

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 blue, translucent, ellipsoidal volume. Inside and around this volume, numerous small molecular models are depicted, each consisting of blue and orange spheres connected by lines, representing atoms and bonds respectively. The overall scene is set against a dark, gradient background.

Yichao Yu

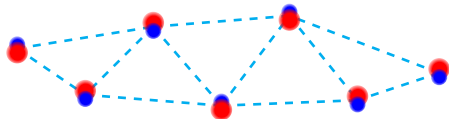
Ni Group/Harvard

Aug 11, 2017

Molecules in optical tweezer

Features

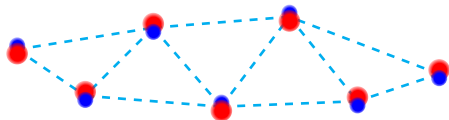
- Strong and tunable interaction
- Rich internal energy levels
- High filling fraction
- Single site detection and manipulation



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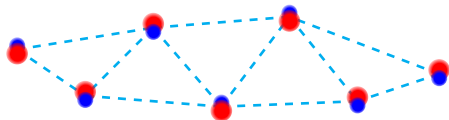
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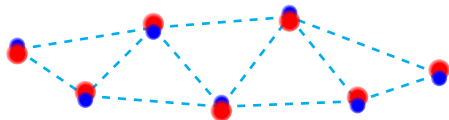
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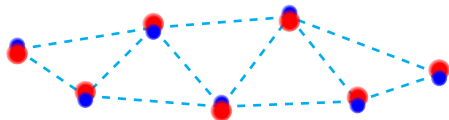
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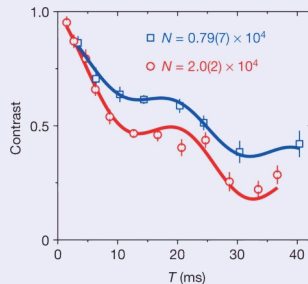
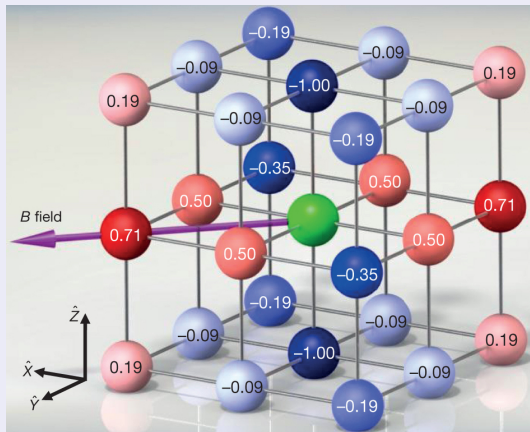
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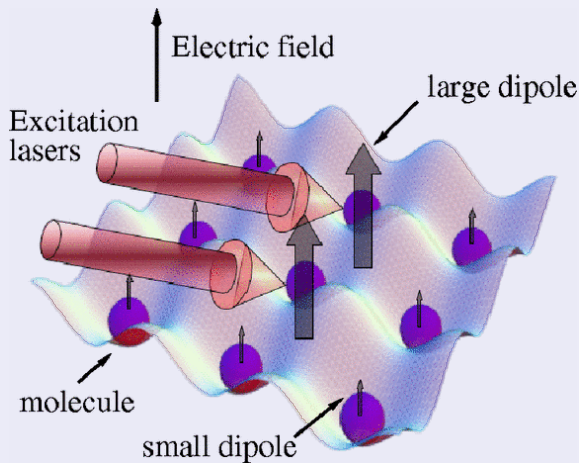


Simulation of many-body system^[1]



[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", 4 (2006).

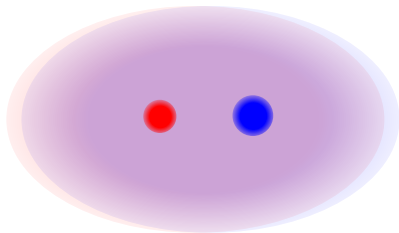
Making molecules from atoms

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



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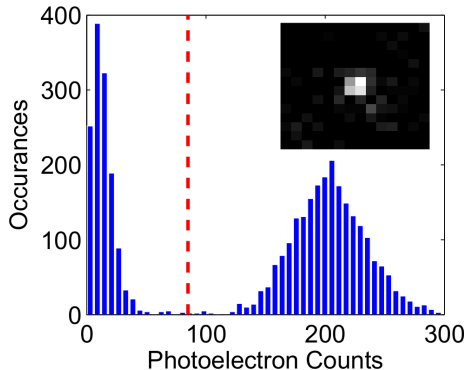
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Atom loading and cooling

Cesium

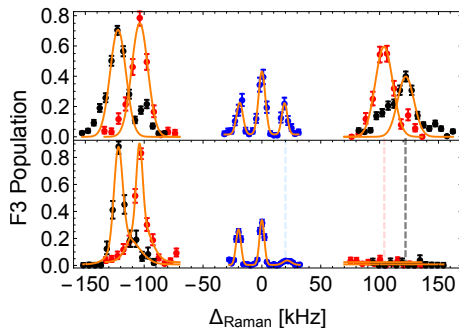
- Single atom
- 85% Ground state



Atom loading and cooling

Cesium

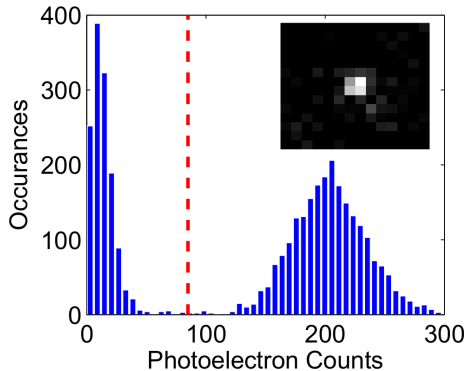
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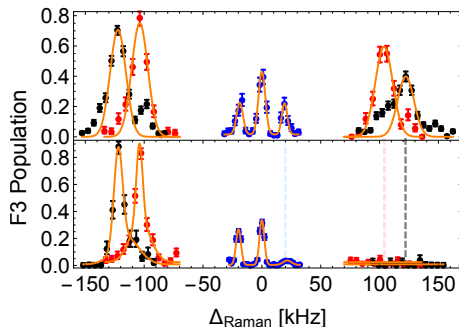
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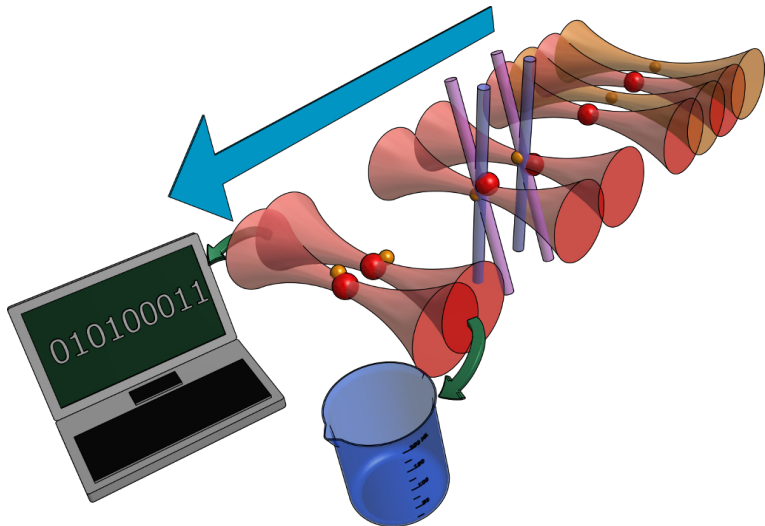
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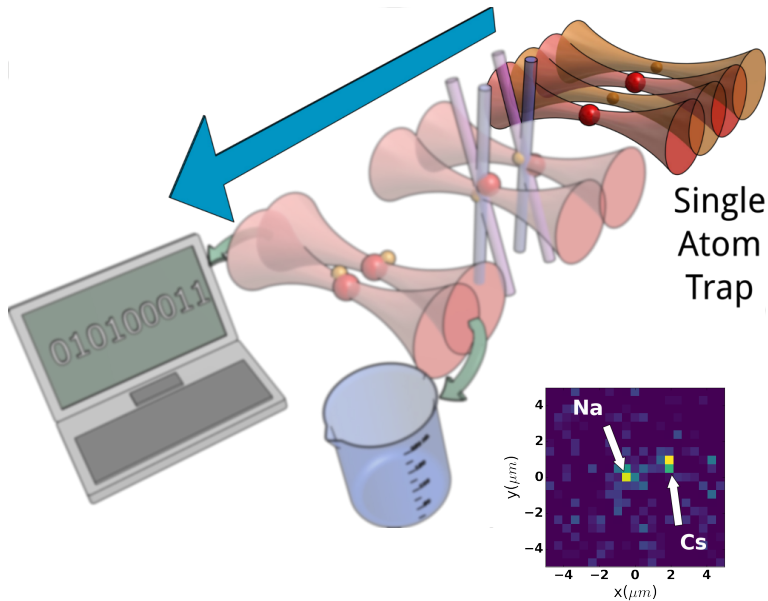
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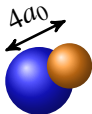
Setup



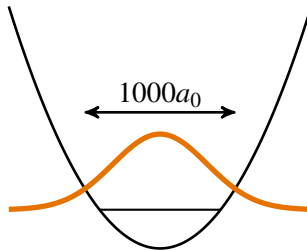
Setup



Wave function size mismatch



Molecule



Atom

Goal of cooling

- Single initial state
- Shrink wavefunction size

Raman sideband cooling of Sodium

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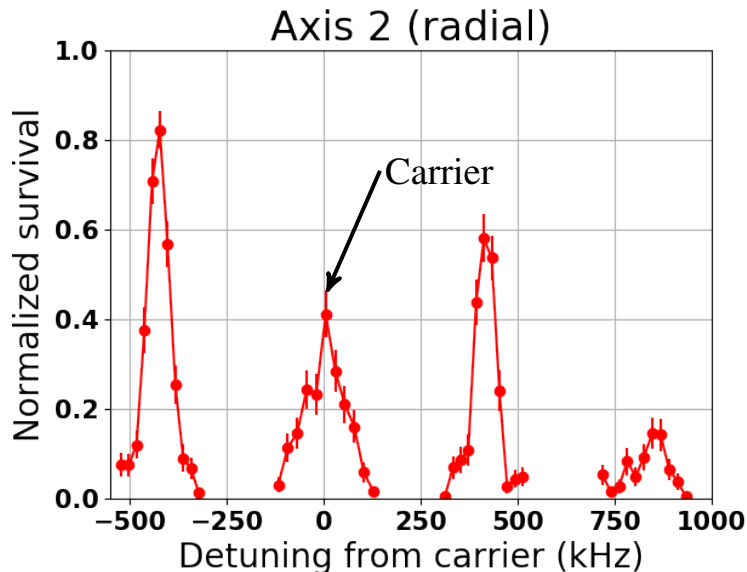
Difficulties

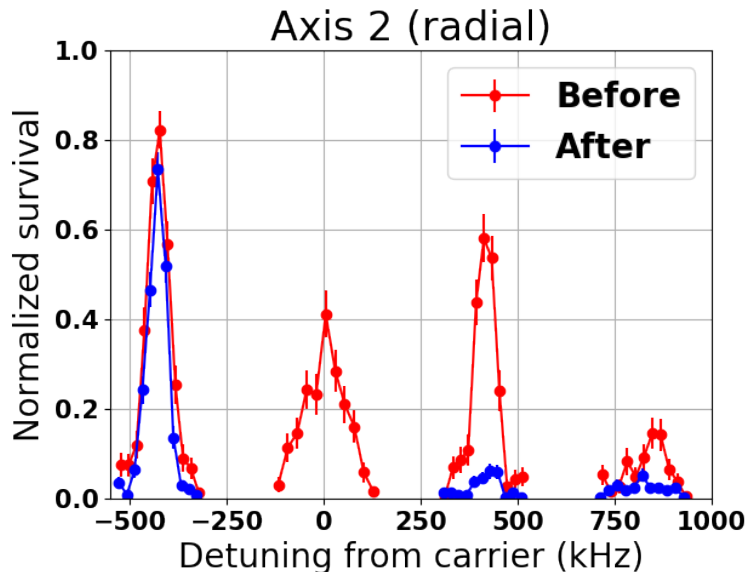
- High initial temperature ($40\mu K$)
- High recoil heating (High Lamb Dicke parameter)

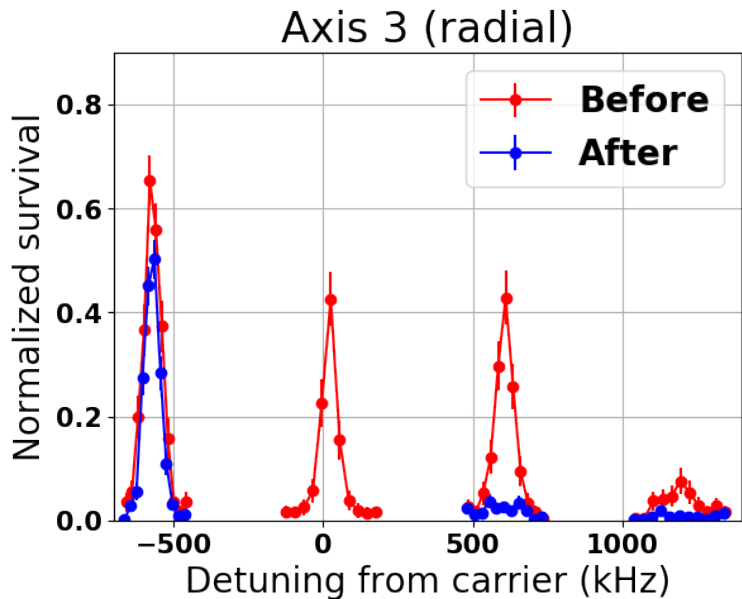
Raman sideband cooling of Sodium

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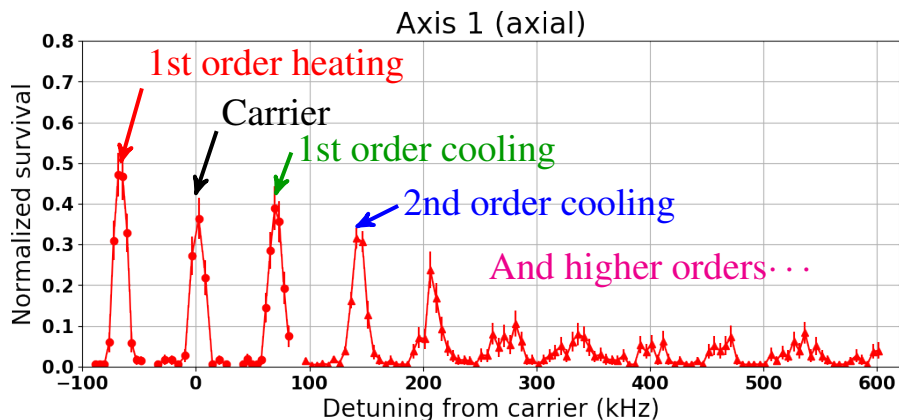
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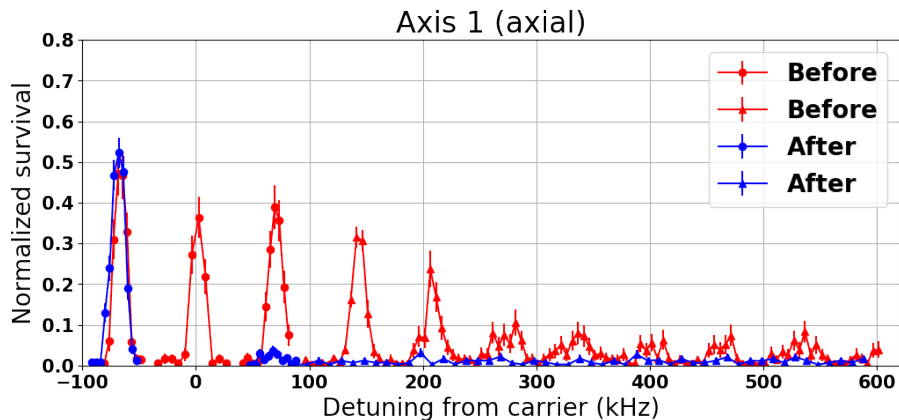




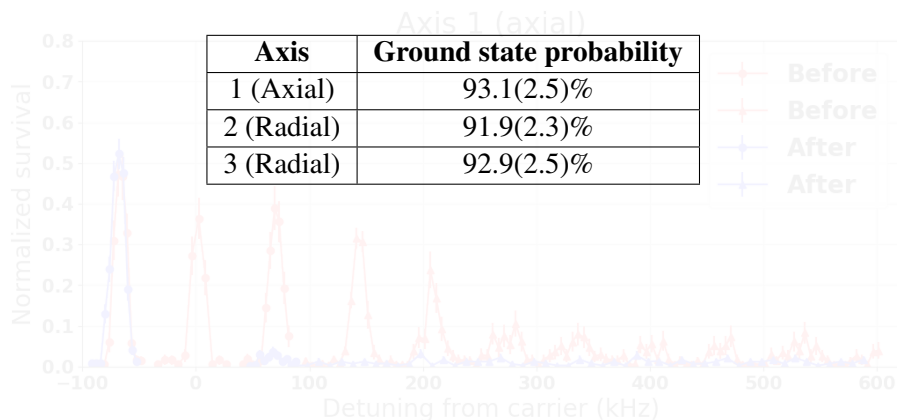
Raman sidebands



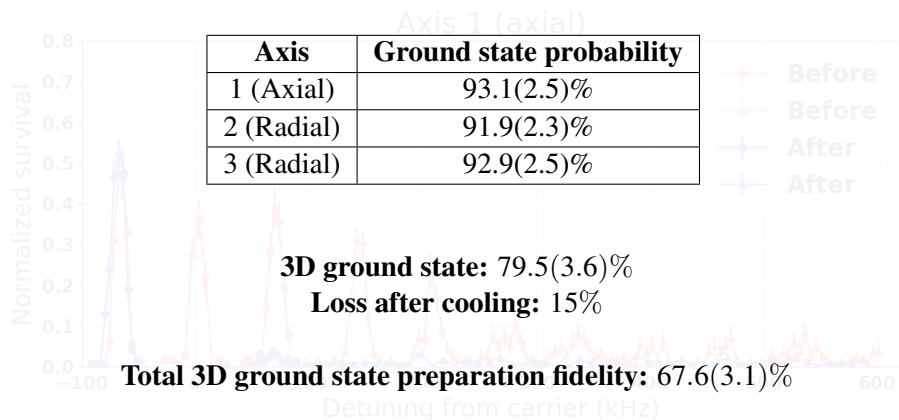
Raman sidebands



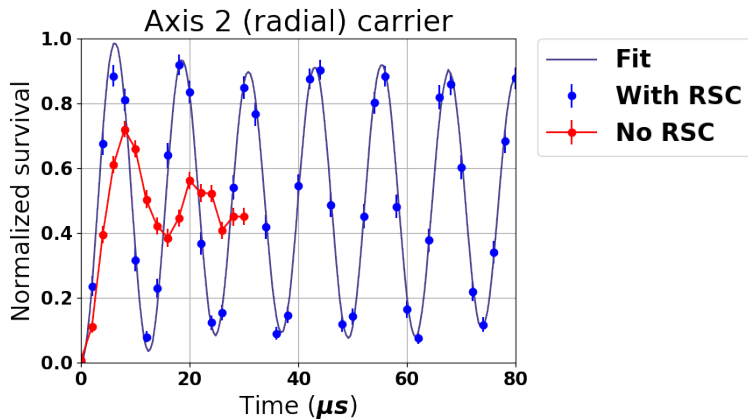
Raman sidebands



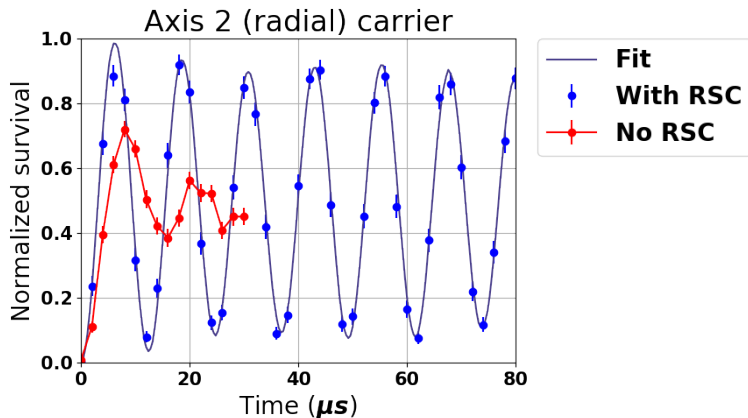
Raman sidebands



Rabi flopping (radial)

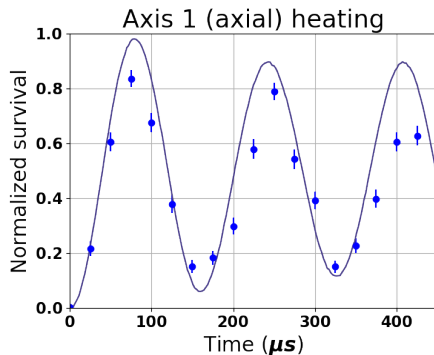
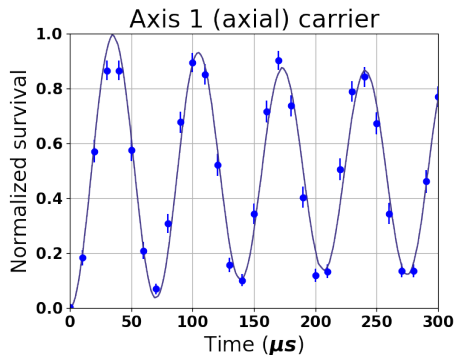


Rabi flopping (radial)



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

Rabi flopping (axial)



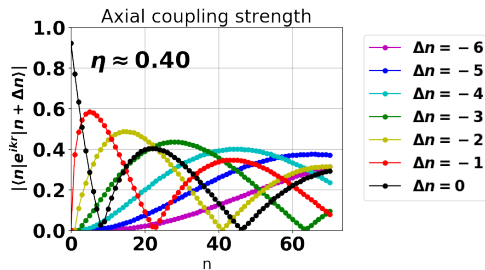
Conclusion

67.6(3.1)% ground state preparation fidelity (79.5(3.6)% without loss)

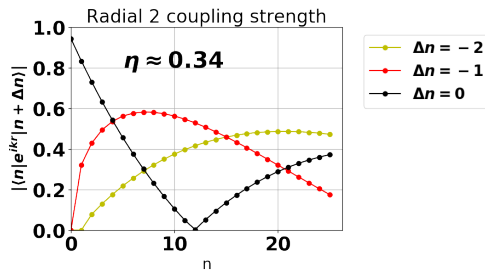
Improvements

- Reduce off-resonance scattering from Raman beams
- Reduce magnetic field fluctuation
- Reduce loss during cooling

Axial matrix element



Radial 2 matrix element



Radial 3 matrix element

