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Second-order density correlations for characterizing non-equilibrium quantum systems

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In this work, we study two-point density correlations in measurements of freely expanding out-of-equilibrium Bose-Einstein condensates. Density fluctuations arise during the excitation process and are distributed throughout the cloud during the relaxation time in the harmonic trap. By imaging the sample after expansion and inspecting the fluctuations in the detected light, we derive correlations in the momentum space and compare the results with simulations. (1) In a non-excited sample, the correlation function shows $c(\Delta k) \approx 1$, exhibiting its coherent nature. For short distances, it shows $c(\Delta k) > 1$; this is simply the matter-wave analog of the celebrated Hanbury Brown and Twiss effect of photon "bunching". (2) An additional and counterintuitive effect appears in the correlation function: an anticorrelation dip $c(\Delta k) < 1$ at separated points. This effect originates from the strong mutual repulsion between atoms and is also related to the anisotropy of the trap. (3) Analyzing the correlation function, we noticed that its maximum value $c(0)$ varies with the excitation amplitude injected into the sample and evolves during the relaxation time; therefore, it is a good indicator of the evolution of the cloud out of the equilibrium. Our study can be expanded and deepened to answer fundamental questions about equilibration or thermalization in non-equilibrium quantum systems.

Palavras-chave: Non-equilibrium. Bose-Einsten condensate. Density correlations.

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