A quantum connection between light and motion

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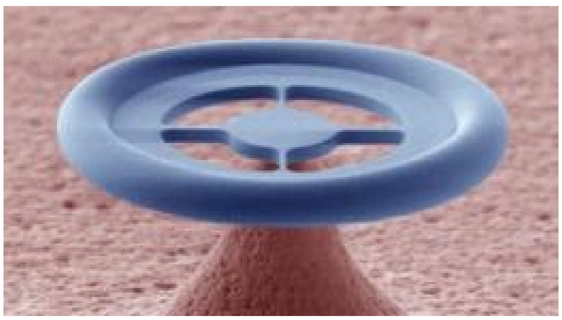

(PhysOrg.com) -- Physicists have demonstrated a system in which light is used to control the motion of an object that is large enough to be seen with the naked eye at the level where quantum mechanics governs its behavior.

The movement of objects is ultimately governed by the laws of quantum mechanics, which predict some intriguing phenomena: An object could simultaneously be in two places at the same time, and it should always be moving a little, even at a temperature of absolute zero - the oscillator is then said to be in its quantum 'ground state'. Until recently, these strange predictions of quantum mechanics have only been observed in the motion of tiny objects such as individual atoms. For large objects, the unavoidable coupling of the object to the surrounding environment quickly washes out the quantum properties, in a process known as decoherence. But researchers in EPFL's Laboratory of Photonics and Quantum Measurements have now shown that it is possible to use light to control the vibrational motion of a large object, consisting of a hundred trillion atoms, at the quantum level. The results of their research have been published in the February 2nd edition of *Nature* magazine.

A ring of light

The object they used was circular in design - a 30-micrometer diameter glass donut mounted on a microchip. Under the direction of Tobias Kippenberg, the team injected a laser into a thin optical fiber, and brought the fiber close to the donut, allowing light to 'jump' to the object and circulate around the circumference of the donut up to a million times. Just as the pressure of a finger running along the rim of a wineglass will cause it to hum, the tiny force exerted by the photons traveling inside the glass ring can cause it to vibrate at a well-defined frequency. But the force can in fact also dampen the vibrations, and thus cool down the oscillatory motion.

Cold, colder...

Cooling is crucial to reaching the regime of quantum mechanical motion, as this is normally overshadowed by random thermal fluctuations. For this reason, the structure is placed in a cryostat that brings it to a temperature of less than one degree above absolute zero (−273.15°C). The light launched into the donut slows down the motion one hundred times, thus cooling it even more, very close to the quantum 'ground state'. And more importantly, the interaction between light and the movement of the oscillator can be made so strong that the two form an intimate connection: A small excitation in the form of a light pulse was fully transformed into a small vibration and back again. For the first time, this transformation between light and motion was made to occur within a time that is short enough so that the quantum properties of the original light pulse are not lost in the process through decoherence. By outpacing decoherence, these results demonstrate the possibility of controlling the quantum properties of an object's motion. It also provides a way to see the peculiar predictions of quantum mechanics at play in man-made objects.

Looking forward

Mechanical vibrations can be coupled to quantum systems of completely different nature (such as electric currents), as well as to light. They could therefore be used to 'translate' quantum information between those systems and light signals. This is especially beneficial as it allows to transport quantum information - the basic ingredient of a future quantum computer - over large distances in optical fibers.

More information: Quantum-coherent coupling of a mechanical oscillator to an optical cavity mode, E. Verhagen, S. Deléglise, S. Weis, A. Schliesser, Tobias J. Kippenberg, *Nature*, January 2012. DOI: 10.1038/nature10787

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