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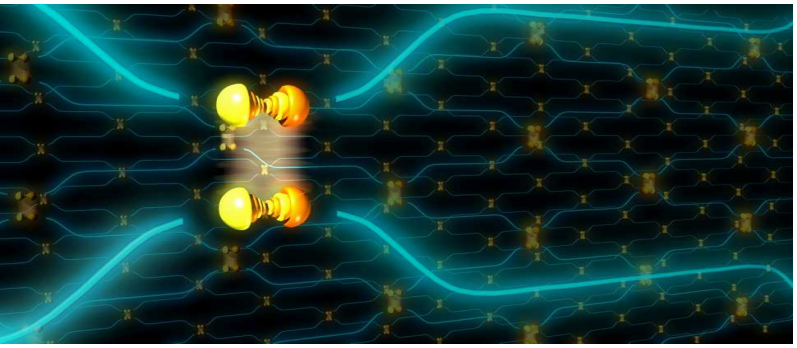

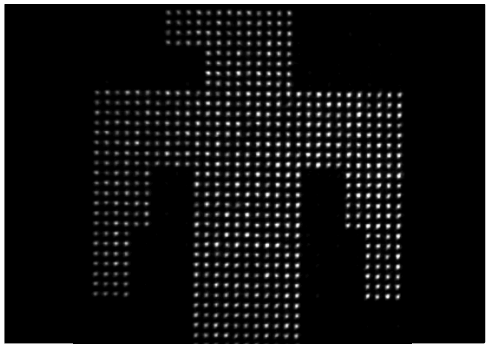

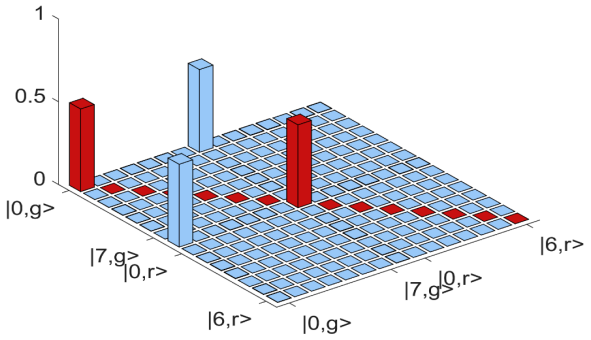

Exploring decoherence in the Sandia Rydberg atom experiment

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- Ivan Deutsch (UNM)

U.S. DEPARTMENT OF ENERGY | NNSA National Nuclear Security Administration

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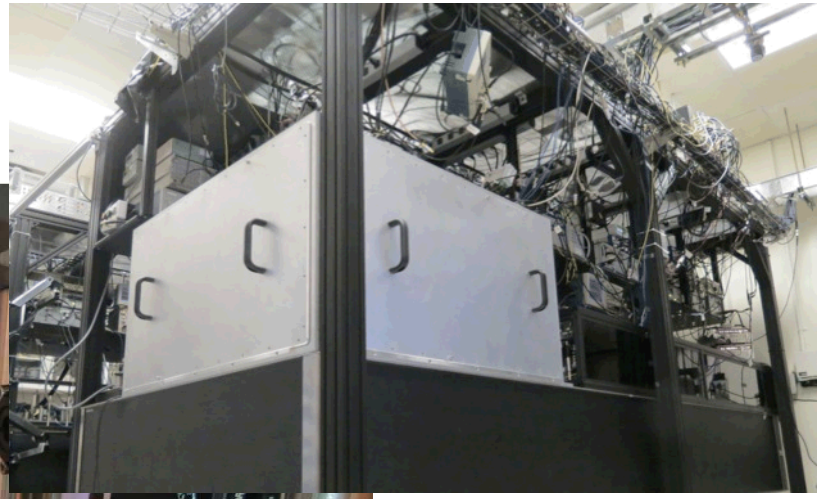
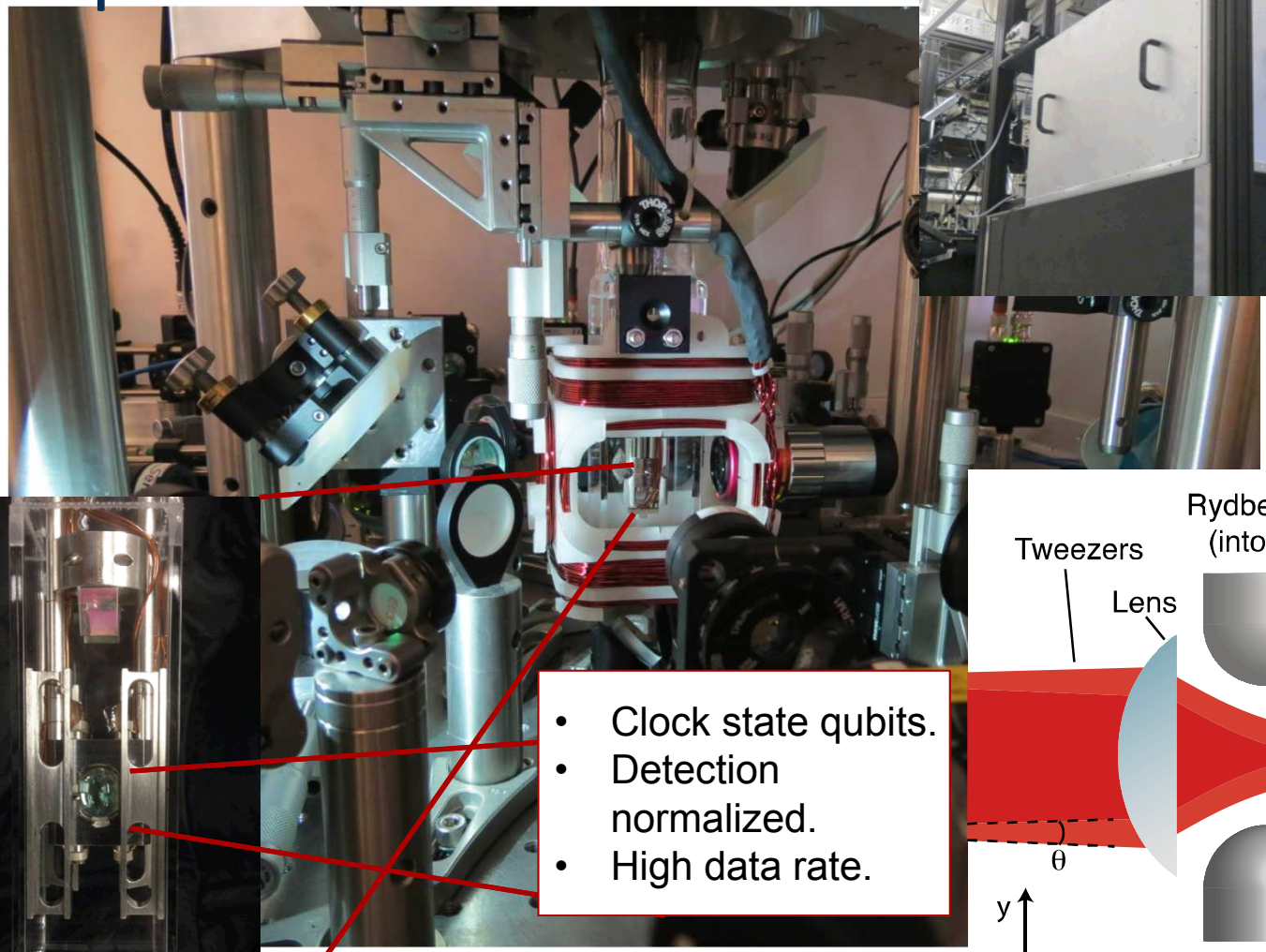
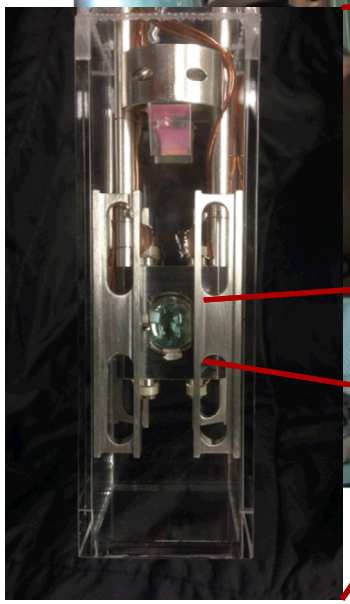
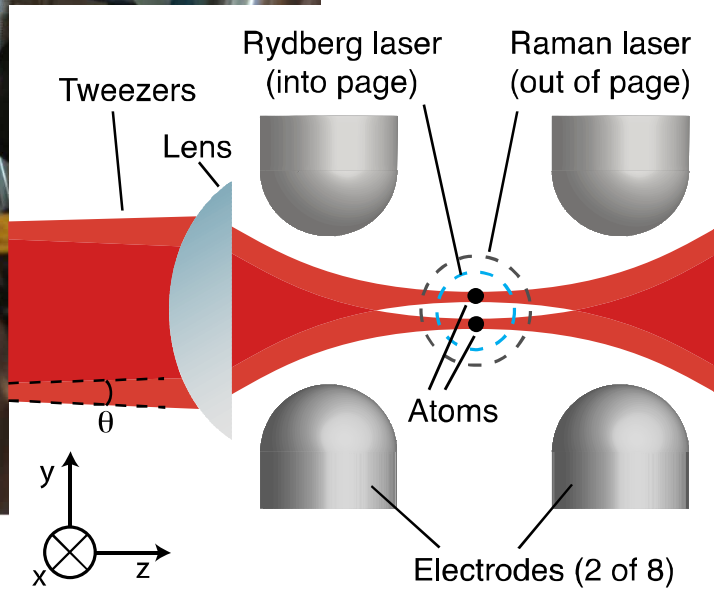
Sandia Rydberg experiment







- Clock state qubits.
- Detection normalized.
- High data rate.



First the easy questions:

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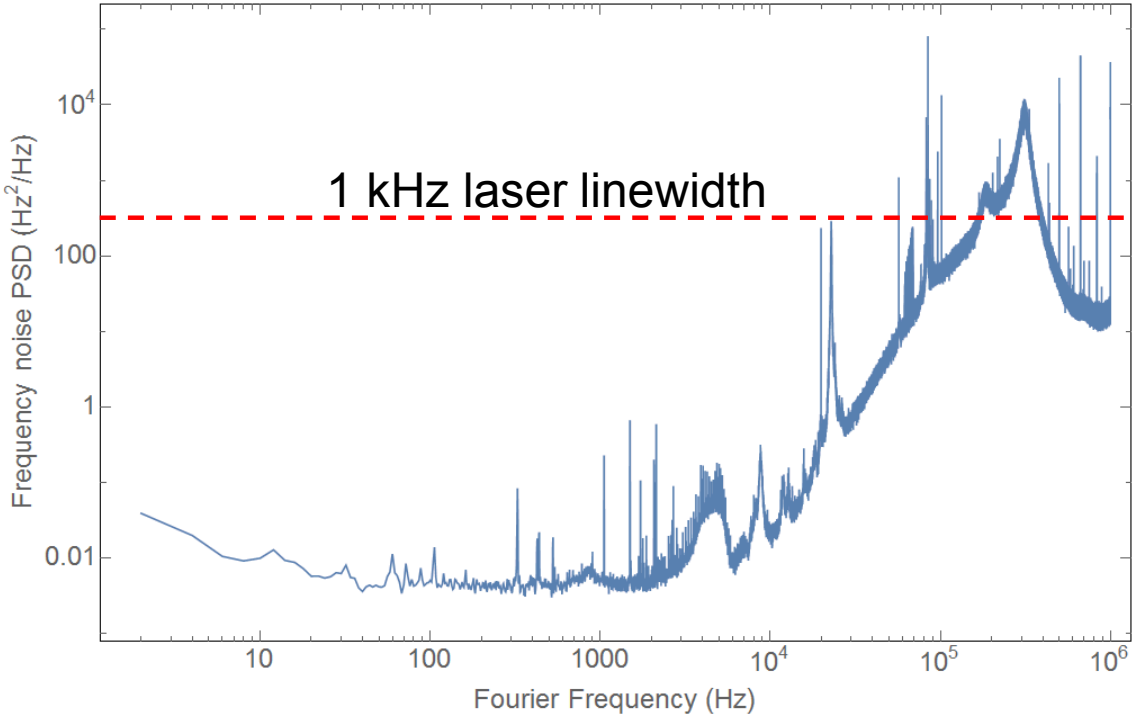
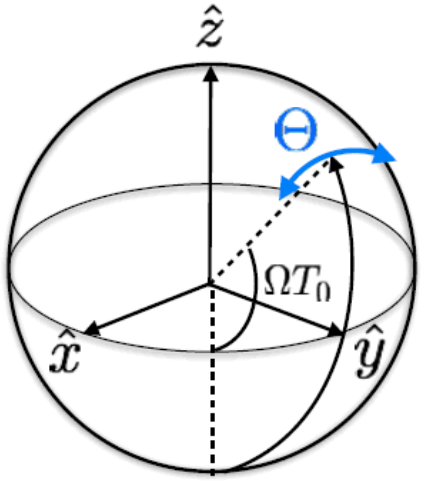
- Principal quantum number? Cs $64P_{3/2}$
- 2-photon or 1-photon excitation scheme? 1 Photon
- Typical atomic temperature? 10 uK
- Chamber type? Glass Cell
- Experiments performed in trap or switched off? Switched off (typically).
- Have you characterized intensity fluctuations of the Rydberg laser at the atoms? Yes, pulse areas consistent to better than 1%

In-loop 318 laser noise

- Represents an absolute best-case scenario of laser noise.





Laser noise can affect contrast:

$$\chi = \langle \cos\Theta \rangle = e^{-\langle \Theta^2 \rangle / 2} \quad \text{where} \quad \langle \Theta^2 \rangle = (2\pi)^2 \int_0^\infty df G_\nu(f) |R(f)|^2$$

At this time, we don't see evidence this is limiting coherence.

Dressed spin-flip blockade (more from Grant)

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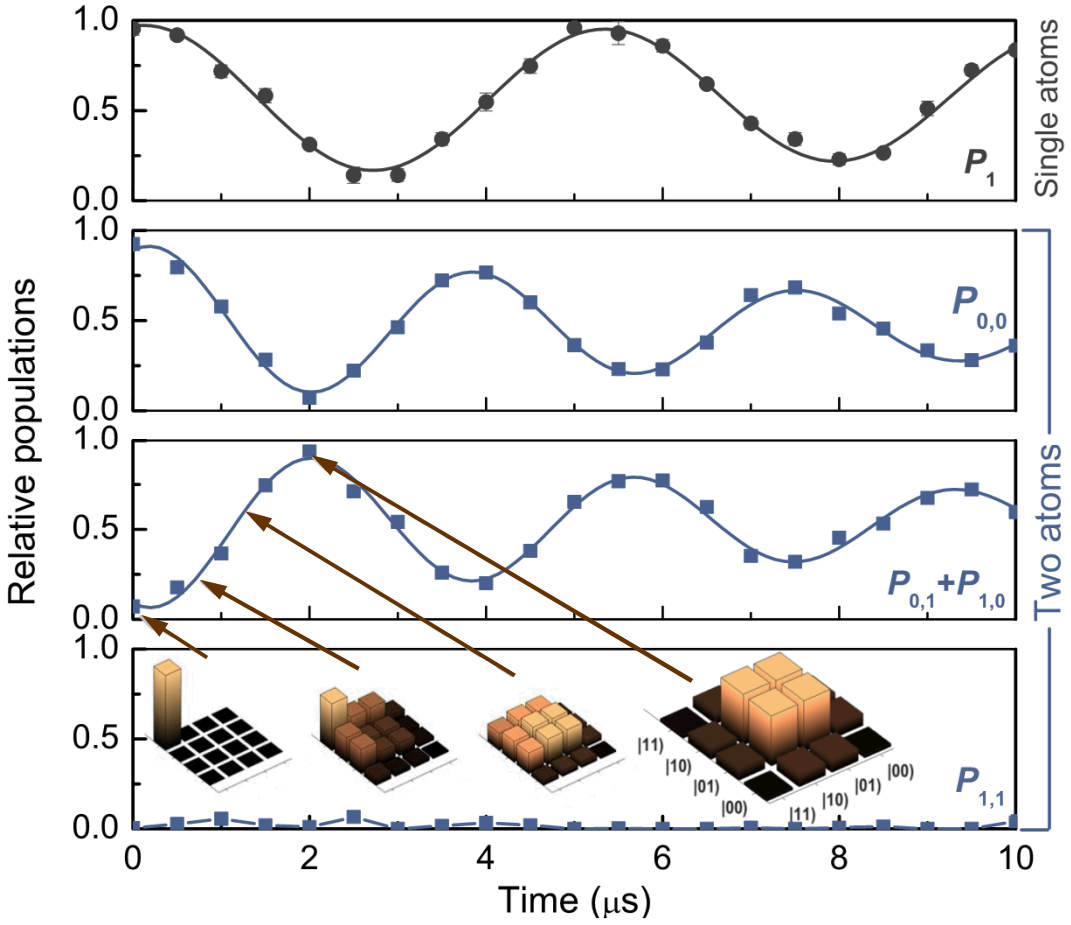
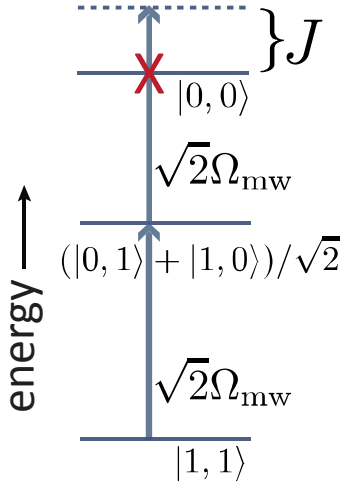
Initial state is $|1\rangle$ or $|1,1\rangle$, $J/h \approx 750$ kHz



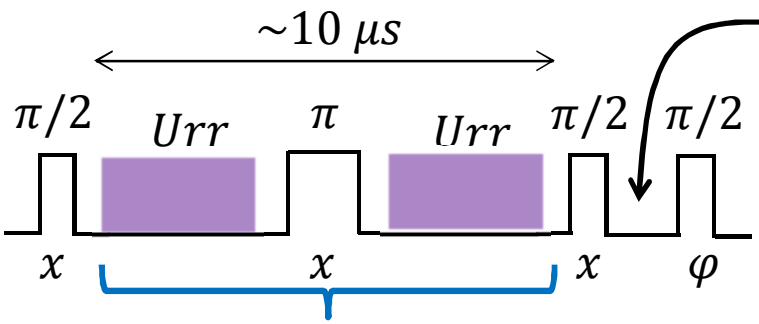


Two-atom Rabi oscillations

- $\sqrt{2}$ faster
- Transfer to $|1,1\rangle$ inhibited
- Bell state $|\Psi+\rangle$ at $t = \pi/\sqrt{2}\Omega_{mw}$

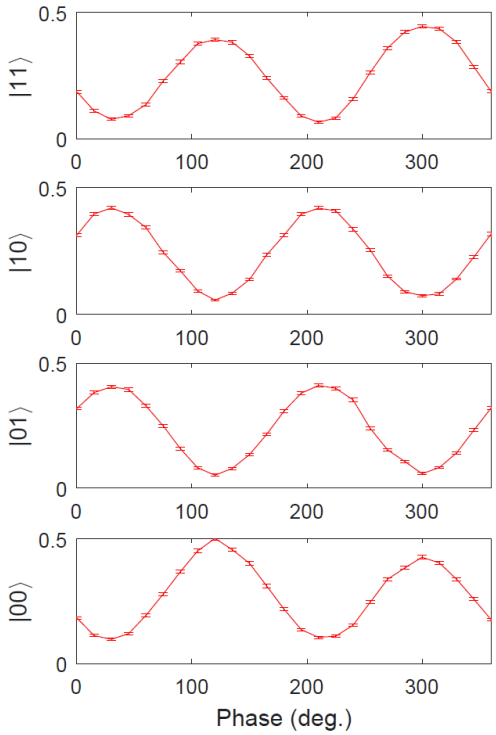
Process occurs entirely and directly in the ground state

Dressed CPHASE gate (more from Grant)

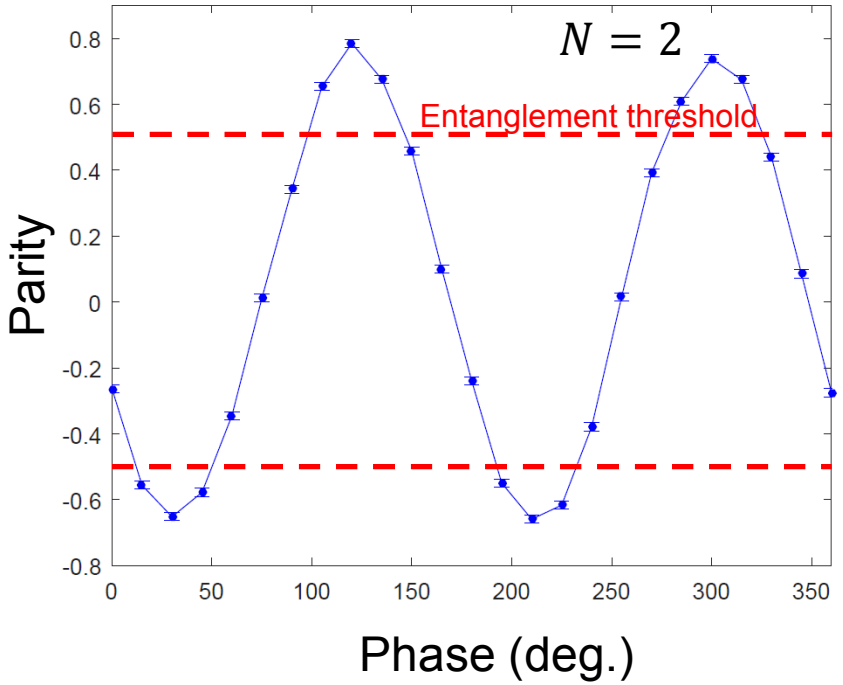


$$|\psi\rangle = \frac{|\uparrow\uparrow\rangle + |\downarrow\downarrow\rangle}{\sqrt{2}}$$

$$\hat{H}_{\text{eff}} = J \times \left(\hat{S}_z\right)^2$$

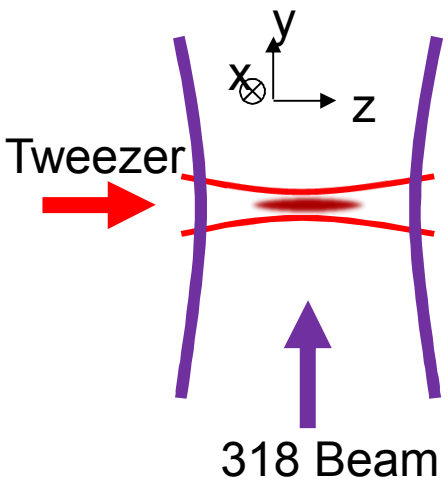


$$\langle \hat{\Pi} \rangle \propto \sin N\varphi$$

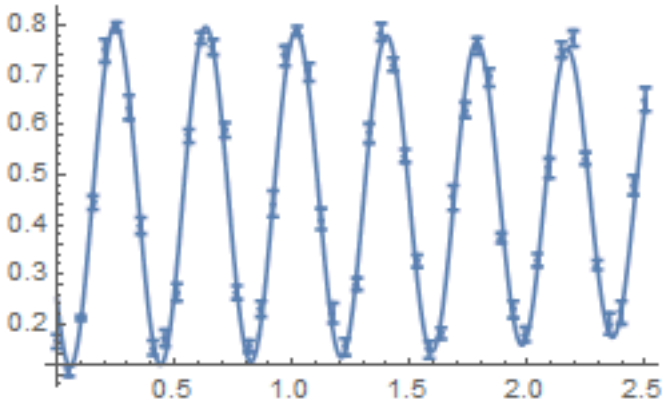


J. J. Bollinger *et al.*, "Optimal frequency measurements with maximally correlated states." Phys. Rev. A **54**(6) (1996).

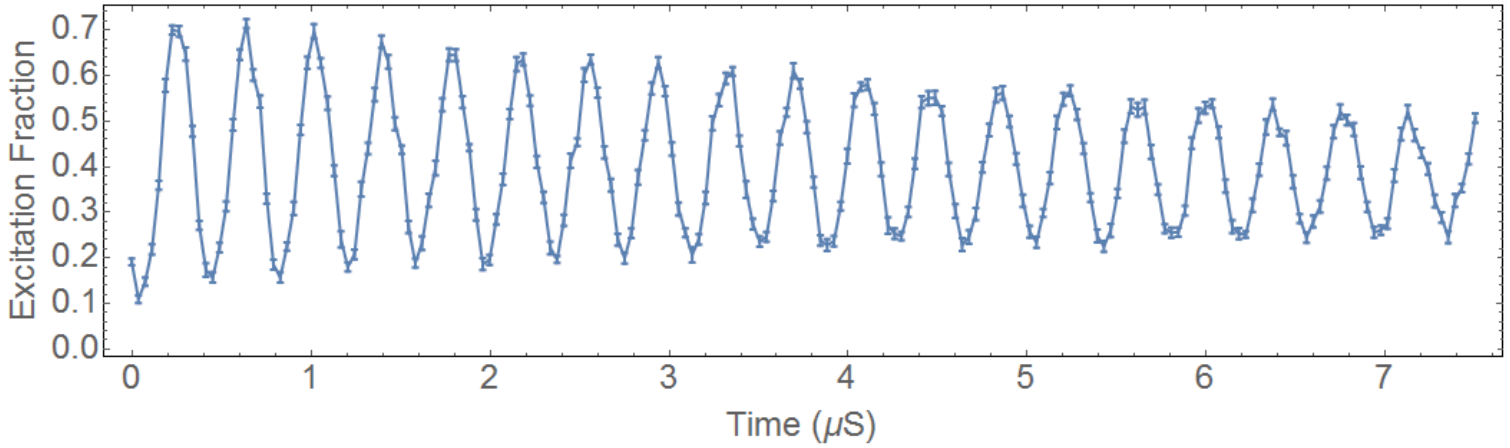
Direct excitation 318 nm Rydberg Rabi flopping



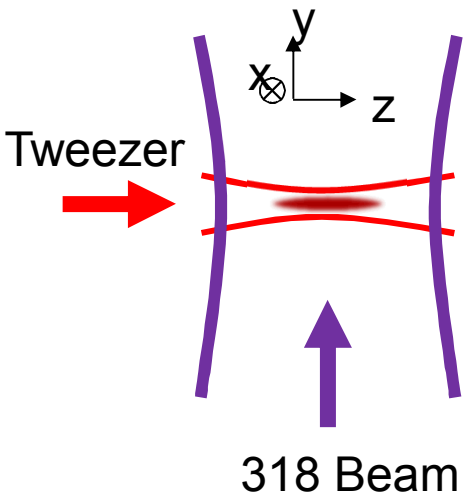
Direct excitation, measured through loss

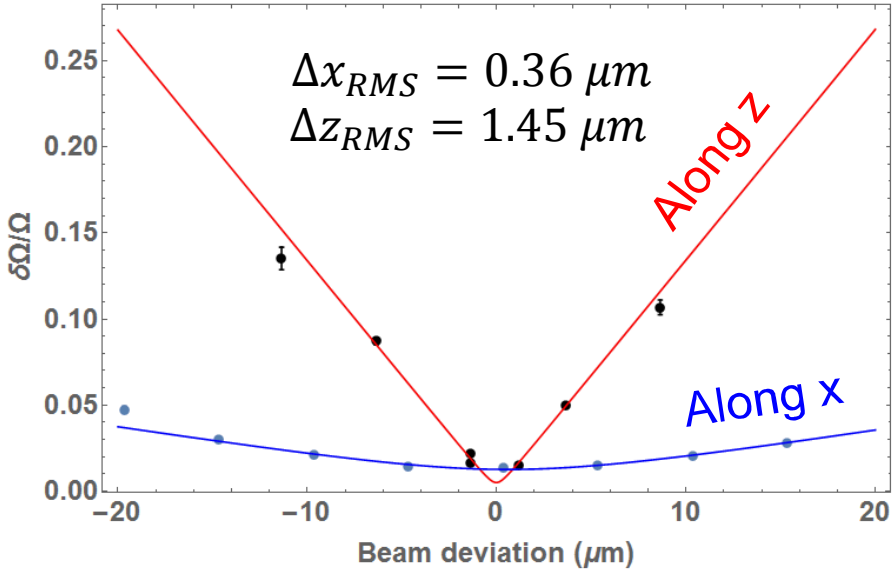


Coherence time(?) ~10 usec ← Coherence time depends on Rabi frequency → $\delta\Omega/\Omega$?

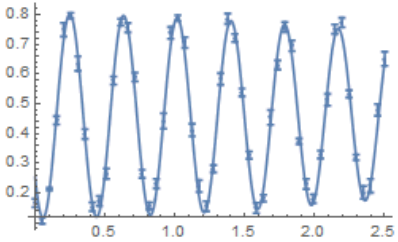


Direct 318 nm Rydberg Rabi flopping

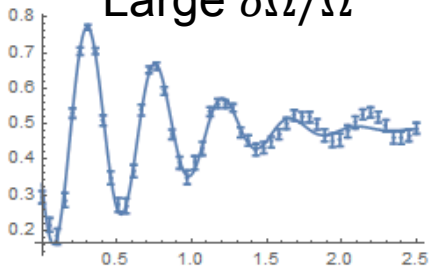


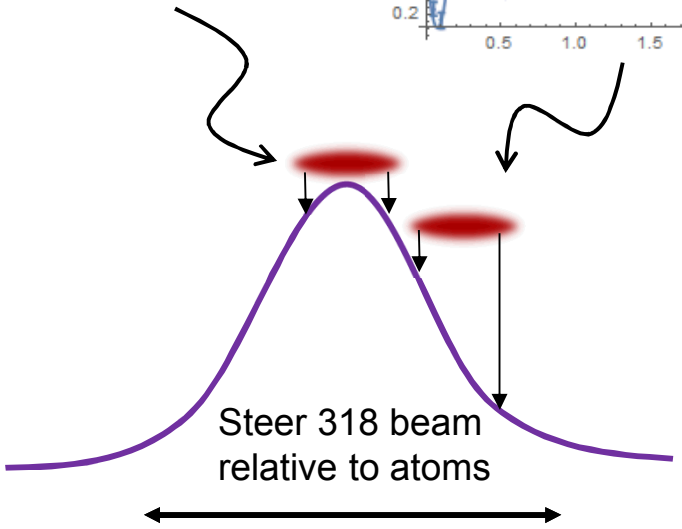


Small $\delta\Omega/\Omega$



Large $\delta\Omega/\Omega$





Wavepacket spread?

- CPHASE gate is sensitive to deviations in relative atomic position that cause fluctuations in *J*.
- Dressed blockade gate is less so, but may still be influenced.