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Edison Explains

Quantum computing

A booming industry

What is quantum computing?

Quantum computing is a nascent technology that exploits the fundamentals of quantum mechanics with the aim of processing exponential quantities of data at exceptionally rapid speeds. We present an overview of the key technologies and concepts involved in developing these complex systems, recognising that they are extremely high-level in nature and potentially difficult to understand. We hope that this at least provides some basic information regarding the subject as it evolves over the remainder of this decade.

Quantum computing, which holds the promise of surpassing the world's fastest supercomputers, is now at the early stage where prototypes are functioning efficiently; it remains uncertain as to what form these machines will eventually take, for example what technology will predominantly be used to house qubits.

What are qubits?

Quantum computing revolves around 'qubits', or quantum bits, which are essentially two-state basic units of quantum information (typically subatomic particles such as electrons or photons). Unlike classical computer units, 'bits', which can be in only one of two states at any moment with values of 0 or 1, qubits are capable of superposition, meaning they can be in both states simultaneously. Currently the two main architectures for housing qubits are the superconducting method (nanoscale loops of superconducting wire chilled to near absolute zero temperatures (-273°C)) and ion traps (ions trapped in magnetic fields), but other technologies may emerge.

Market prospects

The global quantum computer race is intensifying, with the number of new prototype technologies increasing exponentially. To date, the United States has led the way but Europe and Asia are seeing significant growth in the number of startups and new projects. Various sources indicate that the quantum computing market size was

c $470m in 2021 and is expected to exhibit a CAGR of 30% to 2030, surpassing $1bn by 2026. Other sources predict that it will exceed $125bn by 2030. We expect the hardware segment, in particular, to record appreciable expansion, driven by rising product usage in artificial intelligence (AI) and molecular simulation applications.

While hardware revenues are expected to grow, the number of quantum computers is expected to be limited, although the values will be high. As a pricing example, the European Commission selected a consortium to build a 100-qubit quantum computer by 2025 with an initial budget of €18–20m. Most of the market revenue growth is projected to come from cloud access services to a quantum computer.

Over time quantum computer applications are expected to create most value for markets such as finance, energy, materials, telecoms and healthcare/pharmaceuticals.

Key concepts

Two key quantum concepts applicable to qubits are explained below:

Superposition: an electron's spin can either be in alignment with a magnetic field, known as spin-up state (1), or opposite the field, known as spin-down state (0). A pulse of energy generated (usually from a laser beam) can initiate a change in the state of the electron's spin. Besides being in state 1 or 0, qubits can also represent numerous combinations of 0 and 1 at the same time. The ability to be in multiple states simultaneously is called 'superposition'. To put qubits into superposition, researchers need to manipulate them using precision lasers or microwaves. Superposition provides the ability to crunch a high number of potential outcomes at the same time. During a single measurement, the number of possibilities is 2^n (n = number of qubits used); thus a 64-qubit computer has enough memory for over 18 quintillion numbers. This ambiguity (the ability to 'be' and 'not be' concurrently) is what provides quantum computers with such power.

Entanglement: entanglement is the term used for particles that are entangled pairs of qubits that exist in a state where

> ### Edison Insight
> Quantum computers provide a step change in processing speeds and computing power. While still in the early stages of development, the quantum computing market is expected to grow rapidly to c $5bn by 2030 from c $470m in 2021.
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changing one qubit directly changes the other, which will simultaneously assume the opposite spin direction, enabling operations to occur at lightning speed. Knowing the spin state of the entangled particle (spin-up or spin-down) gives away the spin of the other in the opposite direction. This phenomenon is essential for a quantum algorithm to offer exponential speeds compared to classical computations.

What do quantum computers look like?

Quantum computers are complex and resource-intensive, requiring lots of energy and cooling to run effectively. Despite containing contemporary high-tech components and hardware, quantum computers are currently extremely large. While comparisons could be drawn with the early days of electronic computers, it is difficult to know if technological advances will allow for scale reduction in hardware components; the hardware is mostly composed of cooling systems to keep superconducting processors at extremely low temperatures so electrons can flow through superconductors to create electron pairs. Alternatively, in trapped ion quantum computers, ions are confined and suspended in electromagnetic fields in which a laser beam is applied to induce entanglement.

Why the interest in quantum computing?

The main anticipated benefits of quantum computing are summarised below.

- Speed: quantum computers are exceptionally rapid compared to classical computers due to the phenomenon that is entanglement. Qubits are set up according to an algorithm suitable for any chosen problem; the system then applies the laws of quantum mechanics until it reaches the relevant state that represents the answer. They have the potential to speed up financial portfolio management models, such as a Monte Carlo simulation.
- Large memory capacity: superposition means that the capacity of these computers to store data doubles with each qubit.
- Ability to solve problems of the greatest complexity: quantum computers are designed to perform multiple complex calculations simultaneously.
- Simulations: quantum computers can simulate more intricate systems than classical computers, which could be of particular use in molecular simulations, an important aspect of drug development
- Optimisation: quantum computers have the ability to process a huge amount of complex data, which has the potential to transform AI.

Limitations thus far

It comes as no surprise that designing and manufacturing these complex computers has its challenges. These include but are not limited to:

- Operating temperatures must constantly be at near absolute zero to increase stability by slowing down atom movements; any outside influence, such as a vibration or heat, can cause qubits to lose their one-and-zero state (this occurrence is called quantum decoherence). These conditions are costly to maintain.
- The cost of creating high-quality qubits and the technology surrounding them is prohibitively expensive; the high price of quantum computers is impeding the market's expansion.
- Multiple errors can arise during quantum computation; the frequency of errors in delicate qubits, caused by noise, tends to increase as more are connected.

Companies covered by Edison

Creotech Instruments: Creotech (CRI), based near Warsaw, Poland, has developed a contract manufacturing business supplying advanced electronics for third parties and internal applications. Successful partnerships, mainly with the European Space Agency, have built strong flight heritage, facilitating its own satellite development. The capabilities are also being applied to quantum computing and precision time synchronisation products and components.

Filtronic: Filtronic is a designer and manufacturer of advanced radio frequency communications products supplying a number of market sectors including mobile telecommunications infrastructure, defence and aerospace, public safety and space. Filtronic has developed advanced microwave filters that are able to operate at the very cold temperatures required to enable superconducting. The filters reduce electromagnetic interference in the microwave circuits of both the external control racks and the cryogenic dilution refrigerators of quantum computers.

Molten Ventures: Molten Ventures (GROW) is a London-based venture capital firm that invests in the European technology sector. It has a portfolio of c 70 investee companies and includes a range of funds (seed, EIS and VCT) within the group, as well as its flagship balance sheet venture capital fund. One of its portfolio companies, Riverlane, is building Deltaflow.OS, an operating system for error corrected quantum computing. This aims to mitigate errors caused by qubit decoherence by encoding information excessively across numerous qubits.

IP Group: IP Group (IPO) helps to create, build and support IP-based companies internationally, focusing on those that meaningfully contribute to regenerative, healthier and tech-enriched futures. Since 2017, IP Group has been a pioneer alongside Oxford Science Enterprises enabling some of the UK's earliest quantum computing ventures including Oxford Quantum Circuits and Quantum Motion Technologies, with the latter recently raising the largest funding round in UK quantum computing.