FOR IMMEDIATE RELEASE
Thursday, May 15, 2003

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UM Physicists Take Fundamental Step Toward Quantum Computing

COLLEGE PARK, Md. – University of Maryland physicists have come one step closer to a quantum computer by demonstrating the existence of entangled states between two quantum bits (qubits), each created with a type of solid state circuit known as a Josephson junction. Published in this week's issue of the journal ***Science***, the results represent the latest advance in a broad scientific effort to apply properties of quantum physics to the creation of computers far more powerful than any of today's supercomputers.

A team of physicists led by professor Fred Wellstood of the university's Center for Superconductivity Research (a research center housed within the Department of Physics) says their findings are the first to indicate the successful creation of entanglement between two Josephson-junction qubits. Entanglement is an effect of quantum mechanics that blurs the distinction between individual particles such that it is impossible to describe the particles separately no matter how far apart you physically move them.

"Entanglement is essential to quantum computing because it is the linked quality that builds exponentially more information into quantum bits than is possible with classical computing bits," said Andrew Berkley, the paper's lead author and a graduate student in the Department of Physics. "Our current findings, which build on the work of many others, moves us further along the road toward a quantum computer, and indicate that Josephson junctions could eventually be used to build such a computer."

What is Quantum Computing?

A bit (short for *binary digit*) is the smallest unit of data in a computer. In computers today, a bit has a single value, either 0 or 1. However, with entanglement, a quantum bit, or qubit, can have not only its individual states (0 or 1), but also the possibility of shared states with every other qubit. Two bits can represent or store only two pieces of information, but two entangled qubits can store four pieces of information at the same time. This quantum advantage increases exponentially as the number of bits increase. Six bits, for example, can represent only 6 pieces of information, while six qubits can represent 64 pieces of information.

Electrons or Electronics

Current efforts to develop quantum computers can be grouped into two categories. The first one consists of researchers working with atomic particles, like atoms or electrons, for which a quantum nature and entangled states are inherent. A major question for these researchers is how to "scale up" from methods for manipulating individual or small numbers of such particles to actually building workable computers.

The second category, which includes Lobb, Berkley and their colleagues, consists of scientists working with solid-state electronic devices rather than subatomic particles. The leap from such devices to a working computer is potentially much more manageable. Here, the major challenge has been to achieve, at a macroscopic level, the quantum states naturally present at the atomic level. By demonstrating entanglement between two Josephson junctions, the Maryland work has provided important evidence that the necessary quantum behavior is present at the macroscopic level.

The Josephson junction device used by the Maryland team is made up of two superconductors separated by an insulating layer so thin that electrons can cross through it. Quantum mechanics allows electrons to flow through the insulating layer, an effect not allowed by classical physics.

"Josephson junctions are made by the same techniques used to make conventional integrated circuits, so they are well suited for scaling up to the thousand or so junctions needed to make a working quantum computer," said Lobb.

"Entangled Macroscopic Quantum States in Two Superconducting Qubits," *Science*, May 15, 2003, A.J. Berkley, H. Xu, R.C. Ramos, M.A. Gubrud, F.W. Strauch, P.R. Johnson, J.R. Anderson, A.J. Dragt, C.J. Lobb, and F.C. Wellstood, Center for Superconductivity Research Department of Physics, University of Maryland.

For More Information

For the full text of the paper, please visit web address
For more information about the University of Maryland please visit www.umd.edu.
For more information about the Center for Superconductivity, please visit www.csr.umd.edu.

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