Putting the squeeze on quantum information

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Canadian Institute for Advanced Research researchers have shown that information stored in quantum bits can be exponentially compressed without losing information. The achievement is an important proof of principle, and could be useful for efficient quantum communications and information storage.

Compression is vital for modern digital communication. It helps movies to stream quickly over the Internet, music to fit into digital players, and millions of telephone calls to bounce off of satellites and through fibre optic cables.

But it has not been clear if information stored in quantum bits, or qubits, could likewise be compressed. A new paper from Aephraim M. Steinberg (University of Toronto), a senior fellow in CIFAR's program in Quantum Information Science, shows that quantum information stored in a collection of identically prepared qubits can be perfectly compressed into exponentially fewer qubits.

Digital compression in the world of classical information theory is fairly straightforward. As a simple example, if you have a string of 1,000 zeros and ones and are only interested in how many zeros there are, you can simply count them and then write down the number.

In the quantum world it's more complicated. A qubit can be in a "superposition" between both zero and one until you measure it, at which point it collapses to either a zero or a one. Not only that, but you can extract different values depending on how you make the measurement.

Measured one way, a qubit might reveal a value of either zero or one. Measured another way it might show a value of either plus or minus.

These qualities open up huge potential for subtle and powerful computing. But they also mean that you don't want to collapse the quantum state of the qubit until you're ready to. Once you've made a single measurement, any other information you might have wanted to extract from the qubit disappears.

You could just store the qubit until you know you're ready to measure its value. But you might be dealing with thousands or millions of qubits.

"Our proposal gives you a way to hold onto a smaller quantum memory but still have the possibility of extracting as much information at a later date as if you'd held onto them all in the first place," Steinberg says.

In the experiment, Lee Rozema, a researcher in Steinberg's lab and lead author on the paper, prepared qubits in the form of photons which carried information in the form of their spin and in their path. The experiment showed that the information contained in three qubits could be compressed into only two qubits. The researchers also showed that the compression would scale exponentially. So it would require only 10 qubits to store all of the information about 1,000 qubits, and only 20 qubits to store all of the information about a million.

One caveat is that the information has to be contained in qubits that have been prepared by an identical process. However, many experiments in quantum information make use of just such identically prepared qubits, making the technique potentially very useful.

"This work sheds light on some of the striking differences between information in the classical and quantum worlds. It also promises to provide an exponential reduction in the amount of quantum memory needed for certain tasks," Steinberg says.

"The idea grew out of a CIFAR meeting," he says. "There was a talk by Robin Blume-Kohout (Sandia National Laboratory) at the Innsbruck meeting that first started me thinking about data compression, and then discussions with him led into this project."

The paper will appear in an upcoming issue of *Physical Review Letters*.

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