Optomechanics with two-dimensional photonic crystals slab mirrors and cavities

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Inheritor of the recent field of cavity optomechanics, cavity nano-optomechanics has lately emerged as a highly interdisciplinary field of research at the crossroads between nanomechanics and nanophotonics. One- and two-dimensional photonic crystal slabs are natural candidates for the implementation of novel scalable photon-phonon interfaces on a chip, since they enable integration of acoustic and optical functionalities on the same platform at nanoscale.

In our work, we investigate the nano-optomechanics of suspended two-dimensional photonic crystal membranes. These structures may combine cavity enhancement and low mass and thus exhibit strong mechanical coupling to light. The mechanical oscillator consists of a suspended nano-scale InP membrane pierced with a regular array of holes constituting a two-dimensional photonic crystal. Depending on the arrangement of holes, it can either act as a deformable end-mirror in a conventional Fabry-Perot cavity or include a cavity of diffraction-limited volume (see Figure 1).

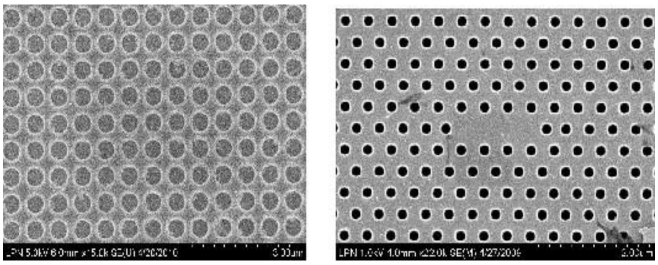

Figure 1 Top view Scanning Electron Microscopy images of photonic crystal slabs. (Left) 210-nm thick slab with square lattice of holes, acting as a mirror at normal incidence. (Right) 260-nm thick slab with triangular lattice of holes, embedding an optical microcavity (cavity = three missing holes in a line).

Conventional two dimensional photonic crystal cavities (Figure 1 right) sustain single optical mode as well as mechanical modes that can be assigned to two different mode families. Low-frequency modes (below 200 MHz) are flexural modes corresponding to the movement of the whole membrane. The second mode family consists of localized modes corresponding to mechanical displacement of the membrane localized in the cavity core. Due to the strong confinement and colocalization of the optical and mechanical modes within the defect cavity, strong optomechanical coupling is observed for the localized modes.

Photonic crystal slabs with a square lattice of holes (Figure 1 left) have been used as mirrors operating at normal incidence in active (VCSEL) and passive optical resonators. Such slabs sustain vibrational modes in the megahertz range while their reflectivity at normal incidence at 1064 nm is higher than 95 %. These two features, combined with their very low mass, open the way to the use of such periodic structures as deformable end-mirrors in Fabry-Perot cavities for the investigation of cavity optomechanical effects.