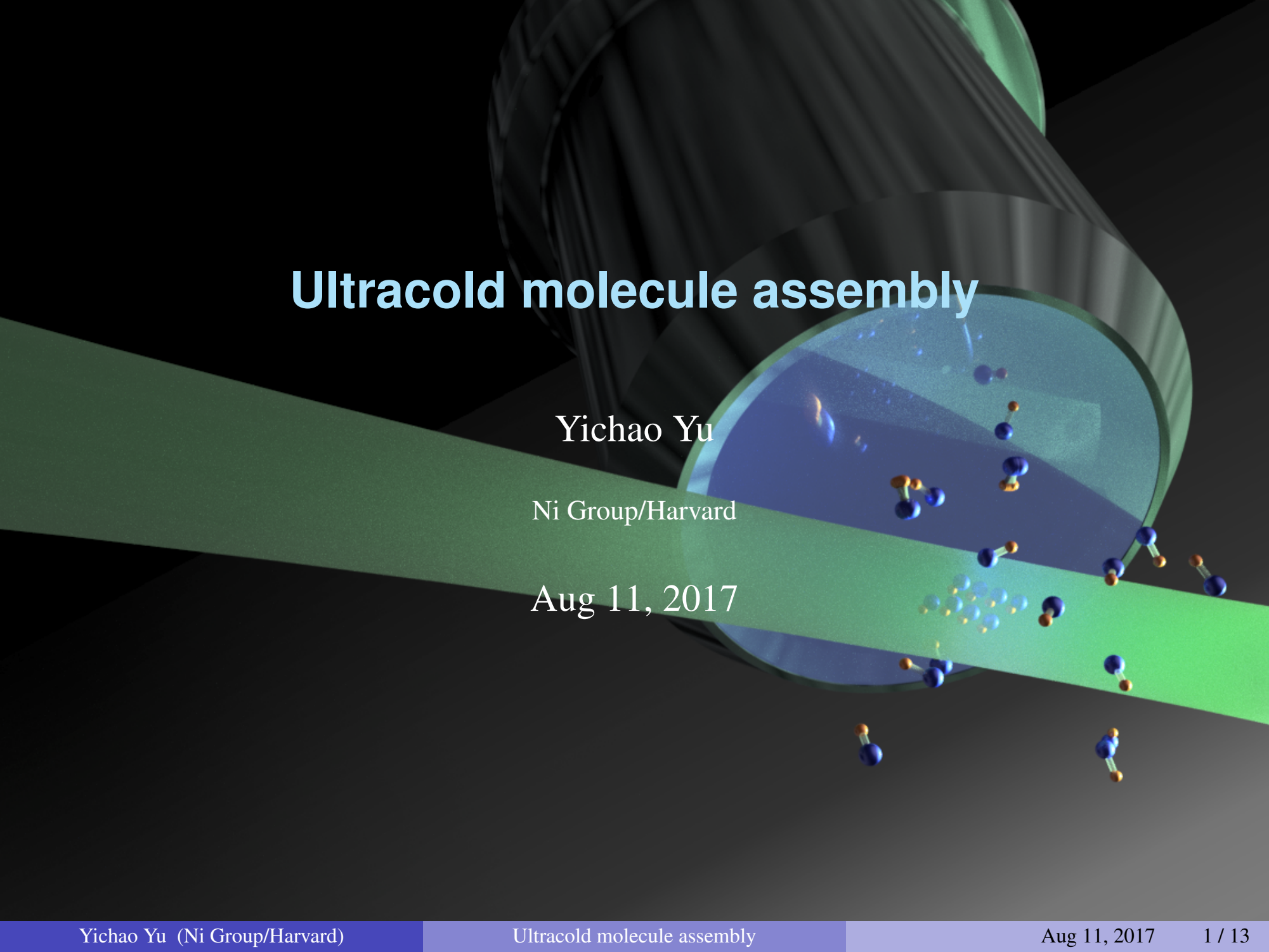


Ultracold molecule assembly

Yichao Yu

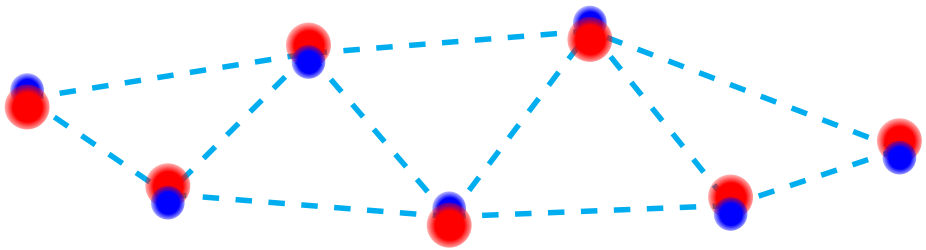
Ni Group/Harvard

Aug 11, 2017

Molecules in optical tweezer

Features

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



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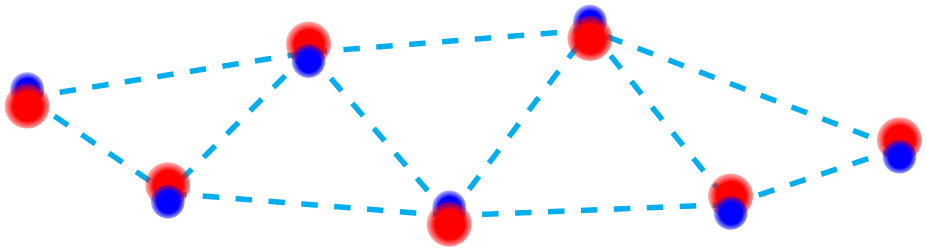

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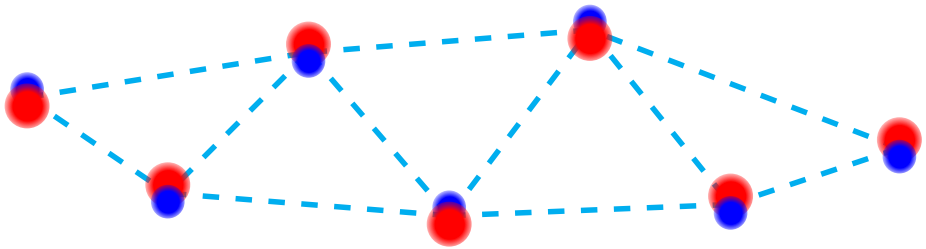

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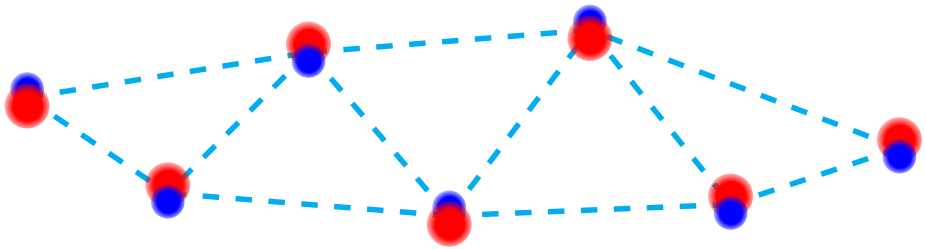

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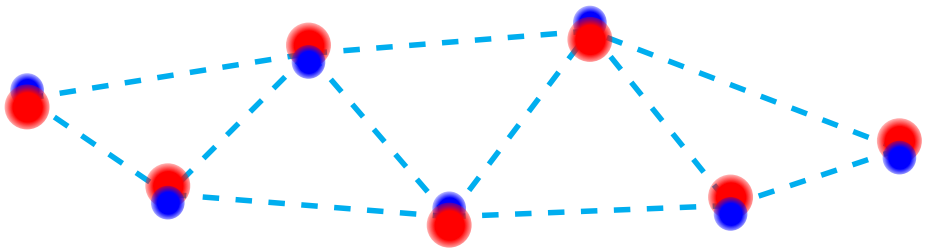
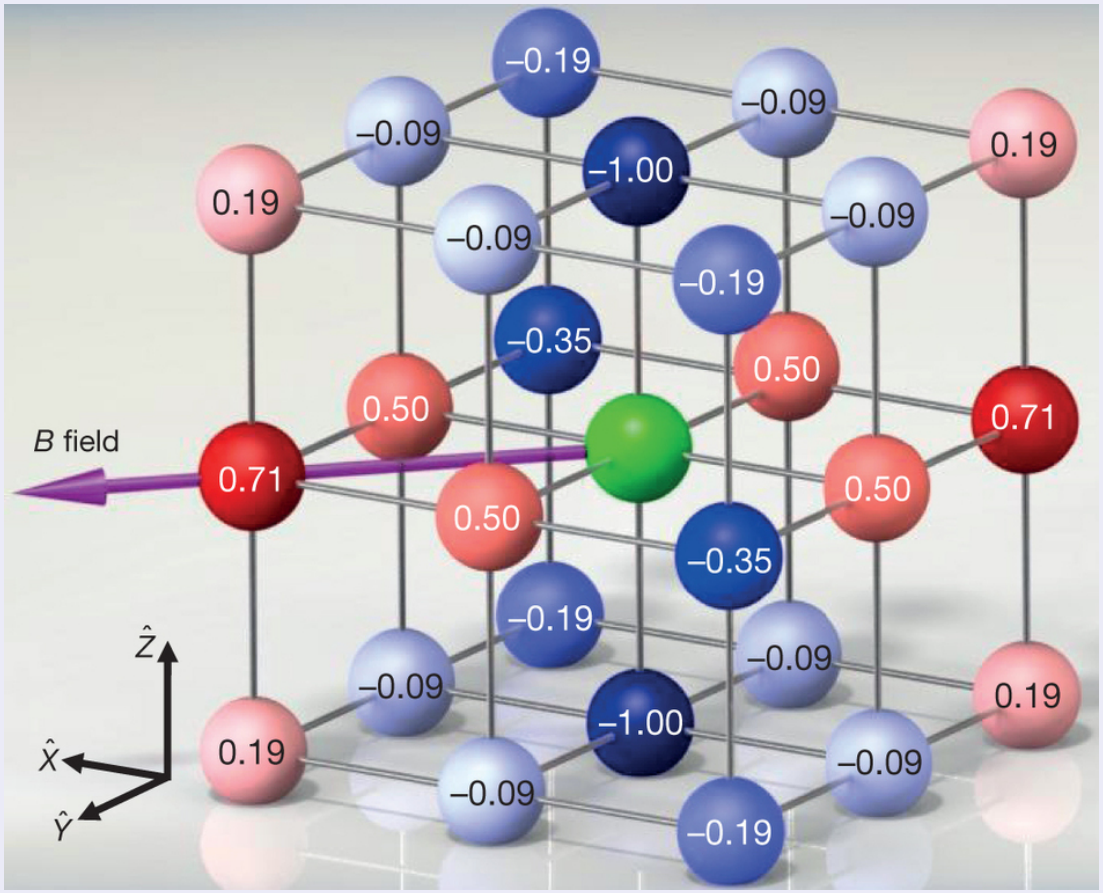
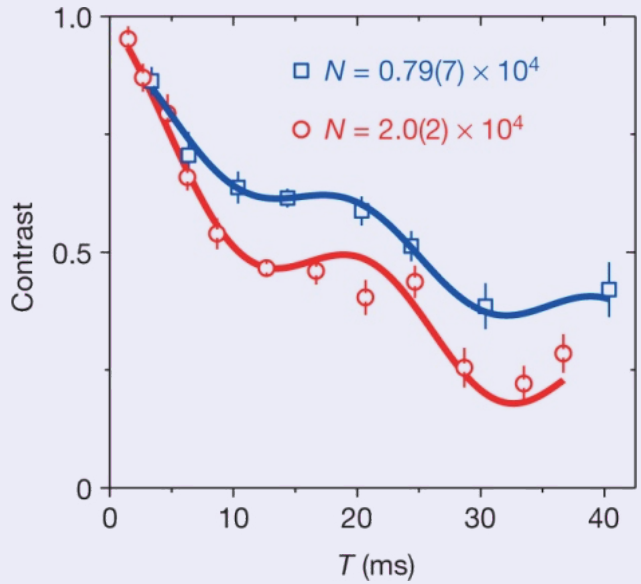


Applications

Simulation of many-body system[1]



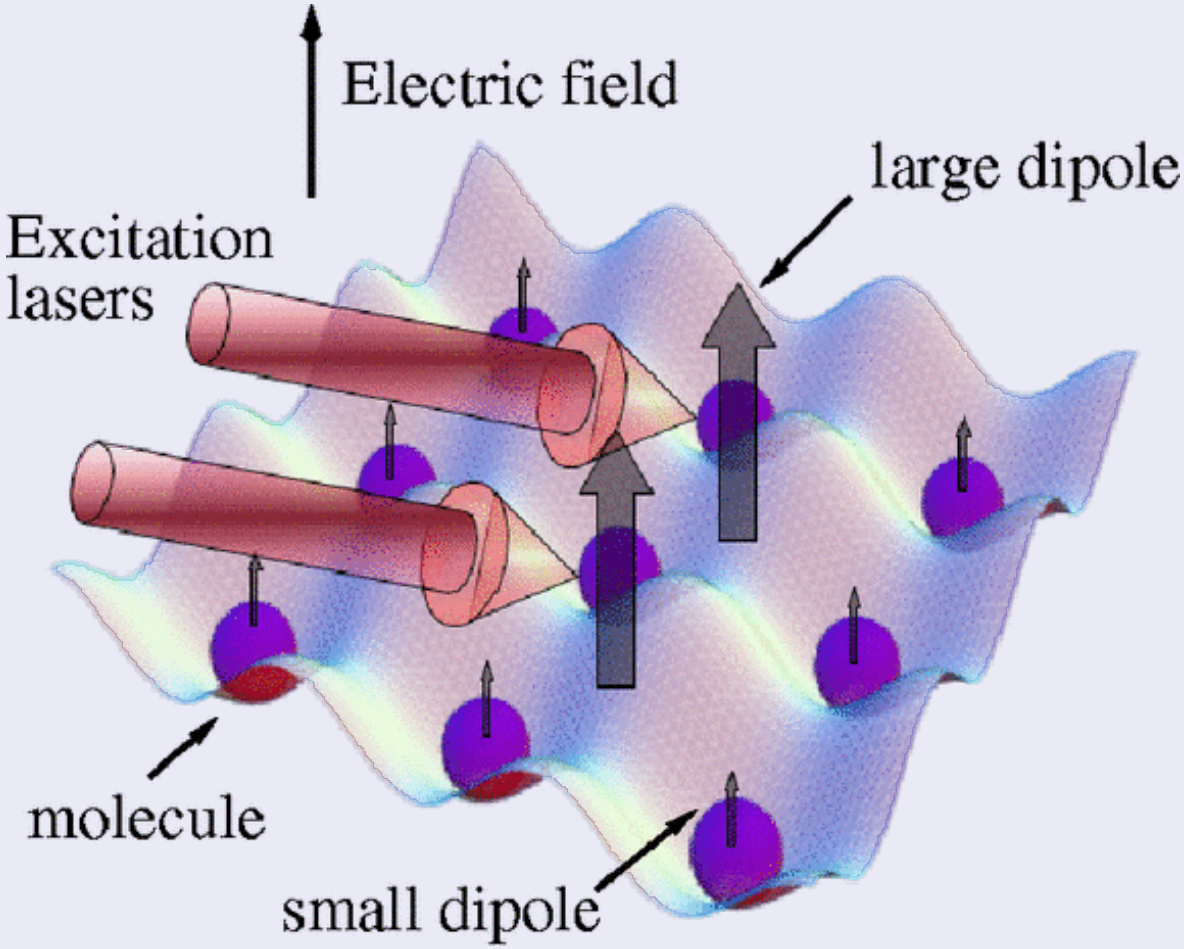
$$H \propto \sum V_{ij}\left(S_i^+ S_j^- + S_i^- S_j^+\right)$$



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

Applications

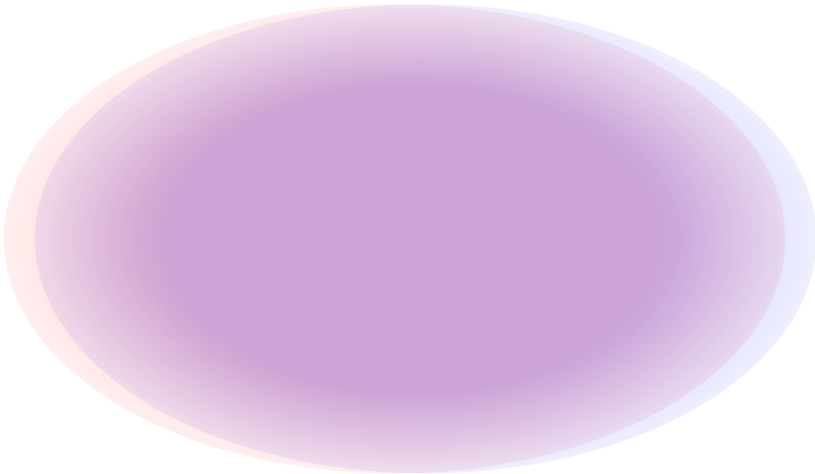
Quantum computation[2]



[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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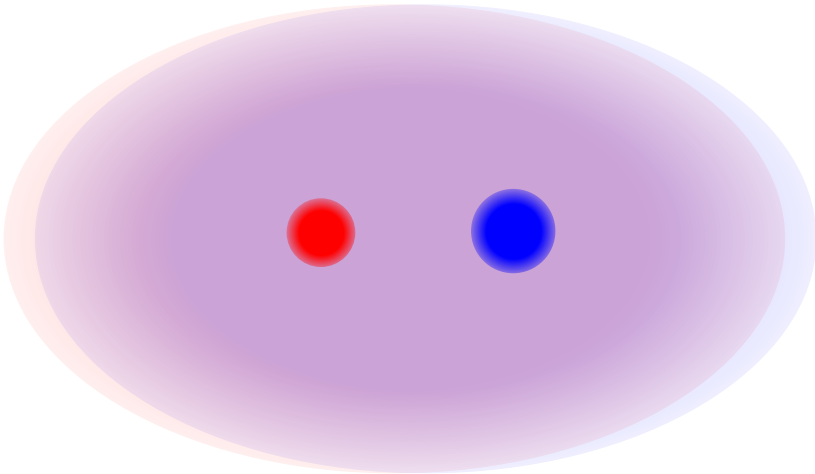

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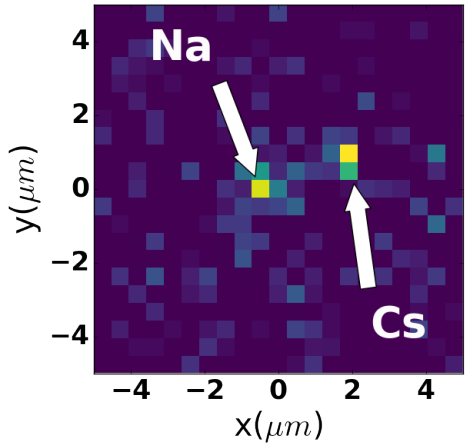
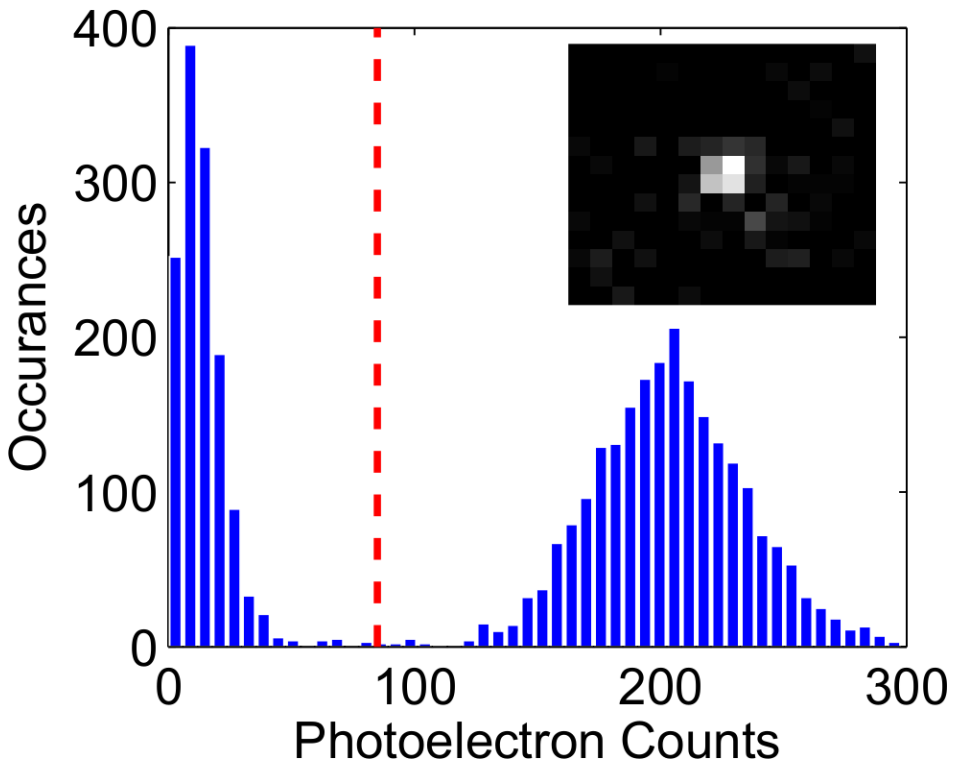


- Single atoms
- 85% cround state after Cesium Raman sideband cooling



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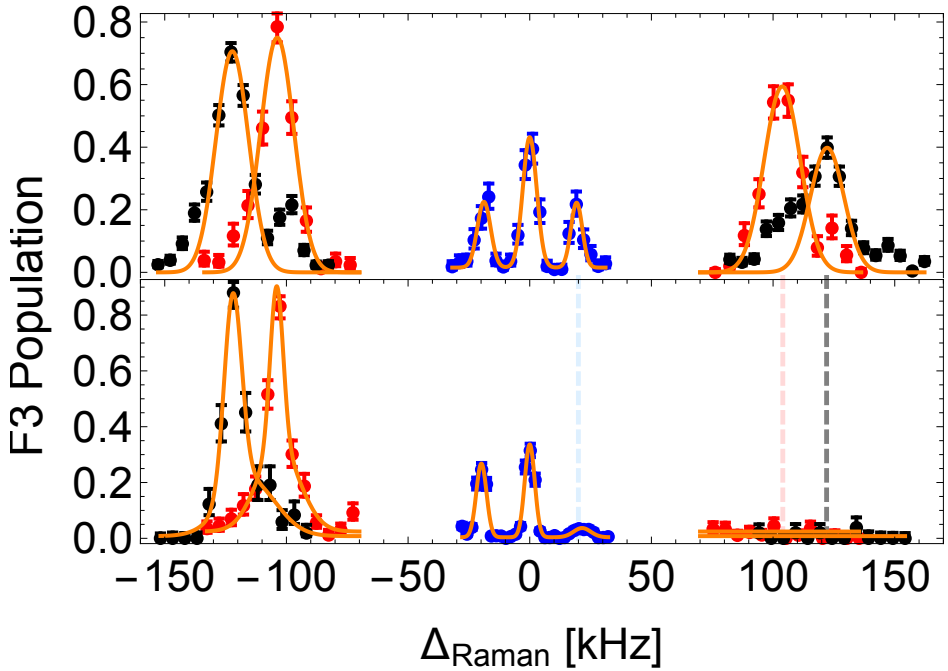
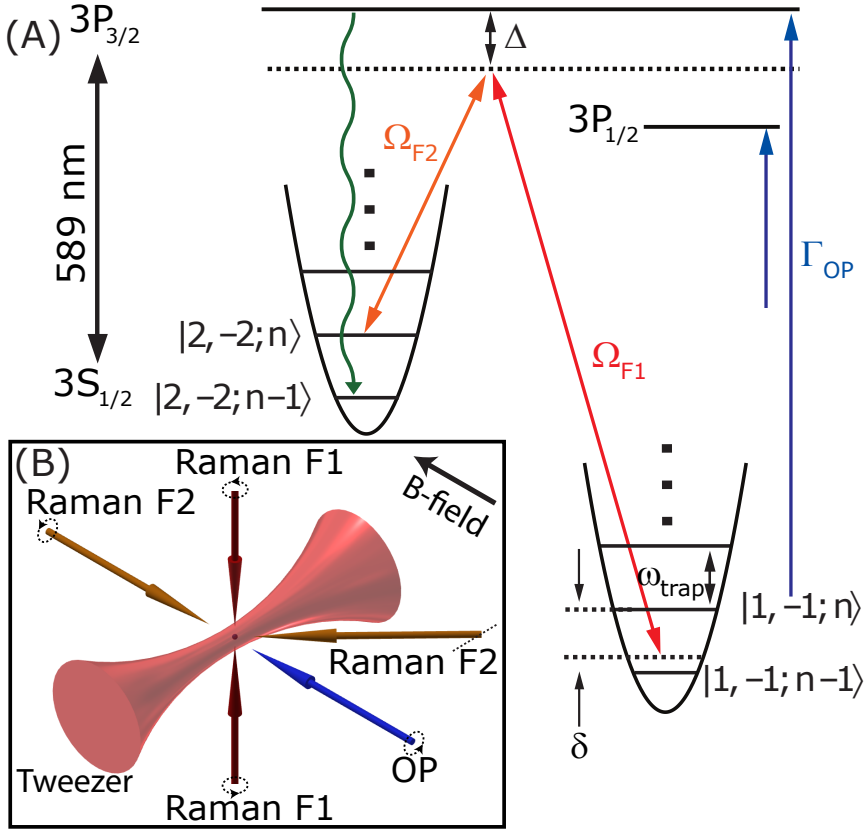
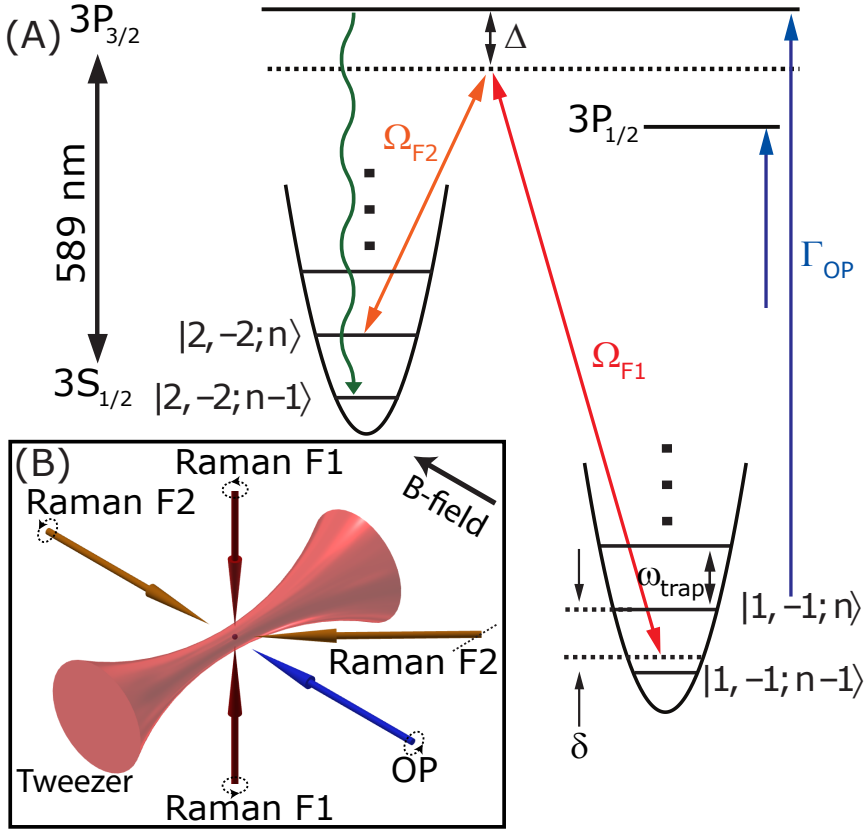


Raman sideband cooling



- High initial temperature ($70\mu K$)
- High Lamb Dicke parameter
- Large light shift (scalar and tensor)
- Trap anharmonicity

Raman sideband cooling



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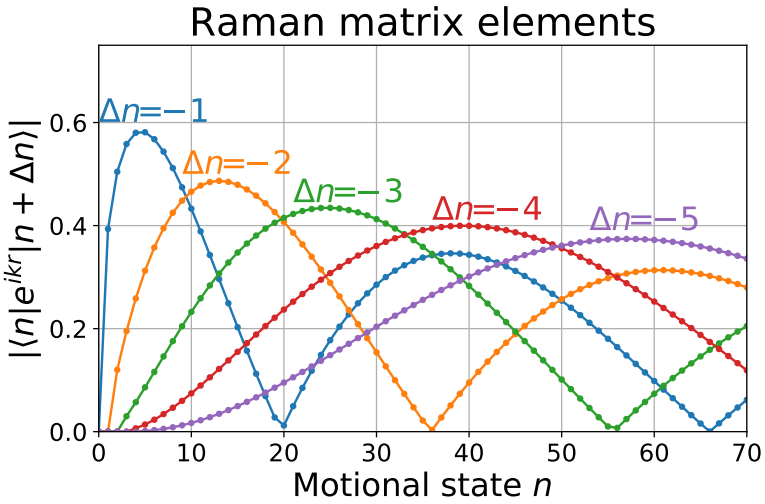

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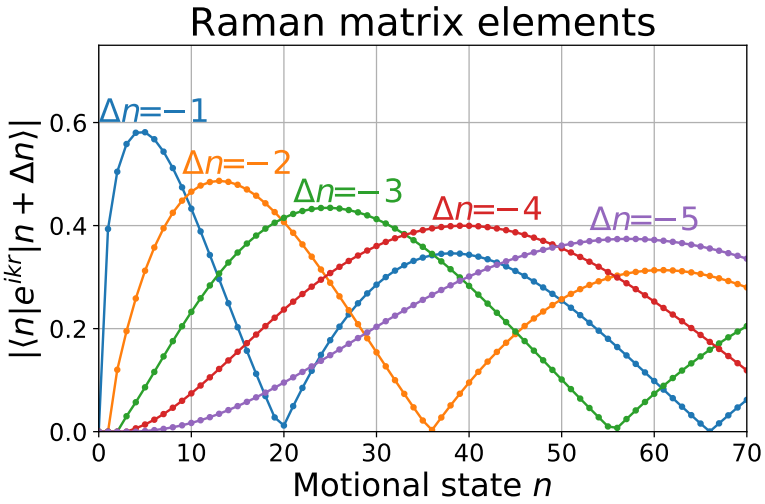

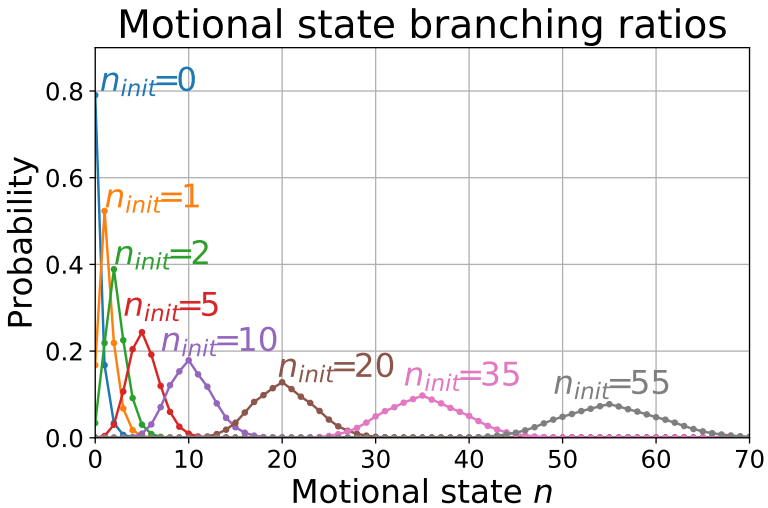

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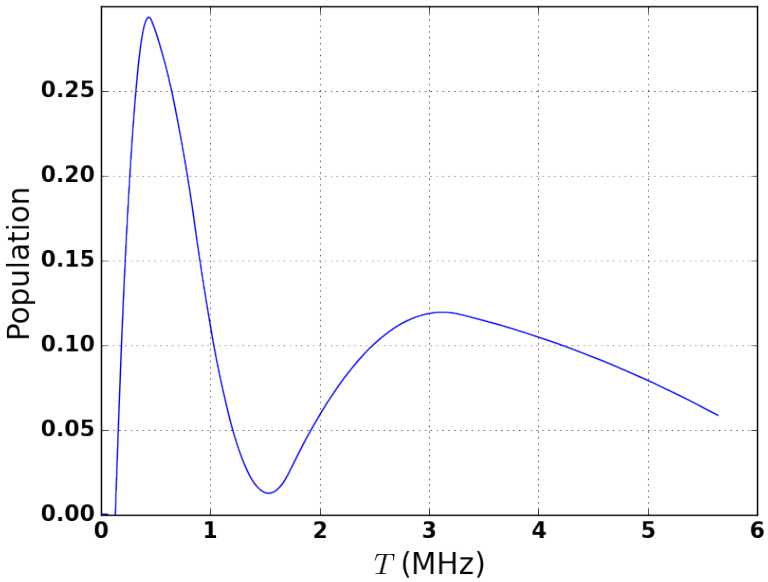

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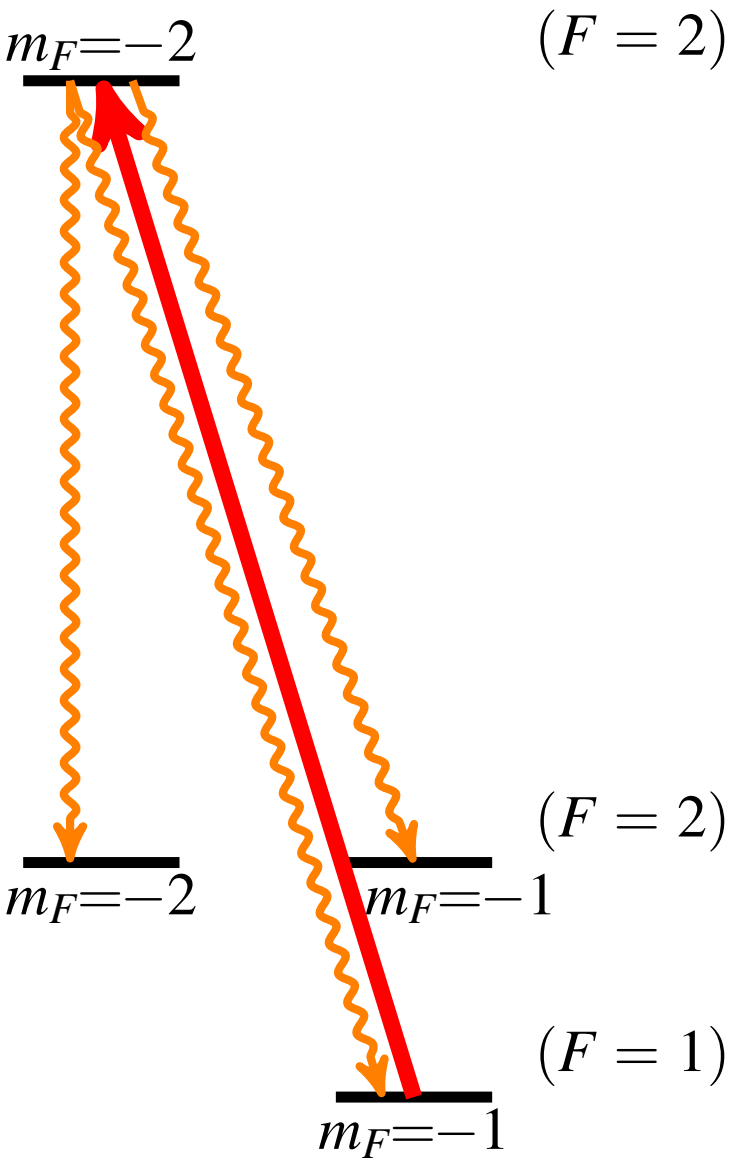

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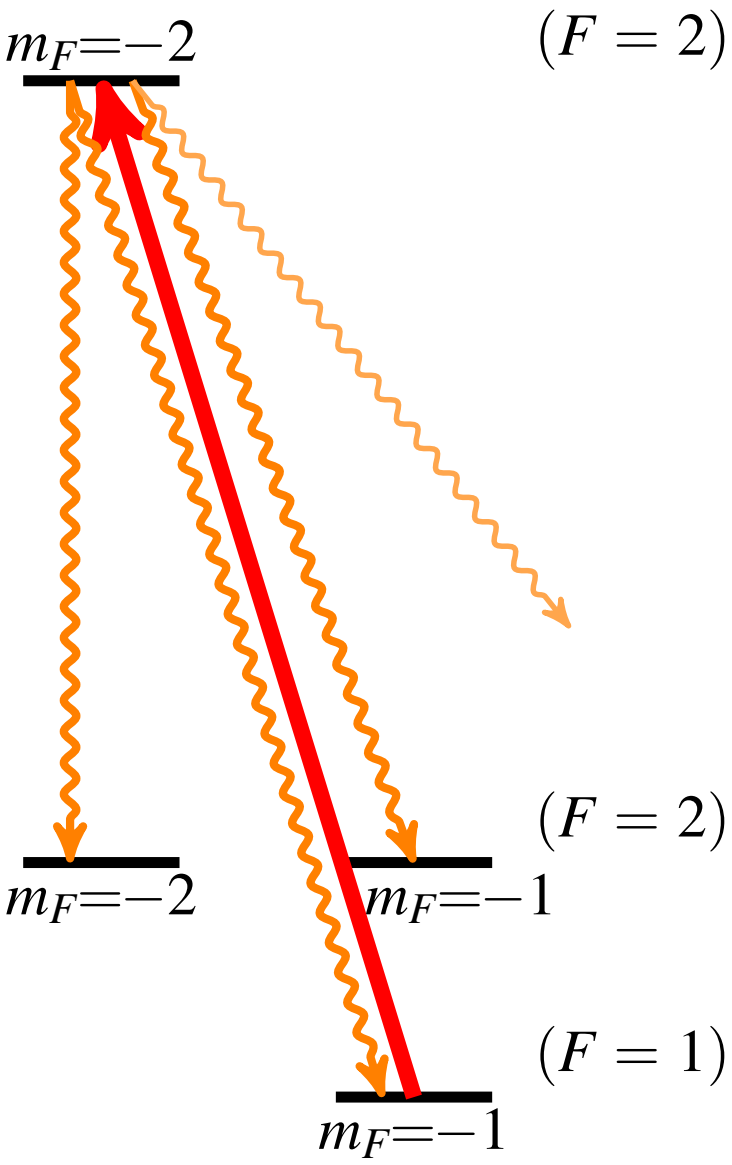

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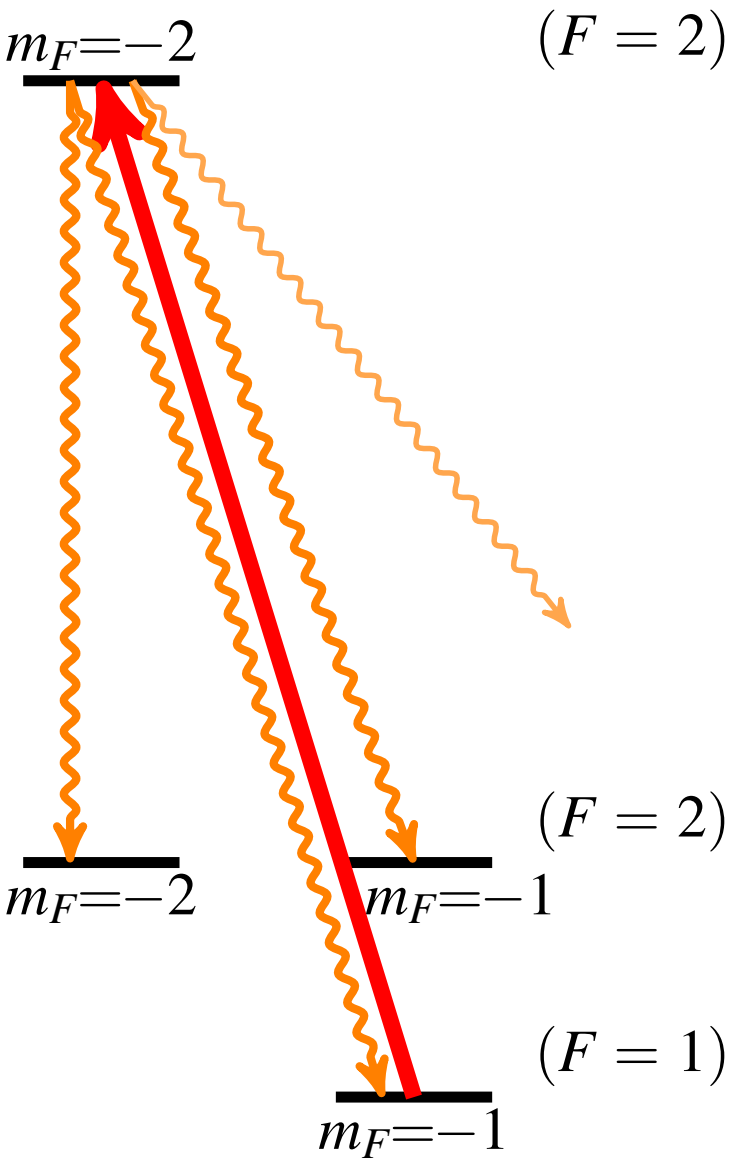
Raman sideband cooling



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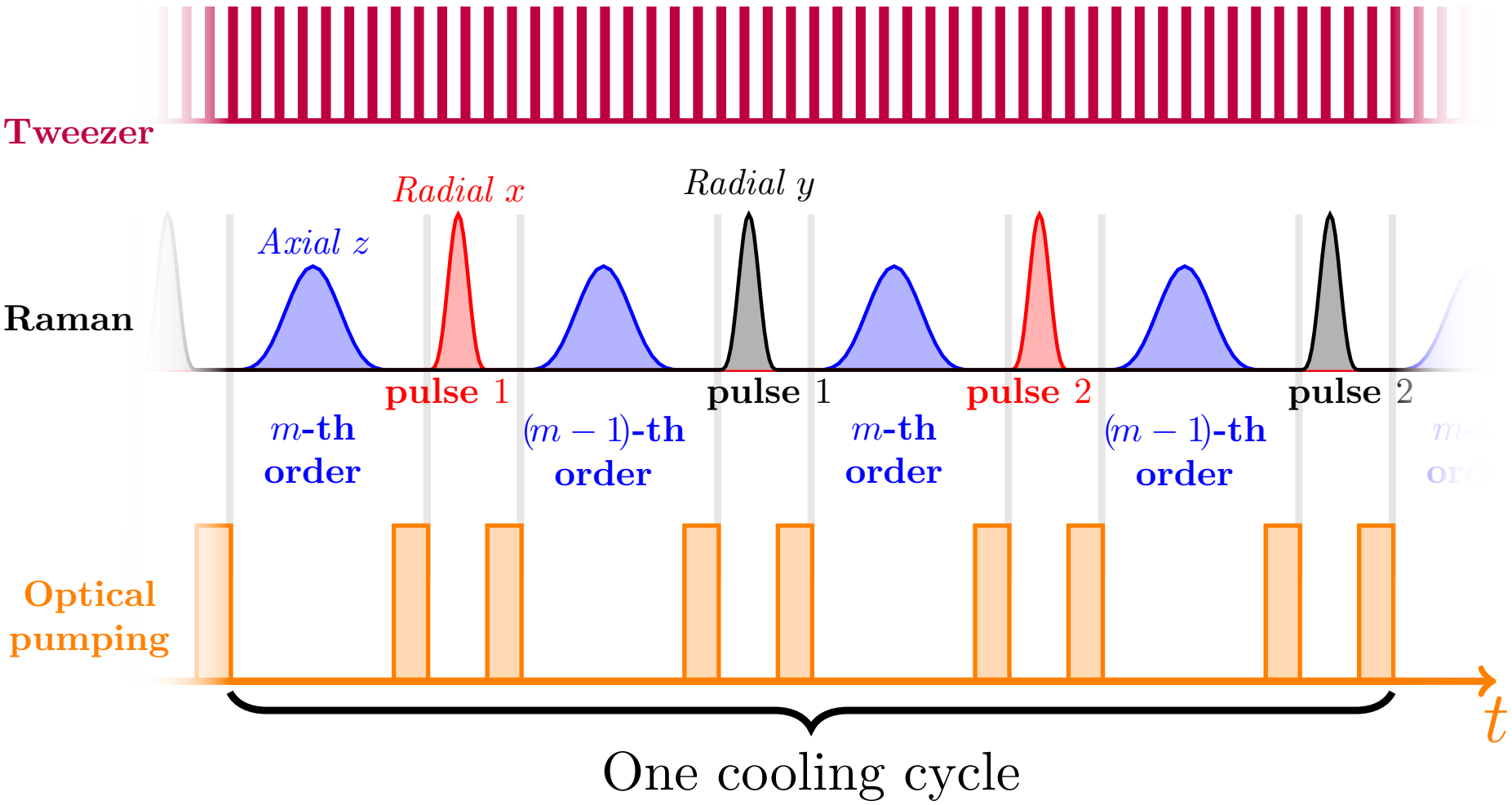
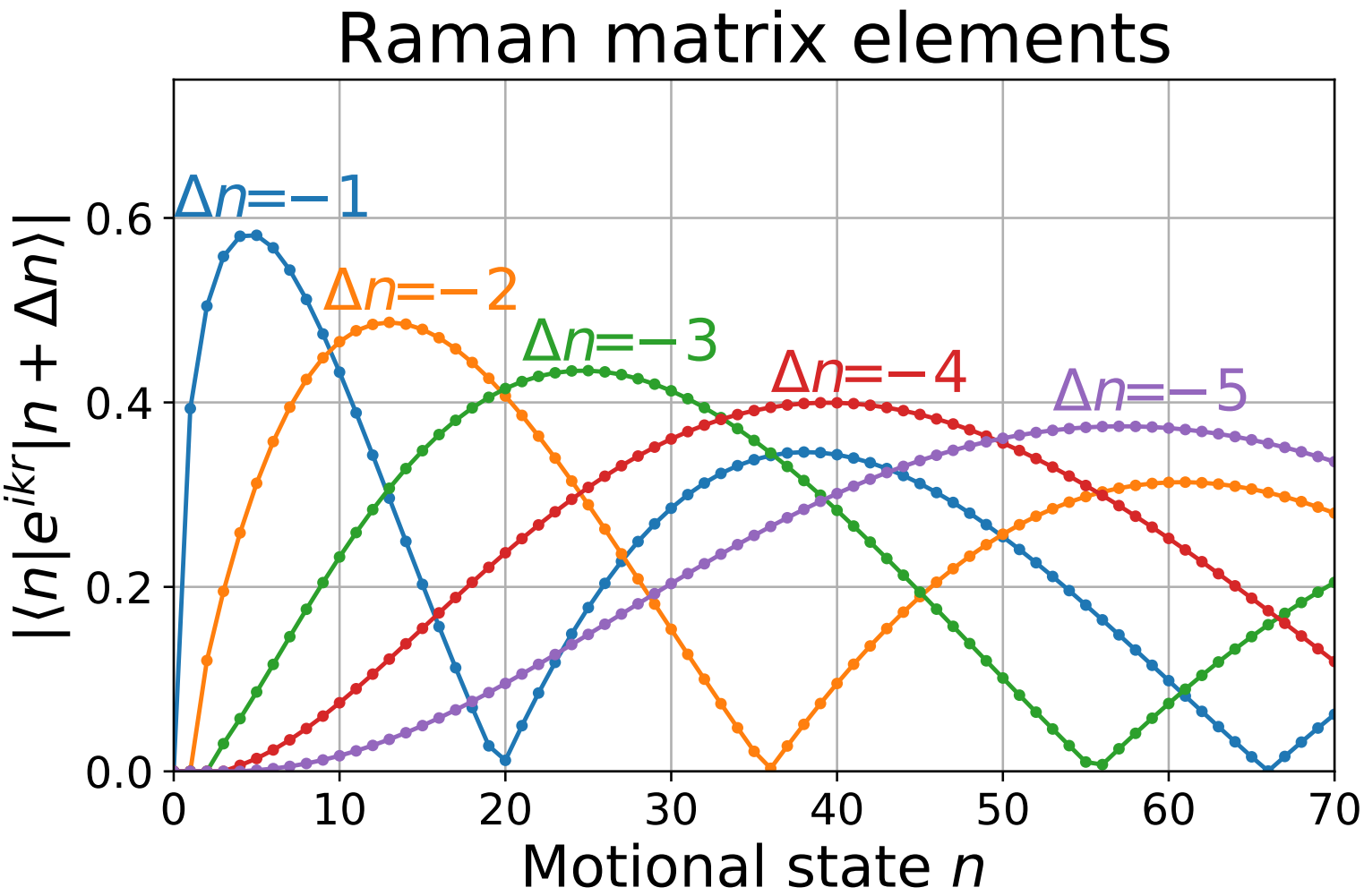
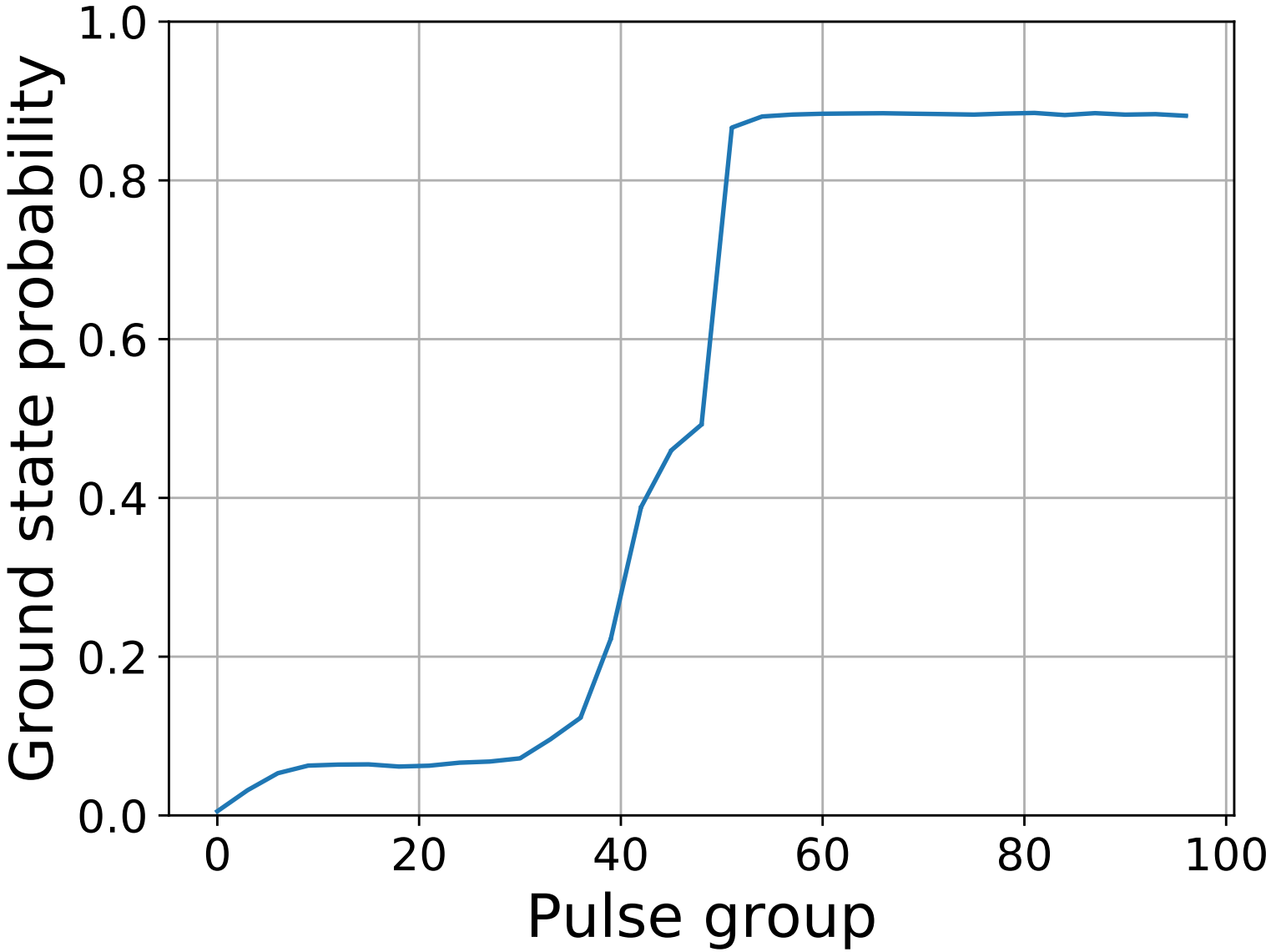
Sequence


Tweezer
Raman
Axial z
Radial x
Radial y
pulse 1
pulse 1
pulse 2
pulse 2
m-th order
$(m-1)$-th order
m-th order
$(m-1)$-th order
Optical pumping
t
One cooling cycle

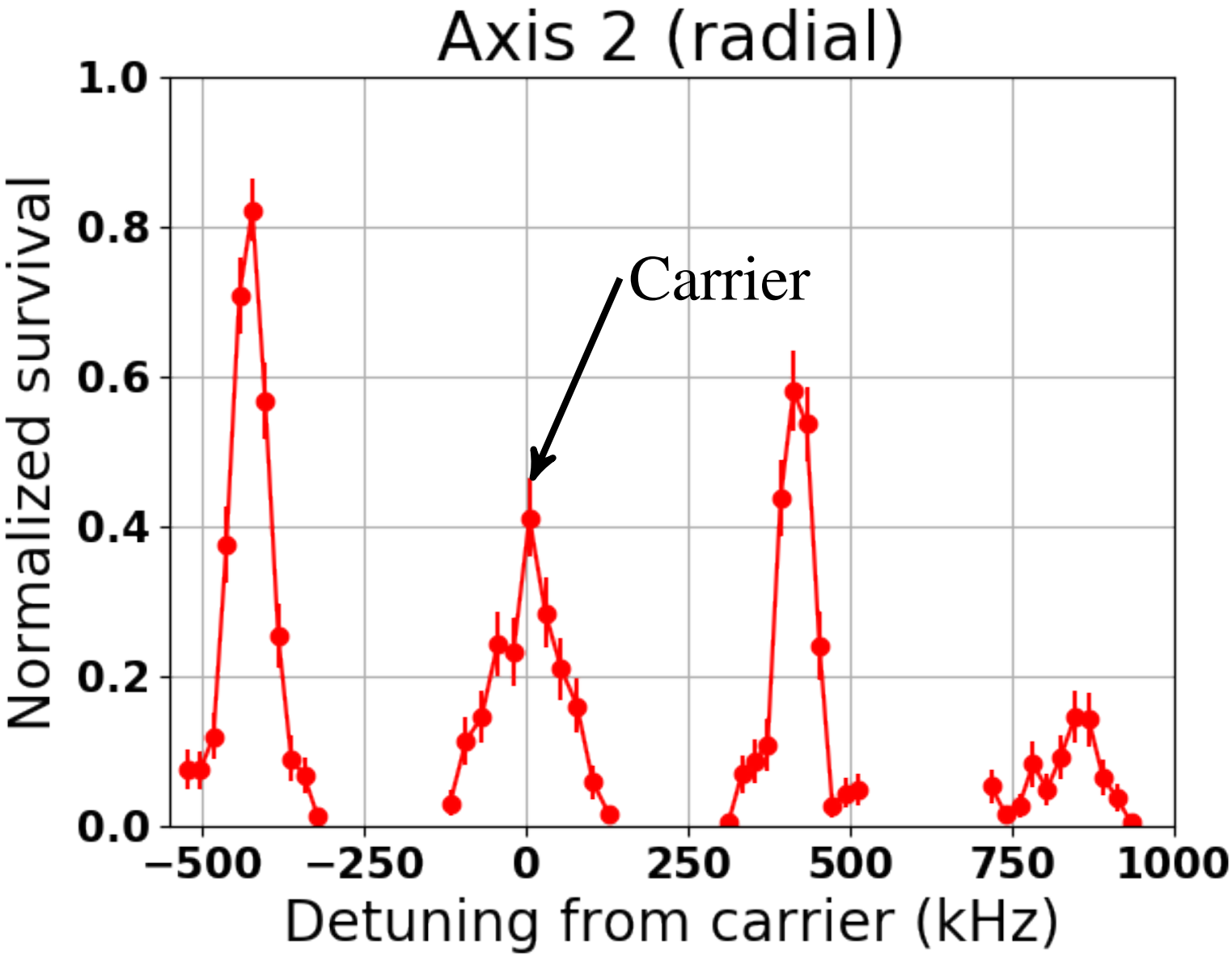
Sequence


Raman matrix elements
$\Delta n=-1$
$\Delta n=-2$
$\Delta n=-3$
$\Delta n=-4$
$\Delta n=-5$
$|\langle n|e^{ikr}|n+\Delta n\rangle|$
0.0
0.2
0.4
0.6
0
10
20
30
40
50
60
70
Motional state n

Sequence


Ground state probability
1.0
0.8
0.6
0.4
0.2
0.0
0
20
40
60
80
100
Pulse group

Raman sidebands



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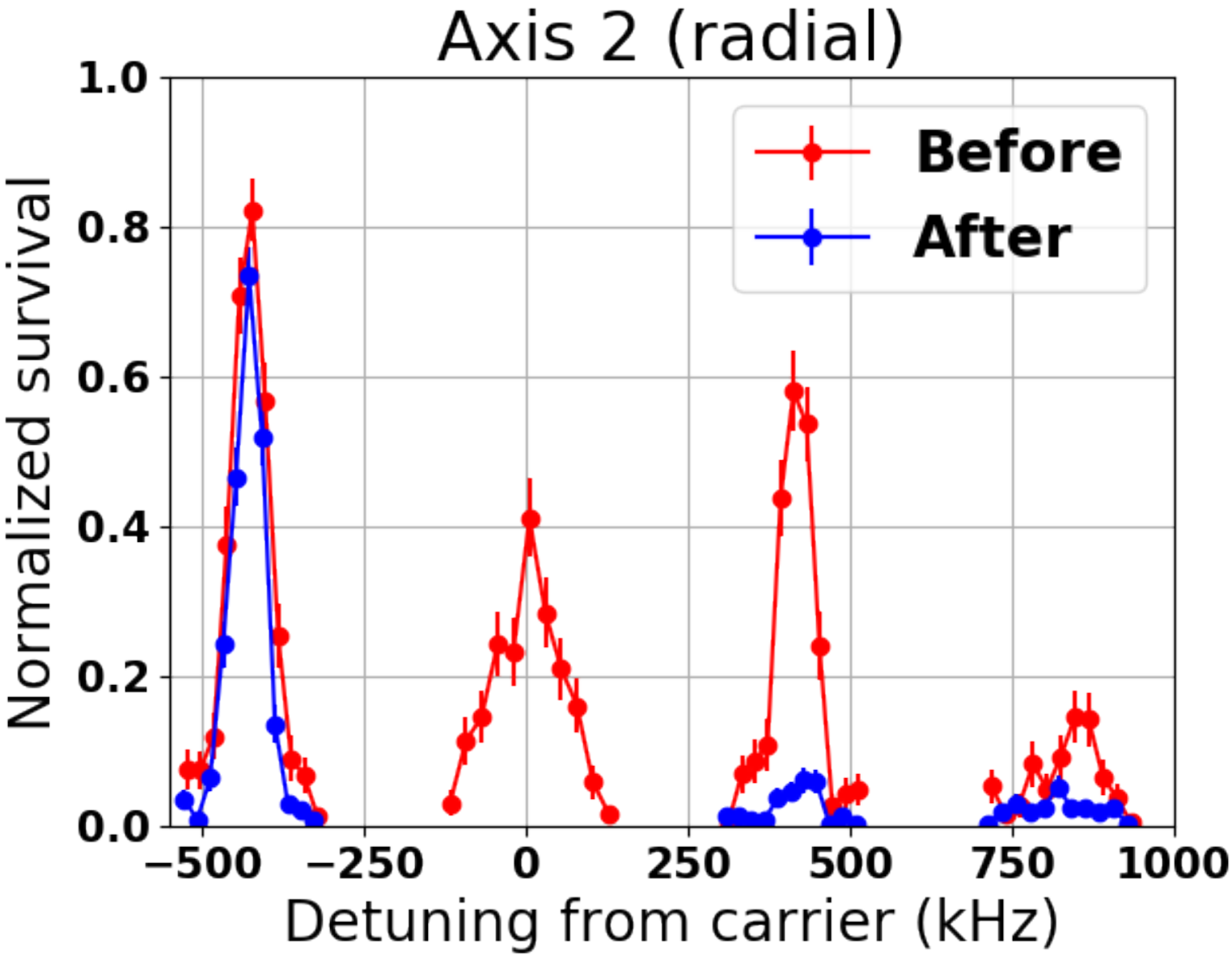
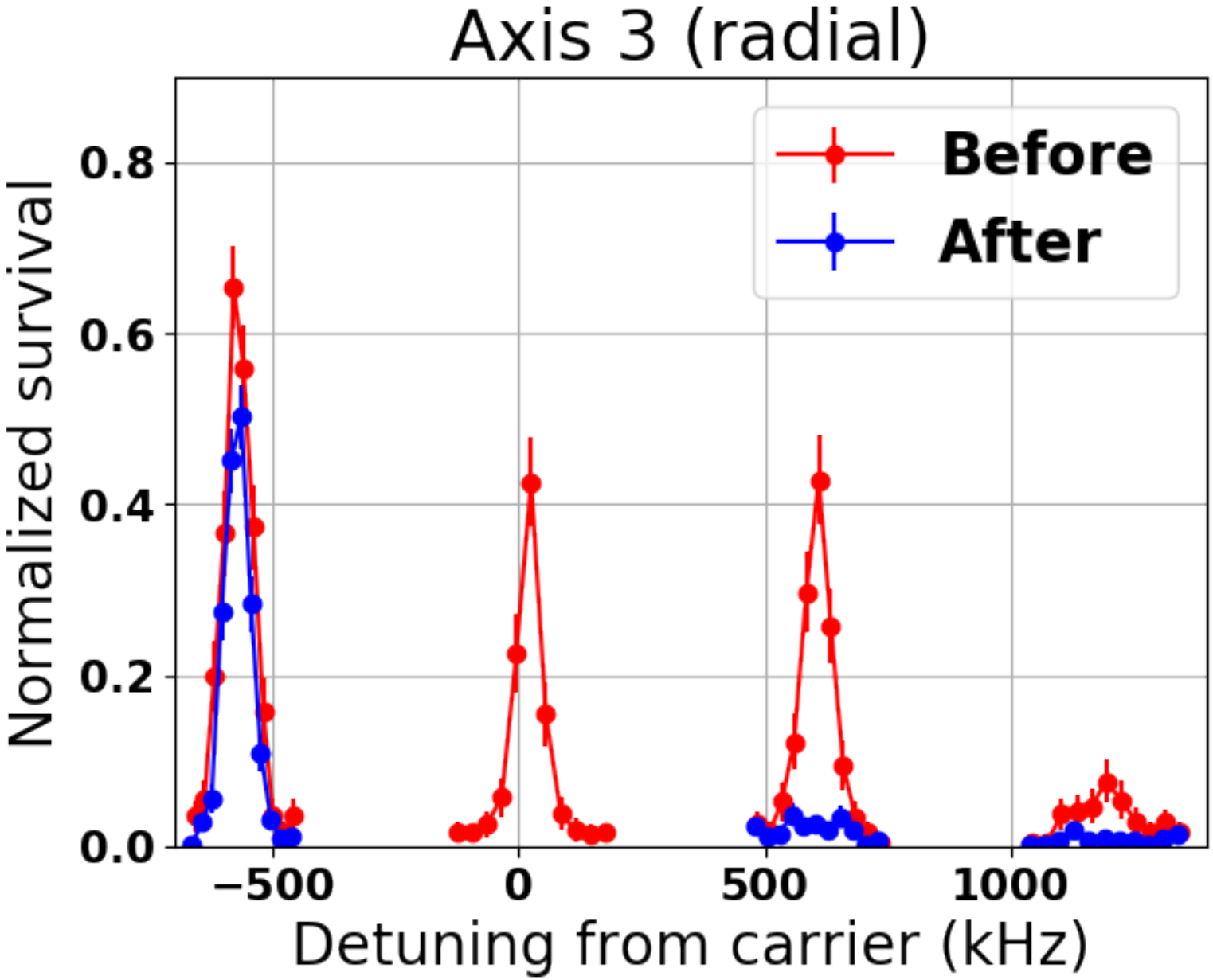
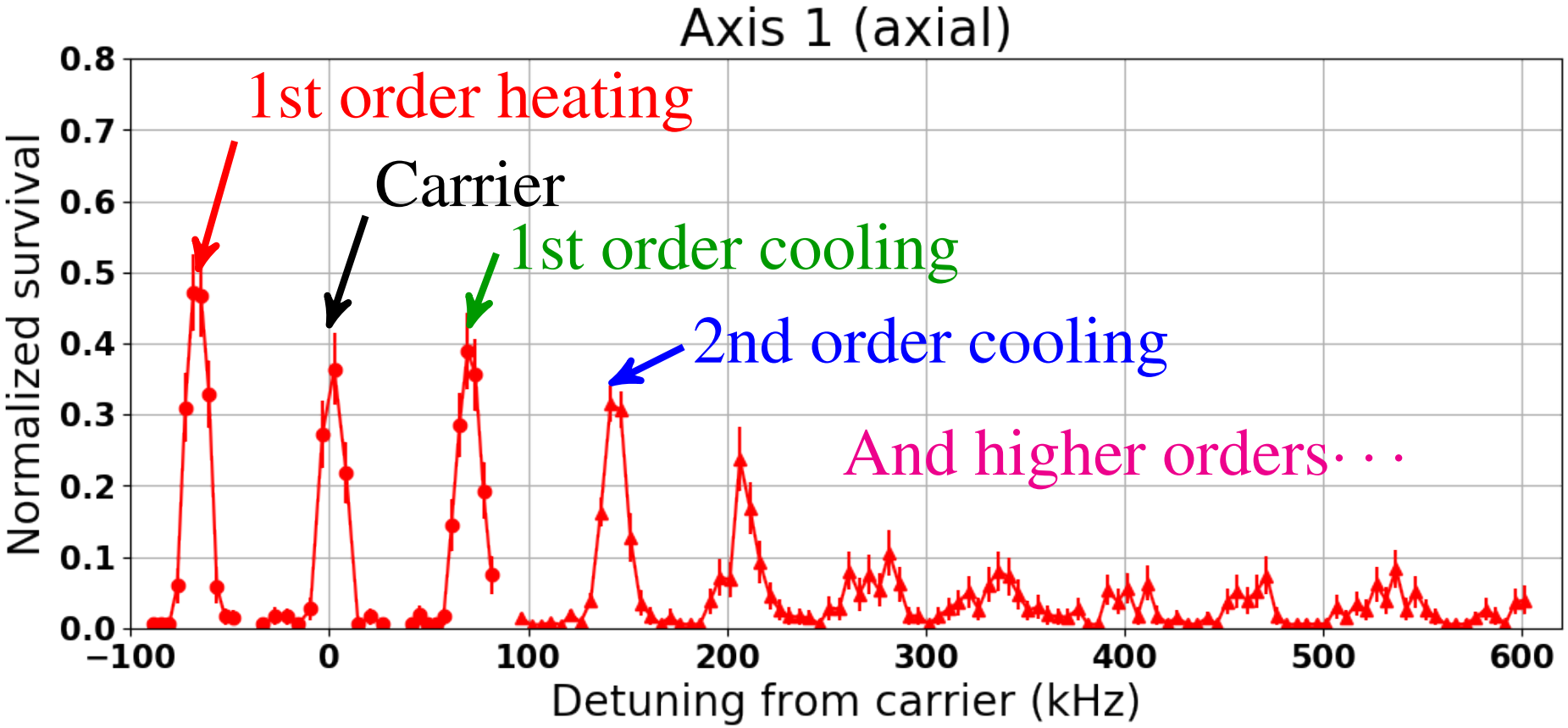


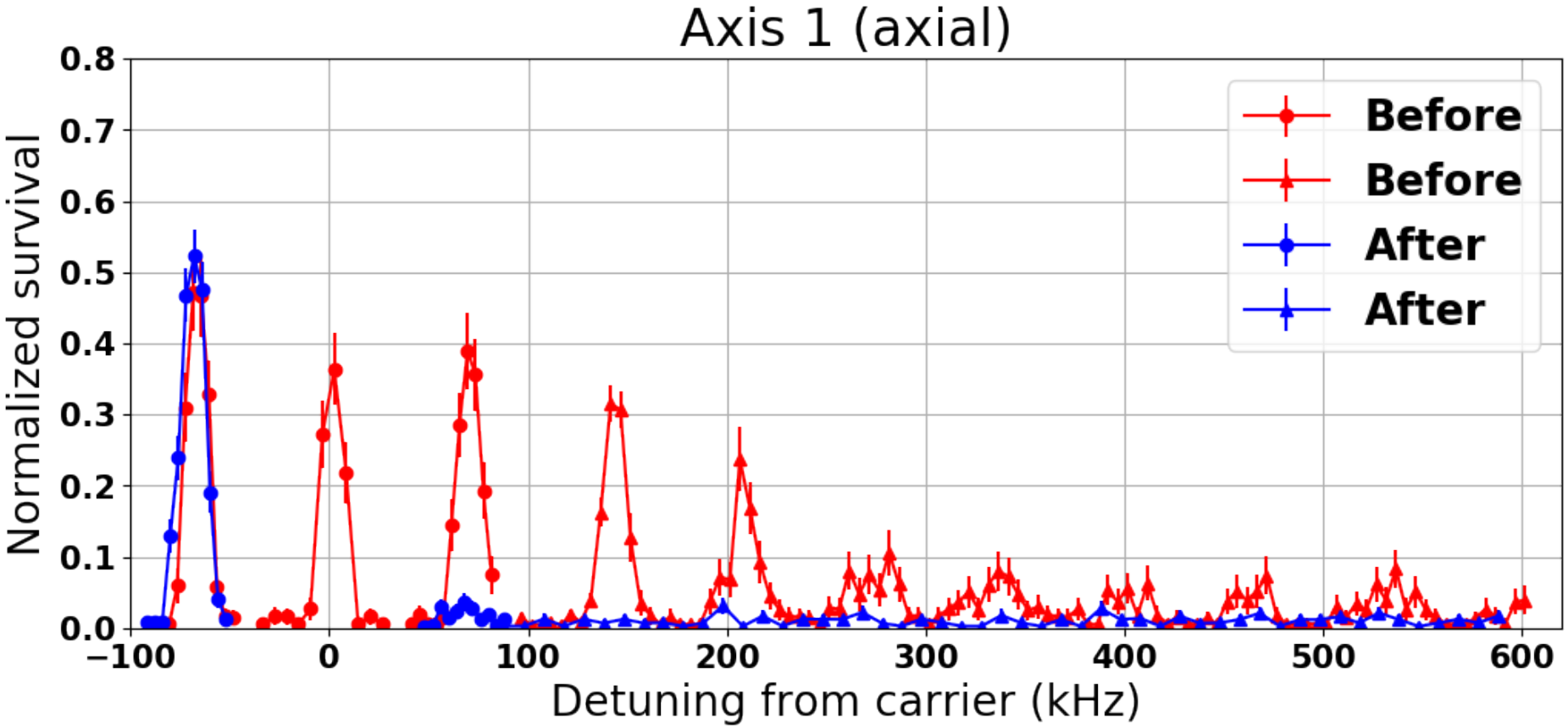
Raman sidebands



Raman sidebands

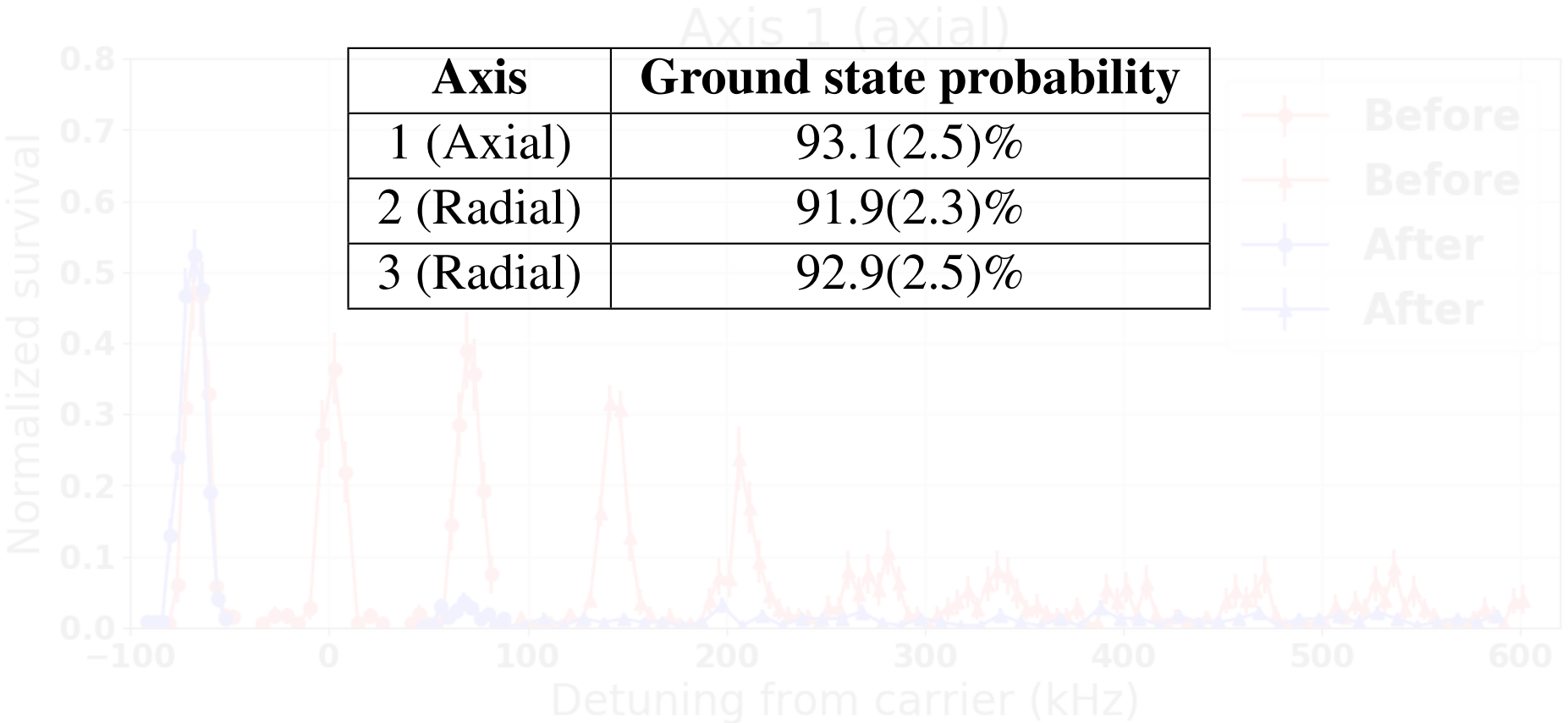


Raman sidebands



Raman sidebands

Axis	Ground state probability
1 (Axial)	93.1(2.5)%
2 (Radial)	91.9(2.3)%
3 (Radial)	92.9(2.5)%



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1 (Axial)	93.1(2.5)%
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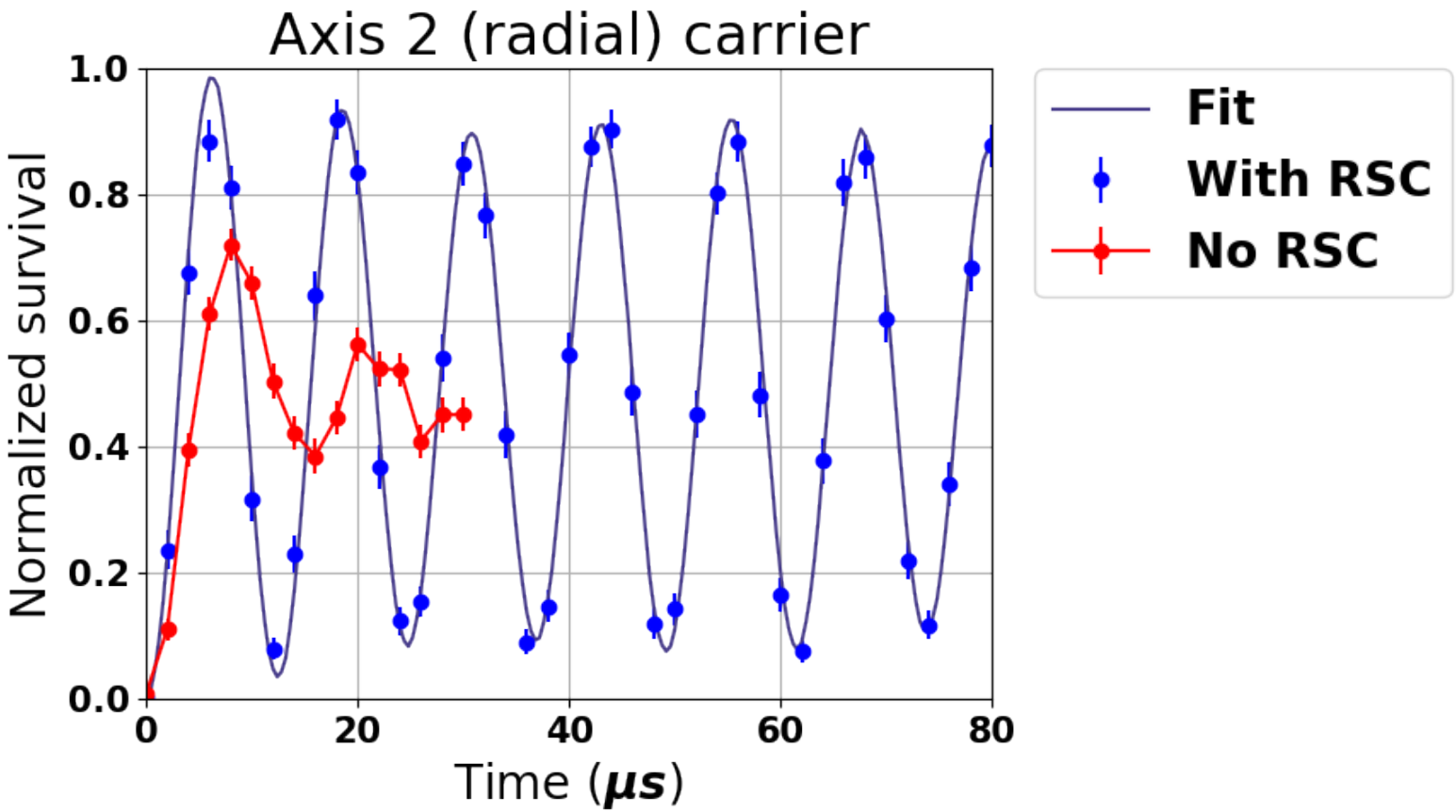
3 (Radial)	92.9(2.5)%

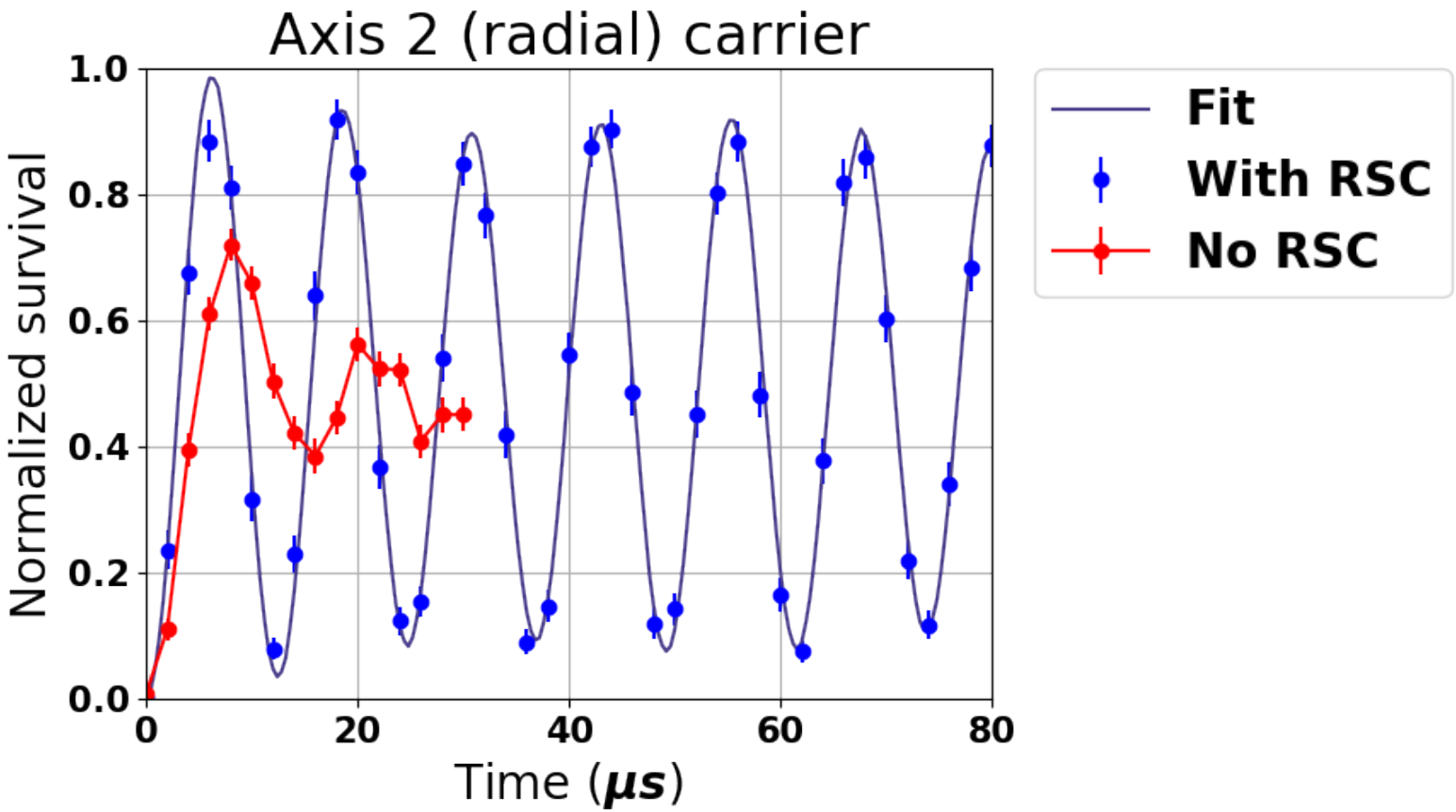
3D ground state: 79.5(3.6)%
Loss after cooling: 15%

Total 3D ground state preparation fidelity: 67.6(3.1)%

Rabi flopping (radial)

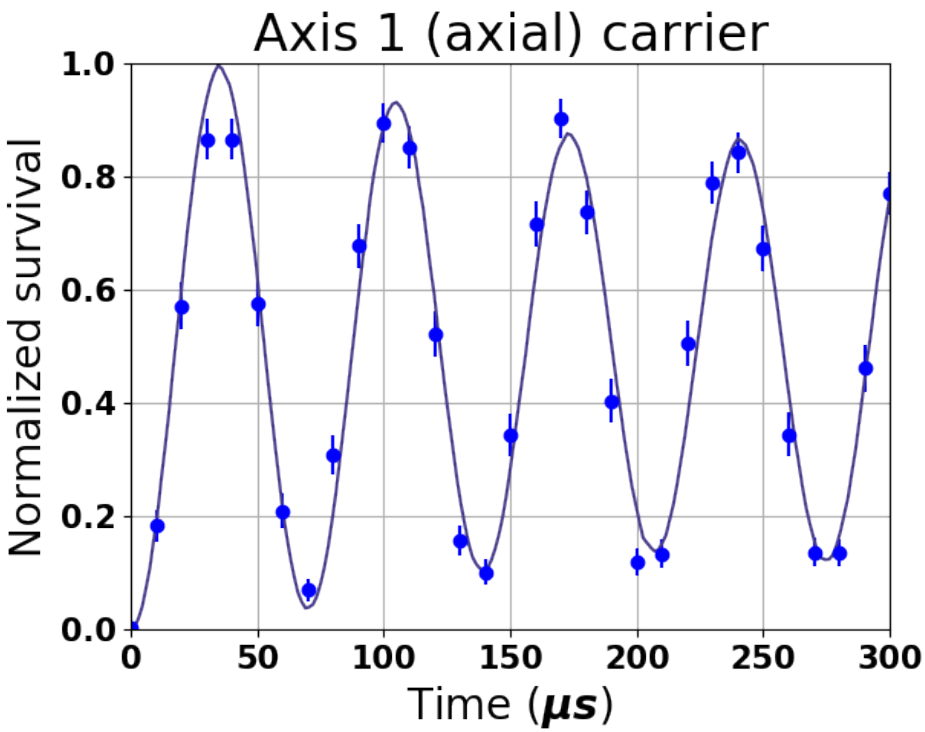


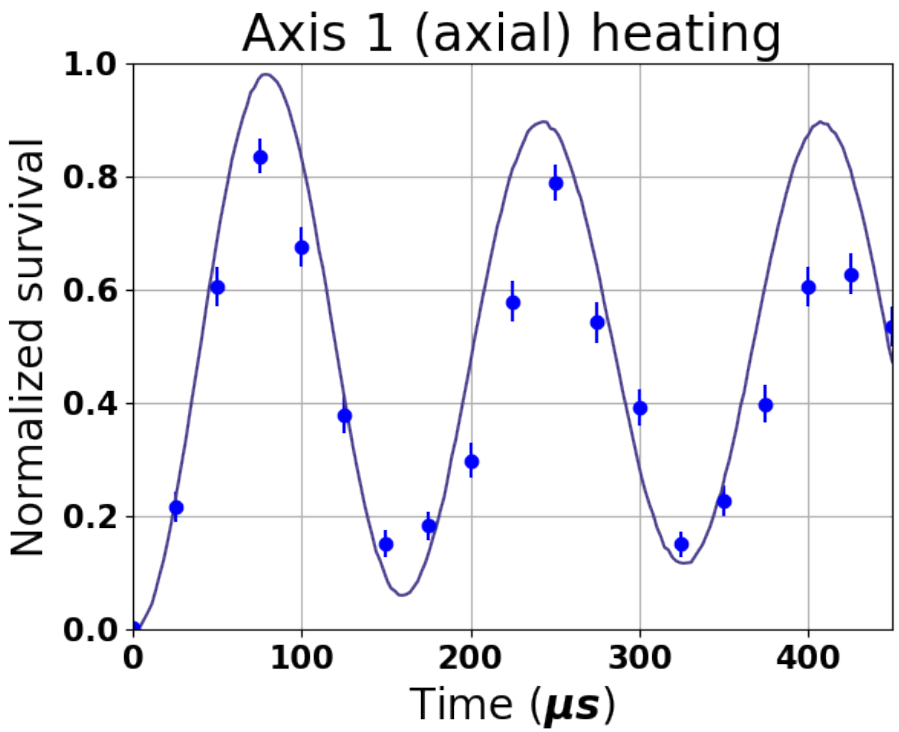
Rabi flopping (radial)



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

Rabi flopping (axial)





Next step