Nonequilibrium Thermo Field Dynamics for thermal relaxation process of confined cold atomic gas

Y. Nakamura, Y. Kuwahara, Y. Yamanaka

Department of Electronic and Photonic Systems, Waseda University, Tokyo 159-8555, Japan

nakamura@aoni.waseda.jp

The thermal relaxation process for the system of confined cold atomic gas is investigated in the framework of nonequilibrium Thermo Field Dynamics (TFD) [1]. There are known two nonequilibrium thermal field theories, i.e. the closed time path (CTP) formalism [2] and TFD. While the CTP formalism is widely used, we have been employing the TFD formalism because the concept of the representation space, which is essential in quantum field theory, is clear even in nonequilibrium situation. In nonequilibrium TFD, which is a real-time canonical formalism, a mixed state expectation in the density matrix formalism is replaced by an expectation of the pure state vacuum, called thermal vacuum. A well-defined quasiparticle picture is constructed on the doubled Fock space, and quasiparticle operators which diagonalize the unperturbed TFD Hamiltonian is defined in a self-consistent manner. Two parameters, the number distribution and renormalized excitation energy, are introduced as unknown time-dependent parameters there. These parameters, characterizing the quasiparticle picture or the representation space, are to be determined by some renormalization condition. While we have pointed out that the diagonalization condition by Chu and Umezawa [3] is consistent with the equilibrium theory only in the leading order, we have proposed a new renormalization condition [4] as a generalization of the on-shell renormalization condition on the self-energy, which is consistent even in the higher order. Our renormalization condition determines the equation for the number distribution, i.e. the quantum transport equation, as well as the renormalized excitation energy. In our previous works [5], we have approximated the renormalized excitation energy by the bare one, and have derived the non-Markovian type quantum transport equation. The transport equation is not based on the phase-space distribution function, but follows from the appropriate choice of the representation space, expect for the approximated excitation energy. In the present work, we self-consistently determine both the renormalized excitation energy and the quantum transport equations for the system of confined cold atomic gas using nonequilibrium TFD, and illustrate the thermal relaxation process for the nonequilibrium initial distribution numerically. It is shown that the time-dependent renormalized excitation energy causes qualitative changes in the number distributions and so in the relaxation process.