PhD Thesis Defense JIL SCHWENDER 'Mass Sensing with Graphene and Carbon Nanotube Mechanical Resonators'

JIL SCHWENDER

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Monday November 12, 11:00. ICFO Auditorium

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Quantum NanoMechanics

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In recent years, carbon nanotube and graphene mechanical resonators have attracted considerable attention because of their unique properties. Their high resonance frequencies, high quality factors and their ultra-low mass turn them into exceptional sensors of minuscule external forces and masses. Their sensing capabilities hold promise for scanning probe microscopy, magnetic resonance imaging and mass spectrometry. Moreover, they are excellent probes for studying mechanical motion in the quantum regime, investigating nonlinear dynamics and carrying out surface science experiments on crystalline low-dimensional systems.

A goal for fully exploiting the potential of mechanical resonators remains: Reaching the fundamental limit of the resolution of mass sensing imposed by the thermomechanical noise of the resonator. Currently, limitations are typically due to noise in the motion transduction. Nanotube and graphene resonators are particularly sensitive to noise in the detection since their intrinsically small dimensions result in minuscule transduced electrical or optical signals.

This thesis researches ways for improving the mass resolution of the intrinsically smallest mechanical resonator systems, which are based on suspended graphene and carbon nanotubes. For this, we follow two complementary pathways. We first see how far we can go in terms of mass resolution with graphene resonators by reducing their size. We fabricate double clamped graphene resonators with submicron lengths and measure their mechanical properties at 4.2 K. The frequency stability of the resonators allows us to evaluate their mass resolution. We show that the frequency stability of graphene resonators is limited by the imprecision of the detection of the mechanical motion.

We then develop a new electrical downmixing scheme to read-out the mechanical motion with a lower noise compared to previous techniques. It utilizes a RLC resonator together with an amplifier based on a high electron mobility transistor operated at 4.2 K. The signal to noise ratio is improved thanks to signal read-out at higher frequency (1.6 MHz compared to 1-10 kHz) and low temperature amplification. We observe an improved frequency stability measuring a carbon nanotube mechanical resonator with this read-out. The stability is no longer limited by the measurement instrumentation noise but by the device itself. Observing the intrinsic fluctuations of the resonator allows in future experiments to study surface science phenomena. We present some preliminary results that hint to the observation of the diffusion of xenon atoms on the surface of the resonator and to the adsorption of single fullerene molecules.

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