Active optomechanical resonators

Débora Princepe, Gustavo Wiederhecker, and Newton C. Frateschi
"Gleb Wataghin" Physics Institute, University of Campinas, Brazil

The incorporation of optical interconnects and functionalities into CMOS circuitry promises reduced power consumption and scalable multi-core processing. In pursuing these goals, key building blocks in the area of silicon photonics [1] have been demonstrated, such as on-chip compact modulators and routers. More recently, several groups included a mechanical degree of freedom into these devices to allow energy exchange between mesoscopic phonons and photons in high-Q resonant cavities. Optical cooling of these phonons down to quantum ground state has been demonstrated through such optomechanical interaction [2]. The reverse process, where mechanical energy is extracted from the optical field, has led to the demonstration of RF oscillators [3], wavelength converters [4], and optical delay lines [5]. Static actuation using optical forces was also used to develop tunable optical micro filters [6,7]. All these devices rely on high-Q passive resonators with some mechanical degree of freedom that affects the cavity resonances. Being passive, they all rely upon external light sources to populate the optical cavities with photons.

In this work we will present our theoretical investigation on optomechanical resonators based on active optoelectronic materials. In these devices, light generation and amplification intermediated by light-matter interaction occurs in the presence of a mechanical degree of freedom affecting the optical system. We will discuss important aspects of the coupling of these three degrees of freedom, including optomechanical bistability, optical RF carrier generation, and laser oscillation, all relying on the light emission from the active material. Finally, we will present the first steps towards the experimental demonstration of such devices using III-V materials.

1. M. Lipson, *J. Lightwave Technol.* **23**, 4222 (2005).
2. J. Chan, T. P. M. Alegre, A. H. Safavi-Naeini, J. T. Hill, A. Krause, S. Gröblacher, M. Aspelmeyer, and O. Painter, *Nature* **478**, 89 (2011).
3. T. J. Kippenberg and K. J. Vahala, *Science* **321**, 1172 (2008).
4. M. Notomi, H. Taniyama, S. Mitsugi, and E. Kuramochi, Phys. Rev. Lett. **97**, 023903 (2006).
5. A. H. Safavi-Naeini, T. P. M. Alegre, J. Chan, M. Eichenfield, M. Winger, Q. Lin, J. T. Hill, D. E. Chang, and O. Painter, *Nature* **472**, 69 (2011).
6. G. S. Wiederhecker, L. Chen, A. Gondarenko, and M. Lipson, *Nature* **462**, 633 (2009).
7. G. S. Wiederhecker, S. Manipatruni, S. Lee, and M. Lipson, *Optics Express* **19**, 2782 (2011).