

PhD Thesis Defense NICOLAS MORELL BENNASSER 'Optomechanical resonators based on transition metal dichalcogenide monolayers'

NICOLAS MORELL

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PhD Thesis Defense, December 17, 2018, 12:00. ICFO Auditorium

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Quantum NanoMechanics

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Suspended monolayer transition metal dichalcogenides (TMD) aremembranes that combine

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ultralow mass and exceptional optical prop-erties, making them intriguing materials for opto-mechanical applica-tions. However, the low measured quality factor of TMD resonatorshas been a roadblock so far. In this thesis, we first show an ultra-sensitive optical readout of monolayer TMD resonators that allows usto reveal their mechanical properties at cryogenic temperatures. Wefind that the quality factor of monolayer WSe2resonators greatly in-creases below room temperature, reaching values as high as 16000 at liquid nitrogen temperature and 47000 at liquid helium temper-ature. This surpasses the quality factor of monolayer graphene res-onators with similar surface areas. Upon cooling the resonator, the res-onant frequency increases significantly due to the thermal contractionof the WSe2lattice. These measurements allow us to experimentallystudy the thermal expansion coefficient of WSe2 monolayers for thefirst time. High Q-factors are also found in resonators based on MoS2 and MoSe2 monolayers. The high quality-factor found in this workopens new possibilities for coupling mechanical vibrational states totwo-dimensional excitons, valley pseudospins, and single quantumemitters and for quantum opto-mechanical experiments based on theCasimir interaction.The sensing capabilities offered by these high Q-factor nanome-chanical oscillators are also of interest for studying thermodynamicproperties in condensed matter regimes that are difficult to access. Inthe second part of the thesis, we use optomechanical systems basedon a MoSe2 monolayer to probe the thermal properties of phononsin two-dimensional lattices. We measure the thermal conductivityand the specific heat capacity down to cryogenic temperature. Thephonon transport crossovers from the diffusive to the ballistic regimewhen lowering the temperature below~100 K. The temperature de-pendence of the specific heat capacity approaches a quadratic depen-dence, the signature of two-dimensional lattices. Both the thermalconductivity and the specific heat capacity measurements are consis-tent with predictions based on first-principles. Our result establishes anew strategy to investigate thermal transport in two-dimensional ma-terials, and allows for exploring the phonon hydrodynamic regime,the anomalous heat conduction, and the phase transitions of electronicmany-body collective phenomena in monolayers.

Monday December 17, 12:00 h. ICFO Auditorium

Thesis Advisor: Prof Dr Adrian Bachtold