**Imagine a computer faster, smarter and more efficient than anything built today. If the development of a quantum computer is one of the ten major challenges in science and engineering in this century, can it actually be achieved? What part will Scientia Professor Robert Clark and the UNSW Centre for Quantum Computer Technology play in this international pursuit?**

# A leap into quantum computing

The Centre for Quantum Computer Technology was established in January 2000 and is an Australian multi-university collaboration investigating the fundamental physics and technology of building, via single atom nano-technology, the critical elements of a solid state quantum computer in silicon and, using single photon technology, a parallel all-optical approach to quantum computing. This is underpinned by semiconductor research that includes sophisticated quantum measurement at ultra-low temperatures and an advanced photonics capability.

The Centre has nodes at UNSW, the Universities of Queensland, Melbourne and Sydney, UNSW@ADFA, Department of Defence, Griffith University and Macquarie University. These nodes also maintain important collaborations with universities and government institutions in the USA and each node encompasses major research infrastructure including an extensive semiconductor nanofabrication facility, crystal growth, ion implantation, surface analysis, laser physics, high magnetic fields and low temperatures.

"The fact that there's a machine that we're ultimately trying to build is giving everyone a real focus," said Professor Robert Clark, a Federation Fellow and Centre Director. "But to build that machine we first need to do some of the most cutting-edge fundamental science because we're working with the quantum world."

A quantum computer could be the most powerful computational tool, able to process information far beyond present or future conventional computers, with a speed and efficiency inconceivable to most.

Meeting this challenge is a global race, but according to Robert Clark, the quantum computer of the future will be a very complex machine combining many aspects of different quantum computation approaches.

A solid state quantum computer will require qubits as basic logic units, substituting the up-and-down atomic spin for the ones and zeroes of the binary code processing of information. Getting qubits to interact with one another and with other components of a quantum computer is a demanding challenge. The Centre's work is focused on two very high profile methods – solid state quantum computer technology and quantum optics to facilitate information processing. Long term, the Centre's researchers are working to make a robust device that is encapsulated in silicon, and possibly integrated with optical transmission of information encoded on semiconductor qubits.

PhD student Nadia Court who is working on the measurements and control of qubits said, "At a recent Australian Physics Conference in Canberra, a world renowned theorist in the field of quantum computing was asked for his honest opinion on when he thought the quantum computer would be built. He said he thought it would not happen in his lifetime.

"Just being here is positive though, and we've got some great research going on. It's amazing to think that what we're pushing for might not happen for a long time, but the technology that comes from that could end up anywhere," she said.

It is worth noting that experimentally, rapid advances have been made in recent years and that the pace of research is broadly in line with the US Government roadmap for the development of quantum computing. "It is becoming clearer how to address the significant issues associated with scaling prototypes to full architectures. Timescales of the order of 10 to 20 years are commonly referred to in this context," said Robert Clark.

While Robert Clark doesn't believe a full-scale quantum computer will ultimately be built in Australia, by working in close partnership with the USA, the Centre is making a very important contribution and ensuring that Australia will be involved at the forefront of this technology, with access to its benefits.

Another PhD student, Toby Hallam, who is working on atomic fabrication describes his work as "the processing steps before we get to a quantum computer".

"As computer chips get faster and faster, the features on them need to get increasingly smaller. Conventional lithographic techniques can only create features down to a certain limit and in the next five to ten years we are going to hit that limit. To overcome this problem we are using a Scanning Tunneling Micro-scope to manipulate individual atoms into electronic devices.

"We know we can make features down to atomic scale. We can arrange single atoms down in a line, so the next big step is to see if we can then get wires from the outside world down to that small size and measure electrical transport through those wires. Our current challenge is how to make those two technologies compatible."

The Centre has some 18 research programs, both experimental and theoretical, and the silicon device fabrication and measurement takes place at UNSW in the Semiconductor Nanofabrication Facility, the Atomic Fabrication Facility and the National Magnet Laboratory, with single atom implantation steps carried out at the University of Melbourne. The Centre's optical quantum computing research programs are located at the University of Queensland and UNSW @ ADFA.

At a cost of around $7M a year, Robert Walton, Operations Manager for the Centre, concedes it's expensive work. "On the other hand, it gets very good scientific results and people are coming here from all over the world," he said.

PhD student Susan Angus, who is working on silicon single electron transistors, agrees that "the people working with you and the facilities are amazing".

With large amounts of funding come great expectations in terms of results and long-term aspirations. The Centre annually generates some 100 papers in high-impact peer-reviewed journals and has a substantial patent portfolio relating to path-way technology which has important potential commercial uses.

"It's as if we're moving towards our goal by cutting a narrow tunnel through a dense jungle with machetes," said Robert Clark. "As we go, we uncover significant things along the way that shouldn't deflect us from our goal, but which are very interesting from the standpoint of fundamental science nevertheless. And this provides a lot of motivation for our researchers, firing their imaginations while they're fighting their way through the tunnel. The heady mix of mission-oriented and fundamental research of the highest quality is the driving force for our young scientists."

Left to right: Scientia Professor Robert Clark, Nadia court, Susan Angus, Martin Brauhart (Laboratory Manager) and Robert Walton (Operations Manager).

**FUNDING**

Australian Research Council, Australian Government, US Army Research Office, US National Security Agency, State Governments of New South Wales, Victoria and Queensland, and participating institutions.

FOR INFORMATION CONTACT Scientia Professor Robert Clark at r.clark@unsw.edu.au