Method to entangle thousands of atoms could lead to record clock stability

19 August 2016, by Lisa Zyga

Physicists have proposed a method for entangling hundreds of atoms, and then entangling a dozen or so groups of these hundreds of atoms, resulting in a quantum network of thousands of entangled atoms. Since small bundles of these entangled groups can function as atomic clocks, this design is the first detailed proposal for a quantum network of atomic clocks.

The scientists estimate that, if realized, these clocks will have an order of magnitude greater stability than today’s best atomic clocks. Superstable clocks are critical for measuring astronomical effects such as gravitational waves and, potentially, dark matter.

The researchers showed that it should be possible to experimentally realize this network of atomic clocks using neutral ytterbium atoms. Even when accounting for errors and physical imperfections, they predict that the entangled atomic clock network will have significantly better stability than non-entangled clocks, making them capable of measuring relativistic effects in the passage of time.

"Superstable atomic clocks allow scientists to measure minuscule changes in the speed of passing time," Kómár said. "Although local time always passes at the same rate for the local observer, time often passes with slightly different rates at different locations. Many physical
phenomena can cause the passage of time to slow down or speed up, all of which are tied to large masses and gravity."

By taking advantage of this relationship between mass, gravity, and time, researchers can use it for practical purposes, such as searching for underground oil reserves or gravitational waves in space.

"If the rocks under a particular spot are denser compared to the rocks under another spot, then time passes more slowly at the former location," Kómár said. "By installing two superstable atomic clocks at the two locations, and comparing their signal, one can measure this small difference in the rate of the passage of time—and, in turn, discover hidden ore or oil deposits beneath the ground.

"Gravitational waves is another phenomenon that causes time to pass at different rates at different locations. A formation of satellites, each equipped with superstable atomic clocks, can be used as a very precise 'space-seismograph.' As the gravitational wave passes through the region occupied by the satellites, their clocks pick up a tiny time difference with respect to each other. This provides a way to detect gravitational waves through the distortions of time as opposed to distortions of space, the method LIGO relies on, providing complementary means of detection."

In the near future, the researchers plan to pursue some of these applications of the entangled network of atomic clocks.

"There are already theoretical proposals and drafts on their way assessing the sensitivity of atomic-clock-based gravitational wave detectors," Kómár said. "Although these require the network to be constructed in space, near future experiments will most likely focus on lab-based and ground-based implementations. Only when the design is perfected will the clocks go on board of satellites."
