Breathing oscillations of a harmonically trapped one-dimensional quasicondensate: frequency beating and damping

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We study the breathing oscillations and their damping in a harmonically trapped one-dimensional (1D) Bose gas in the quasicondensate regime using a finite-temperature classical *c*-field approach. By characterizing the breathing oscillations via the dynamics of the root-mean-square (rms) width $\Delta x_{RMS}(t)$ of the density profile over a long time, we find that the oscillations display beating of two distinct frequencies (see Figure 1). This contrasts with previous findings [1,2] and implies that the 1D Bose gas oscillates as a superposition of two distinct breathing modes. The respective oscillation frequencies are close to $\omega_{B1} \approx \sqrt{3}\omega$ and $\omega_{B2} \approx 2\omega$, where ω is the trap frequency. The breathing mode ω_{B1} dominates the beating at lower temperatures and can be attributed to the oscillations of the bulk of the density distribution comprised of particles populating low-energy, highly occupied states. The breathing mode at ω_{B2}, on the other hand, dominates the beating at higher temperatures, close to the nearly ideal degenerate Bose gas regime, and is attributed to the oscillations of the tails of the density distribution comprised of thermal particles in high-energy states. The two breathing modes have distinct damping rates, with the damping rate of the bulk component, Γ_1, being on the order of $\Gamma_1 \approx 0.08\omega$ and an order of magnitude larger than that of the tails component. At the same time, we find that Γ_1 is at least 3 times smaller than the 1D Landau damping rate Γ_L predicted in [3]. Our results are suggestive of a two-fluid model and are unexpected for 1D Bose gases, where there is no Bose-Einstein condensation and where the conventional 3D two-fluid approach is not *a priory* applicable.

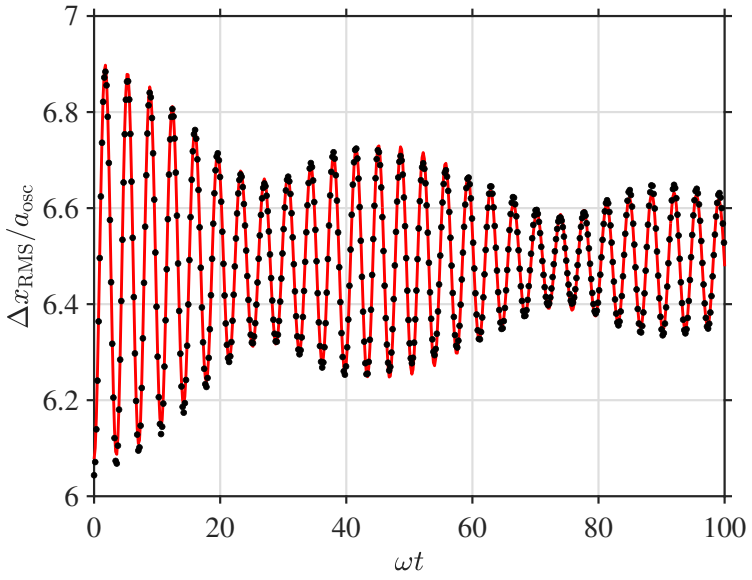

Figure 1. Dynamics of the rms width $\Delta x_{RMS}(t)$ (normalized to harmonic oscillator length a_{osc}) of the density profile of a 1D quasicondensate after exciting the breathing oscillations via a sudden quench of the trap frequency. The black dots are numerical data found from *c*-field simulations, whereas the red line is a fit using a superposition of two damped oscillatory modes, $\Delta x_{RMS}(t) = A_1 \cos(\omega_{B1} t + \phi_1) e^{-\Gamma_1 t} + A_2 \cos(\omega_{B2} t + \phi_2)\, e^{-\Gamma_2 t}$.

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[2] I. Bouchoule, S. S. Szigeti, M. J. Davis, and K. V.Kheruntsyan, *Phys. Rev. A* **94**, 051602 (2016).

[3] Z.-J. Yang *et al*., Comm. Theor. Phys. **57**, 789 (2012).