Soutenance de thèse

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RECONSTRUCTING MODE PROFILES OF OPTOMECHANICAL CRYSTALS BY NEARFIELD SCANNING

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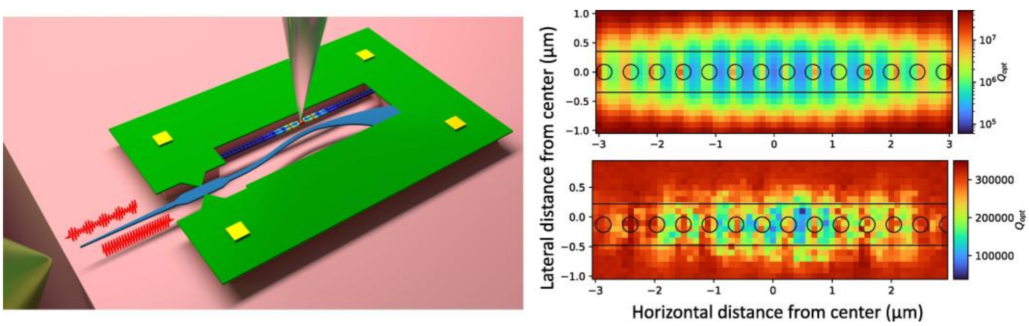
Abstract

Cavity optomechanics in photonic crystals is an active research field, with multiple active developments on possible quantum applications or on creating a new generation of microwave oscillators. In this scope, the performances of the considered application depend among other things on the properties of the used mechanical mode. A high quality factor mechanical mode allows for example to get longer phonon lifetime or to decrease the phase noise of the generated frequency. Moreover, the strength of the optomechanical interaction depends on the effective overlap between the optical mode and the chosen mechanical mode. These two aspects can be predicted and optimized through simulations, but there will always exist differences between the simulated design and the fabricated device. The understanding of the divergences introduced during the fabrication process is thus of the utmost importance in order to be able to efficiently improve the final performances of the crystal. We thus decided to create a new in-situ characterization tool whose goal would be to measure these divergences. This tool is made of a nanotip approached in the immediate proximity of the photonic crystal. Due to its presence, the optical and mechanical modes are perturbed, changing the properties of these modes. By following these changes and the change in the optomechanical interaction, it is possible to create maps of these modes and of the interaction itself. The first objective of this work is the creation of a ”toy” photonic crystal cavity that will be used for the development of the scanning tool. This crystal cavity is made from a GaP membrane, used for its excellent optomechanical properties, and its design is created from first principles following a precise target : have a high quality factor optical mode around 1550 nm while keeping a small and simple design. The final result uses a nanobeam design, with a quadratic modulation of the crystal period in order to efficiently confine the optical mode, which is adressed from the outside of the chip through a lateral waveguide. After cleanroom fabrication, multiple problems were spotted on the inital desigh, which was modified to correct the wavelength of the optical mode and to reduce background noise. Once the crystal design was fixed, its mechanical modes and the optomechanical interaction between these and the optical mode is studied. A mode family in particular, the breathing modes between 2.7 and 2.8 GHz, displays strong optomechanical interaction. Two characterization methods are evaluated, and the Optomechanically Induced Amplification (OMIA) is chosen for its reliability and precision compared to the direct measurement of the thermal noise spectrum. Finally, the perturbation nanotip scan experimental setup is assembled and tested, showing precise maps of the optical mode as well as preliminary results on the identification of mechanical modes and the optomechanical interaction.



Left, Artist view of the measurement setup. Right, perturbations of the optical quality factor through the tip presence, with on top the simulation and on the bottom one measurement with a tip surface distance of 150 nm."