^{7}Li Machine for Quantum Magnetism Experiments

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Introduction

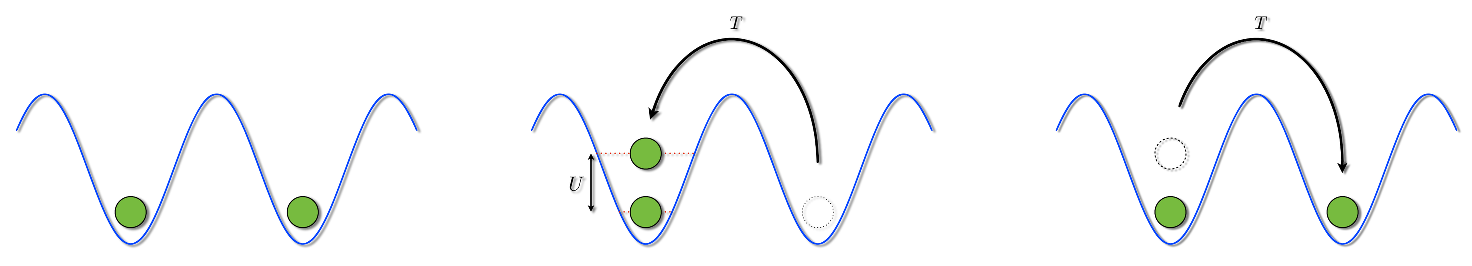
The Need 4 Speed

- Faster tunneling rates with lighter atoms:

$$t \approx \frac{4}{\sqrt{\pi}} E_R \left(\frac{V_0}{E_R}\right)^{3/4} \exp\left[-\left(\frac{V_0}{E_R}\right)^{1/2}\right]$$

where the recoil energy is $E_R = \frac{\hbar^2 k^2}{2m}$

- Higher T_c for magnetically ordered states
- Suitable to study spin dynamics within experimentally relevant timescales



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

Second order tunneling: It allows nearest neighbor interactions with energy $J_{ex} = \frac{t^2}{U}$

Possible Experiments

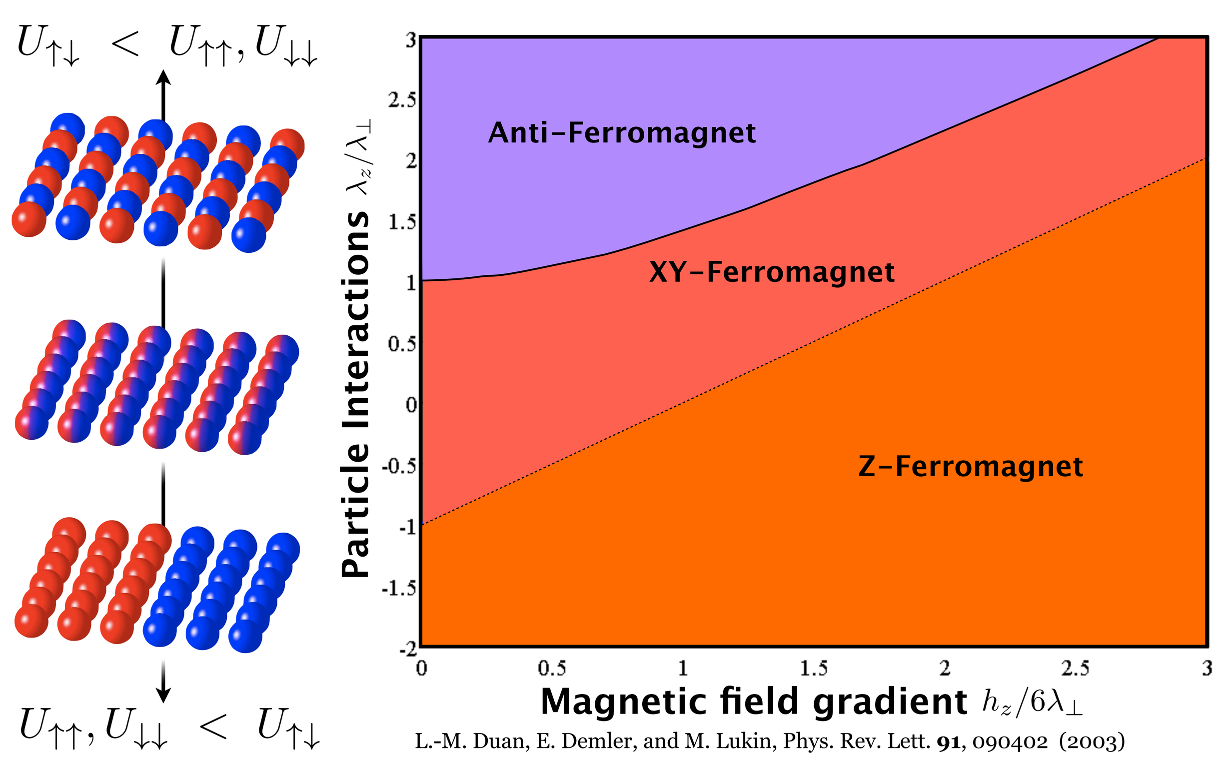
Quantum Simulation

- Realization of 2-component Spin Hamiltonians
- Anisotropic Heisenberg Model (XXZ model)

$$H = \sum_{<i,j>} [\lambda_z s_i^z s_j^z - \lambda_\perp (s_i^x s_j^x + s_i^y s_j^y)] - B_z \sum_i s_i^z$$

$$\lambda_z = \frac{t_\uparrow^2 + t_\downarrow^2}{2U_{\uparrow\downarrow}} - \frac{t_\uparrow^2}{U_{\uparrow\uparrow}} - \frac{t_\downarrow^2}{U_{\downarrow\downarrow}} \qquad \lambda_\perp = \frac{t_\uparrow t_\downarrow}{2U_{\uparrow\downarrow}}$$

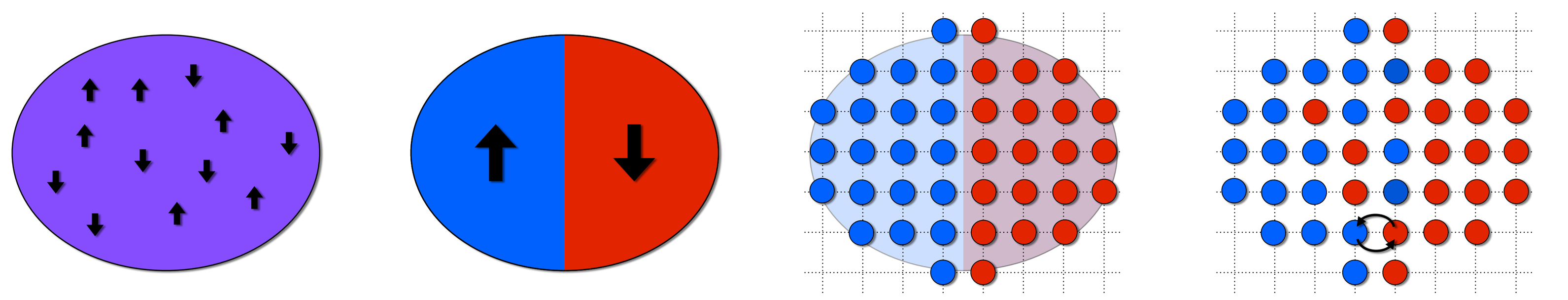
- Study its magnetic phase transitions



L.-M. Duan, E. Demler, and M. Lukin, Phys. Rev. Lett. **91**, 090402 (2003)

Spin Dynamics

- Spin transport by superexchange interactions in a two-component system



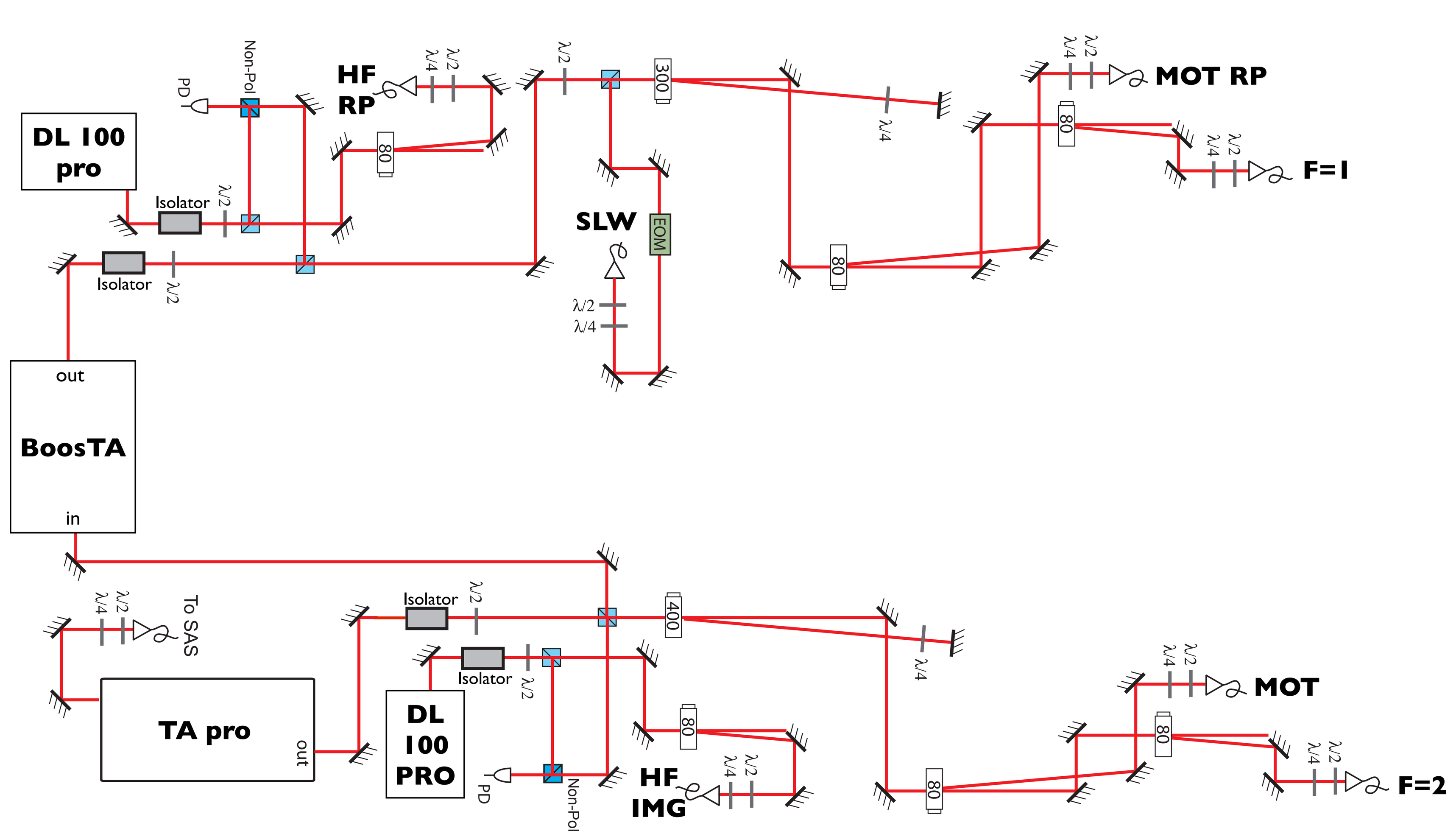
(a) Prepare a 50-50 spin mixture (b) Separate spins by magnetic field gradient (c) Apply optical lattice (d) Allow spins to mix (by decreasing magnetic field gradient)

Experimental Setup

Experimental Model

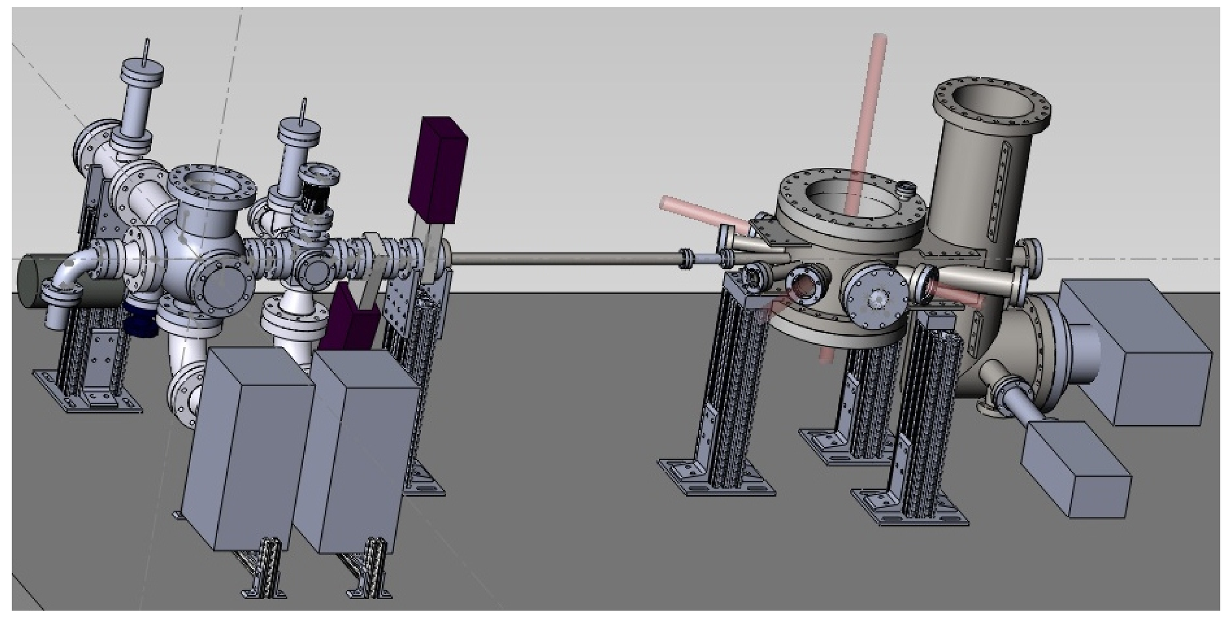
- Two-components Hamiltonian realized by ^{7}Li atoms in two hyperfine states placed in an optical lattice
- Experimental 'knobs:' what we can vary:
  - Energy ratio t/U by optical lattice depth
  - On-site interaction energy U by external magnetic field
  - Spin separation by a magnetic field gradient
  - Scattering length by a Feshbach resonance
  - Temperature

Laser Table

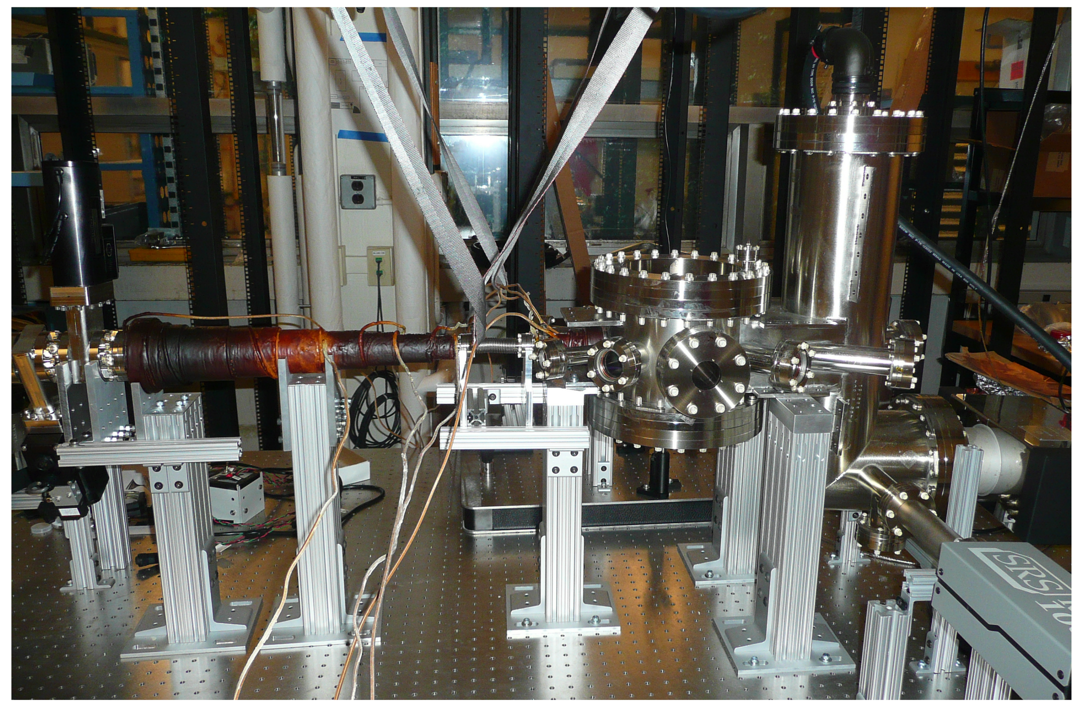


Machine Table

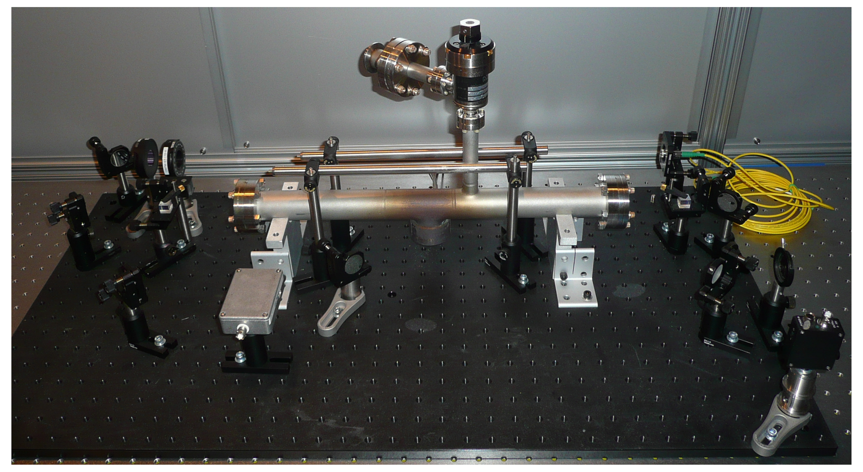
- Oven, Differential Pumping, Zeeman Slower and Main Chamber



- The machine in real space



- Spectroscopy



Funding Acknowledgements

NSF · DEPARTMENT OF DEFENSE · DARPA DSO DEFENSE SCIENCES OFFICE · OLE OPTICAL LATTICE EMULATOR