Quantum 'weirdness' offers huge potential

By Dick Ahlstrom
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Quantum computers will one day solve the kinds of problems that other computers just can't cope with, writes **Dick Ahlstrom**

A wholly new type of computer is on the way, one that will be able to solve problems that can't be solved today. Quantum computing holds great promise but remains a huge technological challenge, explains a specialist from NUI Maynooth.

Dr Jiri Vala recently moved to Maynooth from the University of California, Berkeley, to continue his research into quantum computing. He is a recipient of a Science Foundation Ireland-funded President of Ireland Young Researcher Award, which will provide financial support over a five-year period.

"One of the things that convinced me to move was the possibility of working for five years on my own research project and building my own research group," says Dr Vala.

His team will initially include two PhD students and a post-doctoral researcher and may in time grow to about 10 people. Its focus will be on quantum computing and the development of a computer system based on quantum mechanics.

"Having such a computer would be a major step forward. It would be a computer based on the best knowledge we have about the universe," says Dr Vala. "Quantum computers can solve problems which are not known to be tractable using classical computers."

Today's computers are based on the physics behind classical mechanics, the physics made famous by the great Isaac Newton. Yet despite all the advances in miniaturisation and modern electronics these devices still haven't escaped the classical physics world that created the first computing machine, the mathematical engine built by Charles Babbage, Dr Vala says.

The smallest piece of information in a classical computer is a bit, a small switch which can either be on or off. Quantum computing flies in the face of logic in that it tolerates the idea that both conditions, on and off, can co- exist at any one time.

"It relies on the possibility of having quantum systems in different states simultaneously," says Dr Vala. "Instead of thinking of discrete values you can think of another quality that recognises both values."

Physicists recognise the "weirdness" of the quantum mechanical state, but it is this strangeness that offers huge potential. "It is this weirdness which makes processing of quantum information massively parallel and leaves it without match in classical information processing," says Dr Vala.

In quantum computing the smallest element is known as the qubit and the goal is to be able to assemble large numbers of qubits in a single system. Herein lies the challenge, however.

Scientists want to be able to read the quantum state of a qubit that might be the size of a single atom. But qubits are currently so small and fragile that they are easily disrupted by magnetic and electrical fields and by nearby particles.

"What you would like to do is protect these quantum systems from the natural world. One of the most important characteristics is a system that is not susceptible to outside disruption."

The potential power of a quantum system does promise one possible answer to this challenge, however. "A quantum system should be capable of fixing its own errors," says Dr Vala.

This is true of the approach being taken by Dr Vala in "topological quantum computation". It offers natural fault- tolerance and may provide a way to get away from engineering-based approaches that seek to isolate and protect delicate qubit systems.

The method relies on creating a quantum topology, a sphere or a plain, and then disturbing it to modify the topology. The gross topology provides the information so errors in small elements of the wider topology shouldn't alter the information, he says.

Dr Vala is convinced that quantum computing will come in time despite the challenges.

"People believe that working quantum computer technology is about 20 years away but the research is happening now," he says.

The first true computers built in the 1940s and 1950s didn't have the power of a modern €5 hand calculator, but were able to solve problems.

Dr Vala argues that early quantum computers, when they come, will provide a similar service and eventually give way to newer systems, in the same way that mainframe and mini-computers gave way to the PC when it arrived in the 1970s.