementation [in the post-quantum environment], such as making sure that code does what it's supposed to do, will be more challenging. Auditing code becomes a question of software capability.'[23] Galbraith lamented the lack of capability in New Zealand: 'We need to have some people who know what's going on. We can't outsource it. Cybersecurity must have people who understand the domestic space. Take Māori data sovereignty, for instance. The technical side needs to consider interactions with society.' Galbraith argued for the need for greater co-operation. 'We need a more cohesive approach. New Zealand is really bad at thinking educationally outside the degree process. We need training. No one takes a strategic view of QUAP.' [24]

## 4.4 Partnerships

Given the interdisciplinary nature of the next stage - turning quantum technologies into products and services - the National Quantum Hub and the National Quantum Progress group will need to build relationships with industry associations such as Tech New Zealand (which represents a range of technology sectors, from Agritech and the AI Forum to Biotech NZ, Blockchain New Zealand, EdTech, FinTech, the IoT Alliance, and KiwiSaaS), Manufacturing NZ, and Chambers of Commerce.

Other significant relationships will include partnerships with investors, both with individual funds and with investor groupings such as NZ Private Capital, close working relationships with KiwiNet, Return on Science, and individual technology transfer offices and, where relevant, commercial partnerships.

There is work already underway to set up a Quantum Forum within Tech

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[22] van Deventer et al., *'Towards European Standards for Quantum Technologies'*, Quantum Physics, 2022. `https://link.springer.com/article/10.1140/epjqt/s40507-022-00150-1`

[23] Interview with Steven Galbraith, 31 October 2025

[24] Steven Galbraith, ibid.

New Zealand in partnership with the Dodd-Walls Centre, to improve connections and develop a national community aligned around a shared purpose. A steering group committee for establishing this Quantum Forum had a first meeting early in 2026, which included many of the stakeholders identified above.

The quantum community should continue to actively partner with iwi and other Māori groups to ensure meaningful Māori participation across its workforce. The Māori economy is an increasingly significant part of the NZ economy, and represents a significant opportunity for the commercialisation of quantum tech. This is both in terms of Māori participation in development and deploying the technology (Whitika, NZ's first quantum hardware startup has a Māori CEO) and partnering with Māori businesses as end users.

The Dodd-Walls Centre in 2025 ran a successful series of "Quantum Meets" events. Each of these targeted a particular sector. They grew awareness of quantum technologies and facilitated collaboration between between industry, government and researchers. Identifying challenges that quantum technologies could address laid the foundation for future work with end users. As quantum technologies develop both in NZ and internationally these forums will continue to be important.

# 5 Recommendations

New Zealand's investment in quantum to date has been moderate by international standards, yet we have made a real impact through some outstanding researchers and considerable success in the commercialisation of first-generation quantum technologies.

The level of academic engagement with international counterparts is a true strength, but an overarching strategy is needed to leverage this into greater commercial engagement and results. With a commitment to creating the right infrastructure and support structures, New Zealand can gain enormous value from quantum technologies.

With all this considered, we recommend:

1. New Zealand establishes a 'Quantum Hub' which acts as a centre of gravity for quantum research and commercialisation. The distinction with existing centres of research excellence is, a strong focus on raising technology readiness levels, and creating economic value.
2. New Zealand funds one or more national flagship quantum programmes which will push technology development and demonstrate existing capability. These flagships projects will align with well-defined missions. It is envisioned that these flagships would each have activities throughout New Zealand.
3. Support an educational initiative in quantum science and technology at the Master's level to produce a cohort of students with the skills to develop and use quantum technologies. This would include a deliberate strategy to build a pipeline of Māori students, building on the initiatives developed through the Dodd-Walls Centre and others.
4. Within this development, ensure that a mechanism is put in place for regular and ongoing engagement with sectors with specific needs, including Agritech and Health.

The report identified other gaps, which any comprehensive strategy for the sector should address. For example, investing in quantum software research would help ensure that we don't risk missed opportunities as quantum computers develop.

With these recommendations, New Zealand would be in good shape to build on the long history of excellence in atomic, optical, and materials science developed over many decades in our research institutions. With the right support, new ventures will emerge participating in the global quantum industry and growing the capability for New Zealand to address its own problems using quantum technologies.

# Appendix – People interviewed when preparing this report

## End Users

| **Name** | **Company/Organisation** |
|---|---|
| Simon Arnold | Works with Otago Photonics group; shareholder in Heat and Light Ltd; arnold.co.nz |
| Clint Barnes | DST |
| Mark Bregman | Quidnet Ventures |
| Murray Early (end user; MSL, also researcher) | MSL |
| David Galligan | DST |
| John Harvey | Southern Photonics |
| Andrew Hilliard | F&P Healthcare |
| Claire Johnstone | NZ Police |
| Boyd Multerer | NZ Growth Capital Partners |
| Mahi Paurini | CEO Whitika (co-owned with Harald Schwefel, Otago) |
| Tom Power (per Kirby-Jane Hallum) | DST |
| Andrew Renton | Transpower |
| John Robson (JR) | Bridgewest Ventures |
| Emil Schroder | NZ Growth Capital Partners |
| Cather Simpson | Orbis |
| Steve Smyth, Pete Sutherland, Baljeet Singh | CAA |
| Chris Ward | 365 Cyber |
| The Attendees of Quantum Meets Workshop series | (150 people) |

## Researchers

| Researchers | Institution |
|---|---|
| Associate Professor Mikkel Andersen | University of Otago |
| Professor Richard Blaikie | University of Otago |
| Professor Neil Broderick | University of Auckland |
| Professor John Cater | AUT / University of Canterbury |
| Professor Stephane Coen | University of Auckland |
| Professor Richard Easther | University of Auckland |
| Professor Miro Erkintalo | University of Auckland |
| Professor Steven Galbraith | University of Auckland |
| Dr Johan Grand | Measurement Standards Laboratory |
| Dr Simon Granville | Victoria University Wellington |
| Dr Mark Hogg | University of Auckland |
| Professor David Hutchinson | University of Otago |
| Professor Niels Kjaergaard | University of Otago |
| Dr John Kennedy | Earth Sciences NZ |
| Dr Nicholas Lambert | University of Otago |
| Associate Professor Jevon Longdell | University of Otago |
| Associate Professor Stuart Murdoch | University of Auckland |
| Associate Professor Scott Parkins | University of Auckland |
| Associate Professor Nick Rattenbury | University of Auckland |
| Professor Winston Seah | Victoria University Wellington |
| Professor Harald Schwefel | University of Otago |
| Professor Frederique Vanholsbeeck | University of Auckland |
| Professor Uli Zuelicke | Victoria University Wellington |