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Perfect Quantum Computation

Physicists realize quantum gate quality never achieved before

Early building blocks of a future quantum computer had previously been tested under laboratory conditions. Now, for the first time, Innsbruck scientists have succeeded in building a quantum gate that works almost faultlessly. Experimental physicists from the team of professor Rainer Blatt and Dr. Christian Roos at the Institute for Quantum Optics and Quantum Information (IQOQI) of the Austrian Academy of Sciences (ÖAW) and the University of Innsbruck report their findings in the journal *Nature Physics*.

In recent years individual building blocks of a future quantum computer have been tested successfully under laboratory conditions. A significant contribution to this feat came from Innsbruck experimental physicists in Rainer Blatt's team. These series of tests confirmed the basic functionality of a quantum computer but it was still not very fault-tolerant. Future quantum computers will, similarly to traditional computers, have their own error-correction mechanism to rectify any computation errors. Many theoreticians assume that the computation elements will need a fidelity of more than 99%. Doctoral students Jan Benhelm and Gerhard Kirchmair, working with Christian Roos and Rainer Blatt, have crossed this threshold in their latest experiment. They found clear indications that their quantum gate, made up of two ions, reached a fidelity of 99.3%. "This is the best value ever achieved for a quantum computation system," young researcher Christian Roos proudly reports.

A trick paved the way

The physicists created a so-called Mølmer-Sørensen gate from calcium ions by directing a two-tone laser beam simultaneously onto two very cold trapped ions. The two particles can be entangled through interaction with the laser light. The researchers used a trick to improve the fidelity of this operation. "Previously we used laser pulses of constant intensity in our experiments," Roos explains. "In this set-up we altered the light intensity in time, resulting in a laser pulse with rounded flanks. Only in this way were we able to achieve the high fidelity of over 99%." In this experiment, Rainer Blatt and his team also managed to study the remaining experimental sources of error in great detail. They carried out up to 21 gate operations in a row and analysed any faults that occurred thoroughly.

Very robust and easy to implement

In this method for an experimental implementation of a quantum gate, based on the theoretical design of Danish scientists Klaus Mølmer and Anders Sørensen, the interaction between the ions and the laser light is created in parallel. In this way many ions can be entangled in a single step using the same mechanism. Now the Innsbruck researchers want to try applying this entangling mechanism to more than two ions and create so-called GHZ states, for instance. Another outstanding task is testing other kinds of computational operations with this system. "We have great hopes for this because the mechanism is very robust and very easy to implement in an experiment," says Christian Roos. In their work the scientists can count on the support of the University of Innsbruck, the Austrian Academy of Sciences and the European Union, among others.

Publication: Towards fault-tolerant quantum computing with trapped ions. J Benhelm, G Kirchmair, CF Roos, R Blatt. Nature Physics, Advance Online Publication, 27. 4. 2008.

You can find pictures on: http://www.iqoqi.at/media/download/

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