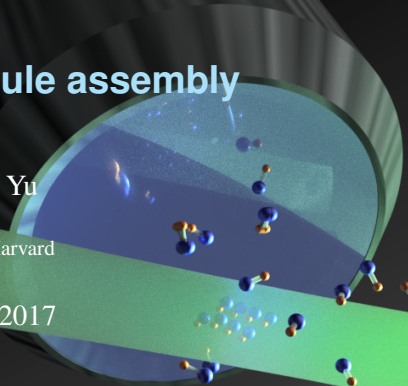


# Ultracold molecule assembly

Yichao Yu

Ni Group/Harvard

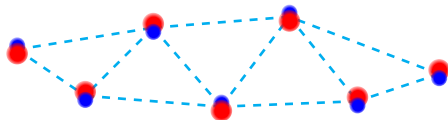
Aug 11, 2017



# Molecules in optical tweezer

## Features

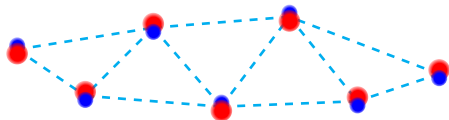
- Strong and tunable interaction
- Rich internal energy levels
- High filling fraction
- Single site detection and manipulation



# Molecules in optical tweezer

## Features

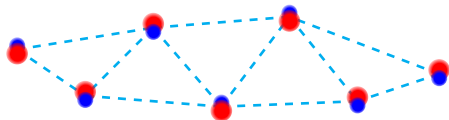
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# Molecules in optical tweezer

## Features

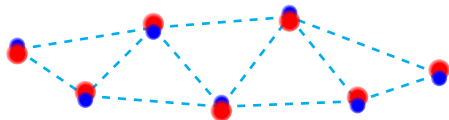
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# Molecules in optical tweezer

## Features

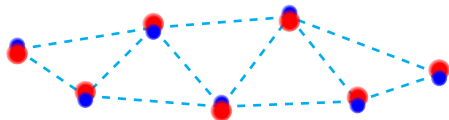
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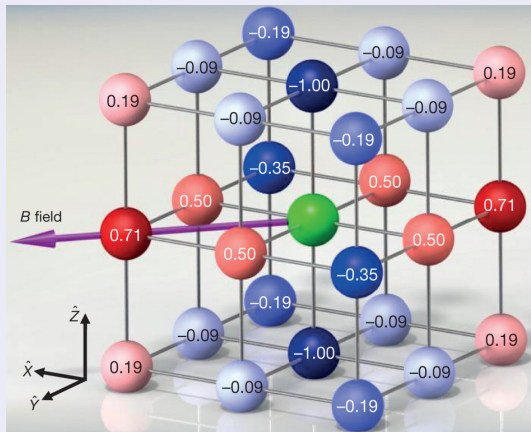
# Molecules in optical tweezer

## Features

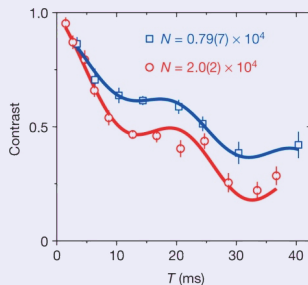
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## Simulation of many-body system<sup>[1]</sup>

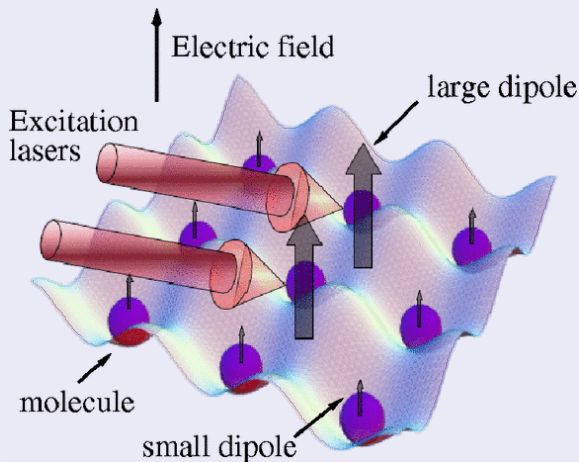


$$H \propto \sum_{ij} V_{ij} (S_i^+ S_j^- + S_i^- S_j^+)$$



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

## Quantum computation<sup>[2]</sup>



[2] S. F. Yelin et al., “Schemes for robust quantum computation with polar molecules”, 4 (2006).



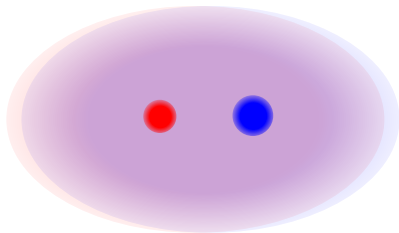
# Making molecules from atoms

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



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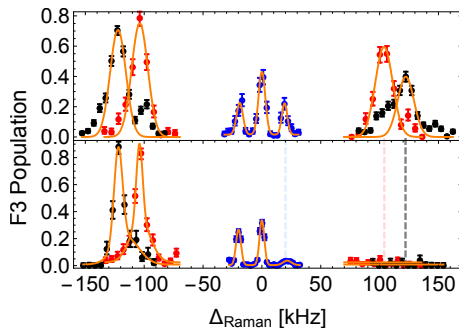
# Atom loading and cooling

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



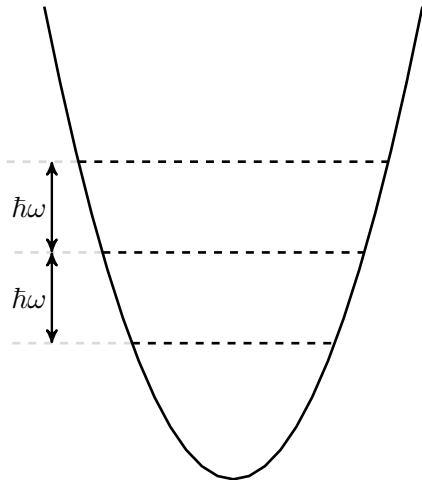
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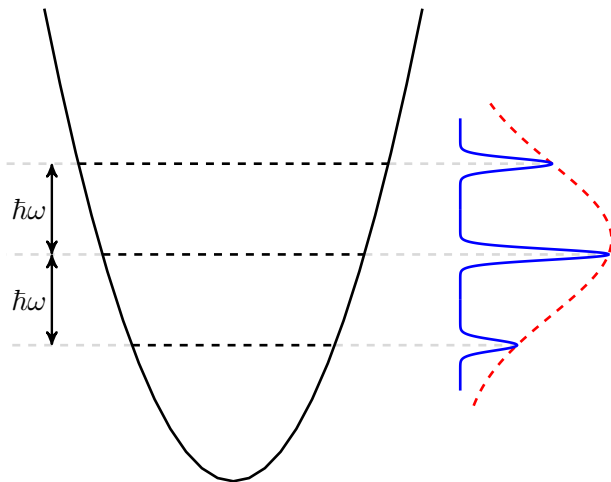




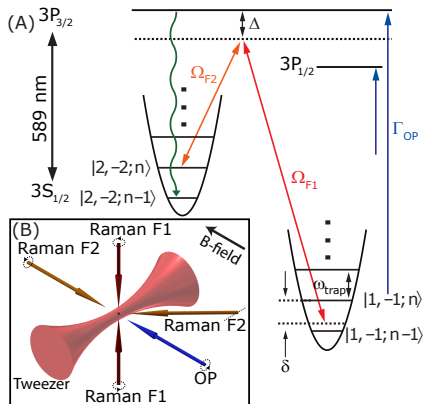
## Raman sideband cooling



## Raman sideband cooling

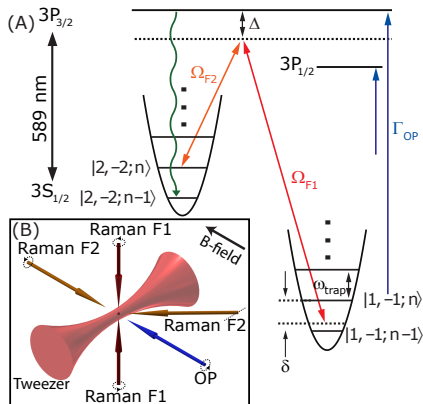


# Raman sideband cooling



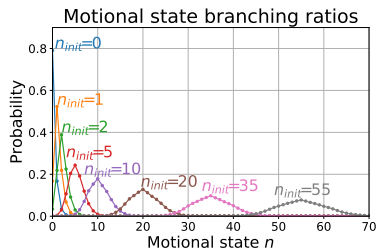
- High initial temperature ( $70\mu K$ )
- High Lamb Dicke parameter
- Large light shift
- Trap anharmonicity
- Off resonance scattering from Raman beams  
 $\approx 0.2 \sim 0.5\text{kHz}$

# Raman sideband cooling



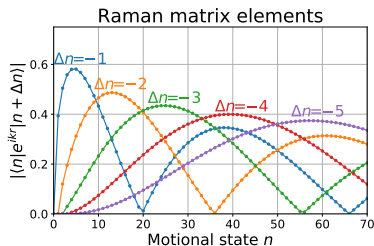
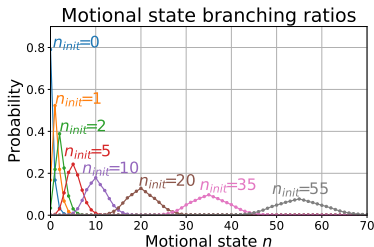
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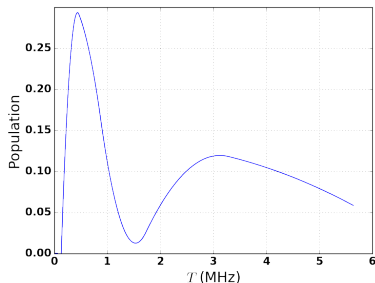
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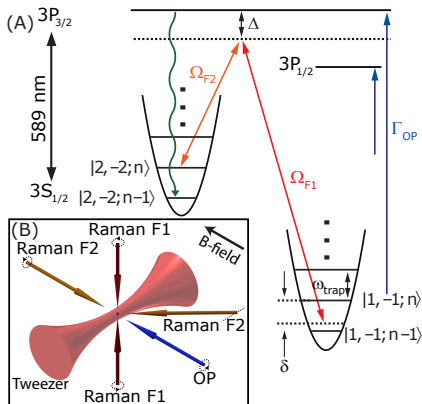
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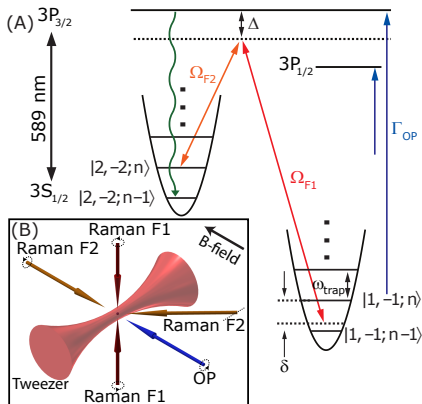
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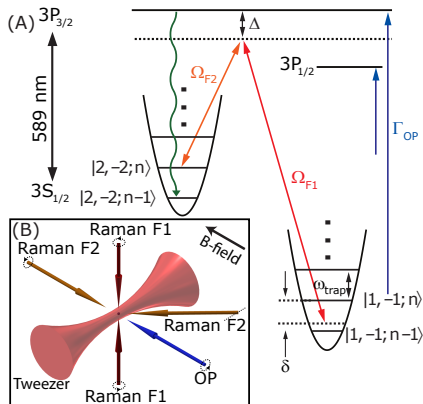


# Raman sideband cooling



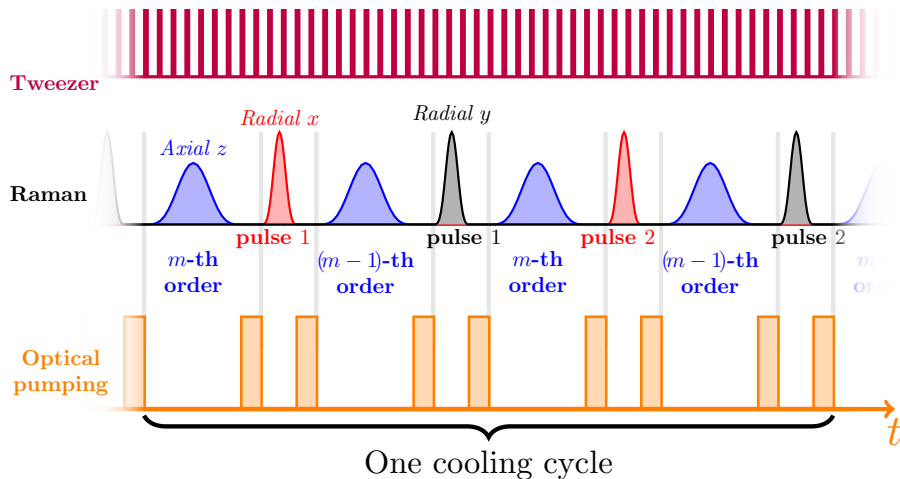
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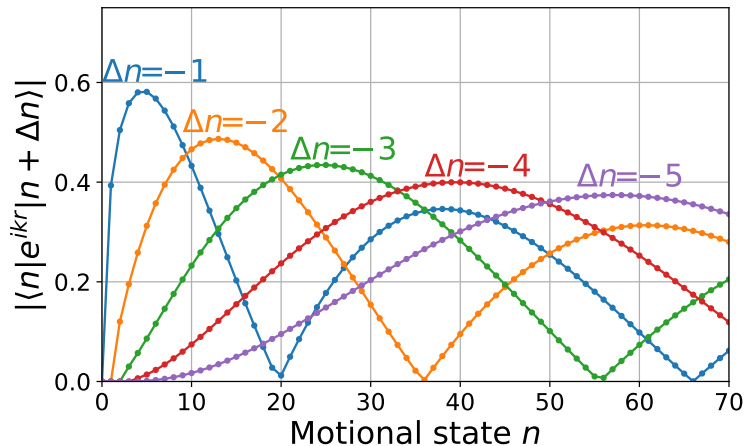


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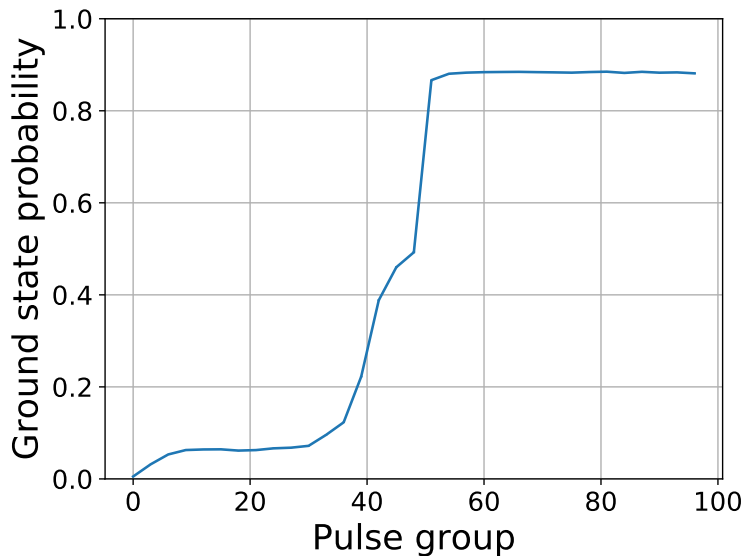
# Sequence and simulation

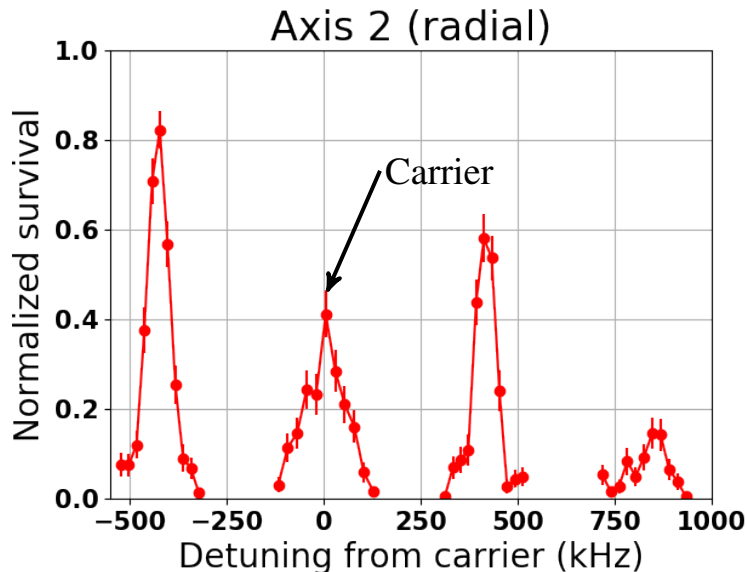


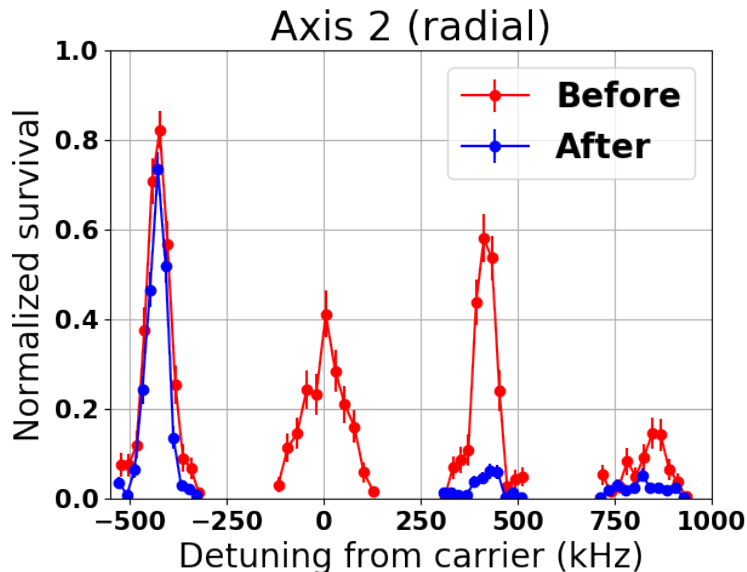
## Raman matrix elements

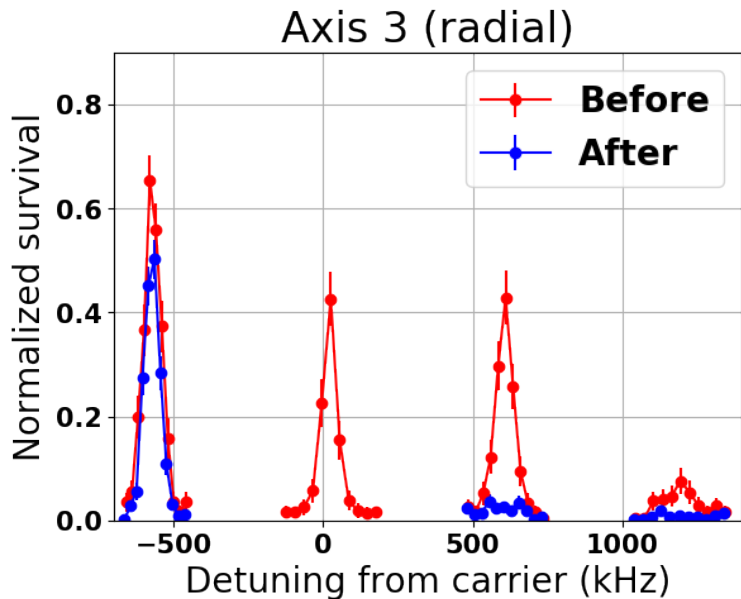


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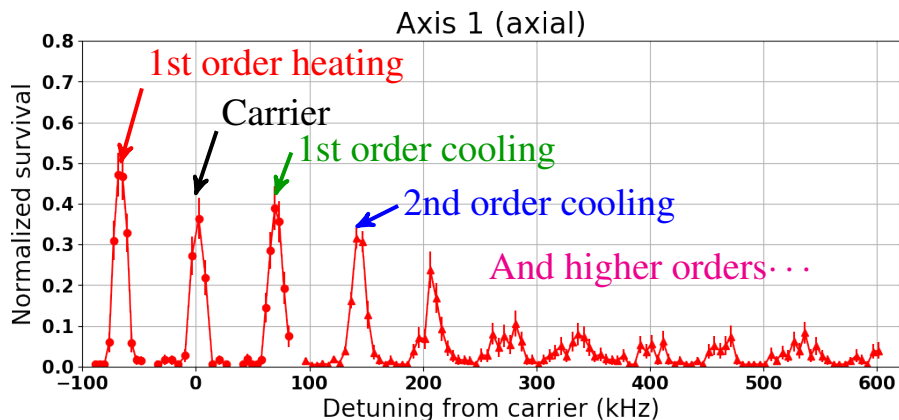




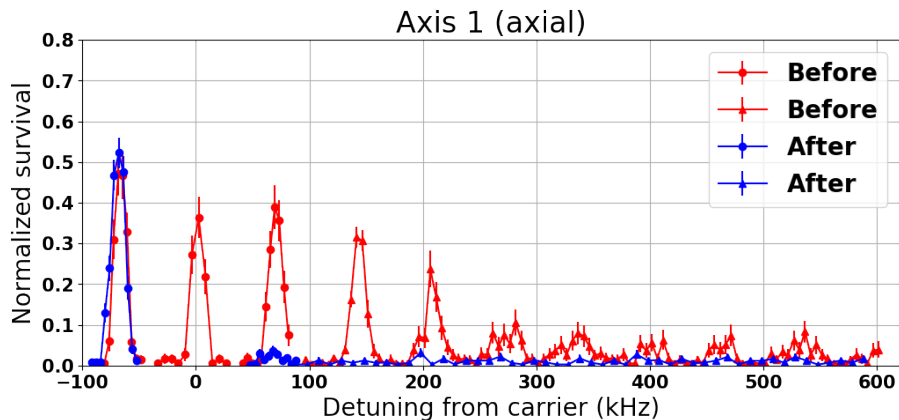




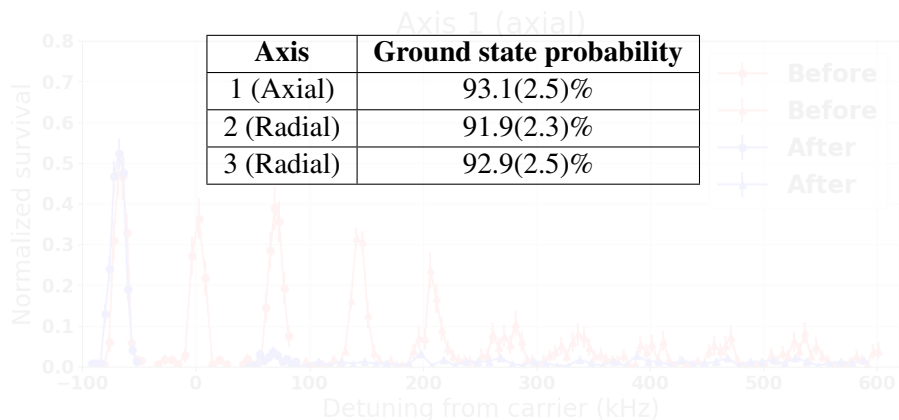
## Raman sidebands



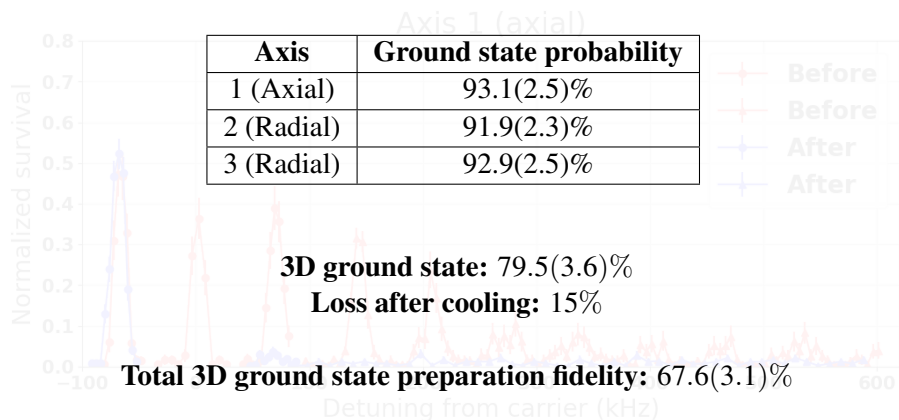
## Raman sidebands



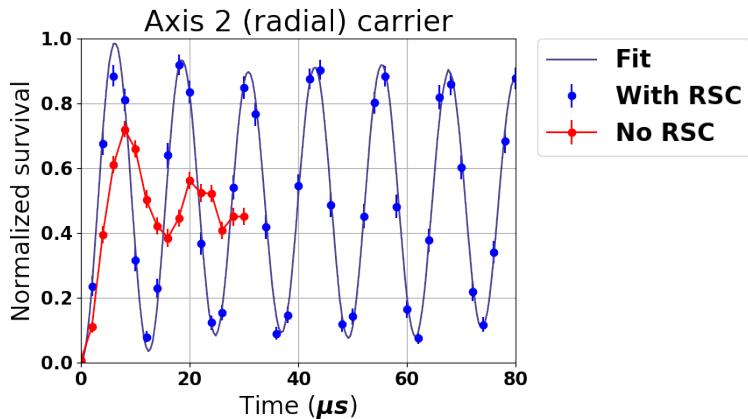
# Raman sidebands



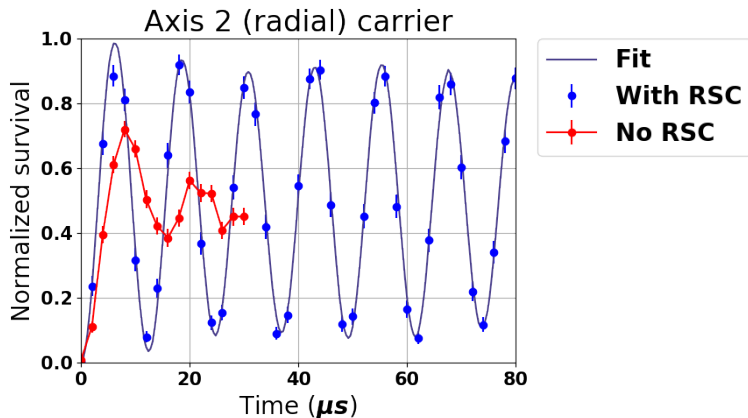
## Raman sidebands



## Rabi flopping (radial)

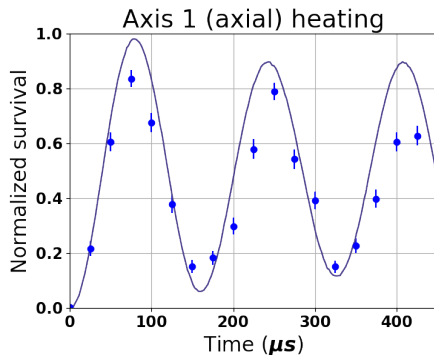
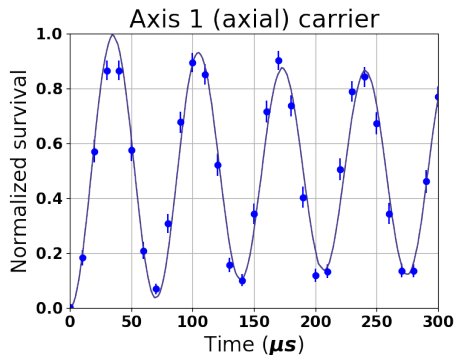


## Rabi flopping (radial)



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

# Rabi flopping (axial)



## Merge

