Critical collisional opacity in a Bose-Einstein condensate

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competing time-scales. In addition, important limitations on the pulse durations are imposed by the "healing" time considerations due to mean-field interactions. We give a detailed numerical calculation based on a modified mean-field (Gross-Pitaevskii type) theory, and show how the results scale with pulse duration and intensity.

We assume that the two laser fields couple the ground electronic state of Rubidium to a single electronically excited molecular state with Rabi frequencies $\Omega^{(i)} = |\ d_M \cdot E_0^{(i)}\ |/\hbar$, where d_M is the molecular electric dipole matrix element connecting these two states. We estimate that up to 85% conversion efficiency may be achieved (see Fig. 1), but with a peak Rabi frequency of $\Omega_0^{(1)} = 10^{11}\ s^{-1}$ for the free-bound transition. This would be realized with around 1 W peak laser power (at a waist size of about 10 μm), which is not impossible—but much higher than we would estimate without the combined effects of spontaneous emission, collisions between atoms and a three-dimensional mode-structure.

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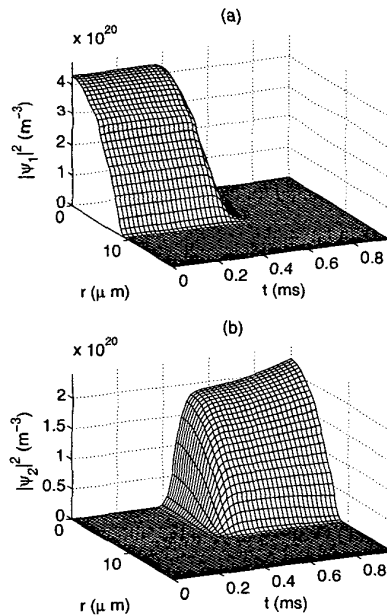
QThM2 Fig. 1. Atomic (a) and molecular (b) field densities in a magnetic trap under STIRAP.

QThM3   **3:15 pm**

Critical Collisional Opacity in a Bose-Einstein Condensate

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In a Bose-Einstein condensate due to the very low temperature the s-wave scattering length can be used as a measure for the strength of the atom-atom interaction. Under typical experimental conditions this interaction is weak and, hence, can be treated in terms of a mean field. However, when the scattering length is large or the density is high, the mean field approximation breaks down. In this collisional (hydrodynamic) regime, effects of the interactions such as quantum depletion[1] or shifts in the frequencies of the elementary excitations[2] become large. It is therefore of great interest to study condensates close to or in the collisional regime. It has been demonstrated in recent experiments that the scattering length and thus the interactions among the atoms can be tuned by means of a Feshbach resonance.[3-6] In the vicinity of Feshbach resonances, however, the increase of the cross-section for elastic collisions is accompanied by a dramatic increase of particle losses.[7,8]

In this paper we report on the observation of anomalous losses from a ^{87}Rb condensate with a high column density in the absence of an inelastic scattering resonance. We identify a loss process that limits the achievable column density of ultra-cold trapped gases in the off-resonant scattering regime as well as in the vicinity of a Feshbach resonance. It is based on collisional avalanches that are triggered by inelastic collisions between trapped atoms or sometimes even by background gas collisions. In the avalanche a considerable part of the kinetic energy that the particles have gained in the inelastic collision is distributed among the trapped atoms by secondary elastic collisions. In our experiment this results in an 8-fold increase of the initial loss rate with respect to the prediction accounting for known loss mechanisms. We present a model accounting for avalanche-like losses which is in good agreement with the observed anomalous decay of our condensate. Our analysis reveals that the collisional opacity of an ultra-cold and dense gas exhibits a critical value. When the critical opacity is exceeded, losses induced by inelastic collisions are substantially enhanced.

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QThM4   **3:30 pm**

Direct observation of growth and collapse of a Bose-Einstein condensate with attractive interactions

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Quantum theory predicts that Bose-Einstein condensation (BEC) of a spatially homogeneous gas with attractive interactions is precluded by a conventional phase transition into either a liquid or solid.[1] When confined to a trap, however, such a condensate can form[2] provided that its occupation number N_0 does not exceed a limiting value.[3,4] The stability limit is determined by a balance between self-attraction and a repulsion arising from position-momentum uncertainty under conditions of spatial confinement. Near the stability limit, self-attraction can overwhelm the repulsion, causing the condensate to collapse.[5-8] Growth of the condensate, therefore, is punctuated by intermittent collapses,[9,10] which are triggered either by macroscopic quantum tunneling or thermal fluctuation.

Direct observation of growth and collapse has been hampered by the stochastic nature of the collapse initiation mechanisms. However, we previously measured the spread in N_0 values at selected times following a fast quench of a gas of ^{7}Li atoms to be distributed between small numbers, $N_0 \approx 100$, and the maximum number of $\sim$1250 atoms, in agreement with the growth and collapse model.[11] The process of making reliable measurements of such small values of N_0 destroys the condensate, preventing an observation of its dynamics in real time. In the present work, direct observation of the dynamics is made possible by dumping the condensate at a specified time, thereby synchronizing the growth and collapse cycles upon repetition of the experiment. To dump the condensate, a light pulse consisting of two co-propagating laser beams whose frequency difference is tuned to resonance between the collisional state of two free atoms and a vibrational level of the diatomic molecule Li_2, is applied to the atom cloud as shown in Fig. 1. When the laser difference frequency is tuned properly, the condensate can be selectively removed, since the observed two-photon linewidth of $\leq$500 Hz is much less than the $\sim$5 kHz thermal energy spread of the trapped atoms.

Following the light pulse, the gas is allowed to freely evolve for a certain time, at which point a destructive measurement of N_0 is made. Figure 2 shows the dynamical evolution of the condensate following a light pulse whose duration is adjusted to reduce N_0 to an initial value of $\sim$100 atoms. N_0 increases immediately following the light pulse as the condensate is fed via collisions between non-condensed thermal atoms, reaching a maximum value consistent with the expected upper limit of 1250 atoms. A collapse is clearly indicated by the