

Magnetic field stabilization in ultracold atom experiments using partial transfer absorption imaging

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We present a non-destructive method for measuring and stabilizing magnetic fields in ultracold atom experiments using partial transfer absorption imaging.

This is the introduction

Proposal

The population transferred by the microwave pulse is

$$|c_e(t)|^2 = \frac{\Omega^2}{\Omega^2 + \delta^2} \sin^2 \left(\frac{\sqrt{\Omega^2 + \delta^2}}{2} t \right) \quad (1)$$

SNR for absorption imaging according to Erin's paper is

$$SNR_{\text{model}} = \frac{OD}{\Delta_0} \left(\frac{2}{1 + e^{OD}} \right)^{1/2} \quad (2)$$

Implementation

Most experiments are performed in the $F = 1$ ground hyperfine manifold with some bias field $B_0 \mathbf{e}_z$ that shifts the energies of the different $|m_F\rangle$ states. Due to the linear dependence of the energies of the $|m_F = \pm 1\rangle$ and the constant changes in the ambient magnetic field we use microwave assisted partial transfer absorption imaging (PTAI) to monitor and stabilize the magnetic field.

The method relies on transferring a small fraction of atoms into the $5^2S_{1/2}$ $F = 2$ manifold using an oscillating magnetic field with frequency close to the 6.8 GHz ground hyperfine splitting. The atoms in $F = 2$ can be imaged without the use of repump light and therefore minimally disturbing the remaining atoms in $F = 1$. We apply two microwave pulses for a total time τ with frequency $\omega_0 - \delta_{\pm}$ where $\delta_{\pm} = \pm 1/(2\tau)$. We typically set ω_0 equal to the Zeeman splitting between the $|F = 1, m_f = -1\rangle$ and $|F = 2, m_f = -2\rangle$ states at a target magnetic field and we set the coupling strength $\Omega_0 \ll 1/\tau$ such that only about 5% of the atoms are transferred by each pulse. We image the transferred atoms following each pulse using absorption imaging and from the measured densities we calculate the imbalance or error

$$n_{\text{imb}} = \frac{n(\delta_+) - n(\delta_-)}{n(\delta_+) + n(\delta_-)} \quad (3)$$

signal that is both insensitive to fluctuations in the number of atoms and linearly sensitive to changes in magnetic field[1]. We use this error signal both to monitor the magnetic field before performing experiments and to cancel long term drifts in the field. In most cases, we chose

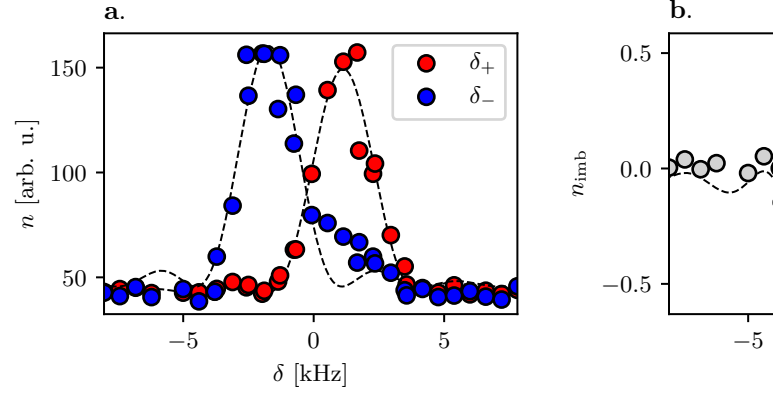


FIG. 1. Magnetic field stabilization using microwave assisted PTAI. **a.** Population transferred into $|F = 2, m_F = -1\rangle$ from $|F = 1, m_F = -1\rangle$ as a function of bias magnetic field (global detuning δ). Each microwave pulse was $\tau = 250 \mu\text{s}$ and detuned by $\delta_{\pm} = \pm 1/(2\tau)$ transfer a small fraction of atoms from $|F = 1, m_F = -1\rangle$ into $|F = 2, m_F = -1\rangle$. **b.** Error signal calculated using the transferred atoms by each pulse. We lock the magnetic field to the $\sim 5 \text{ kHz}$ ($\sim 7 \text{ mG}$) wide linear portion of the signal.

the states $|F = 1, m_F = -1\rangle$ and $|F = 2, m_f = -2\rangle$ as their relative energies are the most sensitive to changes in magnetic field. Figure 1a shows the number of atoms transferred by each microwave pulse for different values of bias magnetic field and Figure 1b shows the imbalance. The microwave frequency ω_0 is on resonance with the $|F = 1, m_F = -1\rangle \rightarrow |F = 2, m_F = -2\rangle$ transition when both pulses transfer the same number of atoms.

In [2] we studied partial transfer absorption imaging as a minimally destructive technique for imaging ultracold atoms.

Results

More results maybe

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detuning.

- [2] E. M. Seroka, A. V. Curiel, D. Trypogeorgos, N. Lundblad, and I. B. Spielman, *Optics Express* **27**, 36611 (2019).

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- [1] A single pulse on resonance is quadratically sensitive to