Probing Many Body Quantum Systems by Matter Wave Interference

Jörg Schmiedmayer
Vienna Center for Quantum Science and Technology (VCQ), Atominstitut, TU-Wien

Interacting many body quantum systems, their dynamics and relaxation, are at the centre of many interesting physics problems ranging from particle creation in the early universe to the properties of quantum materials. Ultra-cold atoms are a model system to build quantum many body systems and study their description by quantum fields in the lab. In this talk I will give an overview of the different possibilities interference experiments offer to probe many body systems and their underlying quantum description.

In a first set of experiments, we look at a quench which splits a single one-dimensional system (quantum field) into two parallel ones. A detailed study of the interference between the split quantum fields reveals that the fundamental quantum noise introduced by this splitting quench leads to a pre-thermalized state [1], that it spreads throughout the system in a light cone like manner [2]. The relaxed state is described by a generalized Gibbs ensemble [3].

Two tunnel coupled super fluids allow us to realize quantum Sine-Gordon model giving access to strongly correlated quantum fields, the field Φ can be directly identified with the phase φ of the interference. Studying under which conditions the higher correlation functions factorize allowed us to characterize the essential features of the model solely from our experimental measurements [4,5]: detecting the relevant excitations and their momentum dependent interactions (running coupling constant) and the different topologically distinct vacuum-states the quasi-particles live in.

Designing the longitudinal confinement allowed us to study how gaussian (classical, thermal) states emerge, and how underneath a classical density matrix quantum physics is fully alive and can be recovered by observing quantum recurrences for interacting systems with >10000 particles [6, 7].

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