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Abstract

Quantum physics and technology are important frontiers in scientific research and development. Universities, governments, and private companies are investing in quantum technology for the potential benefits it might create for future societies and economies.

Australia and Victoria are actively involved in developing QT. Challenges, however, remain regarding how best to achieve the effective transfer of knowledge into technology and industry-based outcomes.

Quantum Technology and Victoria

Ben Reid, Data Journalist

Introduction

Universities, governments, and private companies are investing in quantum technology (QT) for the potential benefits it might create for future societies and economies, and the creation of new jobs. Research and development in these fields are accelerating internationally.

Australia and Victoria are actively involved in developing QT. Challenges, however, remain regarding how best to achieve the effective transfer of knowledge into technology and industry-based outcomes.

What is Quantum Technology?

QT combines technological scientific advances in quantum physics with the delivery of new services and products in a ‘quantum enabled economy’ (CSIRO, 2020, p. 5).

Earlier Newtonian physics focused upon atomic scale processes and their influences, such as gravitation (*Figure 1*). Quantum physics, instead, seeks to understand how sub-atomic systems operate, such as the behaviour of particles and electrons. Quantum physics’ technological applications have accelerated over the past 30 years.

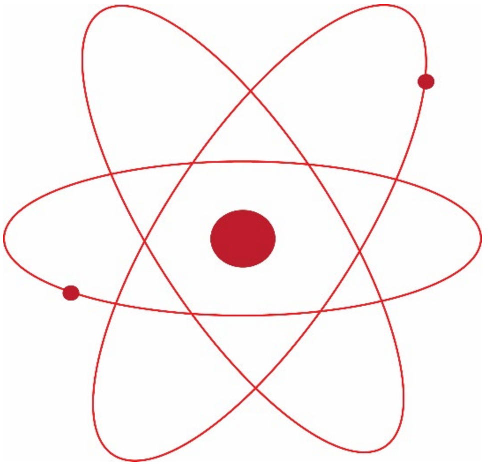


Figure 1: The Atom

What are the existing Quantum Technologies?

The increased understanding and mathematical modelling of quantum physics already underpins many everyday technologies, such as:

Transistors and semiconductors

Computer chips and transistors rely on minuscule quantities of elements to power many devices now used in daily life. These range from home computers and mobile phones, through to many household devices.

Laser technologies

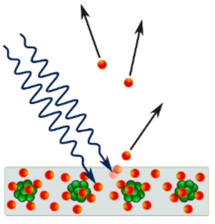
Lasers are used for optical disk storage (DVDs), surgery, fibre telecommunications and internet connections, laser pointers and many other applications. They use the quantized energy levels in atoms, which can be manipulated to emit more light when illuminated through a process called stimulated emission.

Solar panels

Solar cells convert light into an electric current, a process known as the photovoltaic effect. This effect can only be explained if light comes in discrete packets (or photons). (*See Figure 2*)

Electron microscopes

Electron microscopes are used in a range of ways ranging from quality control through to medical science. In the latter, they can compare blood and tissue samples in determining the cause of illness and measuring the effects of treatments on patients. These devices illustrate some of the smallest details in the world by using electrons rather than light as a source of illumination.



Photoelectric effect in a solid - diagram.svg

Figure 2: Photon Energy

What are the new quantum technologies?

However, the potential for a newer generation of QTs has emerged since the 1990s that promises to ‘engineer quantum states’. The newer forms of QT potentially replicate complex energy flows and processes. Although it is not possible to predict what the social and economic implications of these technological advances could be, a range of future applications are being developed:

Quantum computing

A new generation of powerful supercomputers may perform tasks much faster than traditional machines.

All computers are ‘information machines’ that input, store, process, and output data. The main advances in electronic computing have occurred by making computer chips smaller. However, reducing the size of these chips is reaching an impasse.

Quantum computing overcomes these limits by using qubits instead of bits. While bits assume a value of 0 or 1, a qubit can take a value between them.

The physical structure of quantum computers also differs from conventional ones in three major ways:

- First, qubits use a concept known as quantum dots: a (dedicated) spherical volume made of two semiconducting materials (silicon and germanium).
- Second, the long strands of these materials mean that quantum computers look more like ‘chandeliers’ than traditional machines, using copper tubes and wires. (*Figure 3)*.
- Third and finally, they operate at very low temperatures: about -273 degrees Celsius.

Google claimed to have ‘achieved quantum supremacy’ in 2019 by creating a machine that can perform calculations that conventional computers would take thousands of years to complete (Gibney, 2019).

Quantum sensing

High-precision quantum sensors - magnetometers (can measure magnetic waves) and gravimeters (can measure gravity) – have a range of applications:

- Detecting subsurface phenomena for engineering
- Advanced prospecting and mineral exploration
- Precision navigation that is not reliant on satellite signals
- Measuring the inner workings of cells inside living bodies and other dynamic biological systems for health diagnostics.

Quantum communications and internet

Quantum-enhanced information security systems and quantum-safe cryptography promise to increase security through complex random number generation. They provide increased protection for systems and intellectual property.

Other technologies and services

QT-enabled equipment is used in a variety of other ways. Examples include:

- Oscilloscopes and spectrum analysers for measuring and graphing electrical signals in sophisticated systems
- Precision time and frequency generators for signals and measurement
- Nanomaterials such as fluorescent nanodiamonds and phosphorescent nanotubes that simultaneously evaluate and visualise the impacts of drugs on an organism
- Lasers and wavemeters that provide precise measurement of frequencies.

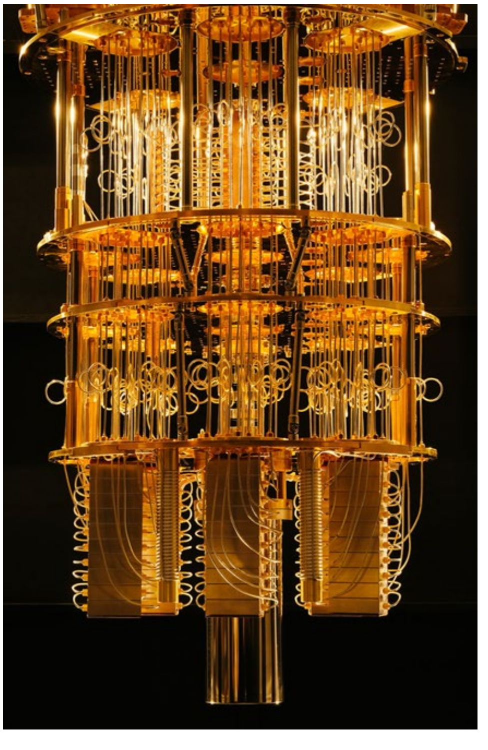


Figure 3: Quantum Computer

What QT research projects exist in Australia and in Victoria?

Both Australia and Victoria already have considerable involvement with the research and development of QT.

According to the CSIRO, an extensive range of research institutions and industries exists in Australia. Many of the former are Australian Research Council-supported Centres of Excellence, and the latter attracted an estimated $125 million in investment between 2017 and 2019. They include Australian subsidiaries of large information technology firms such as Microsoft and IBM.

Victoria currently hosts entities from both categories. Victorian university campuses either head or play major roles in three ARC-backed projects. The ARC Centre of Excellence for Quantum Computation and Communication Technology (CQC^2T) at the University of Melbourne, for example, is heavily involved in the development of quantum computing.

Similarly, private firms like MOGLabs design high-precision laser and other quantum-based machines. Others such as H-Bar: Quantum Technology Consultants deliver broader advice on applying quantum methods to information technology.

What are the main challenges for expanding QT?

These Australian and Victorian-based entities and projects operate in a climate of both intensified international competition and cooperation around quantum research. Obtaining the maximum benefits from the expanding QT sector requires a range of policy measures.
The major economies in the world are increasing their investments in the field. In the United States, the Biden administration enacted a $180 billion research and development plan in 2021 that includes a major focus on QT. Other entities such as the UK, the European Union and China are also boosting their research and development spending.

The CSIRO has called for a 'national road map' policy to be established in 2019 to consolidate and coordinate the sector’s further development. A 'Joint Statement of Australia and the United States of America on Cooperation in Quantum Science and Technology' was also signed in November 2021.

The CSIRO’s roadmap (2020) suggests a framework based on greater 'focus, capability, collaboration and readiness' across the sector. Its main recommendations include:

- The development of a 'national quantum technology strategy' ... with a 'set [of] long-term strategic priorities, commitments and indicators of success for Australia’s quantum industry.'
- These initiatives could be tied to 'efficient and effective funding mechanisms to support the demonstration and commercialisation of quantum technology applications’.
- Carefully targeted and monitored public investment needs to continue.
- Measures are needed to 'attract, train and retain the best quantum talent and assess the future quantum technology workforce’s skill needs.'
- Finally, 'assessing industry capabilities and infrastructure facilities' requires 'developing business cases to address gaps'.

There are other recommendations, such as strengthening training linkages and ensuring the ethical applications and dimensions of the new technologies.

Victoria has many strengths in the field and could be taking more measures to promote state and national-level initiatives.

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https://orcid.org/0000-0001-8086-0737

Enquiries

Victorian Parliamentary Library & Information Service
Parliament House, Spring Street, East Melbourne 3002
Telephone: (03) 9651 8640
https://www.parliament.vic.gov.au