Quenches of the coupling constant in 1D Bose gases : evolution of squeezed Bogoliubov modes monitored by density ripples analysis

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Out-of-equilibrium dynamics of interacting many-body systems is a central subject in the domain of quantum simulation, both because of its relevance, being ubiquitous in nature, and because of the enormous complexity of its theoretical and even numerical description. Here we investigate out-of-equilibrium dynamics induced by a sudden change of the interaction strength in a Bose gas. More specifically, we experimentally probe one-dimensional Bose gases in the low-temperature quasi-condensate regime. Low energy modes are the phononic modes, their conjugate quadratures corresponding to density and phase fluctuations. The effect of a sudden change of the interaction strength is to squeeze each phononic mode, the energy being no longer equally distributed on both quadratures. At the linearised level, the subsequent evolution is, for each mode, a rotation of the squeezed phase space distribution, at the frequency of the mode. Observing this dynamic is however challenging. Density fluctuations are strongly reduced by the repulsive interactions and very difficult to measure. Phase fluctuations on the other hand are large. They give the dominant contribution to the first order-correlation function and its Fourier transform, the momentum distribution. However, in these functions, the contribution of all Bogoliubov modes are mixed, the large phase fluctuations rendering lowest order Taylor expansion inaccurate. The behavior after a modification of the interaction strength is a light cone effect [1] and the underlying oscillatory behavior of each Bogoliubov mode is not transparent. On the opposite, we show that the analysis of the density ripples that emerge from small time-of-flight experiments [2] permits to retrieve the behavior of individual Bogoliubov modes, providing small enough time of flight are used.

Experimentally, we investigated quenches of the interactions strength in 1D Bose gases using our atom-chip experiment [3]. Quench the effective 1D interaction strength is realized performing a fast modification of the transverse confinement. We then probe the system, after different evolution times. The probing consists in analyzing the density ripples that emerge after a short time-of-flight. More precisely, we extract the weight of the different Fourier component of the density ripples, using a set of data taken in the same conditions. We observed the oscillatory behavior of the squeezed Bogoliubov modes, each at its own frequency. We probe different quench amplitude and different quench directions. We also analyze the observed damping of the oscillations.

[1] T.Langen, R. Geiger, M. Kuhnert and J. Schmiedmayer, Nat. Phys. **9**, 640 (2013).
[2] A. Imambekov *et al.*, Phys. Rev. A **80**, 033604 (2009).
[3] M. Schemmer and I. Bouchoule, in preparation.