Characterizing a Parabolic Mirror

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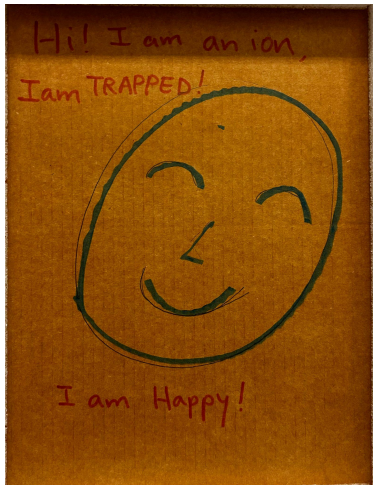
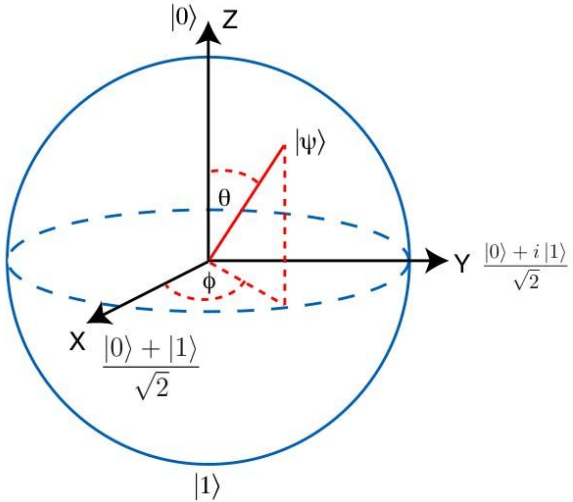
Blinov lab: quantum computing with trapped ions

Trapped ions: viable qubit candidate

Qubit: unit used in quantum computing





Experiments

Quantum jumps

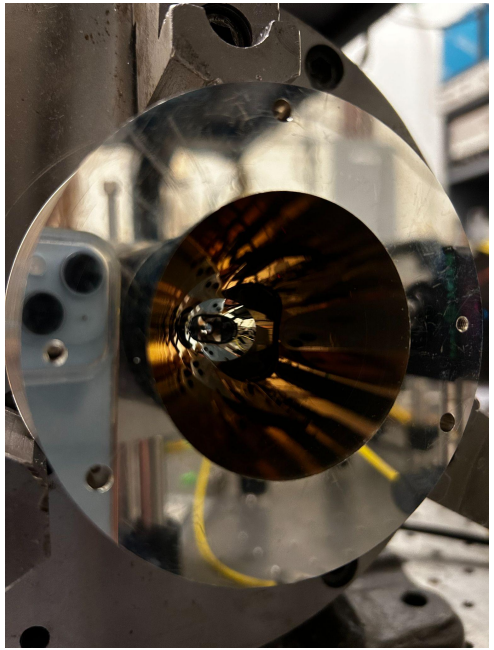
- Jump from one quantum state to the other
- Useful in determining time dynamics of qubits

2D crystals

- Scaling up qubits to quantum computers

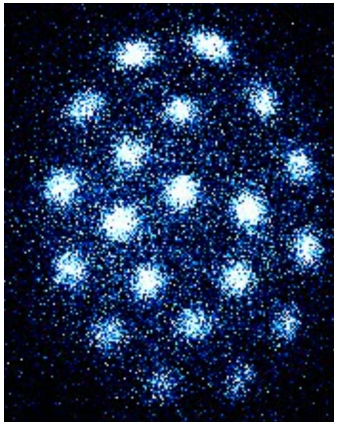
Hybrid quantum systems (with Fu lab)

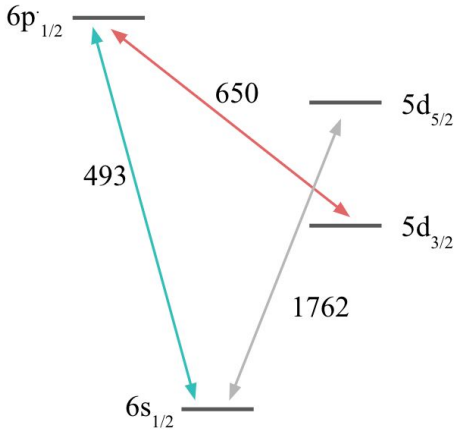
- Entanglement of $^{171}Yb^{+}$ with spin of bound donor exciton in ZnO



Why trapped barium ions?

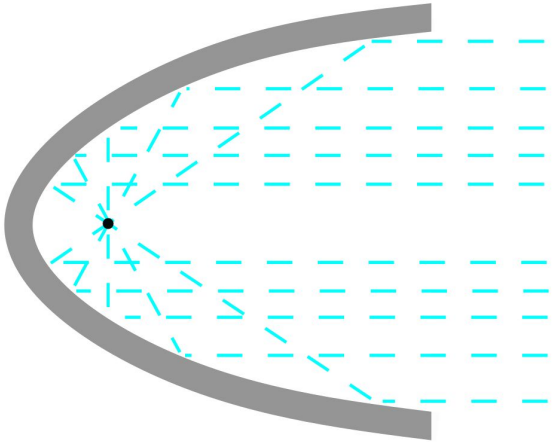
- Ions: easier to scale up due to longer decoherence times; high fidelity qubit state initialization
- Barium: Easier to detect/manipulate
  - Lifetime of $5d_{5/2}$ qubit state: 32 s (metastable)
  - Transition frequency of barium makes experiments more feasible

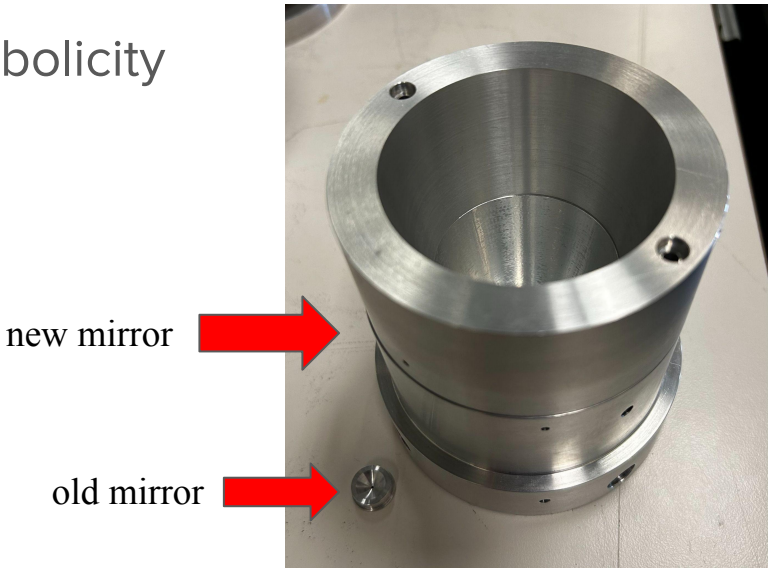




Parabolic Mirror

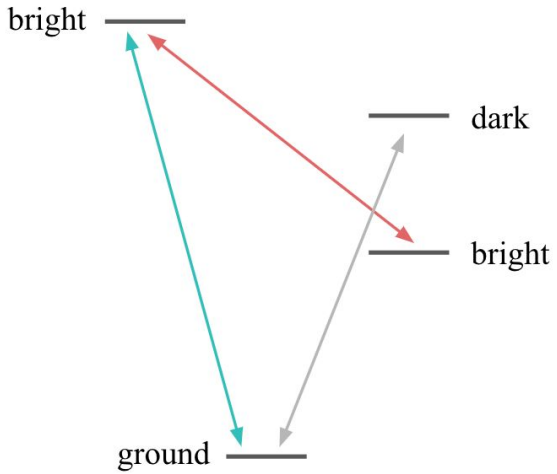
- Deep parabolic mirror (95% of solid angle!)
- Improves retention rate of photons (more photons = better time resolution)
- 2 tests: reflectivity and parabolicity





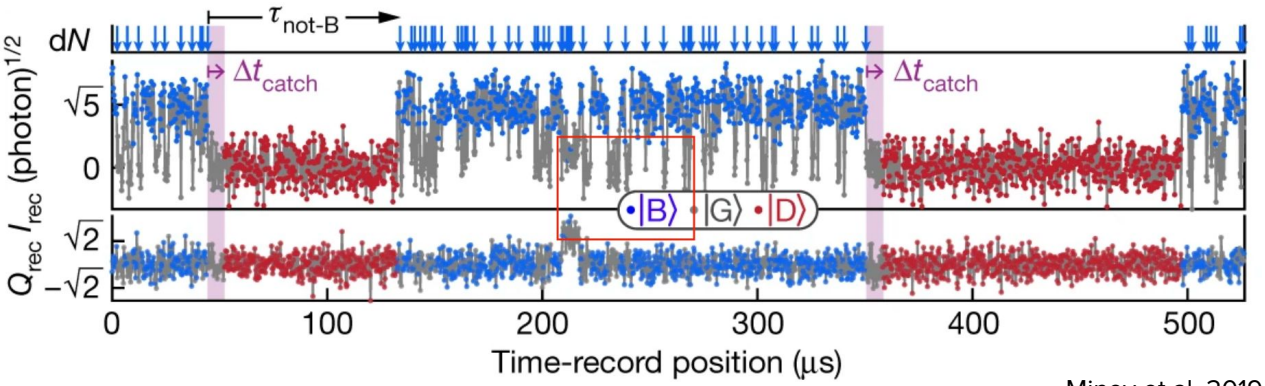
Quantum Jumps

- Quantum jump: spontaneous absorption/emission of photon
- Impede progress in developing quantum computing
- Detection: bright and dark state



Quantum Jumps

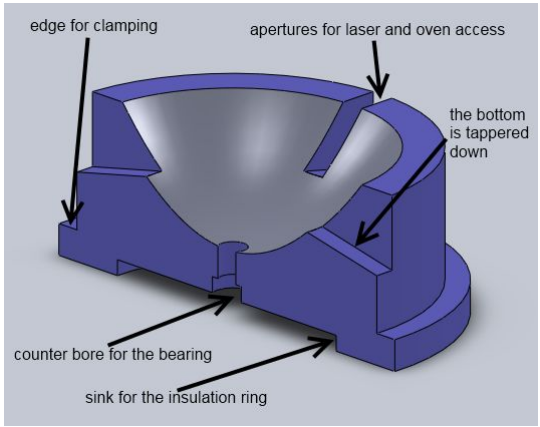
- 2019 experiment with superconducting qubits showed continuous development of system's state during quantum jumps
- "Latency period" before quantum jump

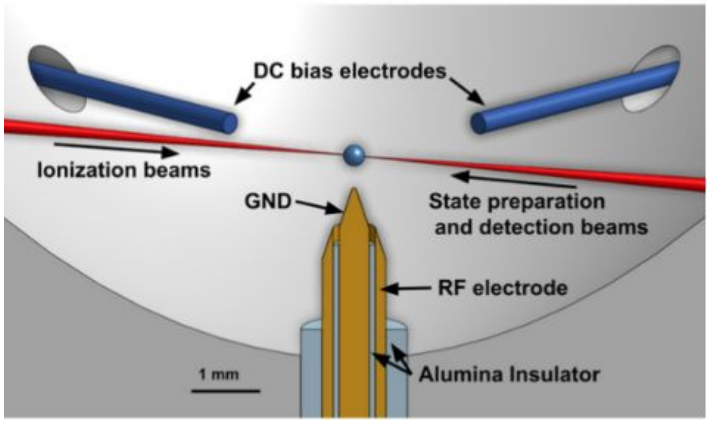


Minev et al, 2019

Trap setup

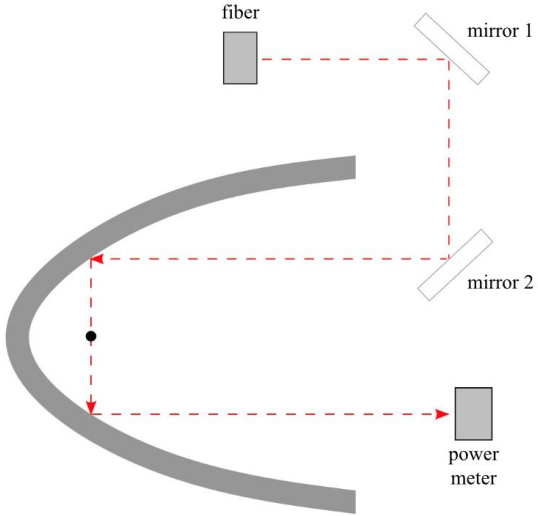
- Stylus trap inside parabolic mirror on micrometer
  - Ion trapped at focus of parabola
- Mirror inside vacuum chamber
- Holes in mirror allow for access from electrodes and laser beams

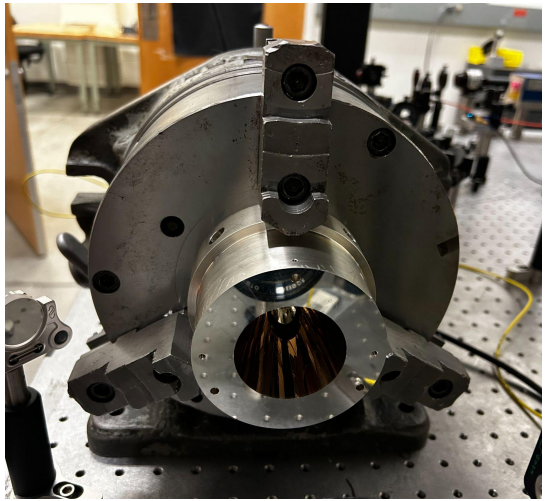




Test 1: Reflectivity

- Measure power going in and out of mirror
- Use 3 wavelengths
- Problems: alignment, fiber coupling, detectors





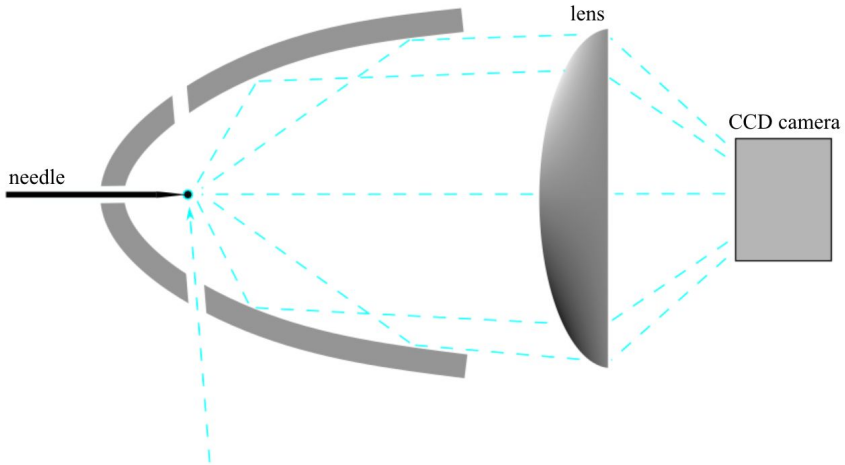
Reflectivity Test Results

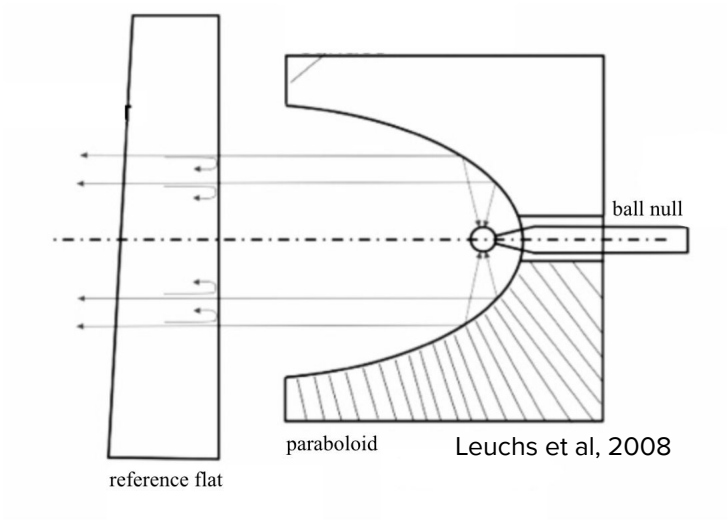
Above 90 percent, as expected (this is good!)

Wavelength	Average Percent Reflectivity	Standard Deviation
650	89.79	1.208
493	90.11	0.802
369	93.1	4.301

Test 2: Parabolicity

- Hard to find tests for deep parabolic mirrors
- Possible methods: sphere (null test), wedge, needle test
- Needle test: less precise, but easier



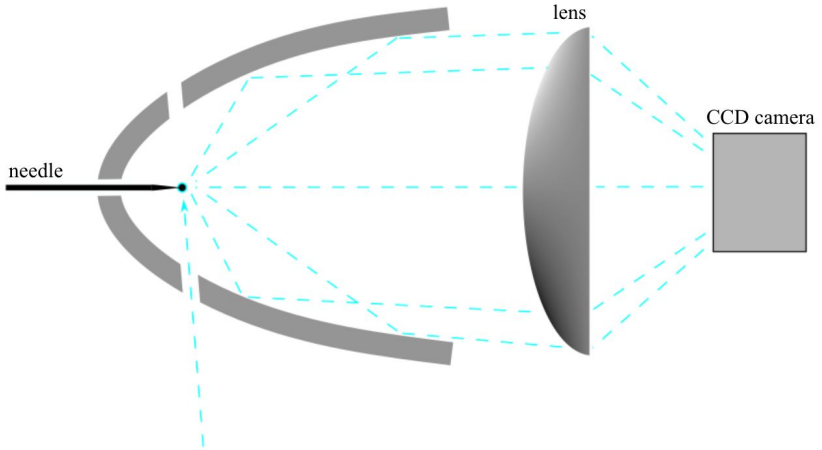


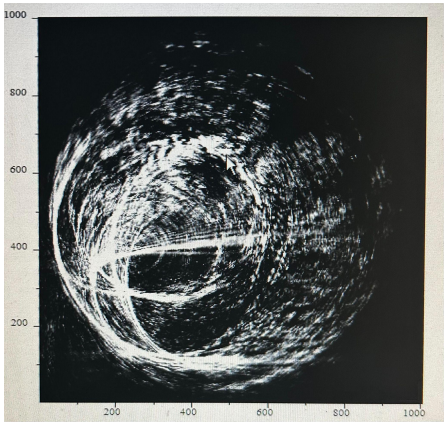
Leuchs et al, 2008

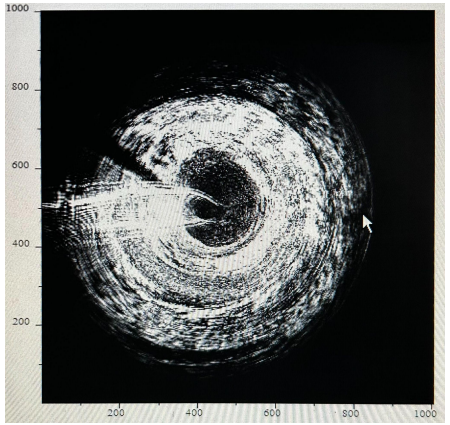
Test 2: Parabolicity

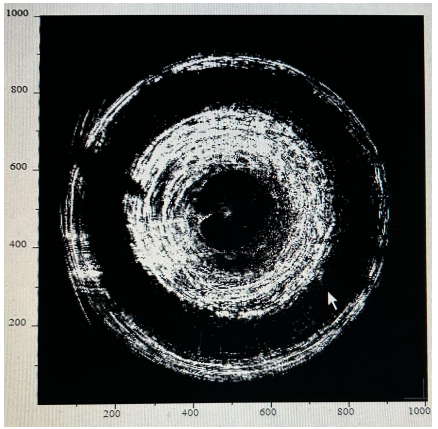
Problems:

- Complicated alignment
- Bent needles
- Aberrations in lenses









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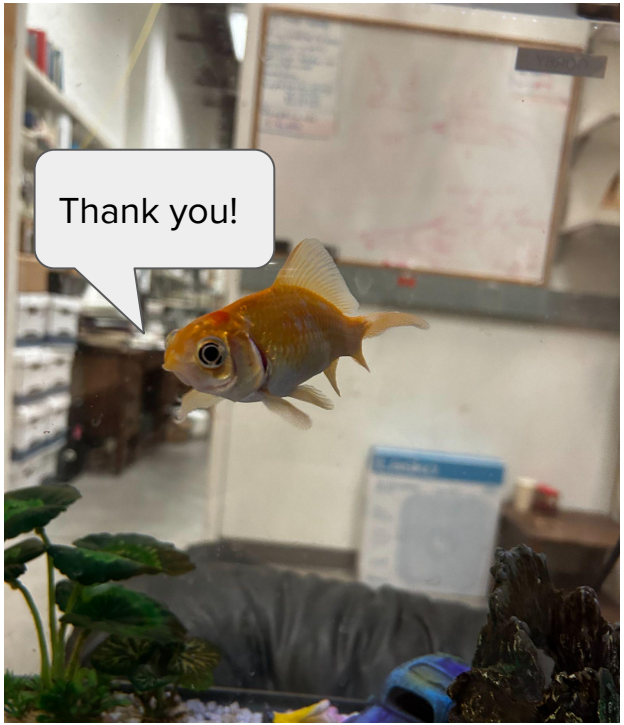

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