

Quantum technologies using cavity-mediated interactions and dissipation

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Coupling atoms to optical cavities allows one to explore collective effects that emerge from strong light-matter interactions. In such setups the cavity mediates long-range atom-atom interactions that can be used to explore many-body effects such as spin squeezing, sub- and superradiance. This is not only of fundamental interest but has also direct applications in quantum technologies. In this talk I will discuss a quantum technology which harnesses such effects: the superradiant laser. This laser operates in a regime where the atomic lifetime exceeds by several orders of magnitude the cavity photon lifetime. As a consequence this laser is extremely robust against cavity length fluctuations which makes it a good candidate for atomic clock applications. I will discuss the theory and the general working principles of this laser and show how it can overcome different forms of broadening and disorder in the atomic ensemble and reach narrow laser linewidths. This is due to a synchronization mechanism of the individual atomic emission amplitudes that is mediated by the cavity. Taking the superradiant laser as a first example I will more generally discuss how cavity modes can be used to engineer tailored interactions and dissipation. Here, I will describe a theory which allows one to integrate out the cavity modes and to obtain effective atom-only Lindblad master equations that describe the atomic dynamics. I will demonstrate the validity of this approach and outline how it can be used to describe networks of interacting and dissipative spins.