Squeezed states of light can improve feedback cooling significantly

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SEM micrograph of a microtoroidal resonator similar to the one used for demonstration of quantum-enhanced feedback cooling. The silica torus forms a cavity for light which is modulated by the mechanical vibrations of the supporting disk. Light is coupled in and out of the system by bringing a tapered optical fiber in proximity of the torus. Credit: Kristian Rasmussen, DTU

How does the tightrope walker manage to maintain her balance and avoid that fatal drop from the sky? She carefully senses the motion of her body and vibrations of the rope and accordingly compensates any deviation from equilibrium by shifting her center of gravity. In a thermally excited system, the amplitude of the mechanical vibrations are directly linked to the system's temperature. Thus, by eliminating vibrations the system is cooled to a lower effective temperature.

In recent experiments at DTU Physics, researchers have employed a quantum-enhanced feedback technique to dampen the motion of a micron-sized mechanical oscillator, thereby cooling its temperature by more than 140 degrees below room temperature. Most importantly, this work demonstrates a novel application of squeezed light allowing an improved sensitivity to the mechanical motion and thereby a more efficient extraction of information on how the damping feedback should be tailored.

In the experiment, the mechanical motion of a microtoroidal resonator was continuously sensed using laser light circulating inside the resonator. Using that information an electric feedback force that was always out of phase with the instantaneous motion was tailored and applied - that is, when the motion was directed upwards the feedback force would counteract this by pushing the toroid downwards and vice versa. Using ordinary - classical - laser light, this technique is ultimately limited by the intrinsic quantum noise of the probe laser, and that sets the classical limit for how efficient the feedback cooling can be.

As now demonstrated by DTU researchers, this limit can be surpassed by using quantum-engineered squeezed light. In the experiment, an improvement of more than 12% over the classical limiting temperature was achieved. This improvement was limited by inefficiencies of the specific system resulting in a loss of information on the mechanical motion. The full potential of the demonstrated technique can be unfolded by application to state-of-the-art optomechanical systems, holding promises for reaching the motional quantum ground state of a mechanical oscillator in room temperature experiments. Achieving this would pave the way for a plethora of new optomechanical investigations of fundamental quantum physics and constitute a crucial step towards development of new quantum technologies for sensing and information processing based on micromechanical oscillators.

More information: Clemens Schäfermeier et al, Quantum enhanced feedback cooling of a mechanical oscillator using nonclassical light, *Nature Communications* (2016). DOI: 10.1038/ncomms13628

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