Entanglement between internal and external degrees of freedom of a driven trapped atom

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The dynamics of a Λ-shaped trapped atom, driven by two lasers to conditions approaching electromagnetically-induced transparency (EIT), is studied numerically via the quantum Markovian master equation [1, 2]. The analysis of the solutions of this equation allows us to investigate the nature of dissipative processes which are responsible for EIT cooling [3].

The numerical approach gives us the possibility to investigate the dynamics of the entanglement between electronic and vibrational degrees of freedom and the quantum mutual information. Far from the Lamb-Dicke limit an intricate behavior of these quantities is found, as well as the emergence of a mixed entangled non-equilibrium stationary state [3]. An example of our results is shown in Figure 1. Initially (t = 0) the atom is in the ground electronic state |1⟩, in vibrational level n = 5. After 3 ms the mean vibrational quantum number of the atom has dropped to ⟨n⟩ = 0.02. In the process of cooling of the vibrational motion, sudden death of the negativity is observed, at a time when the purity of states is practically lost. As the atom approaches EIT conditions a remarkable revival of negativity appears, concurrent with an increase in purity.

The parametric dependence of this behavior and its relationship to the cooling process is under current study, in order to explore measures for non-Markovianity in our complex system [4].

Figure 1: Dynamics of the negativity, N, of the mutual information, I, and of the linear entropy, 1 − P. Parameters are (in units of 2π MHz), the trap frequency, ω = 0.03, the two Rabi-frequencies, g1 = 1.34, g2 = 0.34, the detuning of the two lasers from resonance, Δ1 = Δ2 = −15, and the excited state decay rate, Γ = 6. The Lamb-Dicke parameter is η = 0.1.

REFERENCES