Non-equilibrium quantum relaxation after sudden quenches: Exact results and semi-classical theory

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The non-equilibrium quantum relaxation in many-body systems has gained increased interest over the recent years, not least because trapped cold-atom systemsmade its experimental study possible. In principle, one asks for the fate of an initial state that is not an eigenstate of the Hamiltonian under the time evolution according to the Schrodinger equation. A straightforward method to prepare such an initial state is the instantaneous change of a global or local parameter of the system such as an external field or the interaction strength, denoted as a quantum quench or simply quench. Important issues of interest are then as follows: (1) Is there an asymptotic stationary state, what are its characteristics, is it describable by a general Gibbs ensemble (i.e., does the system thermalize after a quench)? (2) What are the characteristics of the dynamical evolution of order, correlations, and quantum entanglement in the system?

We present a quantitative semiclassical theory for the nonequilibrium dynamics in integrable quantum spin chains after sudden quenches. We obtain accurate predictions for the quench-dependent relaxation times and correlation lengths, and also about the recurrence times and quasiperiodicity of time-dependent correlations in finite systems with open or periodic boundary conditions. We compare the quantitative predictions of our semiclassical theory (entanglement entropy, local magnetization, equal-time bulk-bulk and surface-to-bulk correlations, and bulk autocorrelations) with the results from exact free-fermion calculations, and discuss the range of applicability of the semiclassical theory and possible generalizations and extensions.