Trap Microfabrication Capabilities and Demonstration of Sideband Cooling through the ^{171}Yb^{+} Quadrupole Transition

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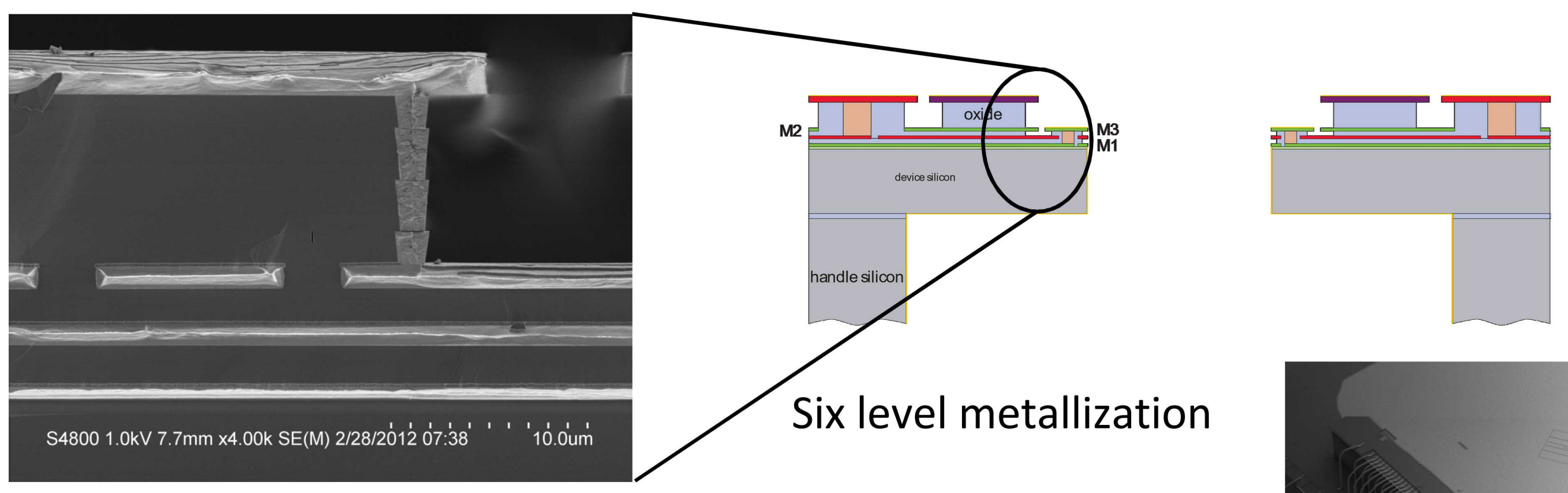
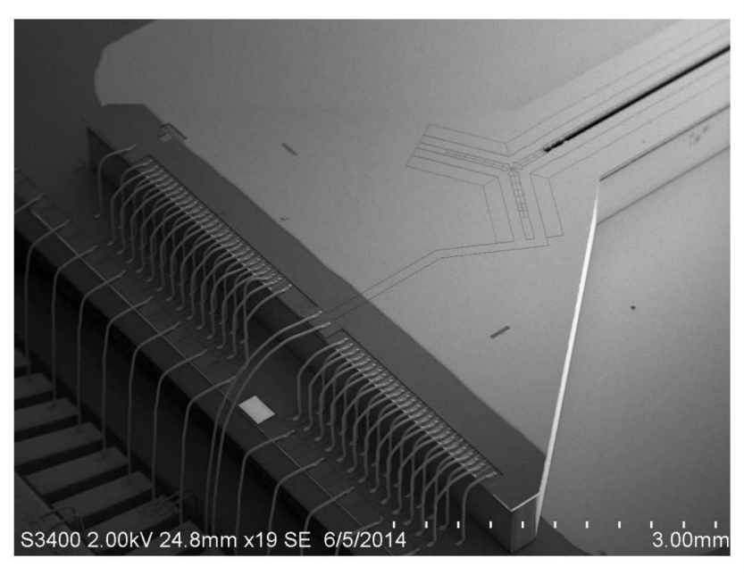
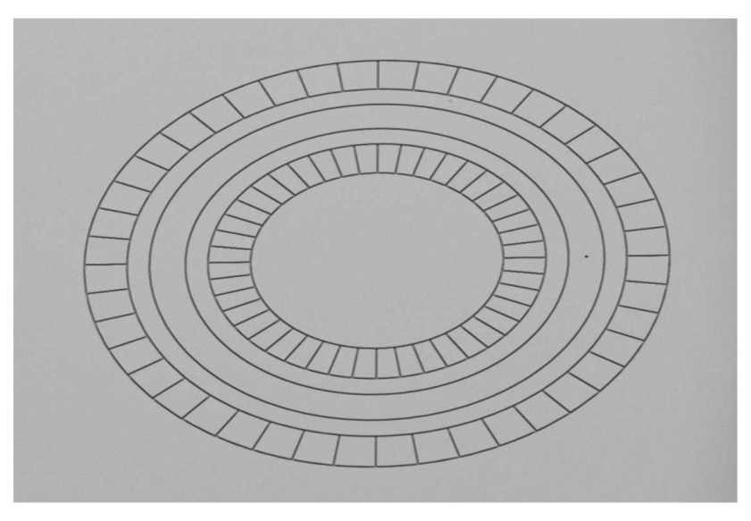
Trap Fabrication Capabilities



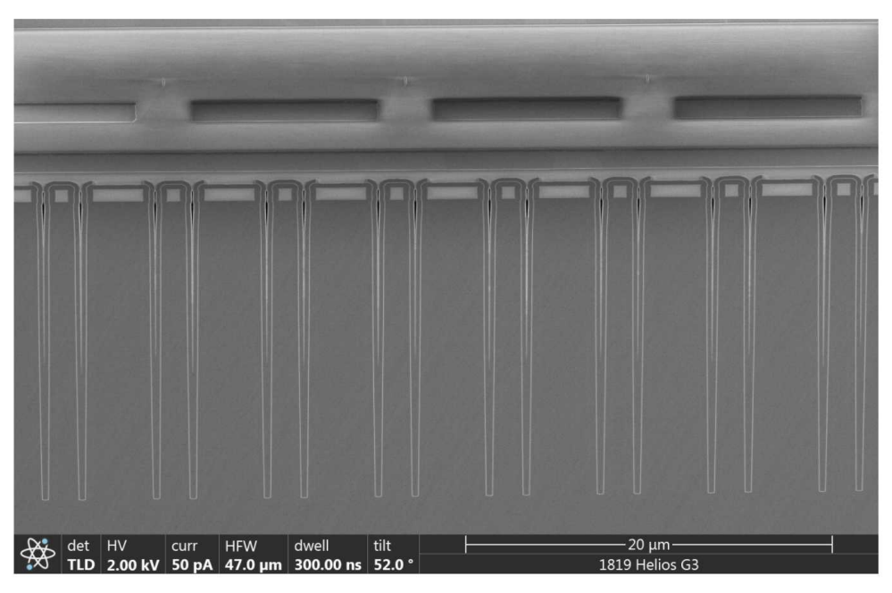
Six level metallization



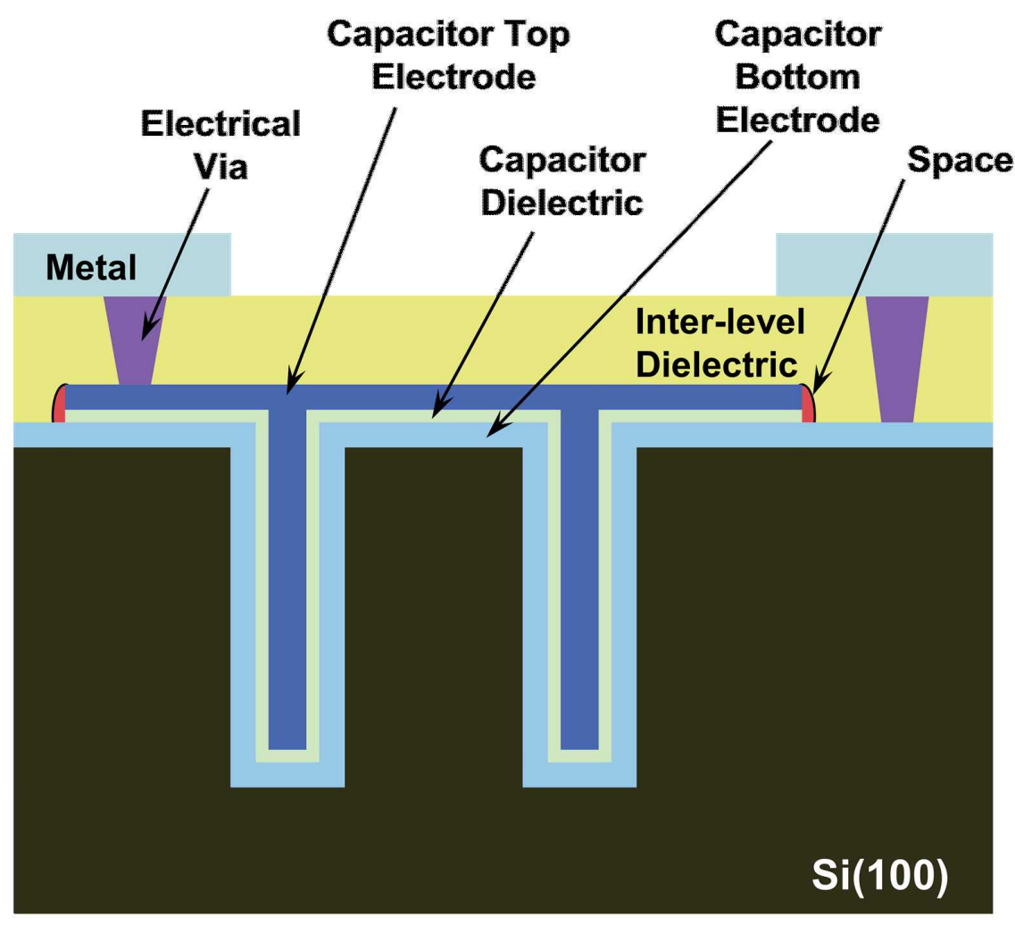


DC electrodes are routed through lower metal layers allowing for:
  - Segmented electrodes close to the trapping location
  - More complex, islanded trap structures, such as circulators and rings
  - Simplified routing as wiring can cross in different metal layers

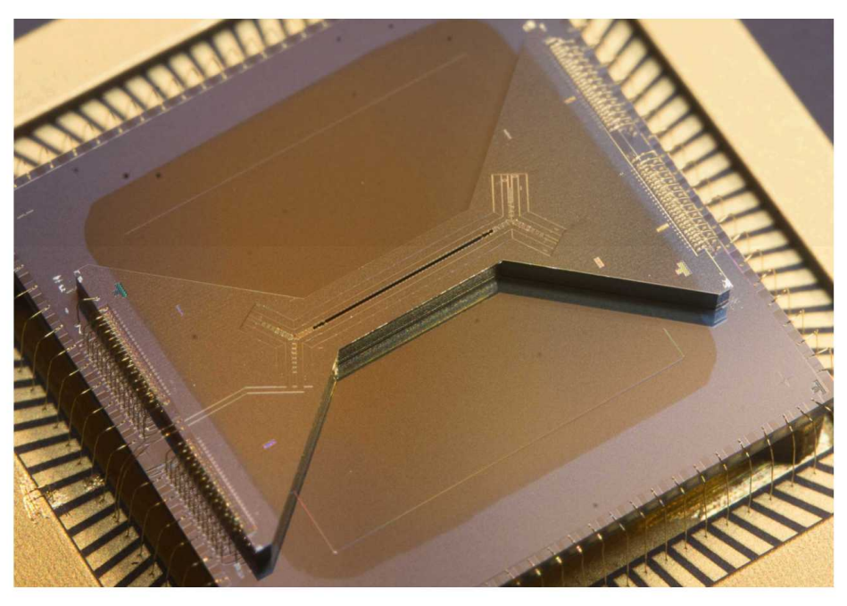
Allows for loading holes and loading slots for improved NA
Defined oxide release minimizes stray charging effects
Trap layouts that are more true to models, since electrode leads do not need to be taken into account

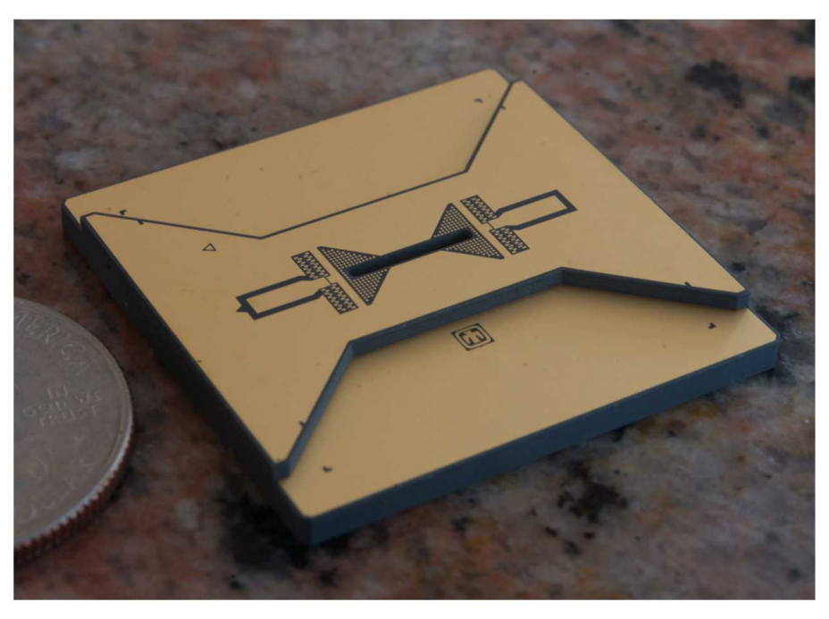


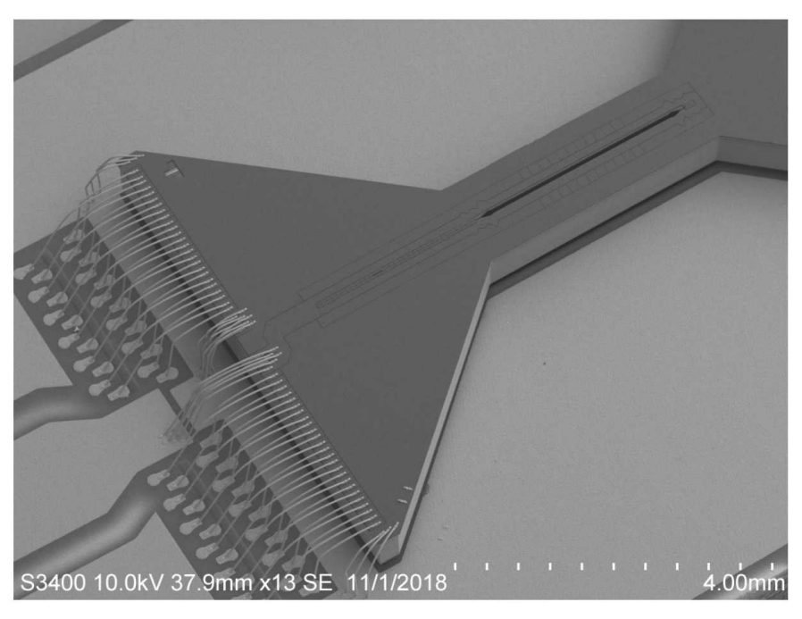
- Trench capacitors can be implemented directly on device to reduce RF pickup
- An interposer chip routes control voltages from the trap to the pads of a standard CPGA carrier.



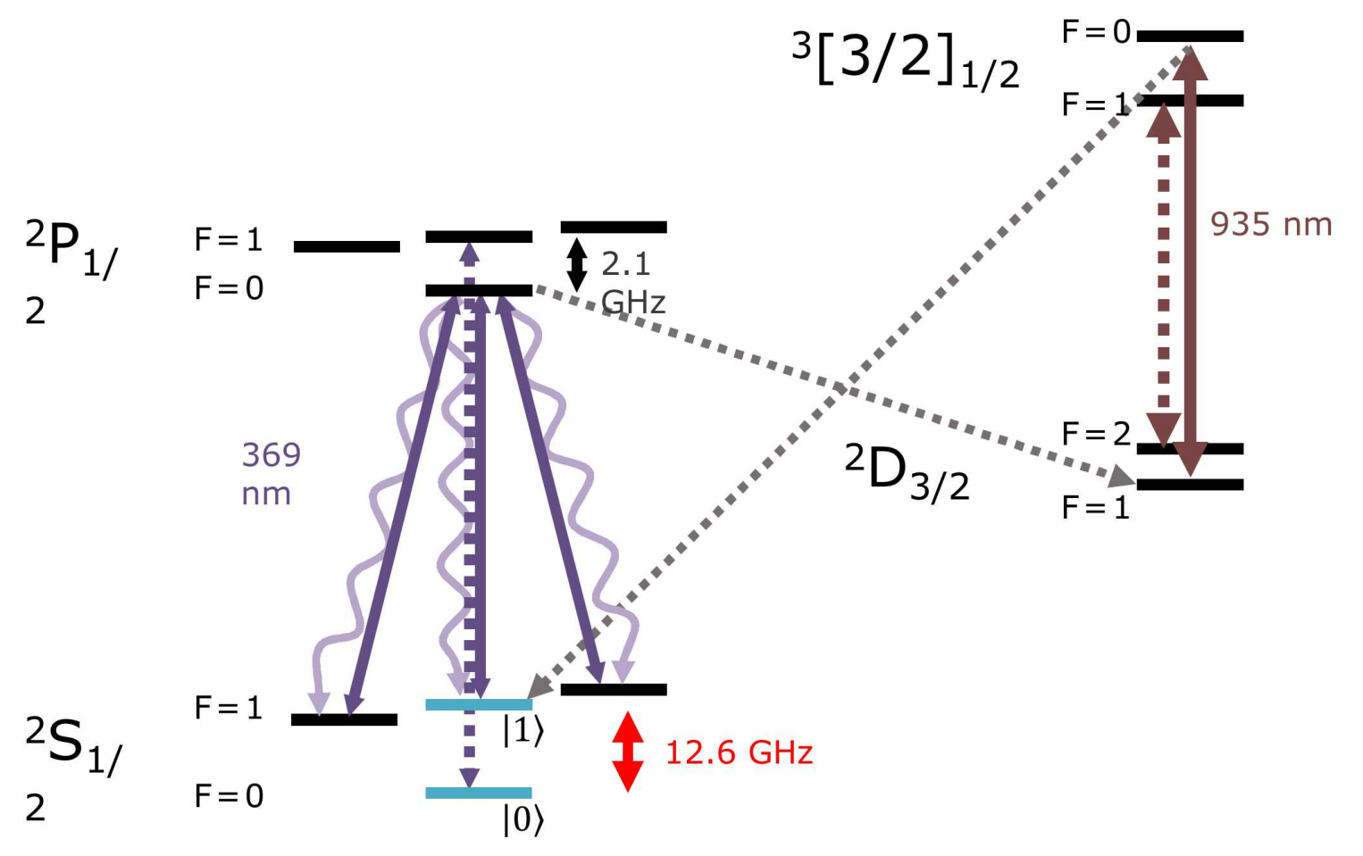
Simplified assembly with the new Phoenix trap design, which includes solder die attach, improved wire bonding, and a further optimized RF trace. Parametric testing ensures fully functional devices.







The ^{171}Yb^{+} Qubit

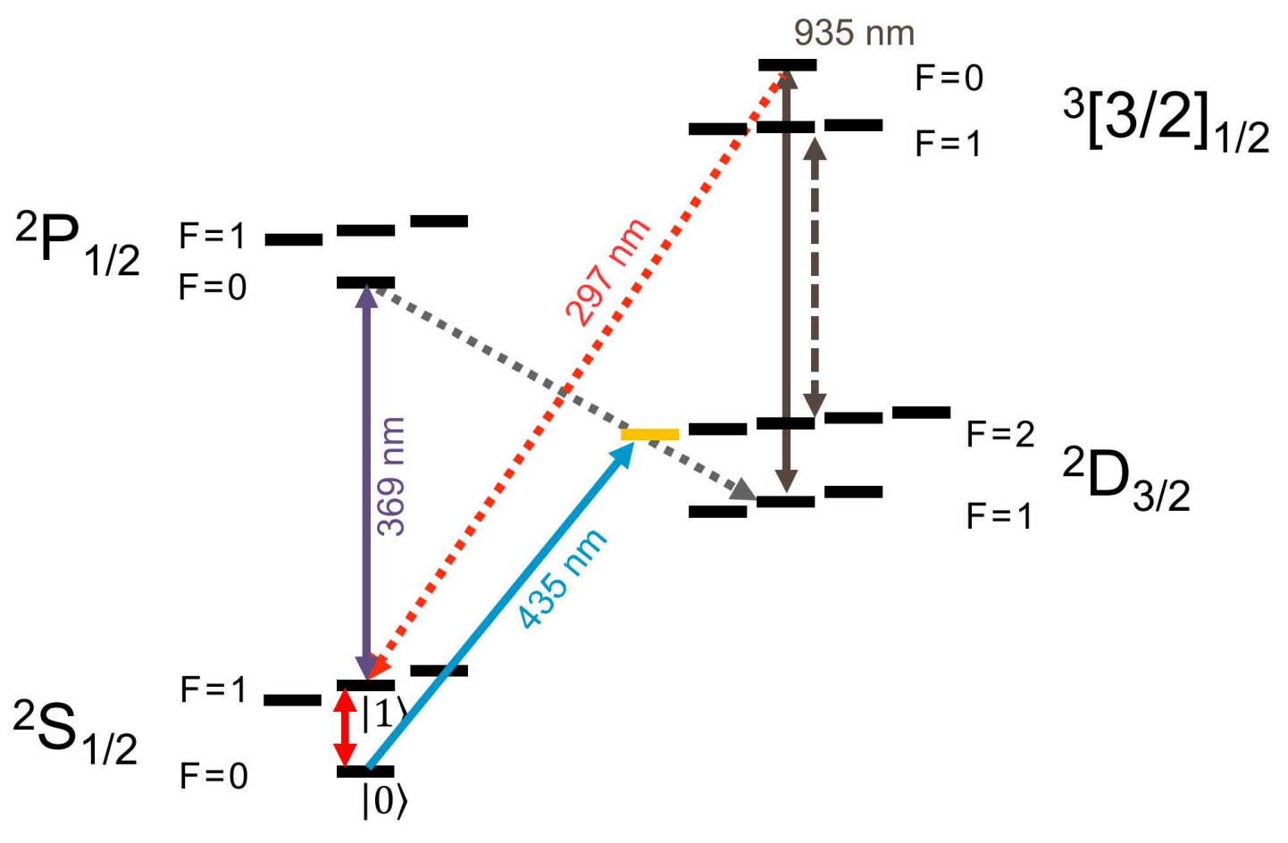


Ion is Doppler cooled then prepared in state $|0\rangle$ via optical pumping

Single qubit gates are realized using either a microwave pulse or Raman lasers.

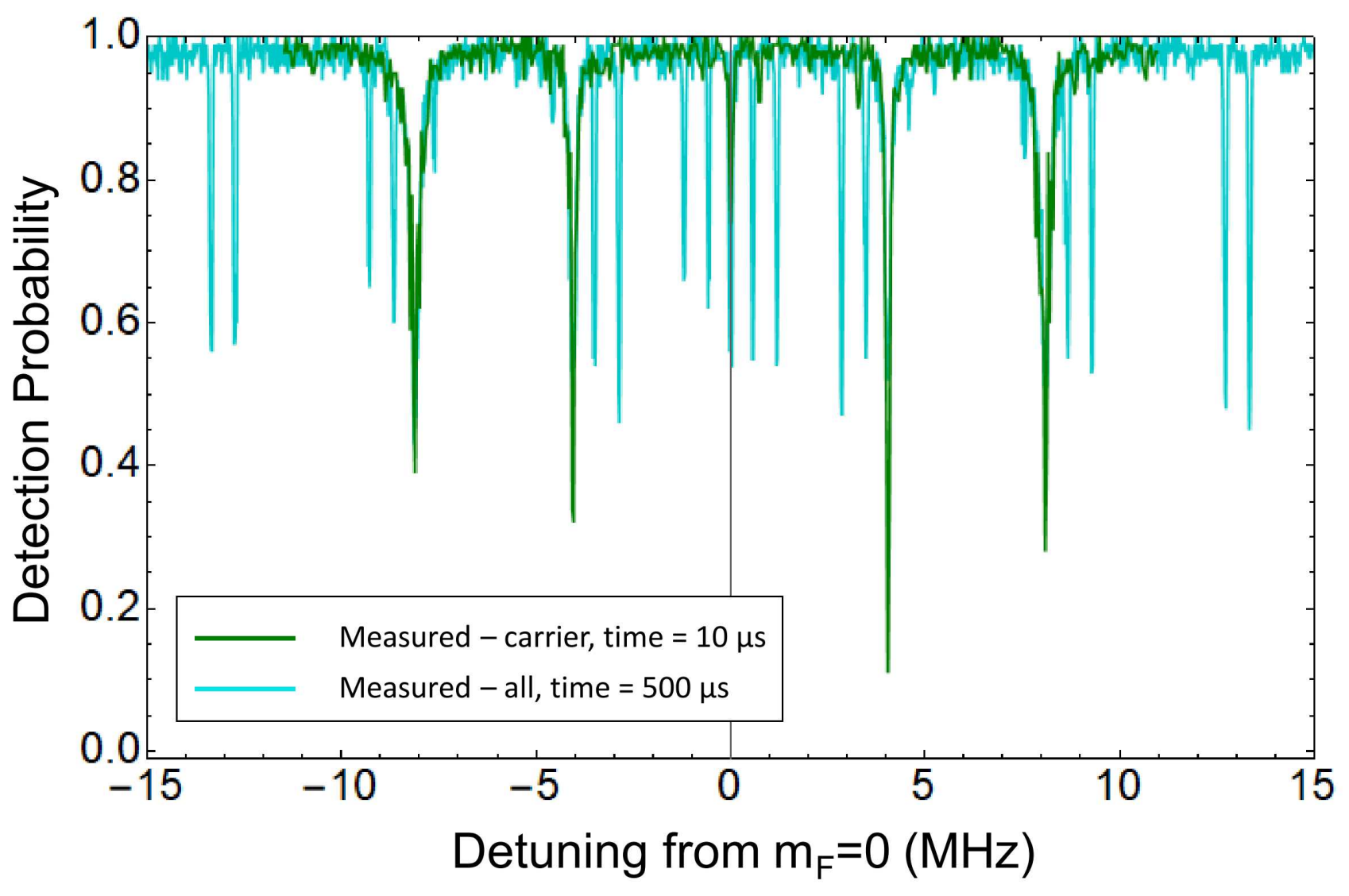
The microwave transition is insensitive to fluctuations in $\vec{\boldsymbol{B}}$

The Quadrupole Transition



Spectroscopy on the $^2D_{3/2}$ transition

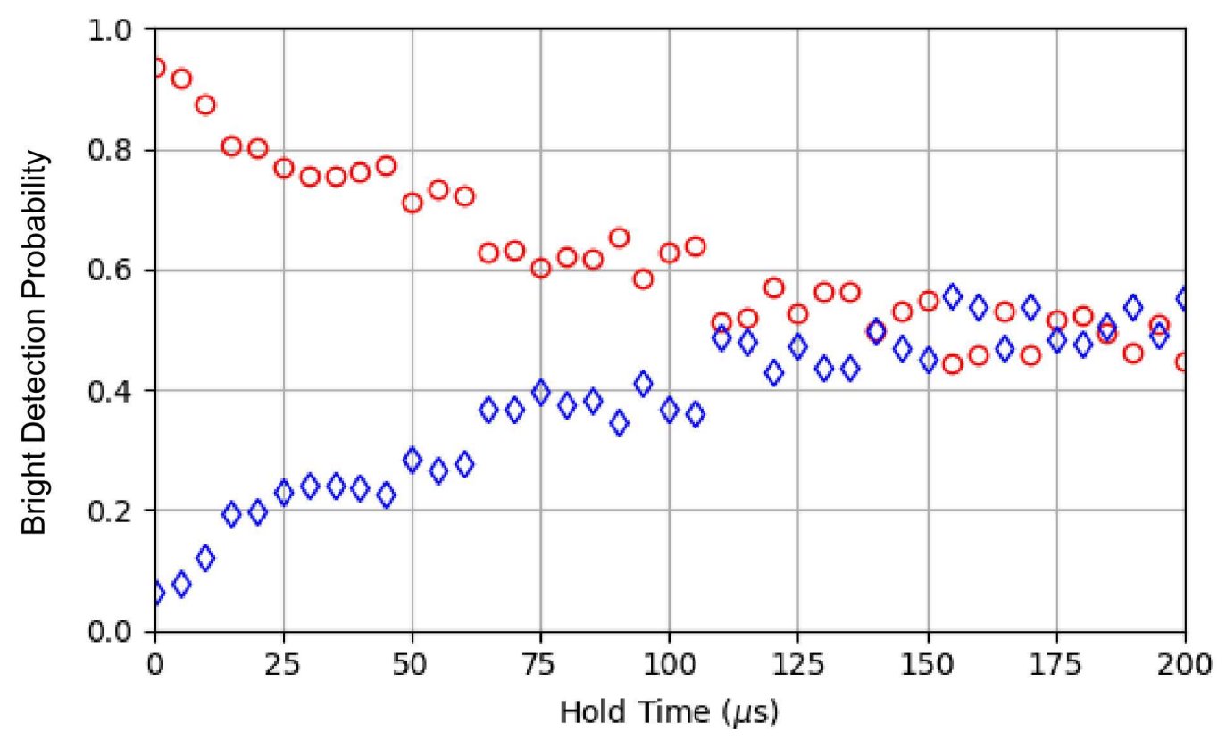
- The $^2D_{3/2}$ state has a narrow natural linewidth, ideal for sideband cooling. ($^{\gamma}/_{2\pi} = 3.02$ Hz)
- The ion is prepared in state $|0\rangle$
- 435nm light is pulsed on, while the 935nm sidebands are off
- A microwave π-pulse clears state $|0\rangle$
- If the ion was successfully excited to $^2D_{3/2}$(F=2) it remains dark, otherwise it is driven to state $|1\rangle$ and detected as bright.



Spectroscopy Parameters

- Radial trap frequencies ≈ 5 MHz
- Magnetic Field ≈ 5 G
- Zeeman splitting of 2D3/2(F=2) = 0.81 MHz/G

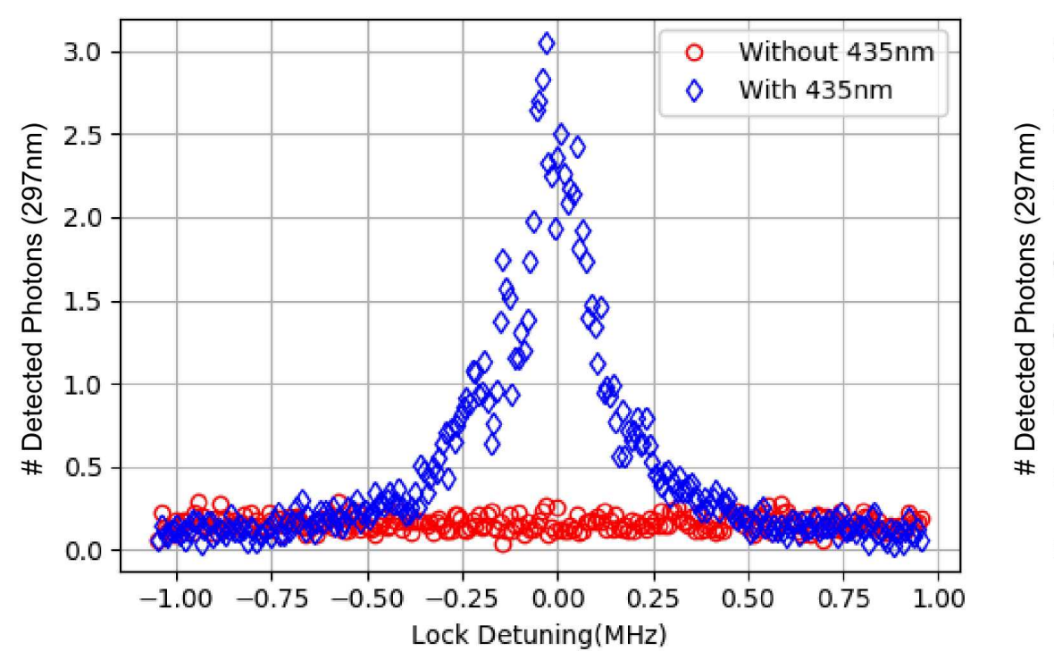
Laser Properties

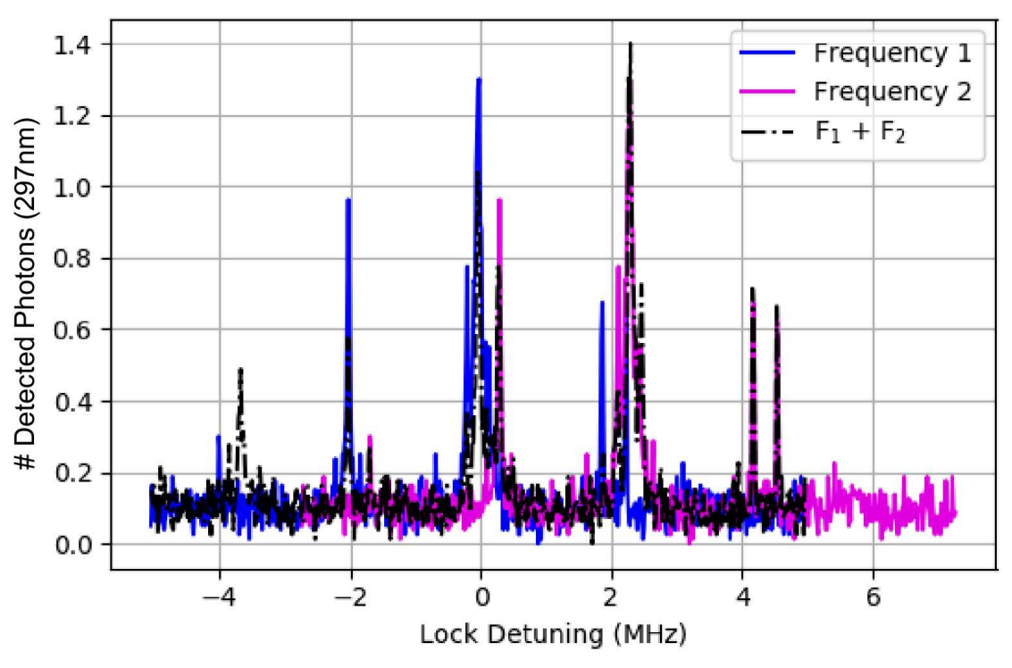


- Ramsey experiment on the $m_F = +2$, $^2D_{3/2}$ state measures a coherence time of ≈ 60 μs, a time scale that allows for sideband cooling
- This is likely limited by the laser linewidth (approximately 40 kHz)

Alternate Detection

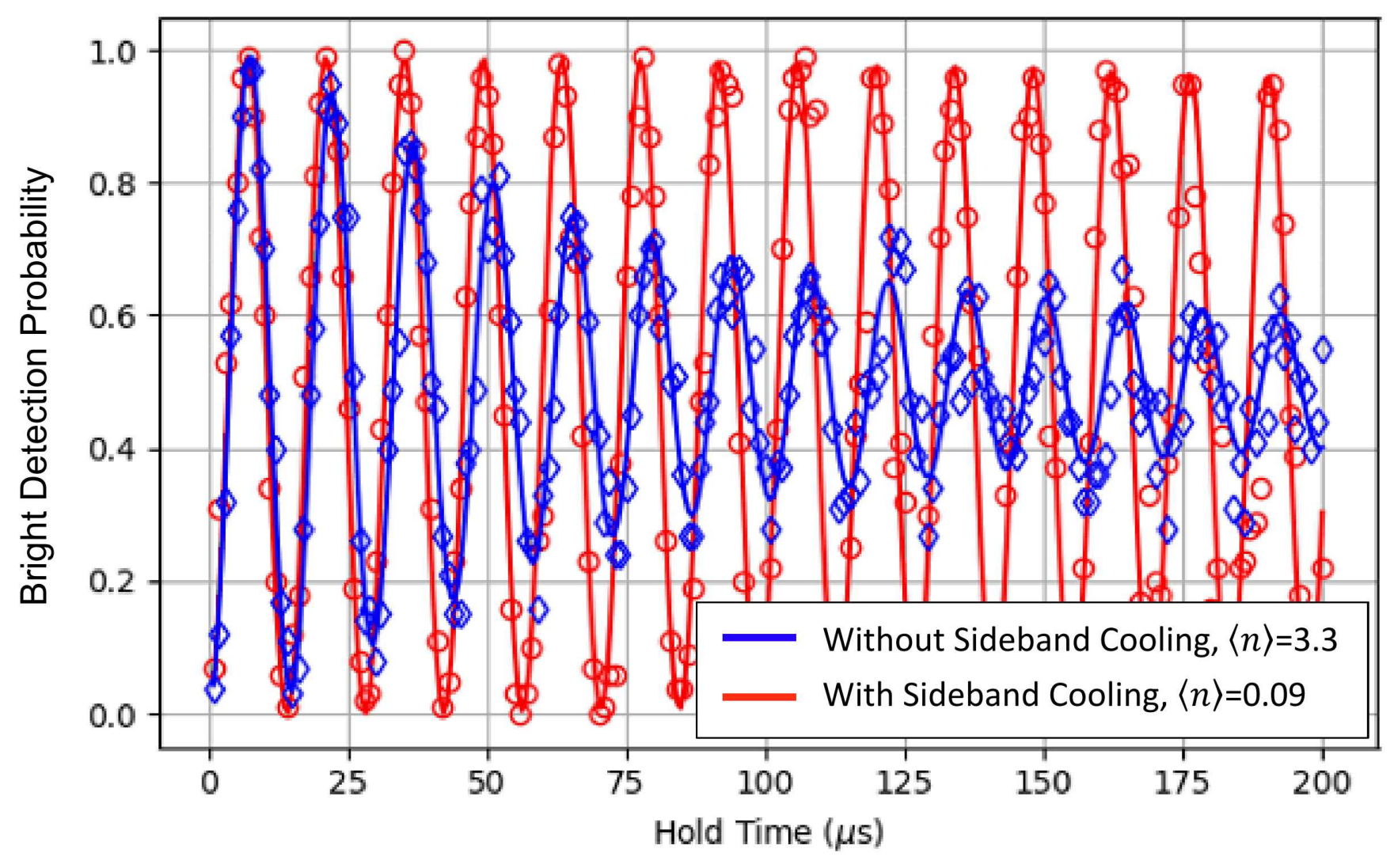
- To detect the 435nm transition without using the qubit – we monitor the fluorescence at 297nm. This is not high enough for state detection, but has enough signal to noise to determine success.
- We also show the ability to drive with dual tones for addressing multiple radial modes simultaneously.

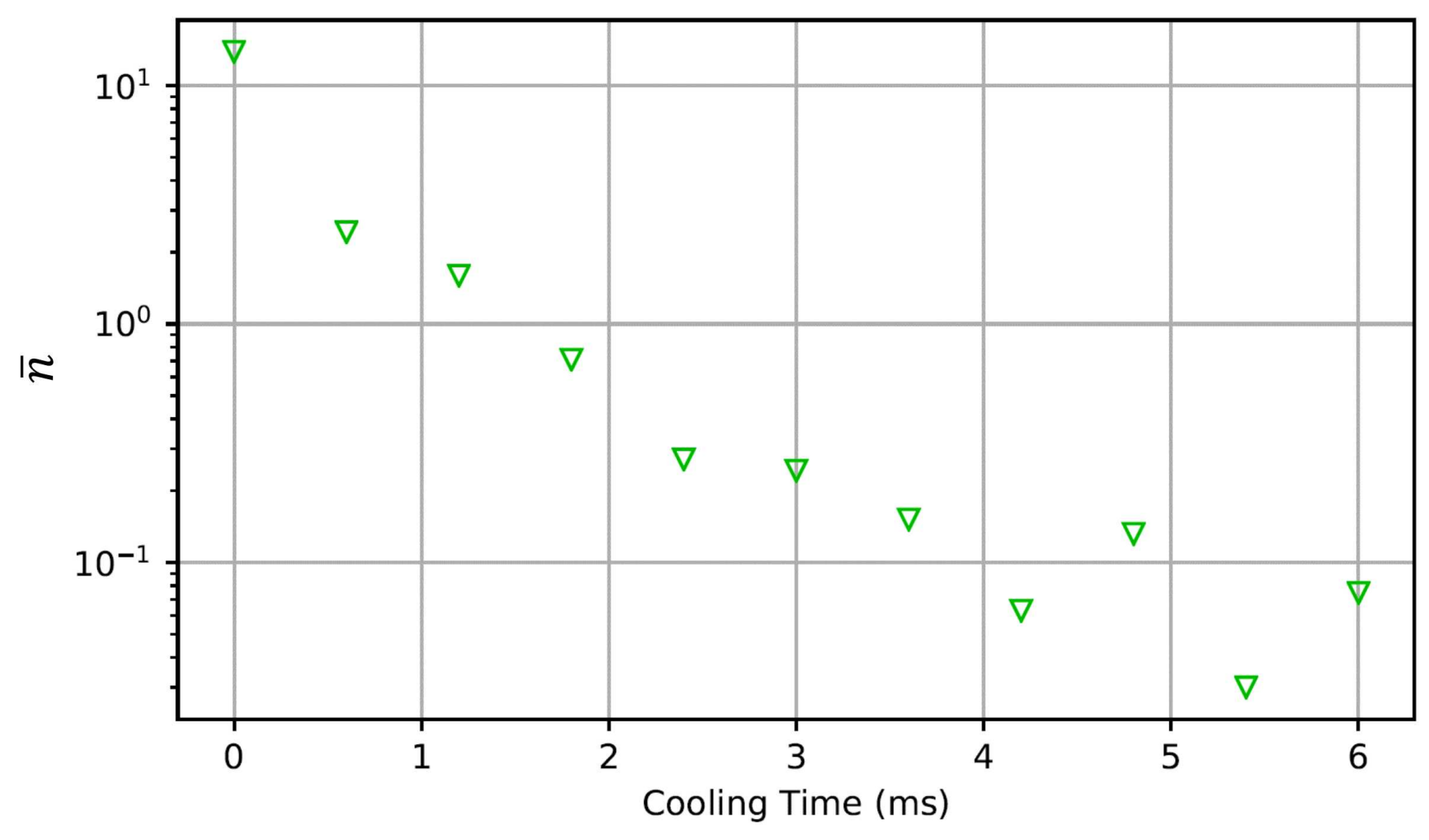




$^2D_{3/2}$ Sideband Cooling

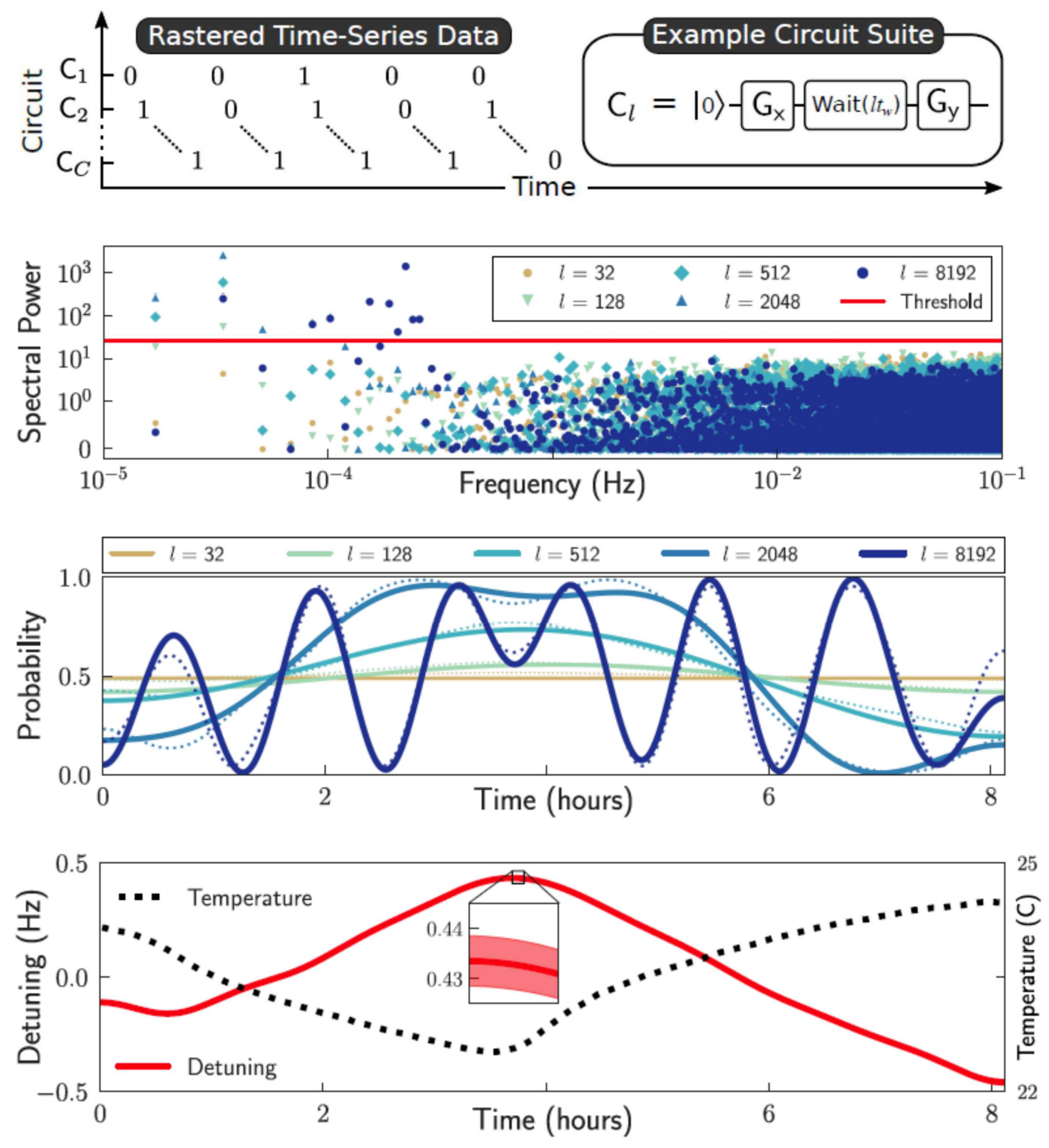
Rabi oscillations of the ^{171}Yb^{+} qubit measured using a 355nm Raman laser with, and without, 435nm sideband cooling enabled.





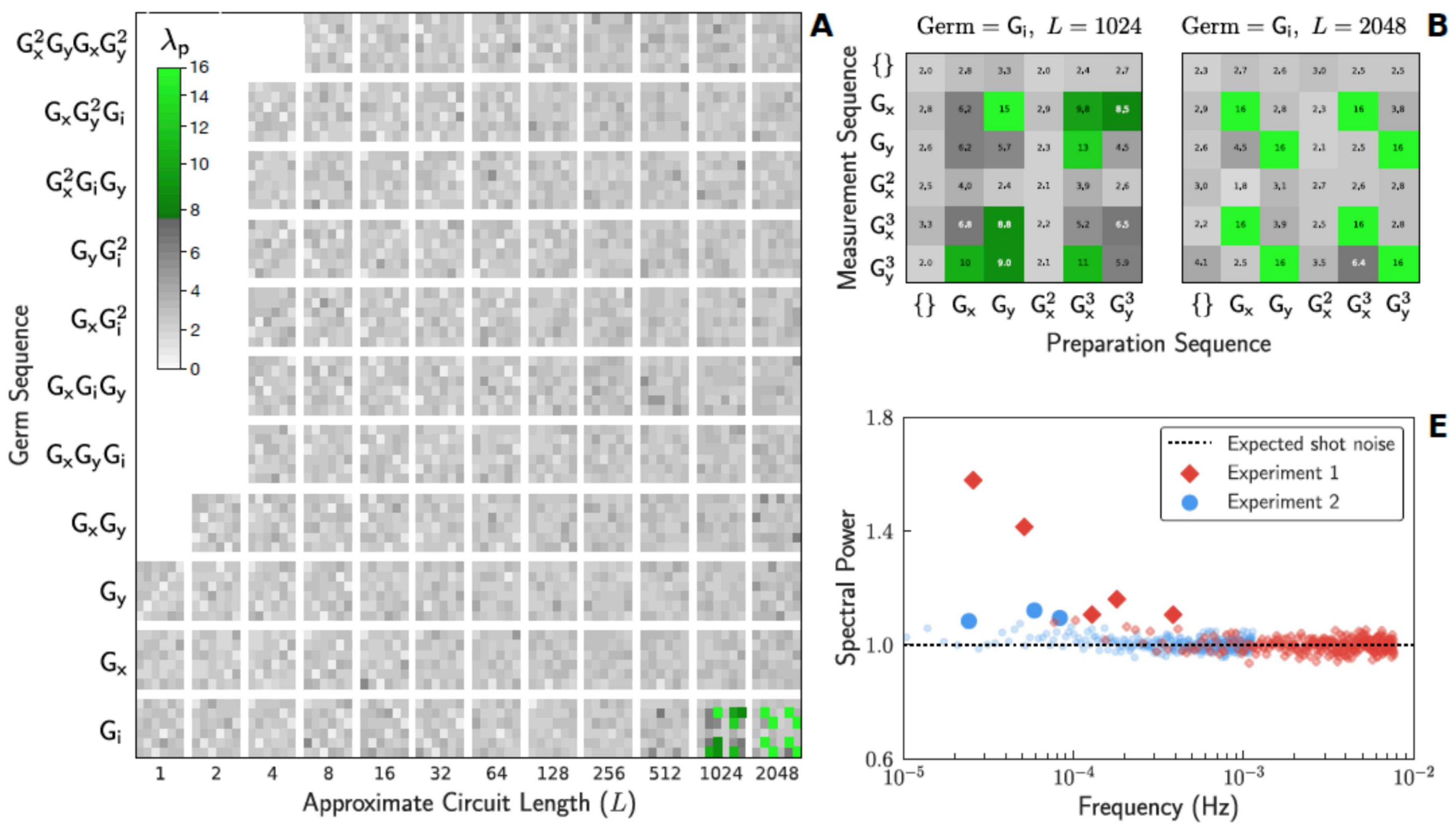
- Using a continuous (<1 mW) pulse of 435nm we achieve sideband cooling rates that are comparable to those using Raman lasers.
- The residual motion measured after a full cooling cycle is also similar to that from Raman cooling

Detecting Time-Dependent Errors



- Data is obtained by rastering – a circuit of gates is performed once in sequence which is then repeated
- A Fourier transform power spectrum provides information for drifts above a significance threshold
- Long sequences increase the sensitivity to slow drifts (below the mHz level)
- A standard Ramsey model can be used to fit the data and provide a estimated detuning which closely mirrors the laboratory temperature
- The measurement of these drifts allows for the reduction below a detection threshold improving experimental stability

Measuring Qubit Stability



Time Resolved GST

- GST provides a powerful tool to measure and help correct for instabilities
- Long GST sequences are required to observe statistically significant phase deviations
- Instability measurements allow for experimental recalibrations which significantly reduce long term drift

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