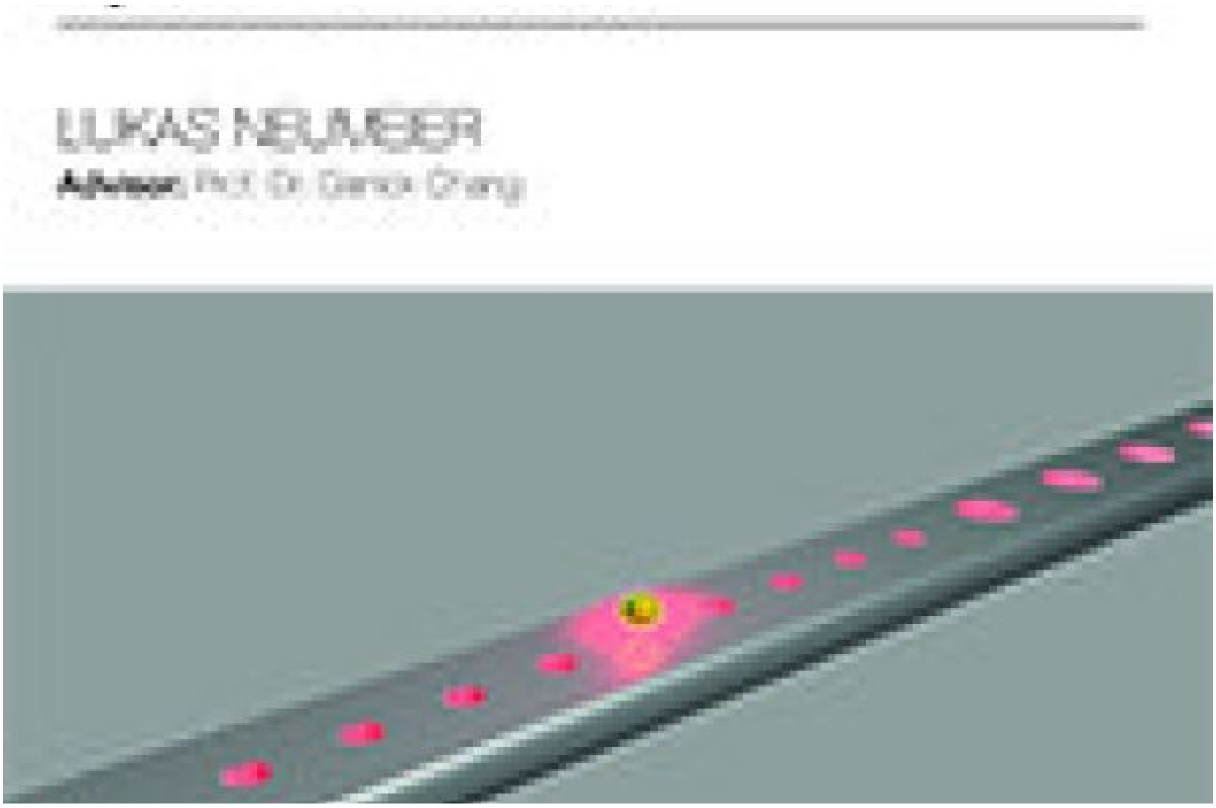

PhD Thesis Defense LUKAS NEUMEIER 'Novel Regimes of Quantum Optomechanics'

LUKAS NEUMEIER

July 02, 2018

Monday July 2, 15:00. ICFO Auditorium

LUKAS NEUMEIER

Theoretical Quantum-Nano Photonics

ICFO-The Institute of Photonic Sciences

In everyday life the impact of light on the motion of mechanical objects is negligible. However, modern experiments making use of high quality optical resonators are able to observe significant effects originating from the forces associated with photons on small mechanical systems. The common feature of these systems is the dependence of the optical resonance frequency on the position of the mechanical object, laying the framework of optomechanics. Many interesting regimes have been explored which allow for photon-light entanglement, laser cooling of motion, generation of squeezed states of light, and even the detection of gravitational waves. Interestingly, the optomechanical interaction is so generic that its underlying concepts and derived insights can be generally applied to a large variety of systems, as we will see in this thesis.

In Chapter 1, we provide a brief overview of key concepts and results from the field of optomechanics, before going on to discuss the novel regimes and applications that we have identified and proposed.

In Chapter 2, we theoretically investigate results from a couple of experiments, that were previously not well-understood. These experiments trap dielectric nano-particles through an optical resonator mode and observe that the intensities experienced by the particles are strongly reduced compared to a conventional optical tweezer trap. We find that these systems can be fully described by a simple optomechanical toy model and derive that the optical potential inside resonators can approach a nearly perfect square well. This potential can be dynamically reshaped by changing the driving laser frequency and we find a dramatic reduction of intensities seen by the trapped particle, which could significantly increase the range of systems to which optical trapping can be applied. These results are quite remarkable and should have important implications for future trapping technologies.

In Chapter 3, we recognize that a major trend within the field of cavity QED is to attain the strong coupling regime. Additional rich dynamics can occur by considering the atomic motional degree of freedom. In particular, we show that such a system is a natural candidate to explore the single-photon optomechanical strong coupling regime of quantum optomechanics, but where the motional frequency cannot be resolved by the cavity. We show that this regime can result in a number of remarkable phenomena, such as strong entanglement between the atomic wave-function and the scattering properties of single incident photons, or an anomalous heating mechanism of atomic motion.

In Chapter 4 we show that an atom trapped in and coupled to a cavity constitutes an attractive platform for realizing the optomechanical single-photon strong coupling regime with resolved mechanical sidebands. Realizing this regime is a major goal within the field of optomechanics, as it would enable the deterministic generation of non-classical states of light. However, this regime is difficult to achieve with conventional mechanical systems due to their small zero-point motions. As an example, we show that optomechanically-induced photon blockade can be realized in realistic setups, wherein non-classical light is generated due to the interaction of photons with the atomic motion alone.

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