A step closer to an ultra precise atomic clock

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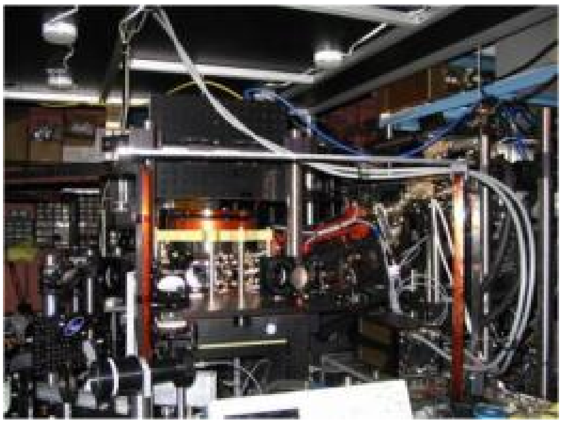
These are ultracold strontium atoms. Credit: University of Colorado

A clock that is so precise that it loses only a second every 300 million years - this is the result of new research in ultra cold atoms. The international collaboration is comprised of researchers from the University of Colorado, USA and the Niels Bohr Institute at the University of Copenhagen and the results have just been published in the prestigious scientific journal, *Science*.

An atomic clock consists of gas atoms captured in a magnetic field where they are held stationary with precise laser light and are cooled down to near absolute zero, minus 273 degrees Celsius. In this state the researchers can use the quantum properties of the atoms and get them to function as a clock movement with a pendulum.

"An atom consists of a nucleus and some electrons that spin in clearly defined orbits around the nucleus. By using the focused laser light one can make the electron swing back and forth in a clearly defined way between these orbits, and it is that which forms the pendulum in the atomic clock", explains nuclear physicist at the Niels Bohr Institute at the University of Copenhagen, Jan W. Thomsen, who has worked with the new experiments together with researchers at the University of Colorado in Boulder, USA.



This is a strontium atomic clock operating at JILA, University of Colorado. Laser light is used to cool and manipulate the atoms for optimal operation of the clock. Carefully designed magnetic field coils compensate for the Earth magnetic field. Credit: University of Colorado

Disobedient atoms

Atomic clocks are not really anything new and are already used to make the most precise calculations in physics. But there was something the researchers did not understand, that they ran into a barrier in their endeavours to make the atomic clock even more precise. They could not get the precision better than the loss of one second every 150 million years.

"The problem was that the atoms did not behave as they should according to the theory of quantum physics", tells Jan W. Thomsen and explains, that atoms have two fundamental states - they either rotate a complete revolution around themselves and are then called bosons or they rotate half-integers (½ or 1½) around themselves and are then called fermions. These two types behave completely differently. The bosons clump tightly together, while the fermions are repelled by each other and it is impossible to get them near to each other.

Journey into the quantum world

For atomic clocks one uses fermions because they do not interact - according to the theory of physics of quantum mechanics. Yet they did, as it turned out. And what was the reason? The researchers wanted to find out what was really happening and they started a colossal series of time consuming experiments that have given a whole new insight into how cold atoms behave.

"It was an fascinating journey into the world of quantum mechanics. We found out that not all fermions were the same. At the very low temperatures the fermions begin to 'see' each other and interact and then the atomic clock begins to go awry", explains Jan W. Thomsen. The experiments showed that the fermion's quantum properties were being affected by the exposure to light itself and this lead to the loss of precision in the atomic clock. By tuning the light frequency in a certain way one could control the fermions and avoid the loss of precision.

Great potential

The result is that an atomic clock is now three times more precise than before and that the clock now loses only one second per 300 million years as opposed to one second per 150 million years. Even though it is only small fraction of a second, it has great potential in the application in areas having to do with the determination of great distances, for example, measuring the distance to distant galaxies in space. If one looks back towards the Earth one could measure the tiny movements in the continental drift and that can perhaps give geophysicists a new tool to work with to predict earthquakes.

The question is whether they are now satisfied with the atomic clock's precision? "Not completely", answers Jan W. Thomsen, "we dream of getting an atomic clock with perfect precision". So the research in the world of quantum mechanics continues towards a new goal.

Source: University of Copenhagen

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