Entangling atomic spins with a Rydberg-dressed spin-flip blockade
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One of the exp. parameter gives, \(0.8|0\rangle + 0.6|r\rangle\)
Backgrounds
Level splitting

• Two conditions

1. $\Omega_L/2\pi = 4.4$ MHz, $\Delta_L/2\pi = 4$ MHz $\Rightarrow$ small shift $(0.91|0\rangle + 0.41|r\rangle)$

2. $\Omega_L/2\pi = 4.3$ MHz, $\Delta_L/2\pi = 1.3$ MHz $\Rightarrow$ large shift $(0.8|0\rangle + 0.6|r\rangle)$
Experimental Procedure

- Extract 2 atoms from MOT
- State preparation
  - Polarization gradient cooling to 20 uK
  - Optical pumping
- Translate the atoms
- Rydberg dressing and entanglement
- Translate the atoms again
- State detection
Experimental method
Translation of atoms

• Optical tweezer (Dipole trap)
  • Driving AOM with two different frequency, two angular-separated beams can be made.
  • Step: 18 nm per 2 us

Two different driving freq.

Focus lens

938 nm

Spot size: 1.29(3) um
Separation Max: 6.6 um
Step: 18 nm
Experimental method
State preparation

• Polarization gradient cooling to 20 uK
• Optical pumping (Bias field 4.8 G)
  Two lasers (as figure)
• Global π pumping from $|0,0\rangle$ to $|1,1\rangle$

Preparation efficiency: 95%
Experimental method
Rydberg dressing

- Turn off the trap beam during dressing
- Dressing beam: 6S_{1/2} <-> 64P_{3/2}  
  319 nm – blue detuned  
  Detuning is small compared to hyperfine splitting(~MHz)
- Sweeping beam(|0⟩ → |1⟩): Stimulated Raman transition  
  6S_{1/2} <-> 6P_{3/2}: 852 nm Δ_{mw} = -50 GHz, Ω_{mw}~160kHz
- Turn on the trap beam after sweeping the states
Experimental method
Bell state preparation

- $|\Psi_+\rangle = |0,1\rangle + |1,0\rangle$ state is generated by applying resonant light.
- $|\Phi_+\rangle = |1,1\rangle + |0,0\rangle$ state is generated by applying global $\frac{\pi}{2}$ pulse on the state $|\Psi_+\rangle$.
- Fidelity: 81(2)%, survival probability of atoms: 74%
Experimental method

State detection

- Using cycling transition to detect $|0\rangle = |F = 4, m_F = 0\rangle$
  $|6S_{1/2}, F = 4\rangle \rightarrow |6P_{3/2}, F' = 5\rangle$

- If dark, then turn on the repump laser and cycling transition again in order to verify atom’s presence.
\textbf{π-polarized light}

- $F-F'=0$, $m_F=0$ is forbidden

proof) Like getting CG coef., we start from $|F + 1, F + 1\rangle = |F, F\rangle|1,1\rangle$.

$|F + 1, F\rangle = J_-|F, F\rangle|1,1\rangle = J_{1-}|F, F\rangle|1,1\rangle + |F, F\rangle J_{2-}|1,1\rangle$

$|F, F\rangle = J_{1-}|F, F\rangle|1,1\rangle - |F, F\rangle J_{2-}|1,1\rangle$

$\Rightarrow |F, 0\rangle = J^F E(J_{1-}|F, F\rangle|1,1\rangle - |F, F\rangle J_{2-}|1,1\rangle)$

$= \cdots + J^F_{1-1} J_{2-}[J_{1-}|F, F\rangle|1,1\rangle] - J^F_{1-}[|F, F\rangle J_{2-}|1,1\rangle] + \cdots$

$= \cdots + 0[|F, 0\rangle|1,0\rangle] + \cdots$