Relative number squeezing in condensate collisions

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We demonstrate sub-Poissonian number differences (or relative number squeezing) in atomic four-wave mixing realised via a collision of two Bose-Einstein condensates (BECs) of metastable helium [1]. The collision between the two BECs produces a scattering halo populated by pairs of atoms of opposing velocities (Fig. 1). By dividing the scattering halo into several symmetric zones, we measure the atom numbers and the relative number fluctuations using a 2D array of time and position resolved atom detectors. We show that the atom number differences for opposing zones have sub-Poissonian noise fluctuations, whereas that of non-opposing zones are well described by shot noise (Fig. 2). The atom pairs produced in a dual-number state are well adapted to sub shot-noise interferometry and studies of Einstein-Podolsky-Rosen-type nonlocality tests.

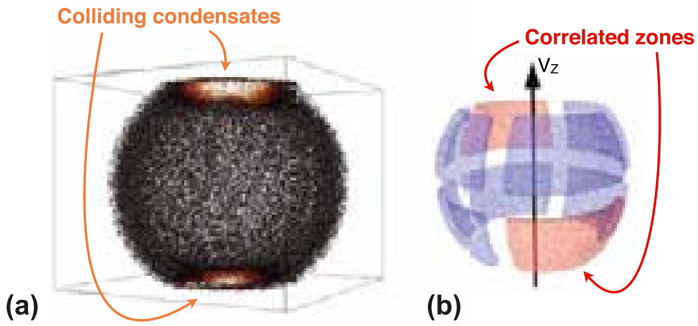

Figure 1. (a) View of the halo of scattered atoms after the collision of two BECs. (b) The analysed part of the halo, divided into $N_z = 8$ zones. An example of two correlated zones is shown (red arrows). The number difference between these two zones have sub shot-noise fluctuations, with the normalised valiance $V < 1$.

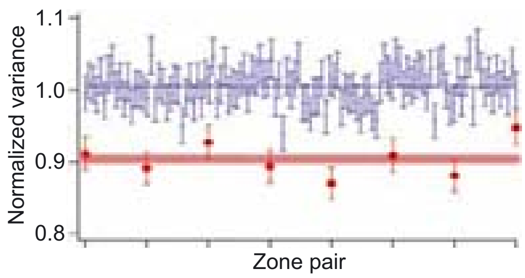

Figure 2. Normalised atom number variance of all possible pairs of zones for the halo cut into 16 zones. Circles correspond to the eight correlated zones and crosses to the 112 uncorrelated ones. The observed relative number squeezing in this example is $\sim 10\%$ ($V = 0.9$), which is in agreement with the theoretical calculations using the positive-P representation method, assuming 12% atom detection efficiency.

In an earlier work [2] (see ACQAO Annual Reports for 2009), we have analysed the 3D momentum distribution of scattered atoms and found that the final momenta of atoms lie on an ellipsoid, and not on a perfect sphere as could have been expected from simple momentum and energy conservations. Numerical and analytical calculations agree well with the measurements and explain the ellipticity by a subtle interplay between many-body effects, mean-field interaction, and the anisotropy of the source condensate.

References

[1] J.-C. Jaskula, M. Bonneau, G. B. Partridge, V. Krachmalnicoff, P. Deuar, K. V. Kheruntsyan, A. Aspect, D. Boiron, and C. I. Westbrook, Phys. Rev. Lett. **105**, 190402 (2010).

[2] V. Krachmalnicoff, J.-C. Jaskula, M. Bonneau, V. Leung, G. B. Partridge, D. Boiron, C. I. Westbrook, P. Deuar, P. Zin, M. Trippenbach, and K. V. Kheruntsyan, Phys. Rev. Lett. **104**, 150402 (2010).