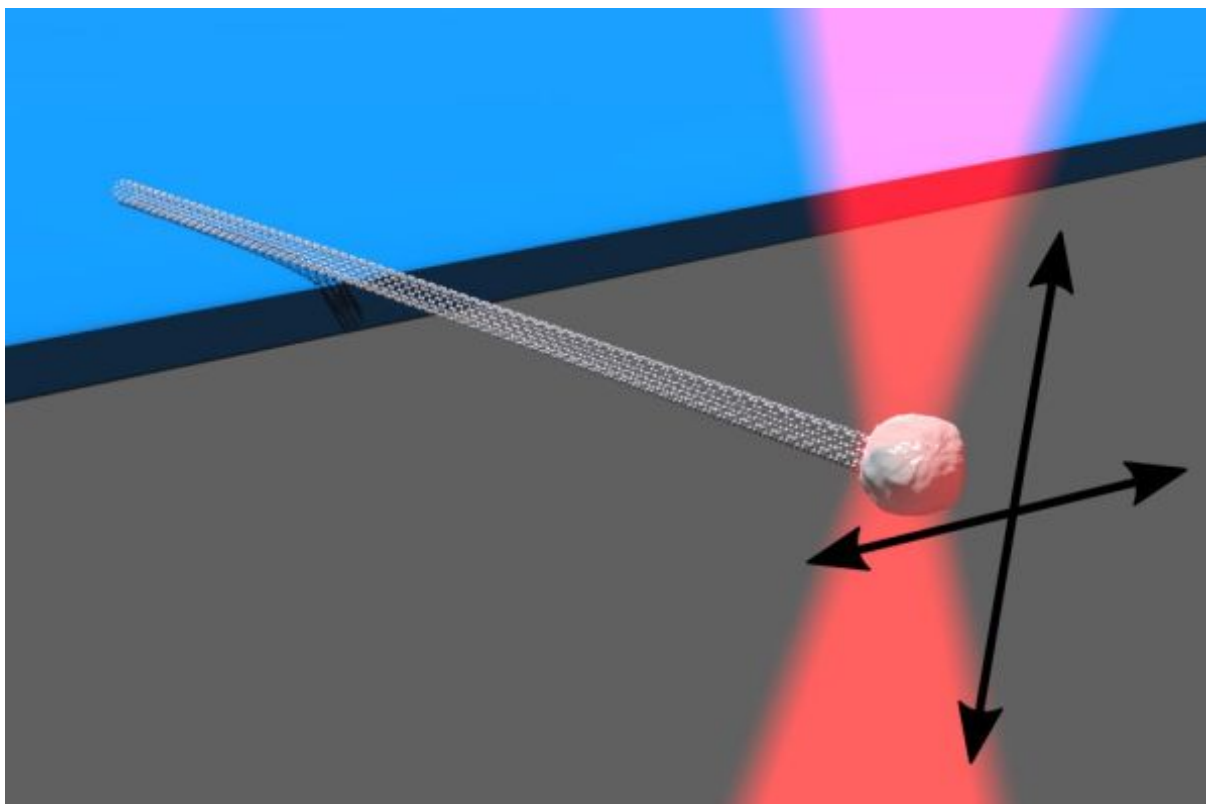




Exploring the stiffness of nano-objects

An international team of researchers, led by ICFO, reports in PRL on an experimental approach that unveils how the elasticity of a single nano-scale system depends on the temperature-dependent motion of the atoms in the lattice of this system.

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When constructing an airplane or a bridge, among the different aspects engineers take into maximum consideration is the elasticity of the materials they use. They aim to build something rigid enough to withhold tremendous amounts of weight, but elastic at the same time so that the expansion of the different parts of the construction does not break the system into pieces when the temperature changes.

The vibrations of the atoms within a solid material are determined by the temperature of a nano-object. When the temperature is higher, the intensity or amplitude of the vibrations is larger. These vibrations affect directly the stiffness of the solid material, although it is rather small compared to other effects. Now, even though scientists are aware of the fact that there is a temperature-dependent change of the elasticity in a single nano-scale system, so far, it

still has not been experimentally detected.

In a study published recently in *Physical Review Letters* and selected as an "Editor's suggestions", ICFO researchers Slaven Tepsic, Gernot Gruber and Christoffer B Moller, led by ICFO Prof. Adrian Bachtold, in collaboration with researchers from the Instituto de Nanociencia y Materiales de Aragon (INMA) of the University of Zaragoza, ICMM-CSIC, Polytechnic University of Marche, TUDelft, and University of Nottingham, have carried out an experimental study with a new approach to measure the small change of the elasticity of a nanotube when changing its temperature. The same methodology can be used with other nanoscale objects.

In their experiment, the team built a 1-10 micrometer long carbon nanotube, called a cantilever, where one of its ends was attached, fixed to a silicon chip, and the other end was free to bounce around in the air. Next, on the free end of the nanotube, the scientists deposited a tiny amount of platinum to form a particle, basically because this metal particle is bright enough to be able to measure the motion of the nanotube with a laser. Then they placed the entire system within a chamber at room temperature, and while lowering the temperature slowly down to a few degrees Kelvin, they shined the nanotube with a He-Ne laser and observed how the system vibrated while decreasing the temperature. They searched and measured the vibration mode with lowest frequency knowing that its motion amplitude was the largest. Such low-frequency modes behave as mechanical resonators, since they exhibit resonance behavior and in resonance, the amplitude of vibration increases drastically. They observed how the resonance frequency changed to measure the stiffness of nanotube, which is quantified by the so-called Young's modulus.

Now, physicists often describe the energy dissipation of resonators with what is known as the thermal bath, or thermal reservoir. Such a thermal bath is a tool to describe how the resonator is coupled to the outside world. It can also account for the noise in the resonator displacement and its temperature. So far, it had been very difficult to identify the microscopic nature of the thermal bath, but in this study, the team was able to show that the thermal reservoir is composed of phonons by a sizeable amount. While lowering the temperature, they saw that the stiffness of the nanotube was dependent of these phonons, that is, the collective excitation in a periodic, elastic arrangement of atoms within the solid.

These measurements are not only important for the understanding of the elasticity of the nanotube but also enable a better comprehension of the physics of mechanical resonators. Understanding how these systems work definitely paves the way to controlling and optimizing nanomechanical resonators to reach unprecedented levels of sensing precisions.