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Another Milestone: Frequency Measured to the 17th Decimal Place

Researchers from the University of Innsbruck participate in world record experiment

Scientists of the National Institute of Standards and Technology (NIST) in Boulder, Colorado, have achieved a new world record in precision measuring of optical frequencies. A major contribution has come from experimental physicist Dr. Piet O. Schmidt, who has been researching at the University of Innsbruck for the last three years. The scientists report their ground-braking findings in the journal *Science*.

Today we are able to measure lapsed time with extremely high accuracy. A number of caesium atomic clocks all over the world determine the length of a second. The most modern of these clocks currently is down to a deviation of just a few seconds over 300 million years, but for the physicians this is not accurate enough. They are researching into optical atomic clocks that work with light frequencies and should be even more precise by a factor of 1,000. Now scientists at the National Institute of Standards and Technology (NIST) in Boulder, Colorado, have achieved a major breakthrough. "My colleagues at NIST have improved the accuracy of two optical atomic clocks by a factor of 10 vis-à-vis the best previously existing clocks. As proof the frequencies of both clocks were compared and it showed a deviation of only 5.2 x 10-17. This is the equivalent of measuring the distance from the earth to the sun to a tenth of the diameter of a hair – definitely a world record," a delighted Piet Schmidt reports. As a post-doc researcher he was one of the scientists who set up the experiment and carried out early measurements. Today the START prize winner researches at the Institute for Experimental Physics at the University of Innsbruck.

A quantum-logical clock

In their optical atomic clocks, the US scientists used individual mercury and aluminium ions. "The aluminium ion has a very narrow clock transition, which has also shown to be particularly resistant against external interferences, but the ion is very difficult to control," explains Piet Schmidt. "We use techniques that are also applied in building a quantum computer." A beryllium ion is added to the aluminium ion and acts as a kind of mediator, assisting both with laser cooling and

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with measuring. This so-called quantum logic spectroscopy was first realized three years ago by Piet Schmidt and his colleagues at NIST. The mercury ion however can be cooled and read off directly with lasers and here the usual quantum leap spectroscopy is used. Since the ions do not provide continuous signals for the measurement, they are coupled with highly stable lasers that act like a flywheel, maintaining the light frequency and are calibrated repeatedly by regular measurements at the ions. The scientist can then compare the frequencies of both atomic clocks using an optical frequency comb, but these measurements are extremely sensitive. Gravitation effects for instance have to be taken into account. The distance of either atomic clock from the centre of the earth must not differ by more than 10 cm. This sensitivity opens up new perspectives for the researchers and means that atomic clocks could also be used to study the gravitational field of the earth.

Are natural constants truly constant?

"Of particular interest for us are longer-term measurements," Schmidt explains. "They allow us to test if fundamental natural constants change over time, which would of course be spectacular, because current theory does not allow for that." The findings of the researchers in Boulder are reassuring: the fine-structure constant α did not change significantly over the period of a whole year. This is the point of departure for Piet Schmidt's new experiments in Innsbruck. He wants to study changes in natural constants further and generate measurement data that would help astrophysicists to improve their data analysis. There are astrophysical observations that suggest that the fine-structure constant α has changed as the cosmos developed. New infrastructure projects might facilitate his plans, Piet Schmidt hopes. "When they build the new House of Physics in Innsbruck, we can create similar conditions here to those they have in Boulder."

START prize winner

Piet Schmidt was born in Schwäbisch Hall, Germany, in 1970. He studied physics at the University of Constance and spent a year at the Portland State University in the USA. He started his doctoral degree in Constance, then went on to the University of Stuttgart, where he graduated in 2003. For two years he held a post-doc position in the working group of David Wineland and Jim Bergquist at the National Institute of Standards and Technology (NIST) in Boulder, Colorado. Since 2005 he has been working as a staff scientist in the working group of professor Rainer Blatt at the University of Innsbruck. In June 2006 he was awarded the START prize, the highest Austrian accolade for young scientists.

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

On the NIST homepage you can find an animation about the experiment:
http://www.nist.gov/public_affairs/releases/logic_clock/logic_clock.html

Publication: „Frequency Ratio of Al+ and Hg+ Single-Ion Optical Clocks; Metrology at the 17th Decimal Place“, Rosenband T, Hume DB, Schmidt PO, Chou CW, Brusch A, Lorini L, Oskay WH, Drullinger RE, Fortier TM, Stalnaker JE, Diddams SA, Swann WC, Newbury NR, Itano WM, Wineland DJ, Bergquist JC, Science Express, March 6, 2008.

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