Measuring densities of cold atomic clouds smaller than the resolution limit.

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Abstract

The cold atoms community explores the physics of dense cloud of atoms, which reveal interesting
phenomena in extremely small and local features such as vortices, density fluctuations, etc. Resolving
such structures is a difficult but rewarding problem that prompted important technical developments,
using for example fluorescence imaging with high-resolution objectives, the newly demonstrated
quantum gas magnifier, super-resolution imaging. In the case of standard absorption
imaging of extremely small and dense objects, the Beer-Lambert law is non linear and cannot be
averaged over the imaging resolution. This excludes the imaging of small features, and can also
significantly distort large features.
We experimentally demonstrate that it is still possible to accurately measure the size and local
density of an object, even when this object is smaller than the imaging resolution, taking benefit of
the non-linearity of the Beer-Lambert law. The number of photons absorbed by a given number of
atoms depends on the size of the sample especially when it becomes optically dense. The method
relies on making an ansatz on the cloud shape along the unresolved dimension(s), and providing an
additional information such as the total number of atoms. We experiment our method to measure

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transverse sizes as small as one fifth of our imaging resolution of in-situ absorption images of quasi-
1D 87 Sr Fermi gases. The measurement is in good agreement with theoretical predictions. Moreover,
we show that the distorted image of density profiles along the long axis can be reconstructed in
agreement with theoretical predictions of Fermi distributions.