^{87}Rb condensate in a triaxial TOP: Particle dynamics beyond the adiabatic approximation

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Magnetic traps with time-dependent magnetic fields are used in several BEC experiments all over the world [1, 2, 3, 4, 5, 6]. In the time orbiting potential (TOP) trap a quadrupole magnetic field is modified by adding a rotating bias field which shifts the location of vanishing magnetic field from the origin onto an elliptical orbit around the trap center and creates an effective harmonic potential if it rotates fast enough for the atoms to be able to average the field over many periods of rotation of the bias field [7]. This adiabatic TOP-approximation accounts for most of the observed features of these traps. In our experiment a condensed cloud of ^{87}Rb atoms is exposed to a time dependent magnetic field $\mathbf{B}$

$$\vec{B} = \hat{\mathbf{e}}_{\mathbf{x}}[-2\mathbf{b}'\mathbf{x} + \mathbf{B_0}\cos(\mathbf{\Omega_T t})] + \hat{\mathbf{e}}_{\mathbf{y}}[\mathbf{b}'\mathbf{y} + \mathbf{B_0}\sin(\mathbf{\Omega_T t})] + \hat{\mathbf{e}}_{\mathbf{z}}[\mathbf{b}'\mathbf{z}] \quad (1)$$

with b' the quadrupole gradient along the vertical z-axis, and B_0 and Ω_T the magnitude and frequency of the bias field, respectively. Assuming perfect alignment of the atomic spin with the instantaneous field but skipping the time-averaging step, a force oscillating at Ω_T acts on the atoms. This force leads to a modulation of the atomic velocity with an amplitude comparable to the atomic recoil velocity for field gradients typically used in BEC setups [8]. We detect this modulation by a time-of-flight technique after rapidly turning off the quadrupole field and find good agreement between experiment and theory starting from Eq. 1.

Dropping the assumption of perfect alignment between atomic spin and magnetic field, i.e. considering the fast dynamics of the spin, new features arise in the center-of-mass motion of the atoms. In fact, perfect alignment in a time-dependent field is an inconsistent assumption as a deviation between spin and field direction is necessary to change the orientation of the spin. The bulk of the effects can be accounted for by introducing a fictitious magnetic field, arising as an inertial field when transforming to a frame rotating synchronously with the bias field, and assuming alignment of the spin to the superposition of real and fictitious magnetic fields. Since the sign of the fictitious field depends on the sense of rotation of the bias field, we look experimentally for signatures depending on the sense of rotation, and find a difference of the equilibrium position of the cloud along the vertical axis [9, 10]. We compare this splitting to both a numerical simulation of the full dynamics and a simple analytical model based on the introduction of the fictitious field and find quantitative agreement between experiment and simulation as well as significant deviations from the simple model at low field gradients.

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