# Breakthrough in Development of Quantum Computers

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***A Hitachi-Cambridge team develops a new silicon qubit***

Hitachi Europe Ltd. announced today that a Hitachi-Cambridge team has developed a new silicon device for quantum computing: a quantum-dot charge qubit. This structure, based on years of work on single-electronics, is the first step in the development of a quantum computer based on conventional silicon technology.

The world's most powerful supercomputers could be made obsolete in the future, by a totally different approach to processing information. In a classical computer, the basic unit of information is the 'bit', which can exist in one of two possible states, 0 or 1. Quantum computers make use of quantum bits (qubits), which can exist in a superposition of both states - a mixture of both 0 and 1 simultaneously. Qubits are also subject to quantum entanglement. When two or more are entangled, they behave as one system, so that the state of one qubit depends directly on the state of the others. Thus the potential processing power of a quantum information system increases exponentially rather than linearly with the number of qubits.

Although the principles behind quantum computing have been established and small model systems constructed, it still remains a considerable task to scale these up to practical, working computers. However, it is a valuable objective as it would make possible certain types of computation that are currently either impossible or impractical within a sensible timescale using classical computers. There are a raft of potential applications including bioinformatics, molecular modelling, codebreaking and encryption. Quantum computers could also be used as simulators to solve quantum mechanics problems.

One approach to building a solid-state quantum computer is by exploiting quantum states of artificial atoms and molecules built in semiconductor quantum-dot systems. The team has demonstrated this with an isolated double quantum-dot as a qubit. The key challenges in producing efficient quantum circuits are to have a system with sufficiently high number of operations within the characteristic coherence time of the qubits, to control the coupling between qubits to form architectures, and to integrate the qubits with manipulation and measurement circuitry. All operations (initialisation, manipulation, and measurement) have been achieved: using electrical gates for initialisation and manipulation, and a single-electron transistor for measurement. The scheme gives a very long coherence time, (100 times longer than shown in other solid-state implementations) and also provides flexibility in design, since the qubits may be combined in a variety of two-dimensional circuits, as in conventional microprocessors. Thus it offers the possibility of scaling-up from one device to a large quantum circuit - a necessary criterion for making a useful quantum computer.

In conclusion, the team have successfully demonstrated qubit operation of a silicon circuit, made using standard fabrication techniques and which is the first step towards making a silicon quantum computer. The report of these findings will be published in Physical Review Letters in August 2005, and will be presented at the 8th International Symposium on Foundations of Quantum Mechanics in the Light of New Technology (ISQM-TOKYO'05), to be held in the Advanced Research Laboratory, Hitachi, Ltd., Hatoyama, Saitama 350-0395, Japan in August 2005.

The team is formed by Dr. John Gorman and Dr. David Hasko of the University of Cambridge, U.K. and Dr. David Williams from the Hitachi

Cambridge Laboratory, U.K. The collaborative activity between the Hitachi Cambridge Laboratory, Hitachi Europe Ltd., and the Microelectronics Research Centre of the Cavendish Laboratory, University of Cambridge, which started in 1989, has resulted in the development of the world's first single-electron memory device, announced in 1992, and the first single-electron logic device, announced in 1995. Subsequent development led to the PLEDMâ conventional memory device, and now the team is heavily involved in the development of devices for quantum information processing, nanospintronics and organic devices.

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