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Quantum logic for a new generation of atomic clocks

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Innsbruck-based scientists develop the basis for ever more precise atomic clocks

The flow of time can be measured very accurately with atomic clocks. In many applications and basic research experiments, however, scientists are looking for ever more precise ways of determining atomic oscillation frequencies. Experimental physicists from the team of Dr. Christian Roos have now conducted an experiment in which they used quantum-mechanically entangled atoms for more precise time measurements. They have written up their findings in the latest issue of NATURE.

For years the Innsbruck-based experimental physicists around Prof. Rainer Blatt have been working successfully on laying the foundation for a future quantum computer. Only last year the scientists managed to produce the first ever “quantum byte”. Their findings will not only revolutionise future information processing, quantum logic also promises applications for constructing new atomic clocks. Even now atomic clocks determine time through the oscillation frequency of single atoms. The precision of such clocks is limited by external interference, e.g. from electric fields. Now researchers from the teams of Christian Roos and Rainer Blatt have developed a system of two entangled calcium ions ($^{40}Ca^{+}$) that gets around the sensitivity of single atoms. In this they were helped by their experience with developing quantum computers. Dr. Roos explains: “In systems of two or more entangled particles classes of states can be found that are insensitive to certain types of interference. These so-called decoherence-free subspaces are important for constructing quantum computers, where delicate quantum states must be protected against harmful effects from their environment. Now we also use these decoherence-free subspaces for our time measurements.”

Entanglement allows even more exact measurement

“In our experiment we were able to show that quantum-mechanical states that are relevant for measuring time can be very stable,” said Dr. Christian Roos of the Institute of Quantum Optics and Quantum Information (IQOQI) in Innsbruck. The scientist does not measure time directly yet, instead he uses these states to measure an atomic quality, the so-called electric quadrupol moments, in a calcium

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ion. This electric measurement is very important for atomic clocks as it determines the extent to which external electric fields may affect the time measurement. In recent years therefore the quadrupol moments have been determined for a number of atoms. "The precision of our measurement exceeds all measurements to date by a factor of 10, "Roos explains, "and it does so despite the fact that disturbing noise is much stronger in the calcium ions we use." In the near future the physicists in Innsbruck hope to use this process for a more precise determination of the oscillation frequency in a calcium ion and thus achieve a better time measurement.

This experiment was conducted at the Institute of Experimental Physics at Innsbruck University. Financial support for the work of the scientists has come from the Austrian Science Fund (FWF), the Austrian Academy of Sciences (ÖAW) and the European Union.

Pictures: http://www.iqoqi.at/media/download/

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