A Quantum Mechanical 'Tune Up' for Better Measurement

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By exploiting the weird quantum behavior of atoms, physicists at the Commerce Department’s National Institute of Standards and Technology (NIST) have demonstrated a new technique that someday could be used to save weeks of measurements needed to operate ultraprecise atomic clocks. The technique also could be used to improve the precision of other measurement processes such as spectroscopy.

The technique, described in today’s issue of Science, effectively turns atoms into better frequency sensors. Eventually, the technique could help scientists measure the ticks of an atomic clock faster and more accurately. Just as a grandfather clock uses the regular swings of a pendulum to count off each second of time, an atomic clock produces billions of ticks per second by detecting the regular oscillations of atoms. The trick to producing extremely accurate atomic clocks is to measure this frequency very precisely for a specific atom.

In the latest experiment, the scientists used very brief pulses of ultraviolet light in a NIST-developed technique to put three beryllium ions (charged atoms) into a special quantum state called entanglement. In simple terms, entanglement involves correlating the fates of two or more atoms such that their behavior—in concert—is very different from the independent actions of unentangled atoms. One effect is that, once a measurement is made on one atom, it becomes possible to predict the result of a measurement on another. When applied to atoms in an atomic clock, the effect is that n entangled atoms will tick n times faster than the unentangled atoms.

Currently, scientists at NIST and other laboratories make many thousands of measurements of the ticks of unentangled atoms and average these results to get highly accurate atomic clocks (currently keeping time to better than one second in 40 million years).

If entangled atoms could be used in a clock, the same or better results could be achieved with far fewer separate measurements. The current experiment demonstrates this new approach to precision measurement with three ions; however, the researchers are looking forward to entangling even more ions to take greater advantage of the technique.

"Even if we could implement this new technique with only 10 ions, in the clock business that's really important because the clocks must be averaged for weeks and even months," says NIST physicist Dave Wineland, leader of the research group. "The time needed to do that would be reduced by a factor of 10."

In the experiment reported in Science, scientists entangled the ions with two laser beams, using a technique originally developed for quantum computing applications. The ions are hit with another series of laser pulses and their fluorescence (emitted light, which represents the ions’ quantum state) is measured for a specific period of time. The duration of the steps, number of ions, and other experimental conditions are controlled carefully to ensure all the ions are in the same state when they are measured, so that either all or none fluoresce, which simplifies the readout.

The research was supported in part by the Advanced Research and Development Activity and the National Security Agency.

As a non-regulatory agency of the U.S. Department of Commerce’s Technology Administration, NIST develops and promotes measurement, standards and technology to enhance productivity, facilitate trade and improve the quality of life.

The original press release find on the NIST web-site.