

Stochastic Schrödinger equations in cavity QED: physical interpretation and localization

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Abstract

We propose physical interpretations, also valid for temperatures different from zero, for stochastic methods which have been developed recently to describe the evolution of a quantum system interacting with a reservoir. As opposed to the usual reduced density operator approach, which refers to ensemble averages, these methods deal with the dynamics of single realizations, and involve the solution of stochastic Schrödinger equations. These procedures have been shown to be completely equivalent to the master equation approach when ensemble averages are taken over many realizations. We show that these techniques are not only convenient mathematical tools for dissipative systems, but may actually correspond to concrete physical processes, for any temperature of the reservoir. We consider a mode of the electromagnetic field in a cavity interacting with a beam of two- or three-level atoms, the field mode playing the role of a small system and the atomic beam standing for a reservoir at finite temperature, the interaction between them being given by the Jaynes-Cummings model. We show that the evolution of the field states, under continuous monitoring of the state of the atoms which leave the cavity, can be described in terms of either the Monte Carlo wavefunction (quantum jump) method or a stochastic Schrödinger equation, depending on the system configuration. We also show that the Monte Carlo wavefunction approach leads, for finite temperatures, to localization into jumping Fock states, while the diffusion equation method leads to localization into states with a diffusing average photon number, which for sufficiently small temperatures are close approximations to mildly squeezed states. We prove analytically that, in the quantum jump situation, the system evolves in the mean towards a Fock state, even if an infinite number of photon-number amplitudes is present in the initial state.