Violation of the Cauchy-Schwarz inequality with matter waves

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Abstract

The Cauchy-Schwarz (CS) inequality – one of the most widely used and important inequalities in mathematics – can be formulated as an upper bound to the strength of correlations between classically fluctuating quantities. Quantum mechanical correlations can, however, exceed classical bounds. I will discuss the experimental demonstration of the violation of a multimode CS inequality for atom number correlations[1]. It was achieved with four-wave mixing of atomic matter waves using colliding Bose-Einstein condensates. The experiment is well described by a stochastic simulation of Bogoliubov theory using the positive-P representation[2]. We find that it is obligatory to consider multi-mode correlations to extract the violation of classical bouds in such systems, as can be shown on a simple model. The correlated atoms have large spatial separations and therefore open new opportunities for extending fundamental quantum-nonlocality tests to ensembles of massive particles.

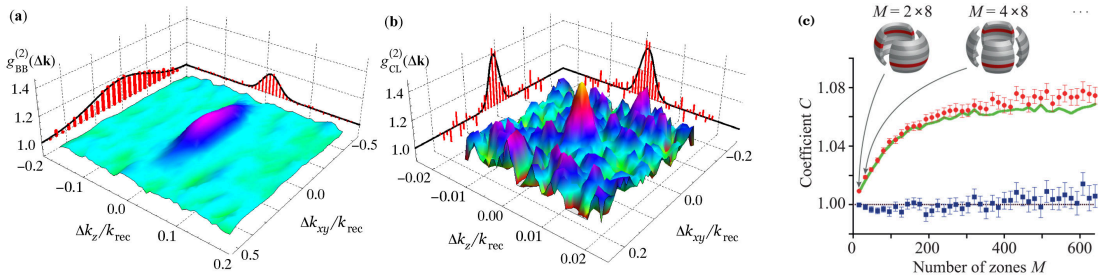

Figure 1: Normalized back-to-back (a) and Hanbury Brown-Twiss collinear (b) density-density correlation functions of the scattered atoms. (c): Observed and calculated (green) violation of the Cauchy-Schwartz inequality ($C > 1$) for back-to-back (red) and collinear (blue) atoms.

References

[1] K. V. Kheruntsyan, J.-C. Jaskula, P. Deuar, M. Bonneau, G. B. Partridge, J. Ruaudel, R. Lopes, D. Boiron, and C. I. Westbrook, Phys. Rev. Lett. **108**, 260401 (2012).

[2] P. Deuar, J. Chwedenczuk, M. Trippenbach, P. Zin, Phys. Rev. A **83**, 063625 (2011).