Tick Tock: Who Needs an Atomic Clock?

March 8 2006

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“Last year the Nobel Prize recognized the significance of this field with John Hall and Theodor Hänsch,” says Chris Oates of studying optical atomic clocks. “There are a lot of new ideas coming out, and we hope that our idea is one of those that will help the clocks.”

Chris Oates is one of six physicists who published a Letter, “Magnetic Field-Induced Spectroscopy of Forbidden Optical Transitions with Applications to Lattice-Based Optical Atomic Clocks,” in *Physical Review Letters* demonstrating a unique technique for creating more stable optical atomic clocks. Building on ideas suggested by two Russian colleagues, Oates and his co-workers at the National Institute for Standards and Technology (NIST) have developed a process to improve one of the most promising types of optical atomic clocks, which divide the second into extremely small pieces in order to enable better timing precision.

Perhaps one of the more intriguing questions to come out of this is: Does it really matter whether we have a more precise atomic clock?

Oates thinks so. “Atomic clocks provide exquisite timing,” he explains to PhysOrg.com. “One of the most practical applications for atomic clocks is GPS. The timing must be very good in order to properly pinpoint a position. Every GPS satellite carries multiple atomic clocks.” He also cites the communications industry, where faster data rates require more precise timing, as other applications that are affected by atomic clocks. But he admits that the new optical clocks will likely not be used for such applications.

“These optical atomic clocks won’t be used in GPS, but rather for more far-out applications,” Oates says. “Space navigation or imaging would be good applications, and communications between satellites is quite likely.” But the real benefits of using optical atomic clocks comes in when one looks at the implications of increased precision in scientific measurements.

“Timing for electronics in high-energy accelerators, where particle physics is investigated, will be improved. Synchronization is very important in these experiments, and what we are developing in the way of optical atomic clocks can only help,” Oates says. A note of excitement creeps into his voice as he continues: “Tests of fundamental physics is the place where these clocks will have the most immediate impact.”

Oates explains that astrophysicists look back into time by observing quasars and other objects in space. He says that these studies reveal that some natural fundamental constants of nature may change over time. While these theories have yet to be tested, the ability to more minutely track seconds can lead to the ability to detect natural constants that change over time. According to Oates, building optical atomic clocks built on different atoms and ions, and then comparing the differences, can provide verifiable laboratory measurements that could possibly answer questions as to whether some natural constants might experience change.

Oates says that already obstacles are being overcome in the area of optical atomic clocks. One of the biggest problems is the magnetic sensitivity that the isotopes of neutral atoms have. In order to get around this, many experiments were done using ion traps. The major drawback to this method, however, is that only one ion can be trapped at a time. So, while the ion environment is very favorable and free of any sort of perturbations, it requires some time to take the number of measurements required.

The team from the NIST and the Institute of Laser Physics SB RAS in Russia instead use about 10,000 neutral atoms, and hence achieve an average measurement almost instantaneously. The problem is that they move around, distorting results. The team put together an array of about 1,000-lattice "wells," which Oates refers to as "pancakes" (see the PhysOrg.com story) that each hold about 10 atoms. The lattice pancakes hold the atoms very still, eliminating one problem. But the problem of magnetic sensitivity still remained.

"The answer was quite simple," Oates explains. "We realized that we could apply a magnetic field to enable the use of a different isotope of ytterbium and get rid of magnetic sensitivity. We could make what wasn't allowed into something that was allowed." He pauses with a small laugh. "Weakly allowed, but enough. We found that this works, and it really removes what looked like a major roadblock to the use of neutral atoms for optical atomic clocks." Indeed, the successful experimental demonstration of this technique by the NIST team led by Zeb Barber and Chad Hoyt is described in another article in the same issue of *Physical*

Review Letters.

So, while optical atomic clocks appear to be making inroads in the world of physics, practical applications for the rest of the world are still down the road. But Oates doesn't mind. "Sharing this with the world is a tantalizing challenge."

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