Silicon Quantum Computing announcement of world's first quantum integrated circuit

FAQ

Who is Silicon Quantum Computing and what has been achieved?

Silicon Quantum Computing (SQC) is Australia's first quantum computing company pioneering a globally unique atom-based manufacturing technology to build a commercial-scale quantum computer here in Australia.

With this result, SQC is announcing **the world's first quantum integrated circuit manufactured at the atomic scale**. This quantum chip was operated as an analogue quantum processor to **simulate** a well-understood molecule, polyacetylene.

Analogue quantum processors can be used to simulate how materials work and design new materials that have never existed before.

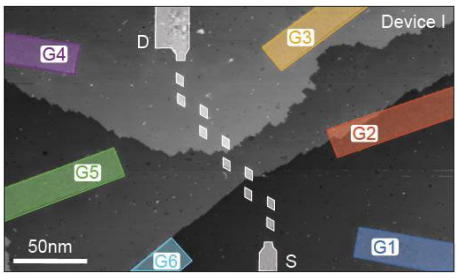
How did they do it?

By placing atoms in silicon with sub-nanometre precision, the SQC team were able to mimic the single and double carbon bonds of a polyacetylene chain.

Starting with a wafer of silicon, they engineered small dots of phosphorus atoms (known as 'quantum dots'), of strictly uniform size and spacing to mimic the bonds and energy levels of the carbon atoms in the molecule.

Using nanoscale precision, they also added six control electrodes (G1 to G6) to both tune the energy levels of each dot individually, and all the 10 quantum dots collectively to give complete control of where the electrons exist within the polyacetylene chain. By adding source (S) and drain (D) leads they could then measure the current through the device as electrons passed through the 10-quantum dot chain.

By embedding a model of polyacetylene into an atomic-scale device, and measuring the current through it, they showed that the device behaved as an excellent polyacetylene model as predicted – including the observation of an electron existing in two places *at the same time*.



A scanning tunnelling microscope image of a 10-quantum dot quantum analogue simulator – mimicking a polyacetylene molecule

Why is this such a big deal?

The analogue quantum processor is the world's first integrated circuit manufactured at the **atomic scale**. Simulating matter at the atomic scale allows us to start to understand how nature and the natural physical world really works.

This ability to simulate materials at the atomic level will revolutionise the way people look at solving problems. As SQC looks to simulate larger, more complex systems it will be able to simulate materials that already exist, but we don't really understand how they work; or to **simulate new materials that have never existed before** to solve a specific need or problem.

For example, if we can simulate and design new catalysts that are used in industrial chemical processes, this could have a significant, real-world impact by making these processes less energy intensive.

What is a molecule?

A molecule is made up of one or more atoms and is the smallest particle of a substance that has all the physical and chemical properties of that substance. To recreate the physical world, you need to be able to imitate – or **simulate** – molecules.

Since molecules are small, their behaviour is dominated by quantum physics. They are also massively dense with information due to the complicated nature of the interactions between the particles that make up the molecule. This means they are enormously complex to simulate.

How is the analogue quantum simulator different to a normal computer chip?

The ***analogue quantum simulator*** is not the same kind of computer chip currently used in computers and smartphones. Instead it is an integrated circuit that harnesses the power of quantum mechanics.

Accurately simulating molecules at the atomic scale is not something conventional computers – or even supercomputers are good at. For a conventional computer chip to accurately simulate the penicillin molecule, for example, it would require 10^{86} transistors – which is more transistors than there are atoms in the universe[1].

What's the difference between quantum mechanics and quantum computing?

Quantum mechanics – also known as quantum physics, or quantum theory – is a branch of physics that deals with physical phenomena at very small length scale, being very strong at the nano to atomic length scales.

Quantum computing is the development of computer technology based on the principles of quantum mechanics.

What inspired this research and breakthrough finding?

The milestone of the first atomic-scale quantum integrated circuit is a culmination of a vision set by SQC founder, Professor Michelle Simmons over 20 years ago. It delivers on a challenge first raised by

[1] *https://www.bcg.com/publications/2019/quantum-computers-create-value-when*

theoretical physicist Professor Richard Feynman in his famous 1959 lecture *Plenty of Room at the Bottom*.

In this lecture, Feynman said that if you want to understand how nature works, you must be able to control matter at the same length scales from which matter is constructed. Put simply: to simulate matter at the sub-nanometre scale, you need to be able to manufacture at the sub-nanometre scale.

63 years after Feynman first put forward this foundational theory, Simmons and her team have brought it to life by building an integrated circuit using atomic components in silicon.

Why is this result significant for SQC as a business?

Over the last 20 years, SQC founder Prof Michelle Simmons and her team have **pioneered a radical new technology** to build electronic devices in silicon atom by atom **to meet the stringent requirements for scaling quantum computing hardware**.

Simmons and her team used these techniques to fabricate and optimise each individual component of the analogue quantum processor then successfully brought all the components together into one integrated circuit – validating the company's technical strategy to focus on precision and quality rather than quantity.

SQC's leadership in atomic-scale precision manufacturing and control has enabled it to build the analogue quantum processor at its in-house manufacturing facilities at UNSW Sydney. The team is now focused on scaling up its manufacturing of hardware devices in Australia, to take on heavy duty computational tasks that cannot be performed by traditional computers.

This significant achievement further reflects SQC's long, sustained track record of delivering on milestones. The results are impossible to realise in any system that does not have this precision and demonstrate that SQC's quantum hardware is well-positioned to scale. SQC is now working on larger devices and modelling more complex, industrially relevant molecules.

The company looks forward to bringing commercial and industry partners on board to address their simulation needs and using this unique technology to solve problems previously out of reach of classical computers.