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TOWARDS QUANTUM OPTICS EXPERIMENTS WITH CAVITY-OPTOMECHANICAL SYSTEMS

Witlef WIECZOREK
Univ. Wien, Fakultaet fuer Physik,
Quantenoptik, Quantennanophysik und Quanteninformation
Wien, Austria

Abstract:

During recent years the control over single quantum systems has reached an unprecedented level and has been expanded to a variety of physical systems, ranging from AMO systems (e.g. atoms, photons) to solid-state systems (e.g. NV centers in diamond, superconducting circuits). A benchmark for the claim of quantum control is the ability to prepare non-classical states - such as squeezed and entangled states - which can, for example, reach classically unachievable performance in metrology and, at the fundamental level, allow one to explore the foundations of quantum physics.

We want to establish this level of quantum control for the motion of massive objects, such as mechanical oscillators, which in our lab consist of typically 10^14 atoms. Ultimately, we aim at the preparation of entangled and large superposition states of these oscillators, thereby transferring quantum optics to the macroscopic domain.

Cavity optomechanical systems offer great potential to achieve that goal. In our case, we exploit the mutual interaction of an intra-cavity light field and a mechanical oscillator via radiation pressure. Requirements to enter the realm of 'quantum' optomechanics are a low-entropy mechanical state as well as sufficiently strong coupling between the light field and the oscillator. Once this level of control has been achieved, the prepared state of the mechanical oscillator has to be verified, which can be accomplished through a complete state reconstruction. Access to the mechanical motion is only provided by the optomechanical interaction. In case of a resonant light beam, this interaction enables one to infer the position quadrature of the mechanical motion from the light beamís phase quadrature. The complete mechanical state can then be reconstructed, if one assumes that the dynamics of the mechanical state evolves according to a harmonic oscillator. However, when entering the strong coupling regime, the correlation of the light field and the mechanical resonator reaches a different quality, resulting in a more involved dynamical evolution of the mechanical motion. This requires alternative methods of state reconstruction. I will report on our approach to reconstruct the mechanical state, which is valid for any optomechanical coupling regime. Our method is based on optimal filtering. I will further discuss how this experimental setting sets the stage for 'quantum' optomechanics in a cavity-optomechanical system.