

Ultracold molecule assembly

The background features a 3D visualization of an ultracold molecule assembly trap. A large, dark, cylindrical structure with a ribbed texture is shown in perspective. A bright green, cone-shaped beam of light originates from the left and focuses into a circular region on the right. Within this focused area, numerous small molecular models are depicted. Each molecule consists of blue and orange spheres connected by lines, representing atoms and bonds. The molecules are scattered throughout the green beam, with some appearing more concentrated in the center of the focus.

Yichao Yu

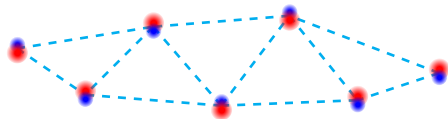
Ni Group/Harvard

Aug 11, 2017

Molecules in optical tweezer

Features

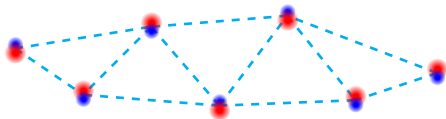
- Strong and tunable interaction
- Rich internal energy levels
- High filling fraction
- Single site detection and manipulation



Molecules in optical tweezer

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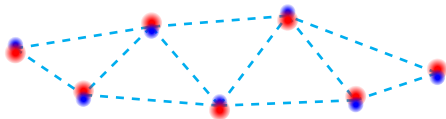
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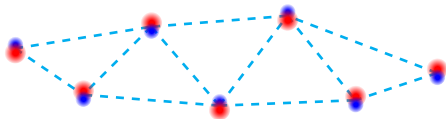
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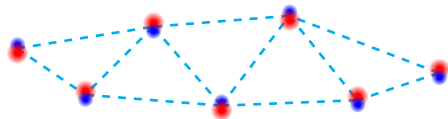
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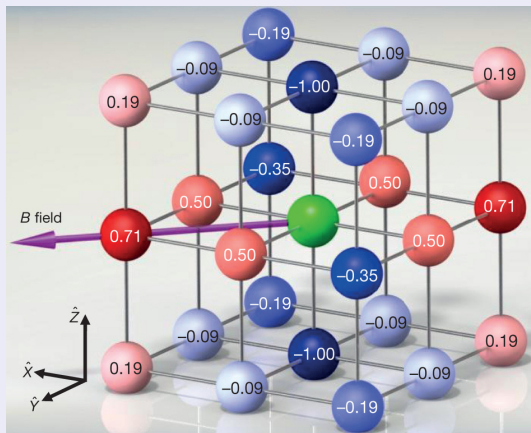
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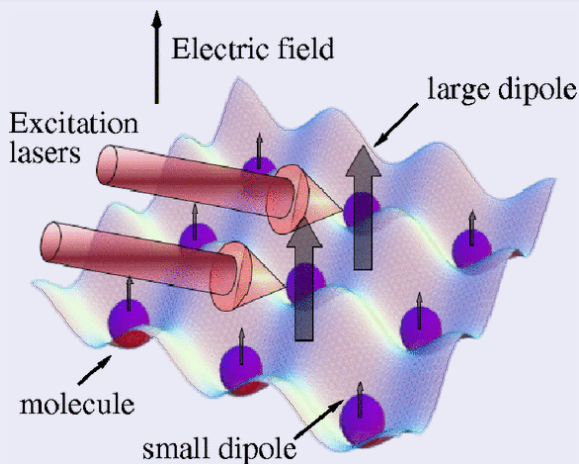
Simulation of many-body system^[1]



$$H \propto \sum V_{ij} (S_i^+ S_j^- + S_i^- S_j^+)$$

[1] B. Yan et al., “Observation of dipolar spin-exchange interactions with lattice-confined polar molecules.”, *Nature* **501**, 521–5 (2013).

Quantum computation^[2]



[2] S. F. Yelin et al., “Schemes for robust quantum computation with polar molecules”, *Phys. Rev. A* **74**, 050301 (2006).

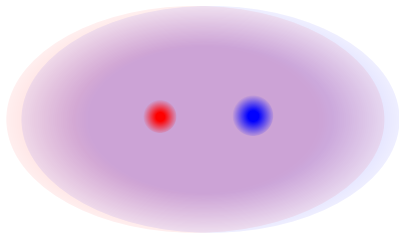
Making molecules from atoms

- MOT (Na + Cs)
- Loading single atoms
- Raman sideband cooling
- Merge traps
- Make molecules!



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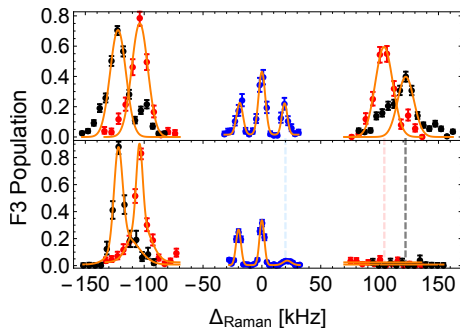
Atom loading and cooling

- Single atoms
- 85% ground state after Cesium Raman sideband cooling

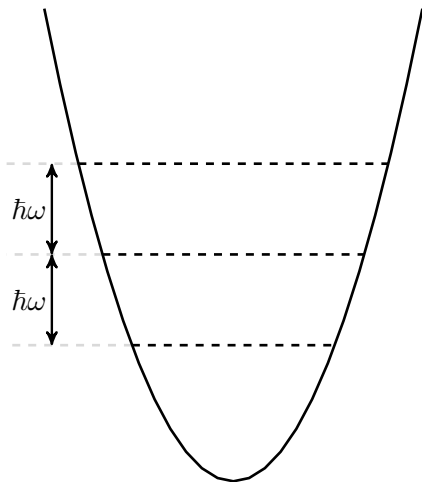


Atom loading and cooling

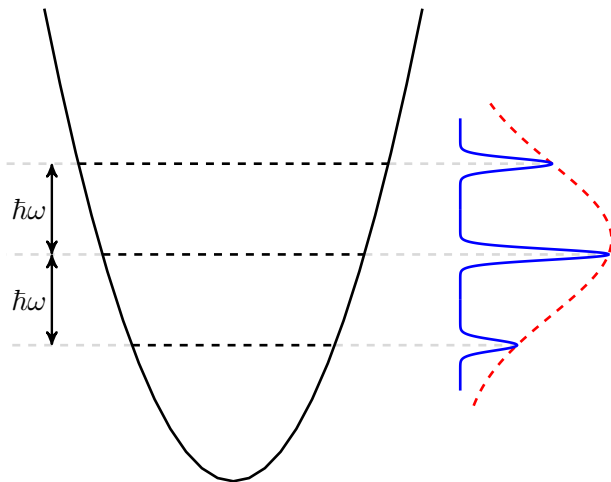
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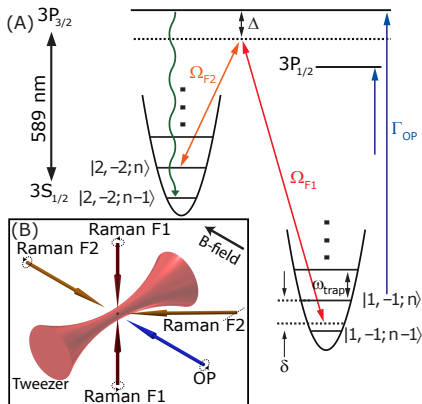
Raman sideband cooling



Raman sideband cooling

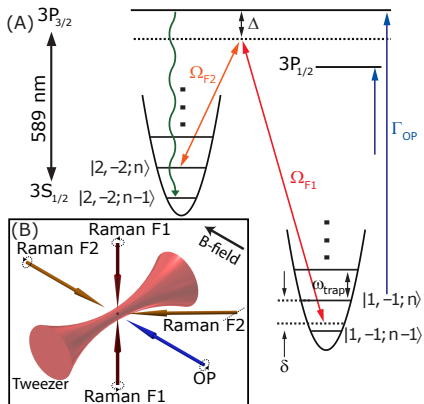


Raman sideband cooling



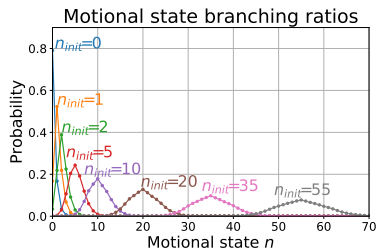
- High initial temperature ($70\mu K$)
- High Lamb Dicke parameter
- Large light shift
- Trap anharmonicity
- Off resonance scattering from Raman beams
 $\approx 0.2 \sim 0.5\text{kHz}$

Raman sideband cooling



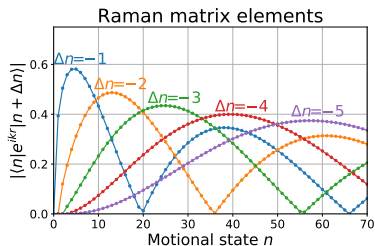
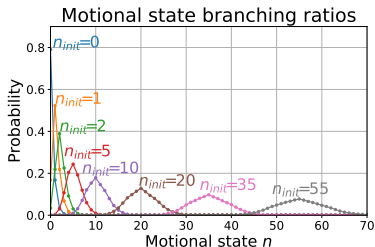
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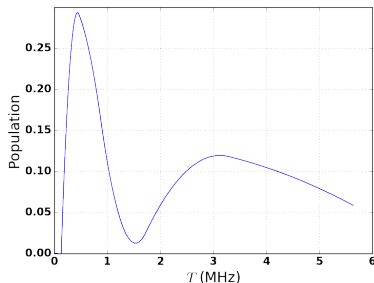
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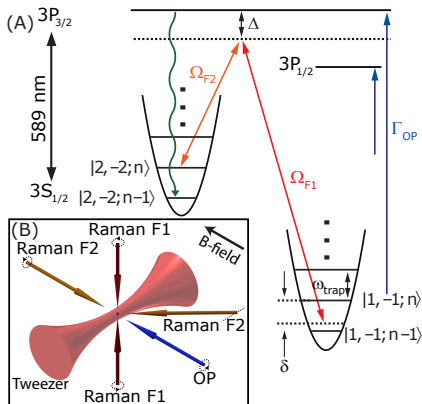
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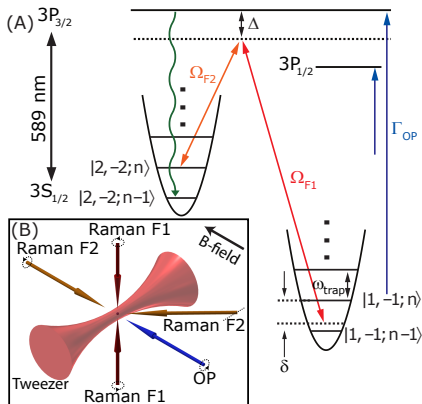
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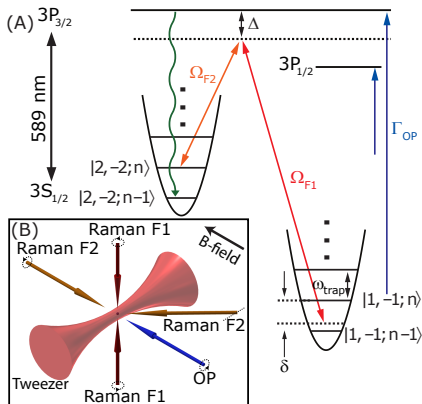
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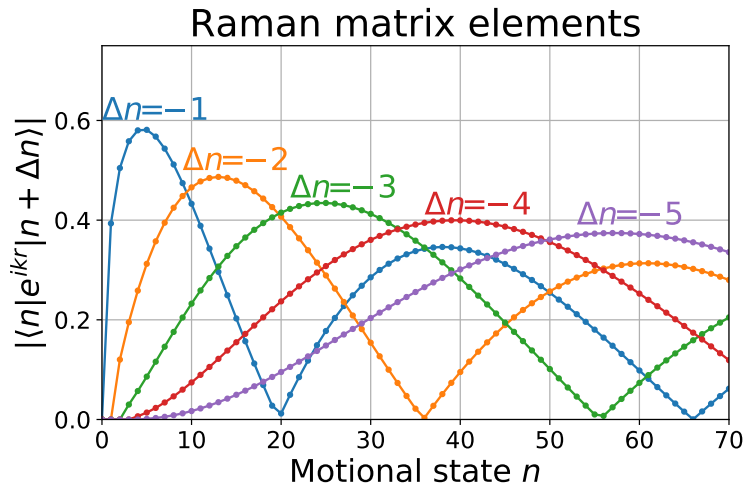


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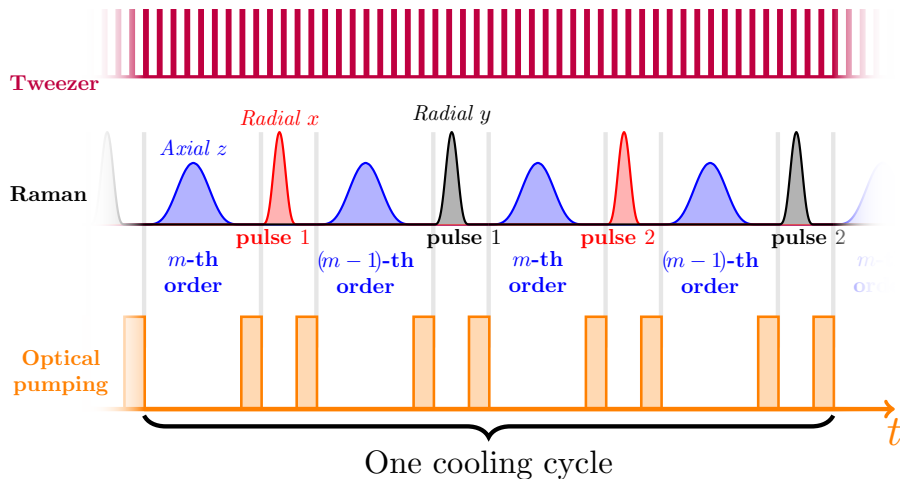
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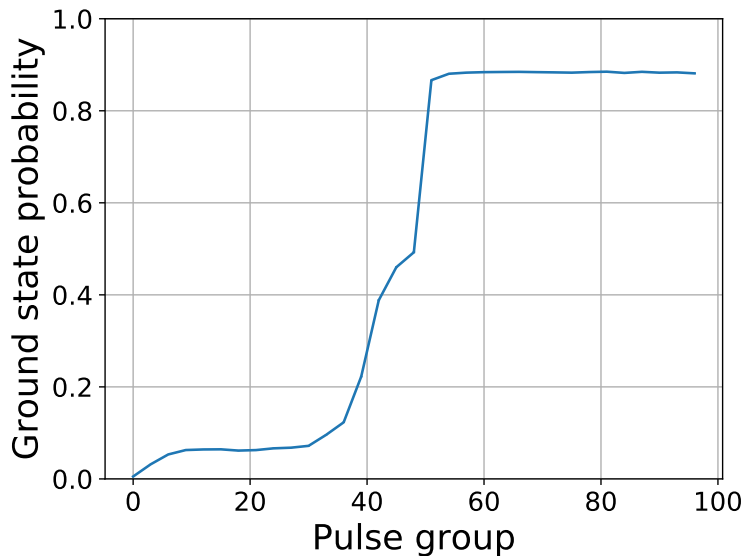
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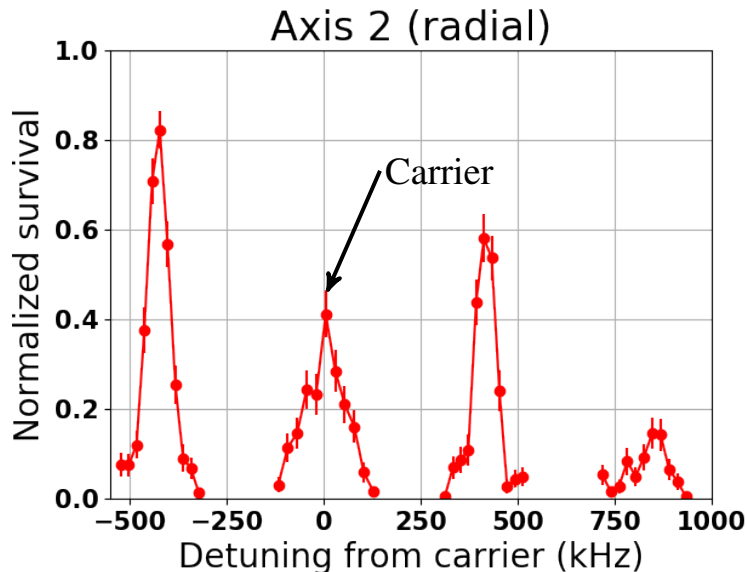


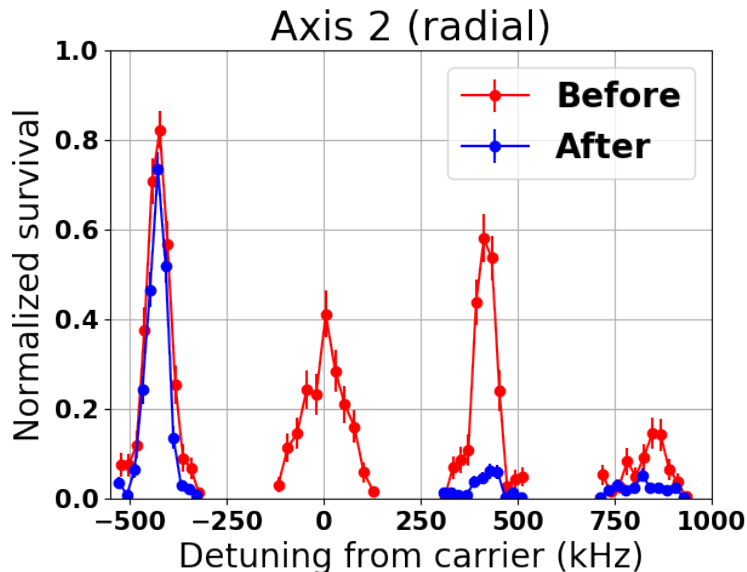
Sequence and simulation

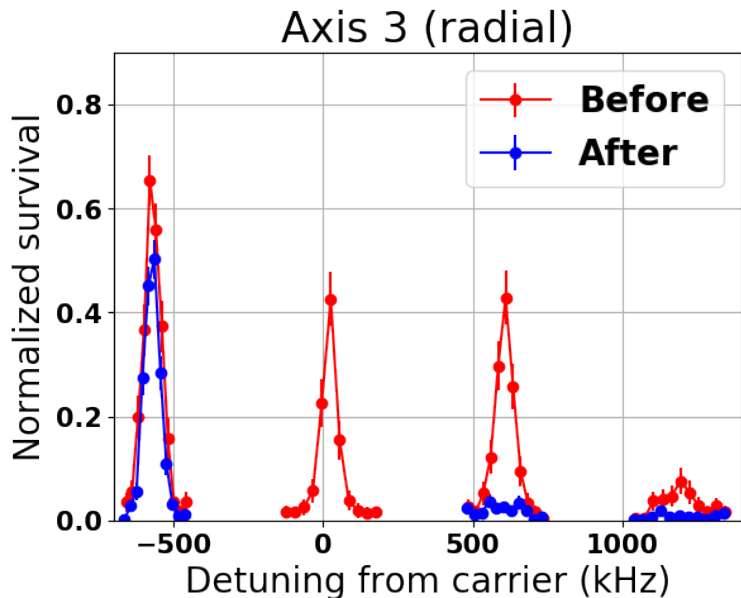


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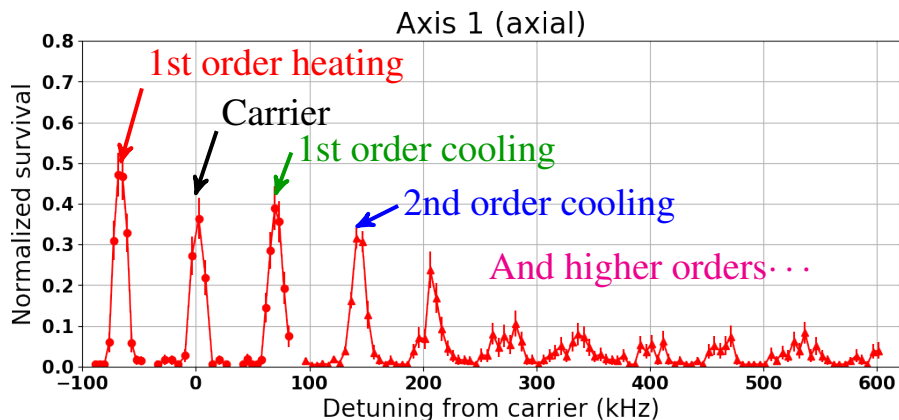




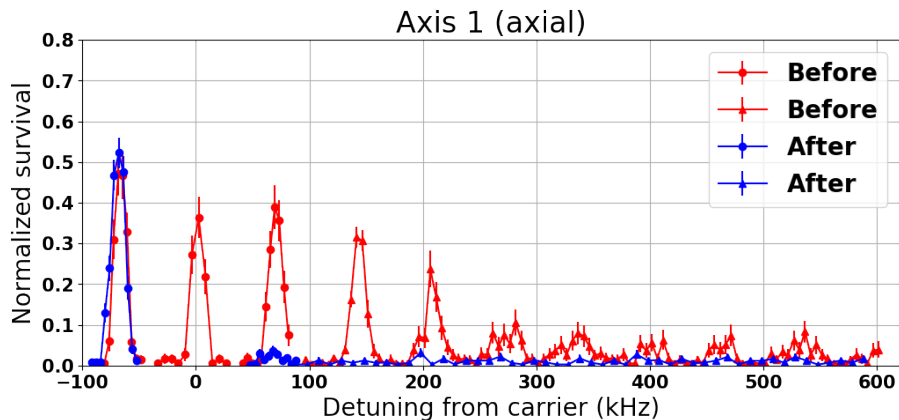




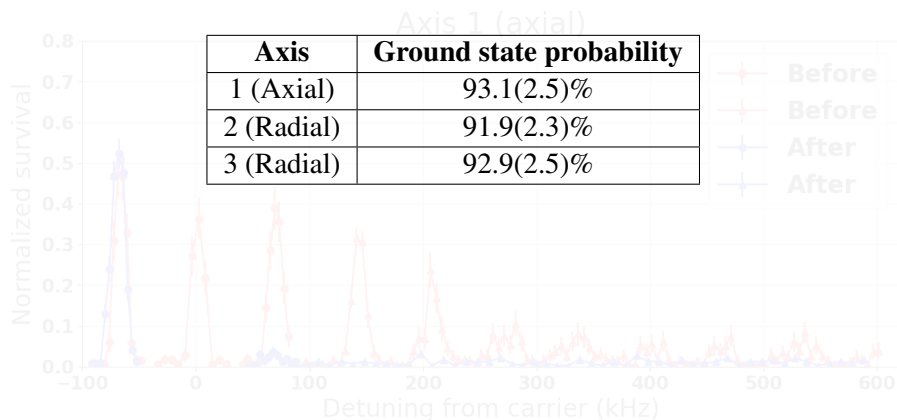
Raman sidebands



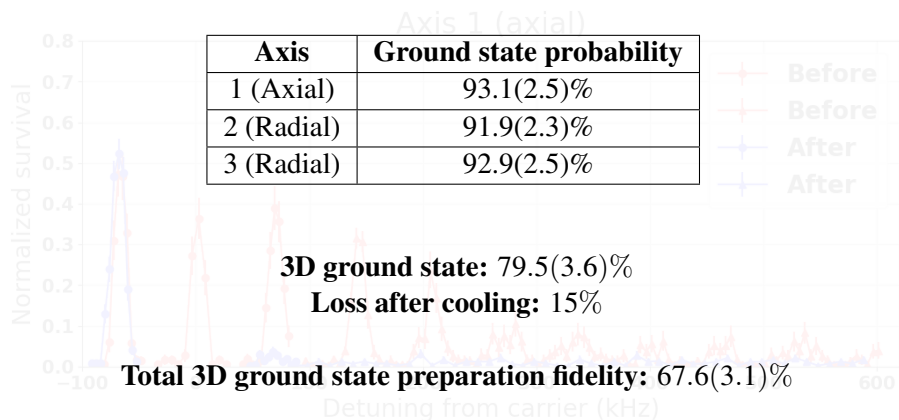
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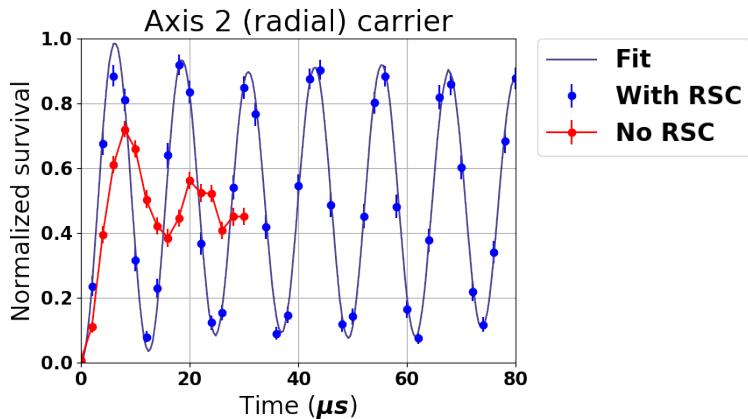
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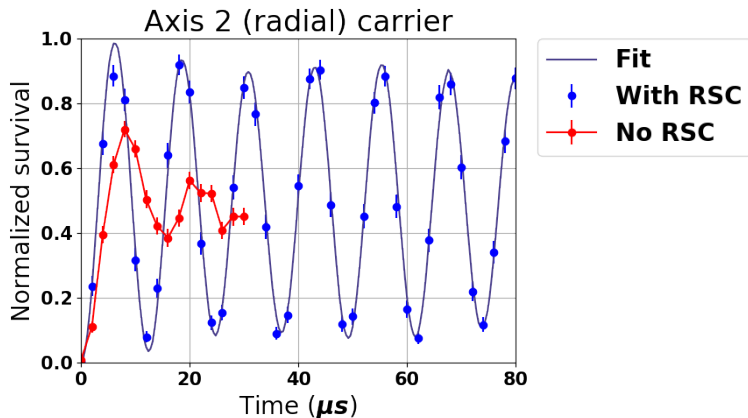
Raman sidebands



Rabi flopping (radial)

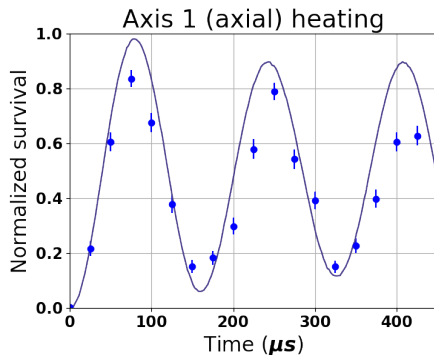
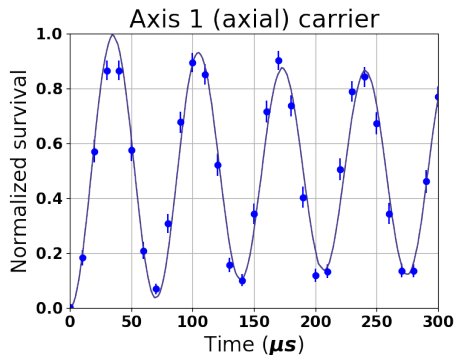


Rabi flopping (radial)

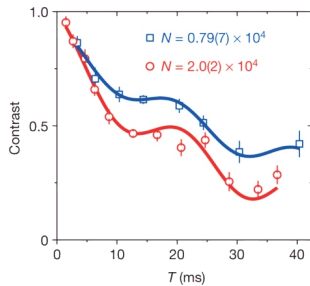


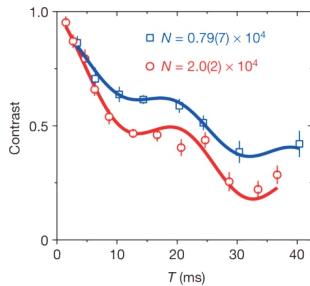
Good agreement in ground state probability between spectrum and Rabi flopping data.

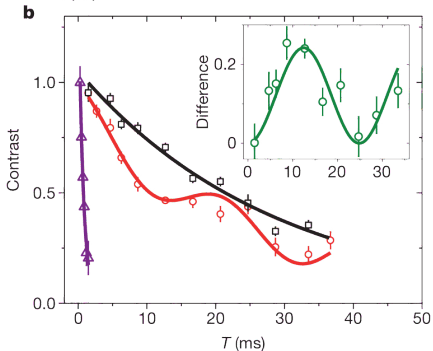
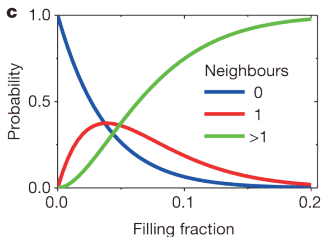
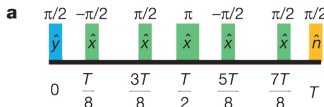
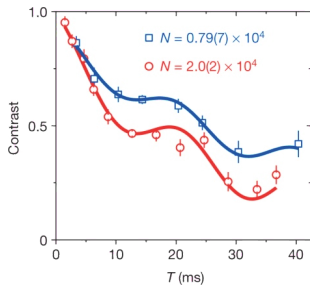
Rabi flopping (axial)



In progress





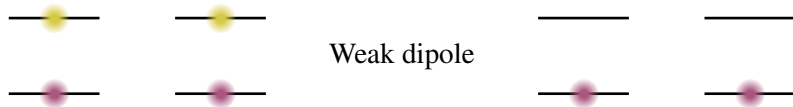
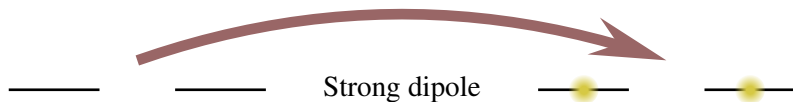


Quantum computation

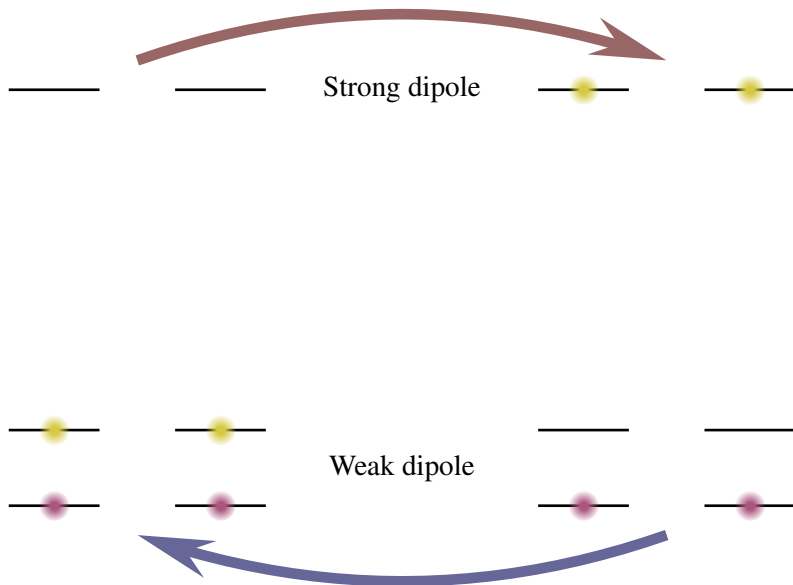
—— ——— Strong dipole

—— ———
—— ——— Weak dipole

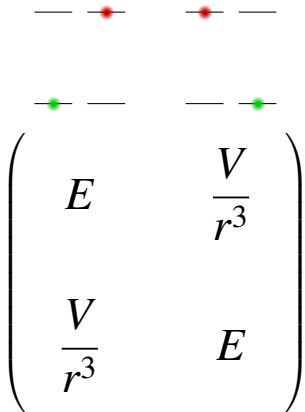
Quantum computation



Quantum computation



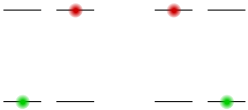
Quantum computation



The diagram illustrates a two-qubit system. At the top, four horizontal lines represent energy levels. The top two levels are occupied by red dots, and the bottom two levels are occupied by green dots. Below the energy levels, a Hamiltonian matrix is shown, representing the system's energy states and transitions.

$$\begin{pmatrix} E & \frac{V}{r^3} \\ \frac{V}{r^3} & E \end{pmatrix}$$

Quantum computation



The diagram shows two horizontal lines representing energy levels. The top line has two red dots, and the bottom line has two green dots. This represents a system with two states, each having two degenerate sub-states.

$$\begin{pmatrix} E & \frac{V}{r^3} \\ \frac{V}{r^3} & E \end{pmatrix} \rightarrow \begin{pmatrix} E - \frac{V}{r^3} & \\ & E + \frac{V}{r^3} \end{pmatrix}$$

Merge trap

