Ultrahigh Frequency Phononics and Mechanics

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Acoustic phonons in the sub-THz range have emerged as a suitable platform to study complex wave physics phenomena. This has spurred the development of a large bandwidth of versatile nanophononic devices for full control and manipulation of phonons on the few-nm length scale. Furthermore, the strong interactions between acoustic phonons and other excitations in solids extend the range of applications for nanophononic devices into other areas of research such as optoelectronics and optomechanics.

The simultaneous engineering of optical and phononic properties led to a new kind of structures called phoXonic crystals capable of confining simultaneously photons and phonons [1]. Usually, in one-dimesional systems an optical microcavity is formed by two identical distributed Bragg reflectors embedding an optical spacer, acting in a similar way to a Fabry-Perot resonator. By the same token, an acoustic nanocavity is usually formed by two distributed Bragg reflectors (DBRs) enclosing an acoustic spacer [1-3]. Layers with thickness of a few nanometers, and atomically flat interfaces are two strong requirements to fabricate devices capable of manipulating acoustic phonons in the GHz-THz range.

Recent advances in material science and fabrication techniques enabled the fabrication of nanometric devices in which photons (VIS-NIR) and phonons (GHz-THz frequencies) are simultaneously confined in a single resonant cavity giving rise to unprecedented large optomechanical coupling factors [1,4-5]. In addition, the engineering of acoustic waves with GHz-THz frequencies is also at the base of the study of mechanical quantum phenomena and non-classical states of mechanical motion.

In this presentation I will first introduce and compare strategies to generate, manipulate and detect ultra-high frequency acoustic phonons using either ultrashort laser pulses or high resolution Raman scattering. Second, I will describe the acoustic behavior of standard nanophononic Fabry-Perot resonators and finally present experimental and theoretical results on a series of novel nanomechanical devices able to control the phonon dynamics at the nanoscale.

References

[1] A. Fainstein, N.D. Lanzillotti-Kimura, B. Jusserand et al., Phys. Rev. Lett. **110**, (2013) 037403.
[2] N.D. Lanzillotti-Kimura, A. Fainstein, A. Lemaitre et al., Phys. Rev. B **84**, (2011) 115453.
[3]A. Huynh, N.D. Lanzillotti-Kimura, B. Perrin et al. Phys. Rev. Lett. **97**, (2013) 115502.
[4] F. R. Lamberti, Q. Yao, L. Lanco, et al., Opt. Express **25**, (2017) 24437-24447.
[5] S. Anguiano, A.E. Bruchhausen, B. Jusserand et al., PRL **118**, (2017) 263901.

Figures

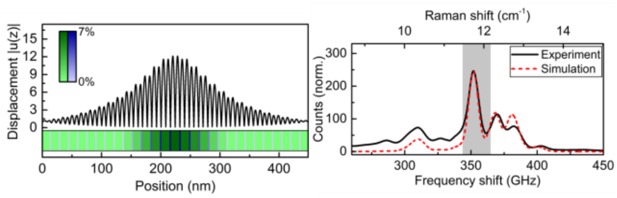

Figure 1: Displacement distribution as a function of position in a phononic adiabatic cavity (left). The thickness deviation from the periodic structure is shown with a color scale. Comparison between the simulated and measured Raman scattering (right). The confined acoustic cavity mode peak is indicated in grey.