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Thermalization and Prethermalization in an ultracold Bose Gas

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ABSTRACT

Atom chips consist of microscopic current carrying structures that generate magnetic trapping potentials for ultracold neutral atoms. These atom chips provide a high design flexibility of possible trap geometries, making the creation of highly anisotropic trapping potentials feasible. The resulting magnetic traps are characterized by a high isolation from the environment and are used to create degenerate, one-dimensional (1d) Bose gases. On typical experimental time scales, these 1d Bose gases can be described as practically closed quantum many-body systems. By applying a rapid quantum quench, the many-body system is brought out of thermal equilibrium and the resulting dynamics are studied via the statistical properties of matter-wave interference measurements. These measured quantum statistical distributions reveal that thermalization of this effectively integrable 1d Bose gas happens in a two-step process. First, the system rapidly dephases to a prethermalized state, characterized by thermal-like correlation properties, which are still distinctly different from the true thermal equilibrium state. Second, on a much longer time scale, the measured distribution functions indicate a further decay to the true thermal equilibrium state.

Furthermore, by studying a highly non-equilibrium system via matter-wave interferometry, the underlying multimode dynamics, characterizing one-dimensional quantum systems, are revealed. This thesis shows that these dynamics are essential in establishing the prethermalized state and that its properties are defined by the quantum shot noise of the splitting process.

In conclusion, this work aims at improving the understanding of quantum thermalization processes in integrable and nearly-integrable systems in the 1d and 1d/3d crossover regimes. Apparently, the general paths to thermal equilibrium in nearly-integrable systems are indirect and complex. This work provides an in depth experimental study of the relaxation dynamics of a highly non-equilibrium system, thereby addressing fundamental questions of ergodicity and thermalization in the context of nearly-integrable quantum systems.