Physicists calculate how to make atomic clocks super-accurate

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(PhysOrg.com) -- When it comes to atomic clocks, every second counts. In fact, according to Marianna Safronova, every quintillionth of a second counts.

Safronova, an associate professor of physics at UD, and colleagues recently reported on their research, in which they have devised a new calculation to aid ultra-precise timekeeping. Their findings could lead to the development of an atomic clock that loses only a second in about 32 billion years -- more than twice the estimated age of the universe.

"Extremely high-precision clocks have a lot of applications, from tracking of deep-space probes to testing the fundamental principles of science," Safronova said, noting that all global positioning systems (GPS) are based on atomic clocks.

Her team's research was reported at the 2011 Conference on Lasers and Electro-Optics, held recently in Baltimore, and the 2011 Joint Conference of the IEEE International Frequency Control Symposium and European Frequency and Time Forum, held in San Francisco. Safronova was the lead author of the research paper, co-authored by physicist Mikhail Kozlov of the Petersburg Nuclear Physics Institute in Russia and Charles Clark, a physicist at the Joint Quantum Institute in Maryland.

The researchers studied the effect of heat on the measurements used to keep time in atomic clocks and found a way to calculate those effects and, therefore, improve precision. The most precise clock currently in existence, developed last year by the National Institute for Standards and Technology (NIST) in Boulder, Colo., loses about a second every 3.7 billion years, for an uncertainty of 8.6 parts in 10 to the 18th power.

The NIST device is a quantum-logic clock, which is based on the atomic energy levels in the aluminum-plus ion, an aluminum atom that has lost one electron. The electrons in the ion vibrate between their highest energy orbit, or excited state, and lowest energy orbit, or ground state, at an extremely precise frequency, and that frequency is what the atomic clock uses to keep time.

"You have to know that difference to evaluate the accuracy of the clock, but it turns out that the frequency does change very slightly with temperature," Safronova said. "The frequency is defined at absolute zero, but the room isn't at absolute zero."

The temperature affects the ion's transition frequency because heat—even the tiny amount that exists throughout the environment and is known as "blackbody radiation"—changes the size of the electron clouds and causes the two energy levels to shift, she said. She and her team have now calculated a way to account for that very small shift and improve the precision of the timekeeping measurements.

In addition to applications such as GPS, atomic clocks may be used to synchronize broadband data streams and in a variety of scientific experiments. Safronova noted that the process of moving toward more and more precise clocks also yields further benefits in the development of state-of-the-art technology such as specialized fibers and lasers.

And, she said, perhaps even more importantly, "With ultra-precision clocks, you can see if the fundamental laws of physics change with time."