“TACK” ION TRAP

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More light from trapped ions!

more light really helps!

photonic link

state detection
Photonic link: qubit types

- **Polarization**
  - Requires small solid angle collection

- **Frequency**
  - Requires frequency-independent collection

- **Time-bin**
  - Requires fast microwave or laser pi-pulse
Photonic link: requirements

• Collect as much light as possible (currently: ~2%)
• Mode-match collected light into a single-mode fiber (currently ~20% fiber coupling efficiency)
• Polarization/frequency selectivity?

Solutions:
- Cavity QED system (clean mode, perfect for fiber coupling; not suitable for frequency qubit; polarization?)
- Large N.A. diffractive/refractive optics in vacuum
- Large N.A. reflective optics in-vacuum (frequency and polarization insensitive; typically poor mode quality)
- Large N.A. Fresnel mirrors on-chip
Photon collection: requirements

• Collect as much light as possible (currently: ~ 2%)
• Collect at multiple locations (or large field of view)
• Mode quality not important as long as images of neighboring ions ~10 micron apart do not overlap

Solutions:
  - micro mirrors integrated with the trap structure
  - large FOV bulk lenses
  - ...
Reflective optics in vacuum: the UW “tack” trap

- Photons collected by a large N.A. metallic spherical mirror
- Mirror surface serves as the RF electrode of the trap
- Trapping point set by an adjustable needle electrode
- Other mirror geometries (parabolic, ellipsoidal) possible, perhaps desirable?

*compare to NIST “stylus” trap.
Trap design
Performance: secular frequencies

![Graph showing PMT Counts vs. Driving Frequency (Hz)]

![Contour plot of Pseudo Potential]
Performance: secular frequencies

![Graph showing secular frequencies](image)
Performance: ion position vs. needle position
It’s a trap! What now?.. Imaging!

- measured ~ 23%
- 30 um spot size with “original” corrector...
- ... but that spot may not be all there is...
Correcting the corrector shape

- These mirrors are cheap
- The original corrector was calculated based on the “specs”
- We measured all (but one) mirrors; ROC = 4.3 mm (not 4.0 mm)
- New corrector... more light!.. but bigger spot.
“Tack” trap conclusions (this is not the end!)

- Metallic reflectors work well in UHV (even if they are not designed to be UHV-compatible).
- Small (and shall I add “cheap”?), high-NA spherical mirrors are suitable for ion fluorescence detection.
- Diffraction-limited imaging should be achievable with appropriate aberration correction, but the exact mirror shape does have to be known – need better mirrors!
- Other possibilities: Fresnel mirrors – maybe natural fit for the chip traps? – micromirrors, ...
Chip trap setup using non-traditional UHV-compatible stuff

- PEEK socket
- Trap chip
- PCB
- 25 pin D-sub adaptors
- PCB reinforce post
Chip trap setup using non-traditional UHV-compatible stuff
6” CF flange
Support Post Mounting Screw Holes
Oven Mounting Screw Holes
1.33” viewport
25-pin D-sub feedthrough
9-pin feedthrough
• On-site filtering capacitors
• No crimping, no messy wires
• Can be mass-produced!
• Sandia iTrap installed
• $1.6 \times 10^{-10}$ torr, still coming down
• Second system on the way