Quantum dynamics and entanglement in Bose-Einstein condensates

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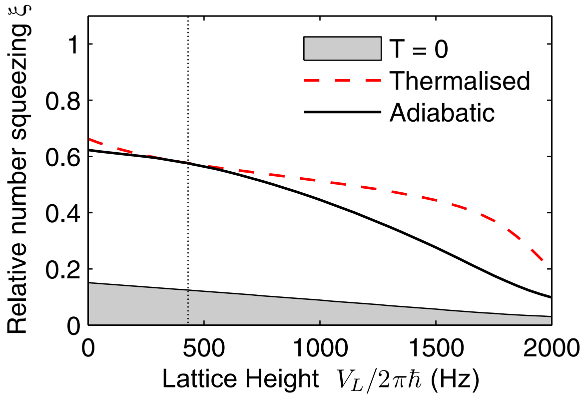
This project considers situations in which beyond mean-field effects are important in the dynamics of Bose gases even at zero temperature. Typically we make use of the truncated Wigner method for solving the quantum evolution of a Bose-condensed gas [1]. The inclusion of quantum noise in the initial conditions means that the technique can incorporate quantum corrections to the classical field dynamics.

1. We have analysed the presence of non-classical correlations in a realistic 3D BEC double-well experiment [2] at finite temperatures using Bogoliubov theory. We have also performed a critical analysis of the procedure of dynamically raising the barrier to drive the system out of thermodynamic equilibrium and found that this can reduce the relative number fluctuations between the two wells [3]. The figure on the right compares the relative number squeezing achievable starting from thermal equilibrium at 11 nK with a 500 Hz barrier height.



2. We have proposed a scheme to generate and measure entangled matter-wave packets via degenerate four-wave mixing of a BEC in a moving 1D optical lattice. In this process atoms from a mother condensate form two entangled daughter condensates with differing momenta. Phase-sensitive homodyne measurements of the atomic fields are necessary in order to prove entanglement between the atomic pulses. We have performed 1D simulations of the scheme including a realistic measurement procedure to demonstrate its experimental feasibility [4].

3. We developed a quantum-metrology protocol to estimate an inter-species scattering length in a Bose-Einstein condensate of N atoms, and showed that using the condensate nonlinearity the measurement uncertainty can decrease faster than $1/N$ without using entanglement [5].

4. Research that was mostly complete in 2008 on the analysis of the formation of multiple 3D bright solitary waves (BSWs) in the collapse of a BEC [6] was published this year. We have found that quantum noise can result in effective repulsive interactions between solitons in one dimension, but not in three dimensions [7].

References

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