Nonequilibrium Atom-Field-Medium Interaction: A unified theoretical framework for fluctuation forces, quantum friction, and quantum optomechanics

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We present a unified theoretical framework for studying the interaction between a moving atom or a mirror with a quantum field in the presence of a dielectric medium. A further development of work begun in [1], the topics range from a) atom-field interactions in free space at strong coupling, b) the mirror-field interactions as in the Casimir and dynamical Casimir effects, c) the atom-medium interactions as in the Casimir-Polder forces to d) *quantum friction* [2] for atoms moving near a dielectric plane, or e) the Unruh-Davies-Fulling effect for relativistic detectors in a field vacuum. We allow the harmonic atom or mirror's external (motional) and internal (electronic) degrees of freedom (dof) to be dynamical and represent the medium by a harmonic lattice. A problem studied recently with this model is that of atom-field entanglement in *quantum optomechanics* [3]. For fully nonequilibrium processes we show the added advantages of this method (see also [4]) beyond the popular macroscopic or stochastic electrodynamics approaches. In this talk based on [5] we describe the procedures for deriving the graded influence action under successive coarse-graining and describe three aspects for a stationary atom coupled to a quantum field: radiative emission in free space at strong coupling, spatial decoherence and atom-field-medium entanglement. Our next stage of work will treat a moving atom in a prescribed trajectory for quantum friction, motional decoherence and entanglement. Memory (non-Markovian) effects naturally appear in these processes as the back-action of relevant dynamical variables are treated self-consistently.

References

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