Plugging the leaks in a quantum computer

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New work by two researchers at HP Laboratories Bristol sets out to solve one of the major difficulties in quantum computer architectures that use directly interacting qubits.

The problem is that the million-or-so qubits necessary to do useful calculations in a quantum computer would all feel the presence of each other, meaning that the information would leak in an uncontrollable way. The more qubits that are put together this way, the harder it is to control them.

The solution put forward by Dr Sean Barrett and Dr Pieter Kok, working at HP Laboratories Bristol, is to put every qubits in its own box, so that they cannot directly talk to each other. However, for quantum computing to work, there does need to be some interaction between qubits so that they can become entangled. In the HP Labs system this is achieved by using the fact that every qubit can emit light particles (photons).

Quantum computing is expected to be much more powerful than conventional information processing. It should be able to search faster and simulate better, factor large numbers efficiently and virtually guarantee secure communications. The technology might still be several decades away from practical implementation.

Barrett and Kok's research is described in a recently published paper in Physical Review A [scitation.aip.org/getabs/servl … dtype=cvips&gifs=Yes]()

Their solution works like this: a detection system is arranged so that when an emitted photon is registered, it is impossible to tell -- even in principle -- which qubit it came from. This "quantum erasure" process generates an interaction between qubits, even though they remain in their separate boxes.

Now, the problem with current photon detector technology is that it isn't good enough to produce a high-fidelity interaction between qubits -- the result is very prone to error. This problem is solved in Barrett and Kok’s scheme by a clever re-run of the interaction process. After a second photon detection (leading to the name of the technique, "double-heralding") the errors are removed, leaving a very high-fidelity interaction between qubits.

It is still the case that sometimes the whole procedure fails, for example when photons get lost along the way. However, the crucial point is that when the observer knows, through the double-heralded signature, that the procedure has worked, it is known that it has worked very well.

Because of the chance of failure, the procedure cannot be used directly in a quantum computation. However, there is a way of doing quantum computing that relies on first making a large collection of entangled qubits -- a network of qubits called a "cluster state". Despite the chance of failure, the researchers’ double-heralded interaction procedure can be used to build efficiently such a cluster state. Quantum computation is then performed simply by making measurements on individual qubits of the cluster state.

The researchers say that this is a practical, scalable and efficient scheme for quantum computation.

The key features of this new scheme are that the qubits can be a wide variety of physical systems (such as quantum dots, defects in solids or trapped ions) and that it can be implemented with current detector technology. Consequently, there is already interest from several experimental groups in building this system.

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