Towards ultracold single neutral atoms in microscale optical dipole traps
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Goals
1) Advance quantum information with neutral atoms in microscale dipole traps
   - Uncontrolled atom motion limits:
     - Rydberg gates
     - Single photon sources
     - Coupling to small optical modes
2) Study few-body neutral atom systems
   - Connections to many-body neutral atom work
     - Double-well, Plaquette systems

Envisioned experiment
- Single atoms in microscale dipole traps
- Define motional state with laser cooling: 3D Raman sideband cooling
- Create a few neutral atoms with individual readout, sub-micron separation, and motional-spin control
- Utilize trapped ion techniques

Single atom and multiple single atom system

Two implemented schemes for Raman sideband Cooling

- Degenerate sideband cooling
  - \( \text{lin}(\theta=40^\circ) \text{lin lattice:} \)
    - \( B_{\text{eff}} \) local lattice-polarization interacts with spin like an effective magnetic field
    - \( \text{Lattice potential localizes atom at lower portion of} \ B_{\text{eff}} \text{ yielding} \ n = 1 \text{ coupling} \)
- Non-degenerate sideband cooling: coupling provided by external Raman beams
  - \( \text{Non-degenerate sideband cooling} \)

Present setup: Proof of principle

Temperature Characterization

- Adiabatic lowering: spectroscopy of energy distribution
  - \( \text{Microscopic objective:} \)
    - 0.61 NA, 780/850 nm diffraction limited

Conclusions

- Apparatus capabilities:
  - Single atom detection
  - Raman cooling in microscale potential
  - Cooling can be provided by external beams or inherent to trapping potential

Relevant References

- A. J. Kerman, Stanford, Dissertation
- Foerster et al., Phys. Rev. Lett. 103, 233001
- Monroe et al., Phys. Rev. Lett. 75, 4011
- Schlosser et al., Phys. Rev. Lett. 89, 023005
- Sackett et al., Nature 404, 256