Quantum Magnetism with $^7$Li

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Introduction

The Need 4 Speed

Two-component Bose-Hubbard Hamiltonian

$$H = -\sum_{\langle ij\rangle} (t_{ij} a_i^\dagger a_j + h.c.) + \frac{1}{2} \sum_{i} U_i n_i (n_i - 1) + U_{ij} \sum_{i} n_i n_j$$

Super-exchange dominated spin-interactions $J = t^2 / U$

(a) Neighboring atoms (b) Virtual Excitation of energy (c) Particle tunnels back

Advantages of our experimental setup:

1. Light mass of Li-7
2. Green optical lattice
3. Feshbach resonance

$E_R = \sqrt{\frac{3}{4} k (V_0 / E_R)^{1/4} E_R}$

Higher critical temperature for magnetic ordering ($k_B T_c \sim t^2 / U$)

Faster spin dynamics within experimentally relevant timescales

Experimental Realization

Experimental Model

- Two-component Hamiltonian realized by $^7$Li atoms in two hyperfine states placed in an optical lattice
- Freely tunable experimental parameters:
  - Energy ratio $t / U$ by optical lattice depth
  - On-site interaction energy $U$ by a Feshbach resonance
  - Spin separating potential by a magnetic field gradient
  - Temperature by evaporation time

Experimental Sequence

1. Zeeman-slowing and Magneto-optical trapping
2. Gray Molasses followed by Evaporative cooling in a Plug trap
3. BEC in an IR dipole trap, interactions enhanced by a Feshbach resonance
4. Green lattice supported by an IR dipole trap

(1) Light mass of Li-7
(2) Green optical lattice
(3) Feshbach resonance

Gray Molasses Cooling

A grey Molasses sub-Doppler cooling scheme has been recently realized in $^7$Li in the Salomon group:

$\frac{E_R}{t} \sim c / \sqrt{\lambda}$

$\lambda = - \frac{t^2}{2U}\frac{t^2}{U} = \frac{t^2}{2U}$

Spin transport by super-exchange interactions

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Possible Experiments

Quantum Simulation

- Anisotropic Heisenberg Model (XXZ model)

$$H = \sum_{\langle ij\rangle} [\lambda_a s_i^a s_j^a - \lambda_\sigma (s_i^\sigma s_j^\sigma + s_i^\sigma s_j^\sigma)] - B_s \sum s_i^\sigma$$

- Magnetic phase diagram

Spin Dynamics

(h) Prepare a 50-50 spin mixture
(i) Separate spins by magnetic field gradient
(j) Apply optical lattice
(k) Allow spins to mix (by decreasing magnetic field gradient)