Ultra-sensitive force sensing with a levitating nanoparticle

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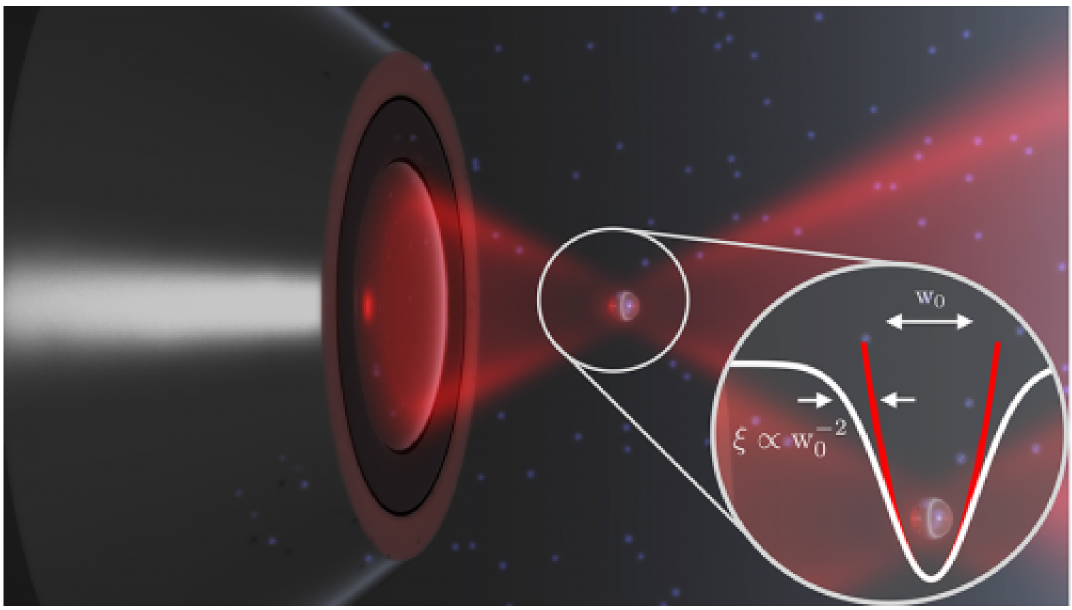

This is a silica nanoparticle trapped by tightly focused laser beams. Credit: ICFO

A recent study led by researchers of the Institute of Photonic Sciences (ICFO) achieved the highest force sensitivity ever observed with a nano-mechanical resonator. The scientific results of this study have been published in *Nature Physics*.

Nano- and micromechanical oscillators with high quality (Q) factors have gained much attention for their potential application in sensing, signal processing and transduction as well as in fundamental research aiming at observing quantum effects in increasingly larger systems. Despite recent advances in the design and fabrication of mechanical resonators, their Q-factor has so far been limited by coupling to the environment through physical contact to a support. To overcome this limitation, the present work proposes to use optically levitated objects in vacuum that do not suffer from clamping losses.

In this recent ICFO study, scientists have optically levitated nanoparticles in high vacuum conditions and measured the highest Q-factor ever observed in nano- or micromechanical systems. The combination of an ultra-high Q-factor together with the tiny mass of the nanoparticles leads to an unprecedented force sensitivity at room temperature. The system is so sensitive that the weak forces arising from collisions between the nanoparticle and the residual air molecules are enough to drive it into the nonlinear regime. For the first time, this study demonstrates that ultra-high Q-factor nano-resonators intrinsically behave nonlinearly. In addition, the researchers show that, when combined with feedback cooling, the levitating nanoparticle can be used as a force-sensor, sufficiently sensitive to detect ultra-weak interactions, such as non-Newtonian gravity-like forces and tiny forces arising from quantum vacuum fluctuations.

Gieseler remarks that "Thermal motion is commonly observed in nano-mechanical systems. However, observing nonlinear features of thermal motion is a true novelty and, thus, challenges our understanding of how these high-Q nano-mechanical systems behave."

The advent of this new class of nano-mechanical oscillators will open new avenues for ultrasensitive force sensing and benefit the experimental investigation of quantum physics.

This discovery has been possible thanks to the collaboration between the Plasmon Nano-optics group led by ICREA Prof. at ICFO Romain

Quidant and the Nano-Photonics group led by Prof. Lukas Novotny, from the Photonics Laboratory (ETH Zurich), as well as the support from the Fundació Cellex Barcelona through its Nest program.

More information: Jan Gieseler, Lukas Novotny & Romain Quidant, Thermal nonlinearities in a nanomechanical oscillator, *Nature Physics* (2013), DOI: 10.1038/nphys2798

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