Optomechanical cartography of vibrational and thermal properties of a suspended monolayer graphene resonator

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Nanomechanical oscillators are now routinely used in fundamental and applied physics as ultrasensitive force or mass sensors. The inherent reduction in size make them increasingly sensitive to their environment. The understanding of dissipation at the nanoscale is a necessary step towards achieving high mechanical Q factors, which is one of the enabling step towards extreme sensitivity operation.

In this work, we investigate a suspended monolayer graphene membrane with optical access from both sides, which allows non-local investigation of its optomechanical and thermal properties. Graphene combines the benefits of having an extremely low mass and high stiffness so that monolayer graphene resonators can attain resonance frequencies in the MHz range. These ultimate 2D membranes are extremely sensitive to their environment and also show exceptional heat conduction properties.

For the first time, we probe the static and dynamic properties of a monolayer suspended graphene membrane in a cavity-free optical pump-probe setup. Interferometric detection allows for the detection of the graphene Brownian motion as well as its local temperature while an independently movable intensity modulated pump laser permits establishing a cartography of the optical response of the membrane. This measurement gives access not only to the mechanical and thermal properties of the resonator, but also reveals the influence of more intricate structures such as grain boundaries or local deformations of the graphene, which have a strong impact on the membrane dynamics.

Furthermore we report on the observation of a strong coupling in a nanomechanical system consisting of a suspended graphene membrane coupled to a supporting SiN nanomembrane. It becomes manifest in an avoided crossing of the resonance frequencies of the two subsystems, while generating asymmetric Brownian motion spectra. A detailed analysis of this mechanism reveals a deviation from the normal mode expansion due to the inhomogeneously distributed mechanical damping in the two-component device. The understanding of this phenomenon is crucial in order to properly describe the thermal motion of coupled nanosystems.

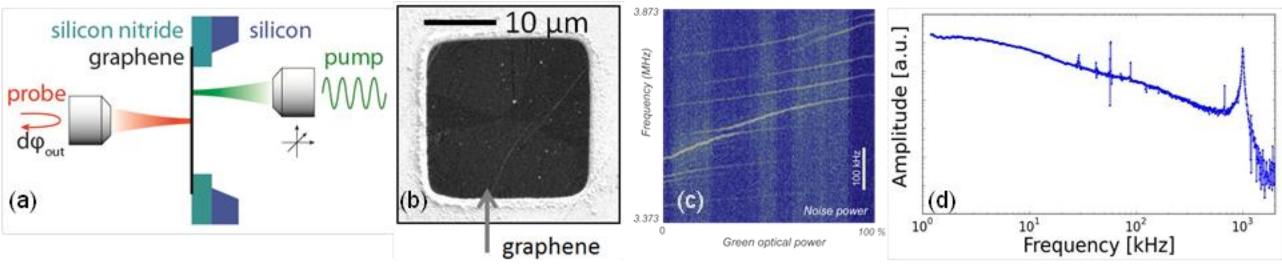

Figure 1: (a) Cavity-free optical pump-probe setup, (b) SEM image of a suspended graphene membrane, (c) Frequency anti-crossing of the coupled resonators, (c) Bode diagram of the response of the graphene resonator to an external drive. It clearly shows the thermal low-pass behaviour and the first mechanical resonance mode

References

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