

Time Evolution of Freely Expanded Bose-Einstein Condensates Containing Small Numbers of Atoms

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We investigate the time evolution of freely expanded Bose-Einstein condensates by measuring their aspect ratios at different times after their release from a magnetic trap. In these measurements the condensates contain no more than 9000 ⁸⁷Rb atoms. By varying the trapping frequency and atom number, we measure the condensate aspect ratios at different expansion times in free space. We compare our measurements with those calculated from the Thomas-Fermi model and a direct numerical solution. Under our trapping condition, the data of the time dependent aspect ratios of the freely expanded condensates reasonably agrees with the numerical calculations, but shows a clear deviation from the predictions of the Thomas-Fermi model when the atom number in the condensates is small.

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The achievement of a Bose-Einstein condensation (BEC) of dilute alkaline atoms in magnetic traps [1–3] provides an unprecedented opportunity for studying the physics in many fields [4]. The dilute atomic condensate is well described by the nonlinear Gross-Pitaevskii (GP) equation [5]. A GP equation contains the kinetic energy, the trap potential, and the mean-field energy, which is proportional to the local density of the condensate and plays a fundamental role in its dynamics. One of the special features in the experiments of trapped atomic condensates is that the trapping condition can be tuned on a time scale comparable to the atomic oscillation period. This provides the system with good test conditions for studying the time-dependent dynamics of the condensates either in or out of a trap.

Many investigations of the condensate dynamics are mostly on collective excitations, vortices generation, and sound speed measurements [6–9]. Those measurements are carried out with high precision, thereby allowing for a detailed comparison with theory. Measurements on the time evolution of an untrapped condensate, such as in a free space, is another important and interesting topic of investigation. One of the key parameters for describing an expanding condensate is its aspect ratio σ , which is normally defined as a ratio of the condensate widths along the two symmetric axes. For the magnetic TOP trap [10] that we use in this experiment the axes are parallel to the axial and the radial direction, respectively. Not only does this measurement show the first convincing evidence for a distinction between a thermal cloud and a condensate, it is also a direct test of the validity of the GP equation when applied to a dilute atomic sample in the degenerate regime.

The early studies of measuring the free-falling condensate aspect ratio were mostly on those with atom number $N \geq 10^5$ [2, 11–13]. Their measurements prove that the TF