Single Trapped Ba^+ Ion

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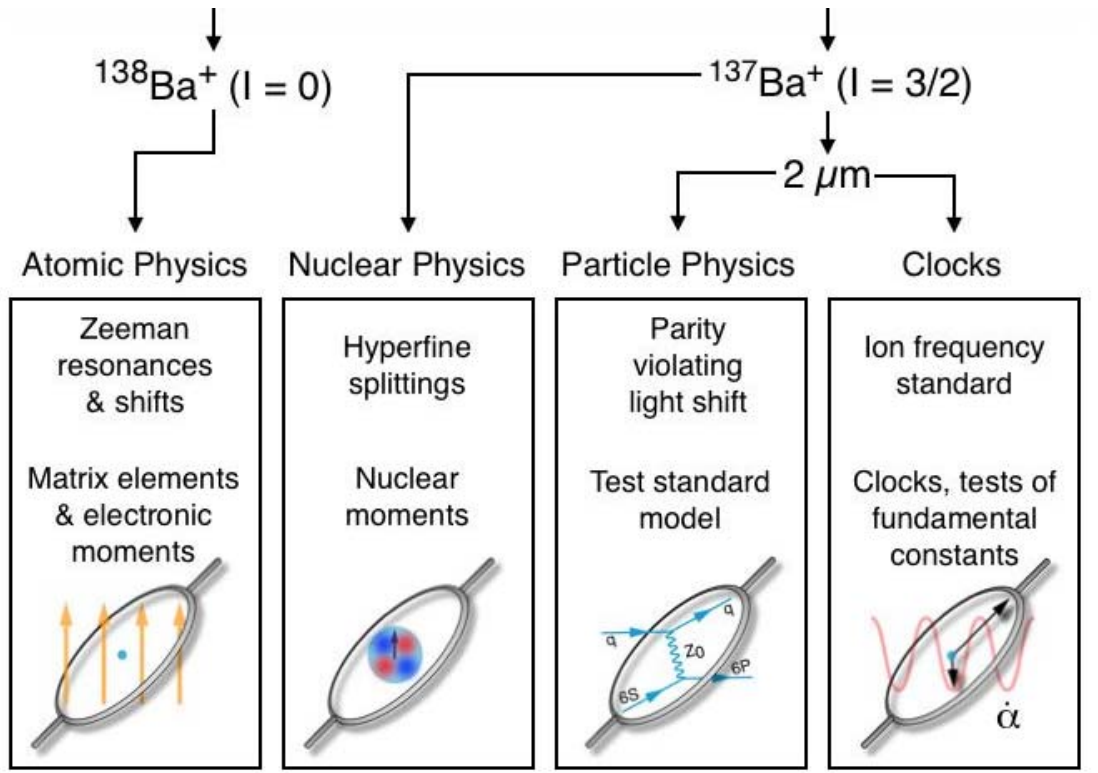
Outline

- Barium Ion Energy Levels
- Trapped Barium Ion Experiment
  - Trapping, Cooling, Shelving
- Circuitry
- Conclusions

Trapped Barium Ion

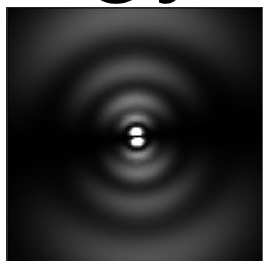
- Single atom system
- Barium is hydrogen-like
- Fine structure splittings are on the order of nm, and are optical
- Meta-stable states have unusually long lifetimes



Barium Ion Energy Levels

Electric Dipole Selection Rule:

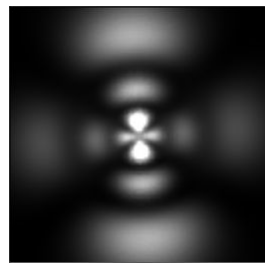
$$\Delta \ell = \pm 1$$



$6P_{3/2}$ τ = 6.3ns

$6P_{1/2}$ τ = 7.8ns

615nm



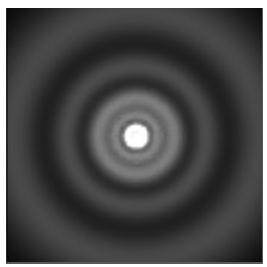
650nm

$5D_{5/2}$ τ = 32s

493nm

455nm

$5D_{3/2}$ τ = 83s

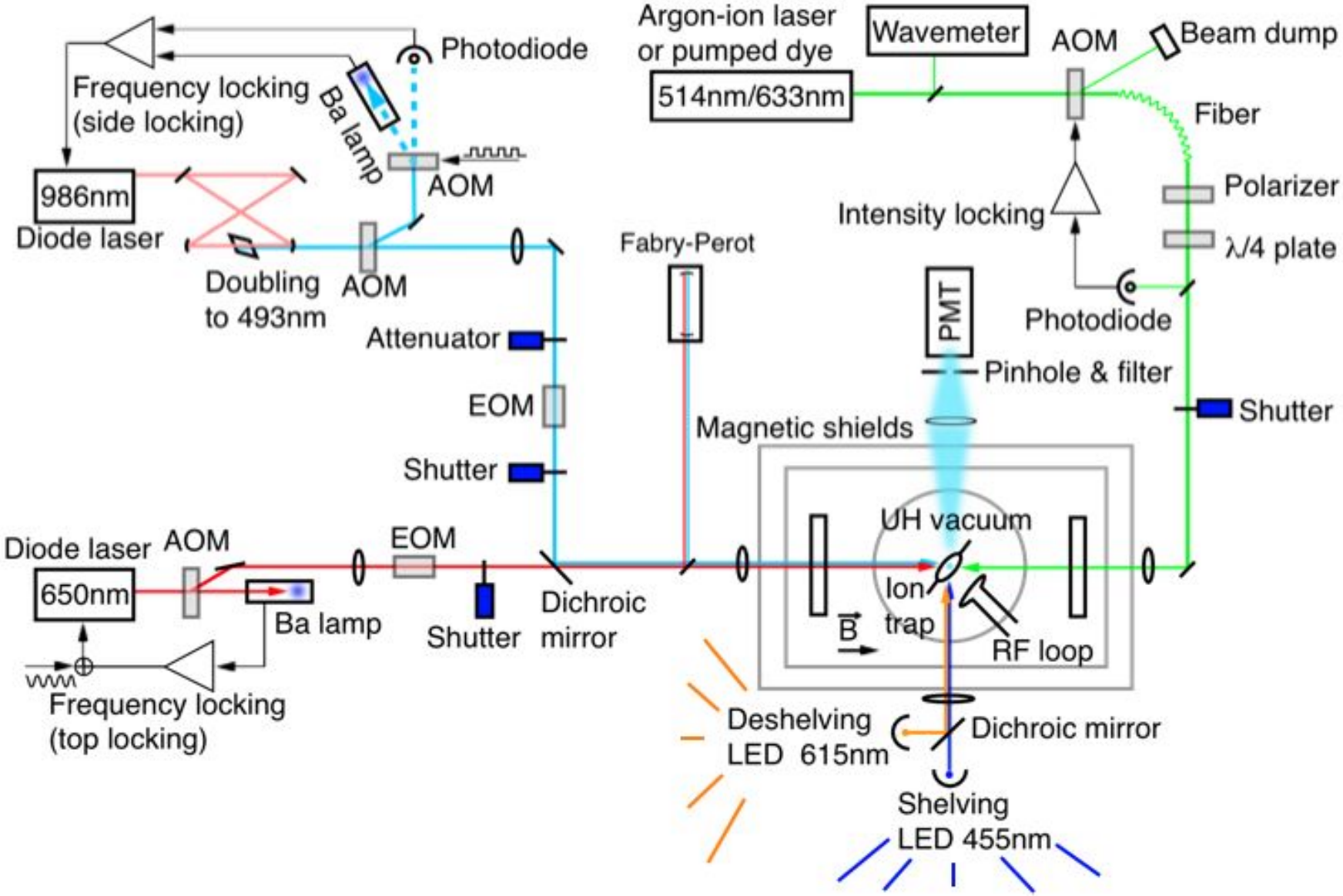


$6S_{1/2}$

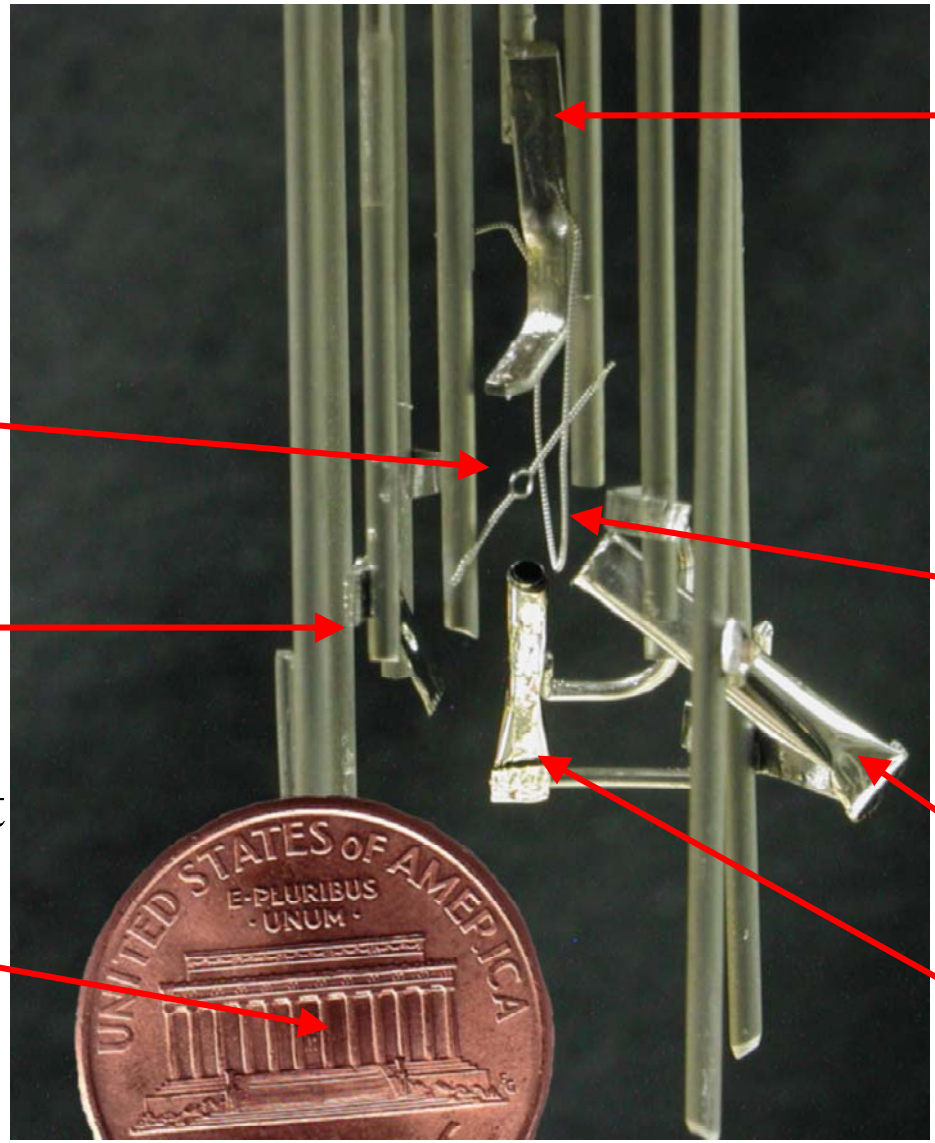
Energy

Angular Momentum

Experimental Setup



UW Barium Ion Trap 2003



Compensation electrode (1 of 3)

RF ring trap

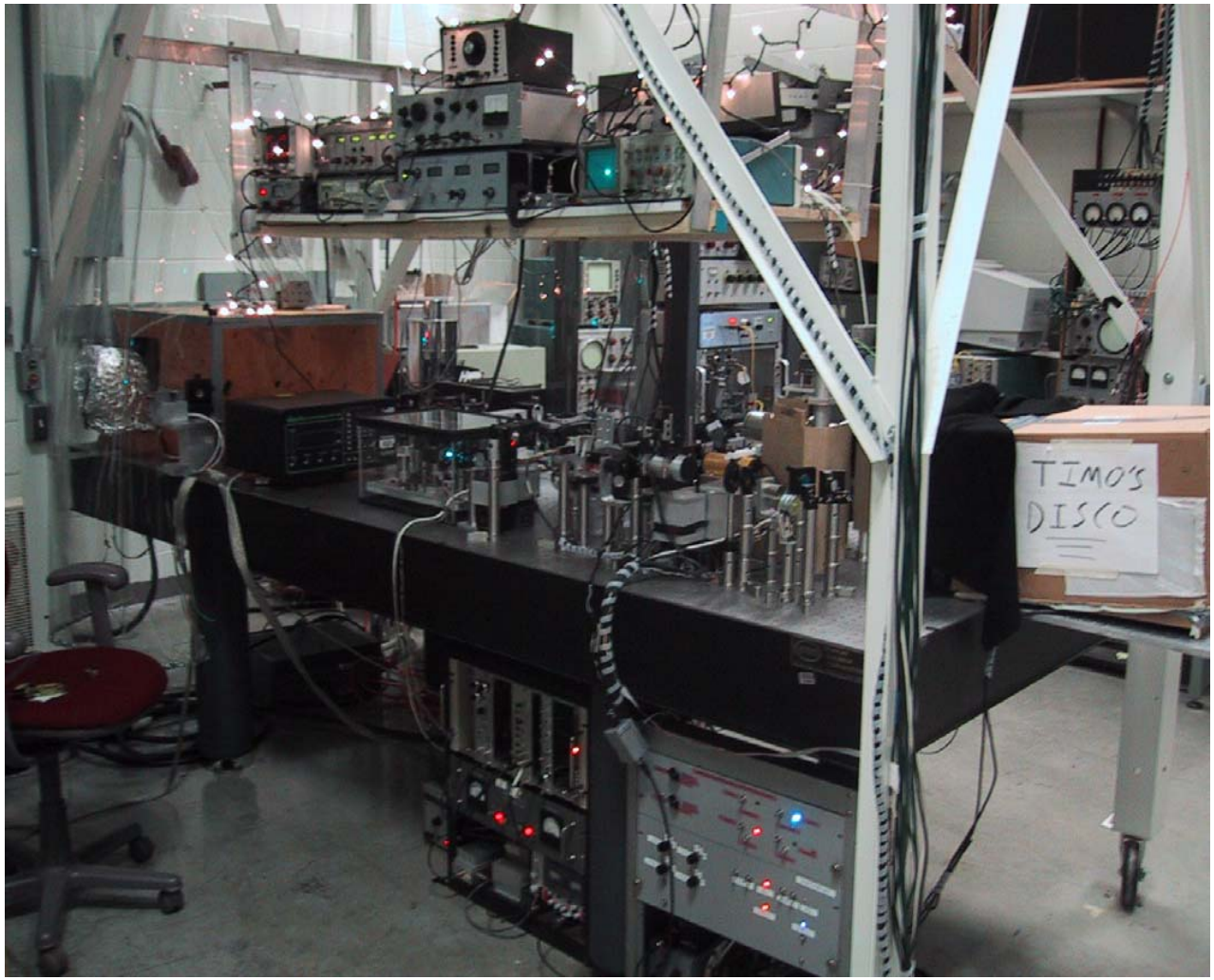
RF spectroscopy antenna

Anode

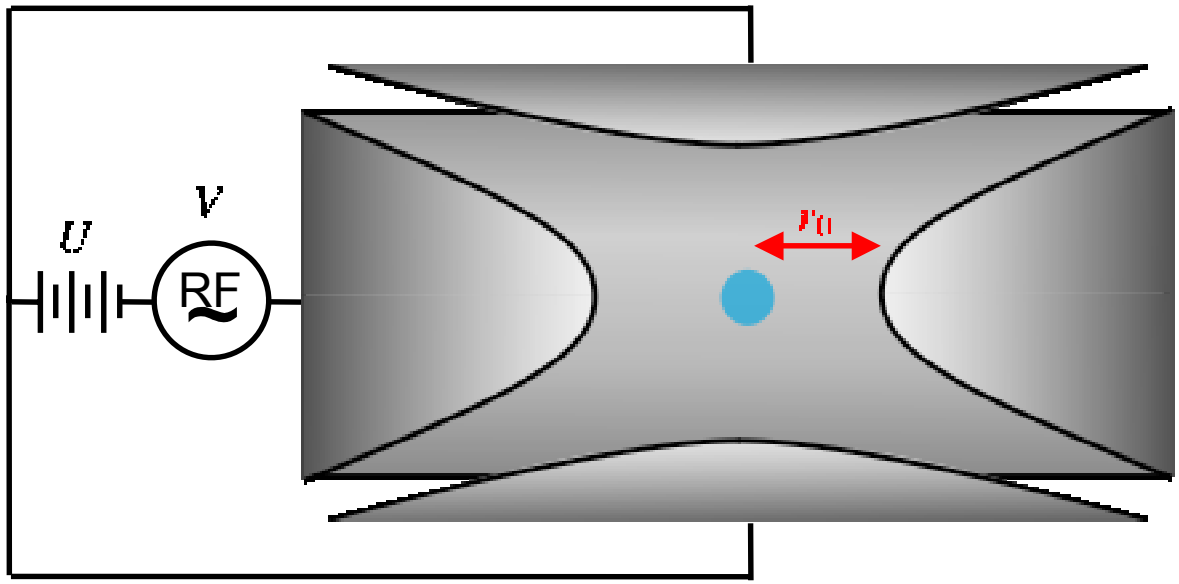
Electron Filament (behind penny)

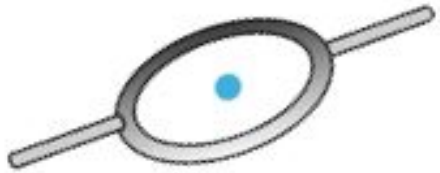
Barium ovens

The Ba^+ Lab



Trapping



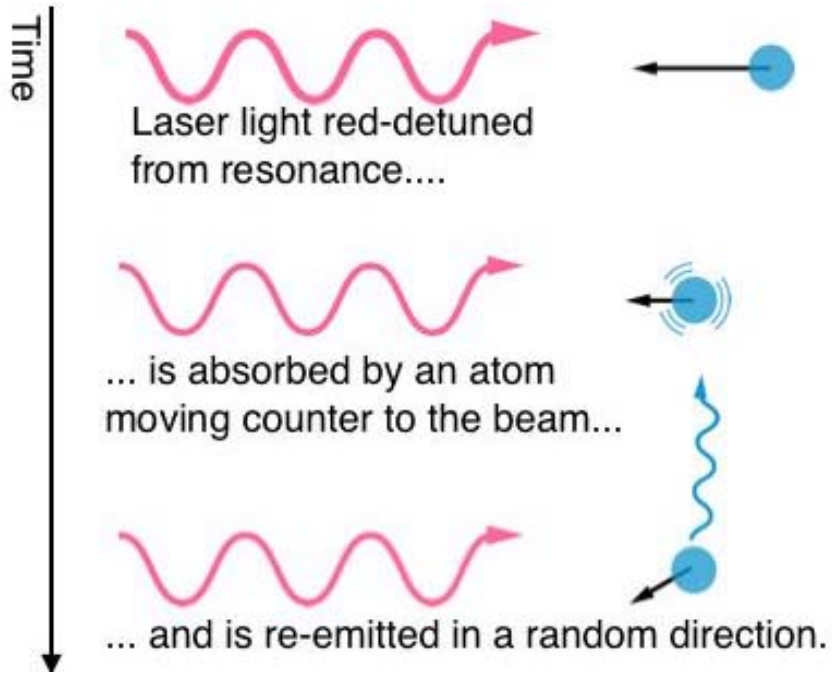


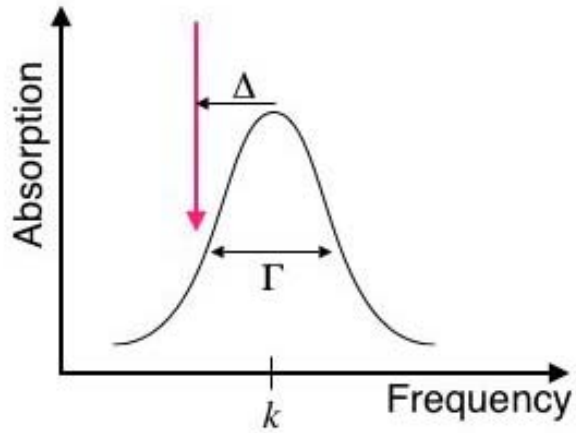
Wire ring trap

Even less harmonic
Highest RF voltages
Great optical access
Wire ring trap cleanable

- Potential is harmonic, but static fields alone cannot confine charged particles in three dimensions.
  - Paul Trap Solution: Make the electric field oscillate and create a confining pseudo-potential.

Cooling



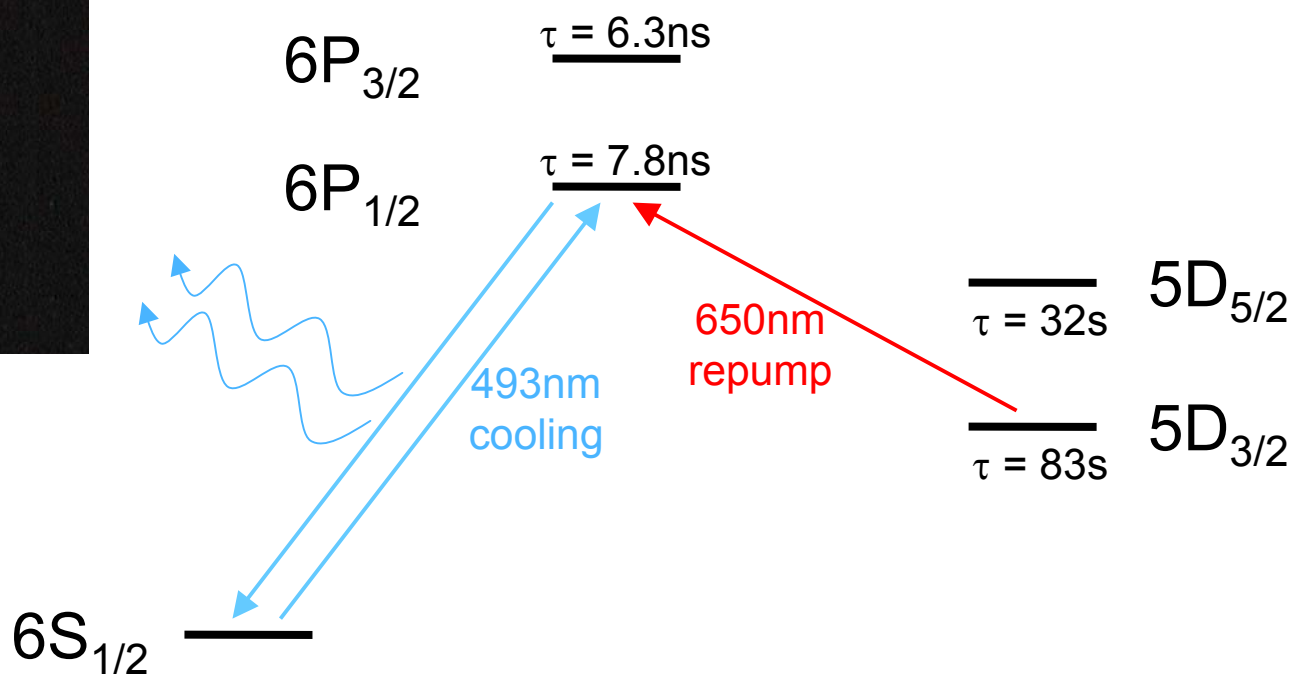


$$T_{\text{doppler}} = \frac{\hbar\Gamma}{2k_B} \approx 100\,\mu K$$ for Ba^+ ion

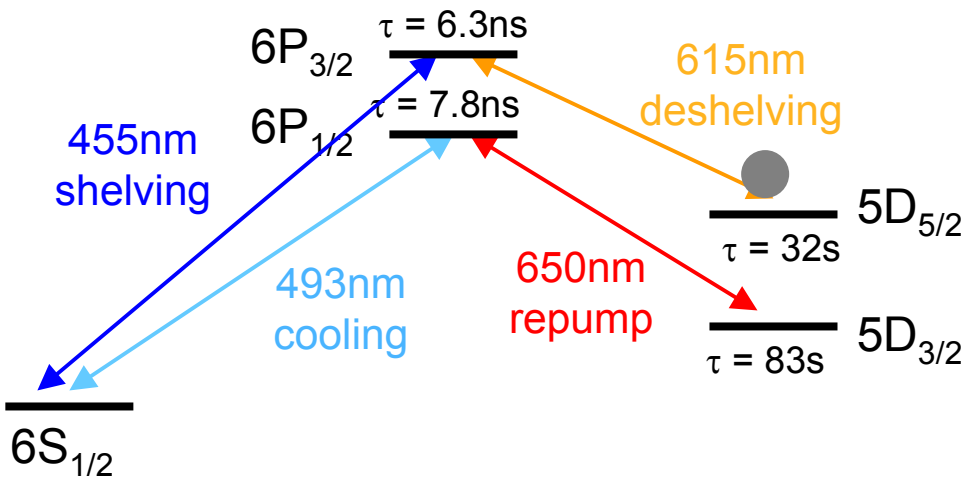
- The ring trap creates a potential that always brings the ion back towards the laser light to be cooled

Absorption/Emission Cycle

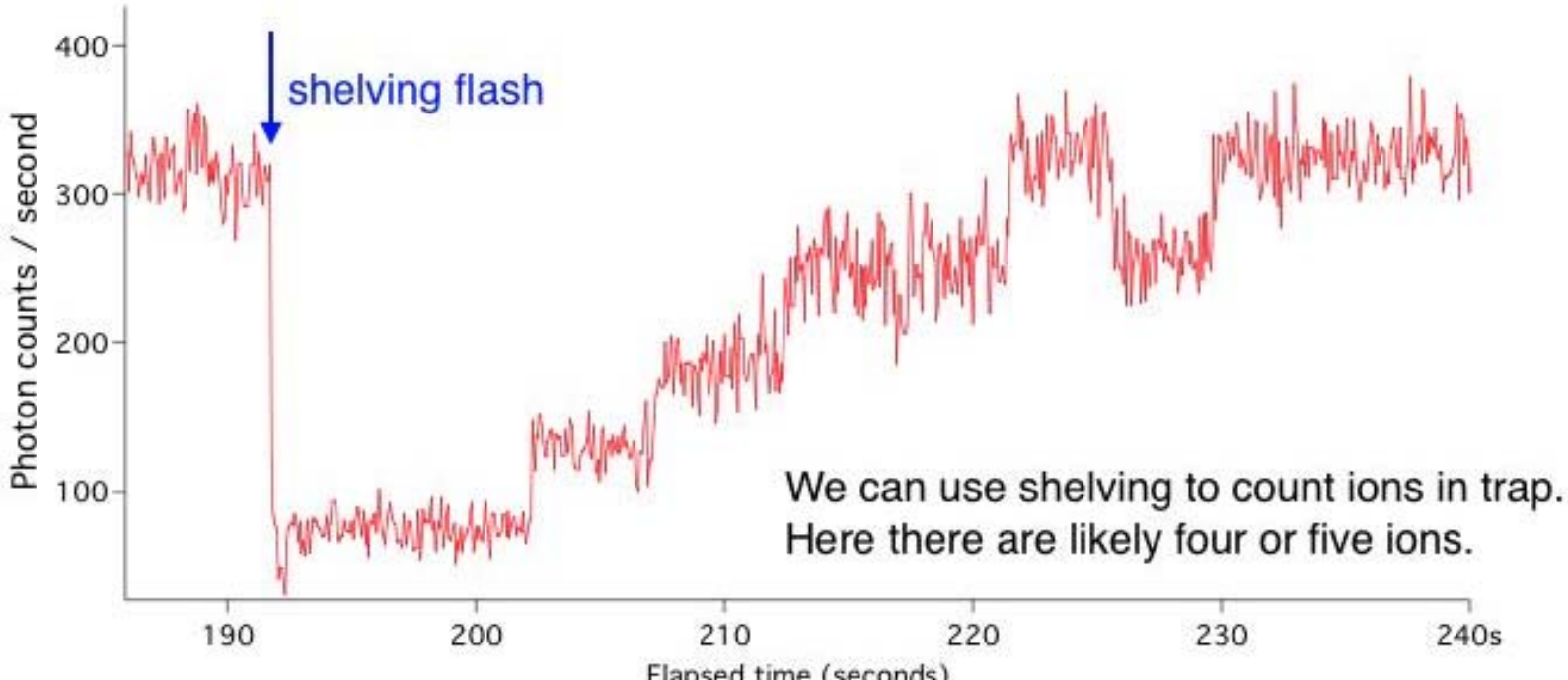
- 493 nm laser light used to cool ion, also excites ion into $6P_{1/2}$ state
- Ion spontaneously emits photon, goes back to ground state, or to meta-stable $5D_{3/2}$ state
- 650 nm laser light used to pump ion out of meta-stable state



Role of LED's - Shelving

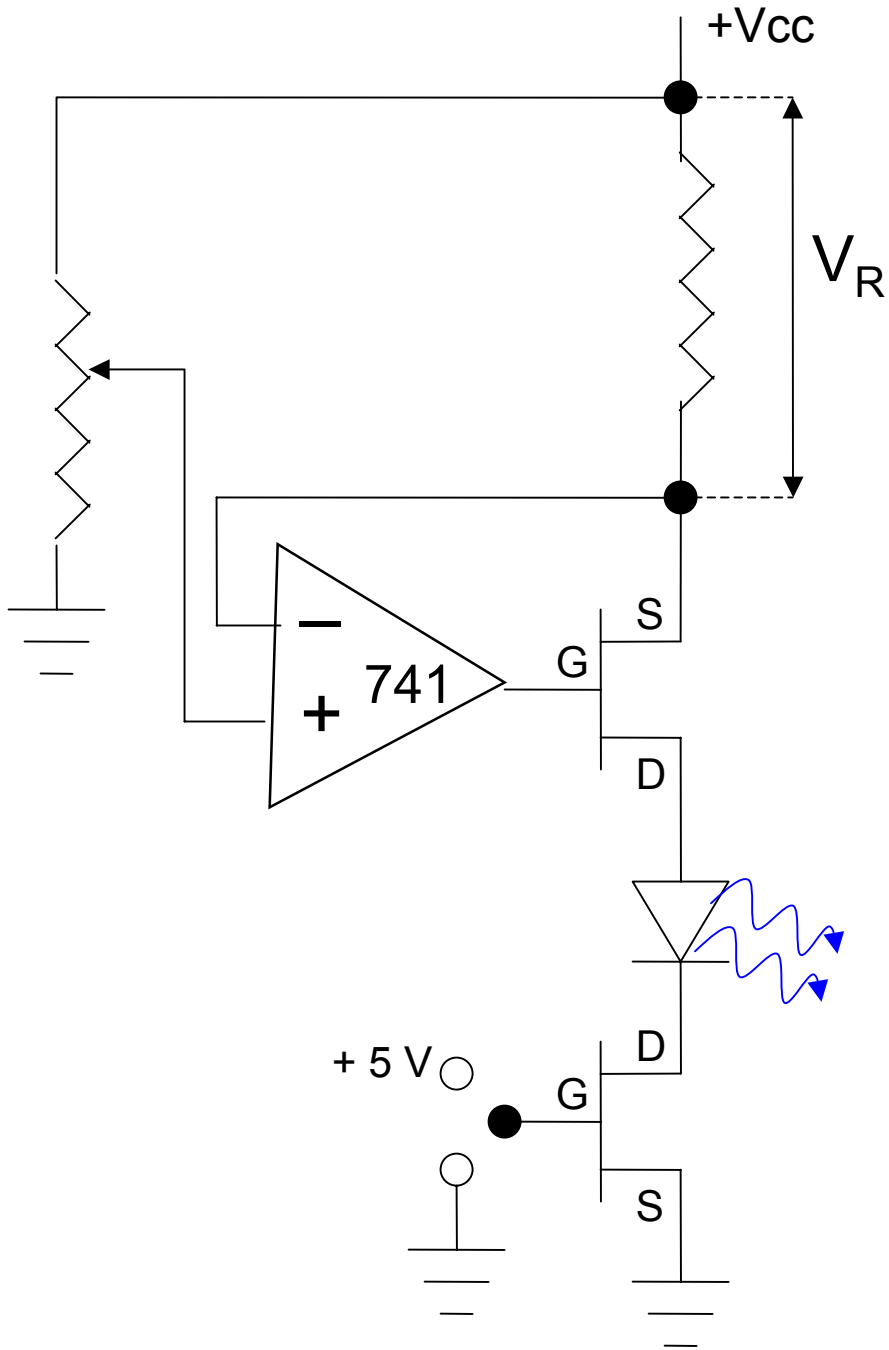


493nm fluorescence stops when the ion is in the "shelf state"

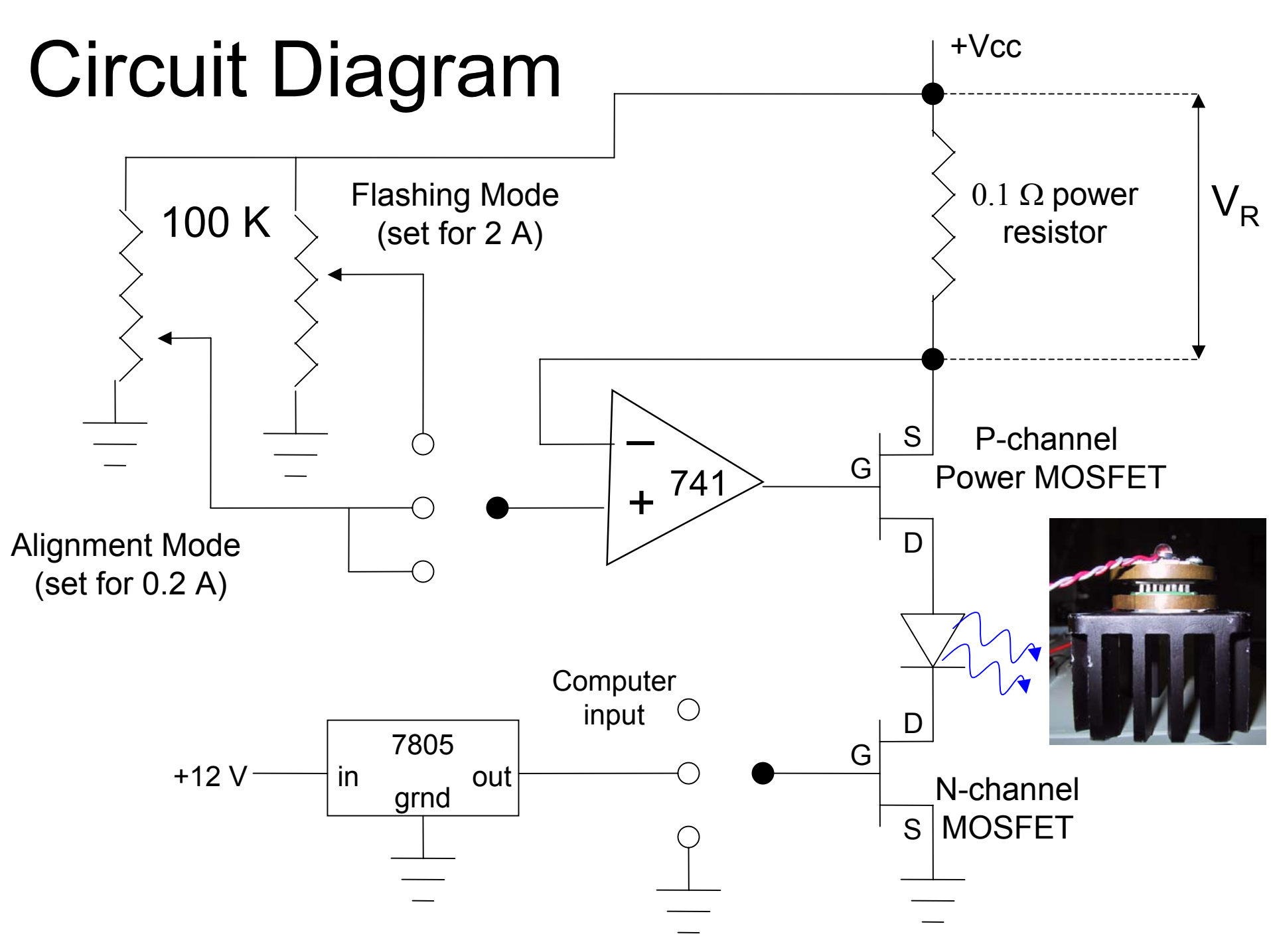


Circuit Analysis

- Op amp rules:
  - No current flows through the op amp
  - The output of the op amp does whatever is necessary in order to keep the two inputs the same.
- FETs as switches (FETS conduct with voltage - gate draws no current)
- Voltage across resistor/0.1 Ω = Current through the LED
- Circuit allows for an adjustable current from 0 to 3A.

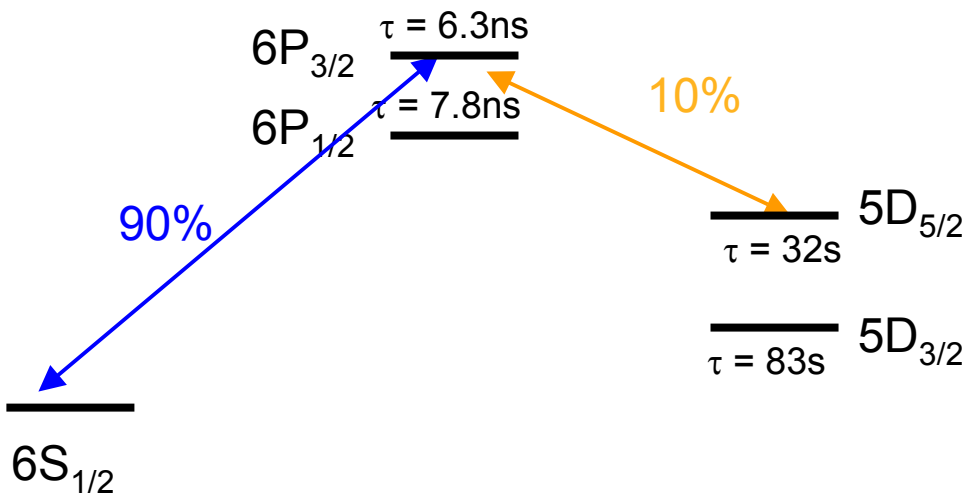


Circuit Diagram



Hopes for the Future

- Circuit isn't constructed yet
- More current = more brightness = faster transitions = less time



Acknowledgements

- University of Washington, REU Program
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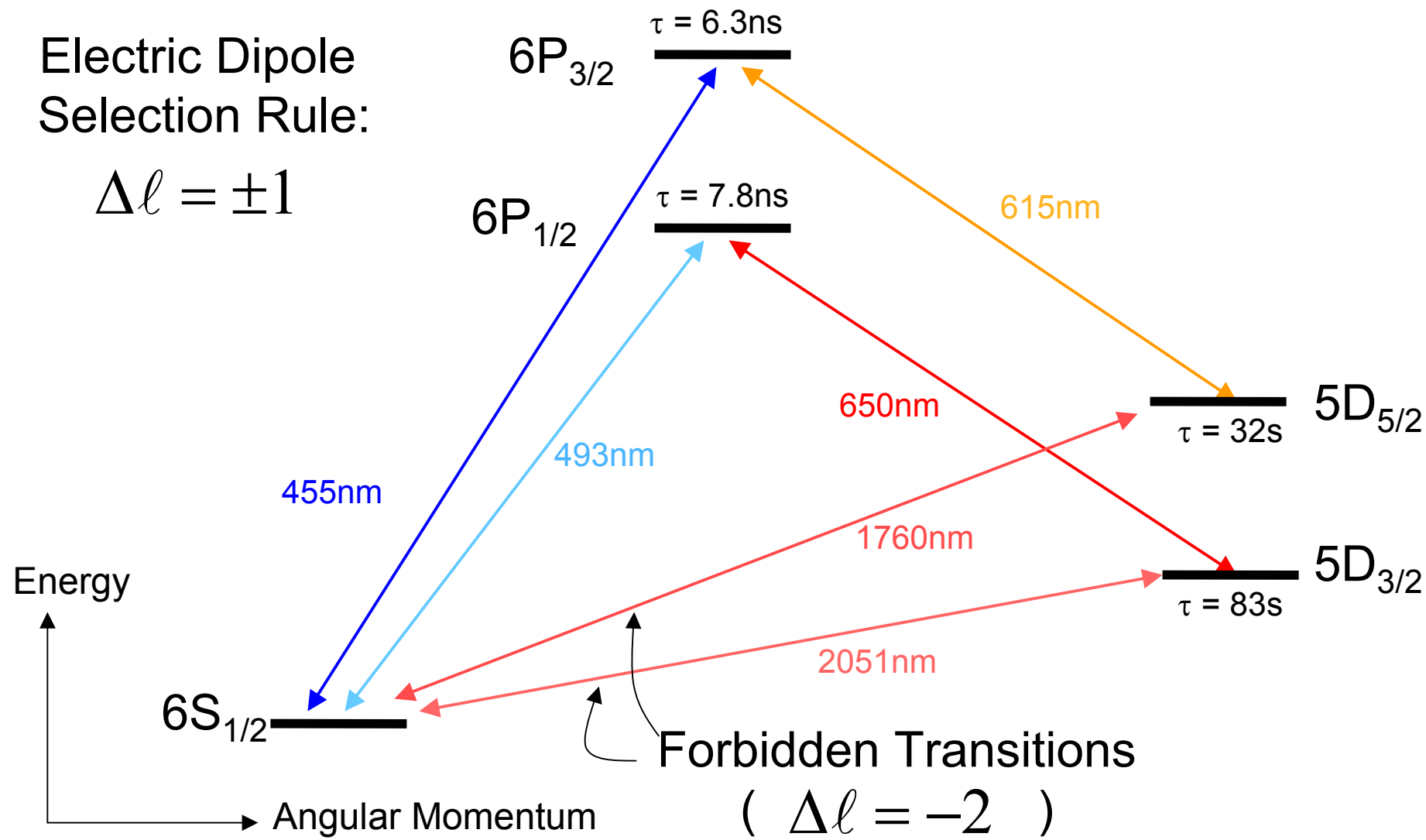
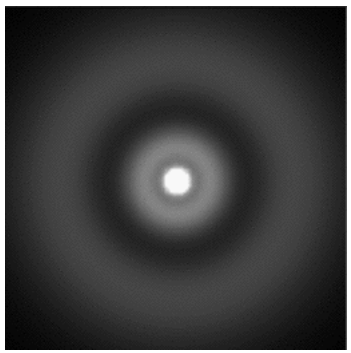
- Jeff Sherman

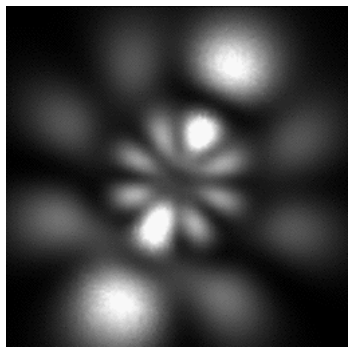
Barium Ion Energy Levels



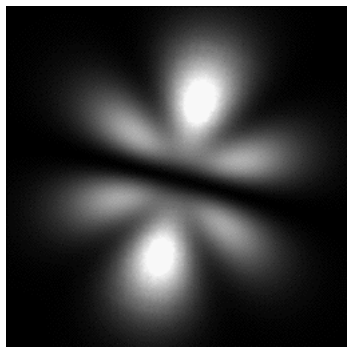
Some other orbits



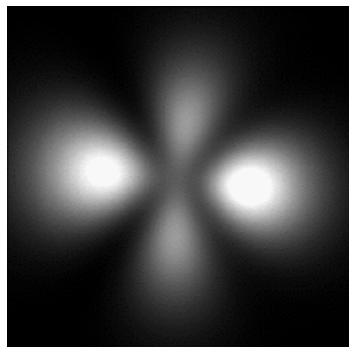
3s



6g



4f



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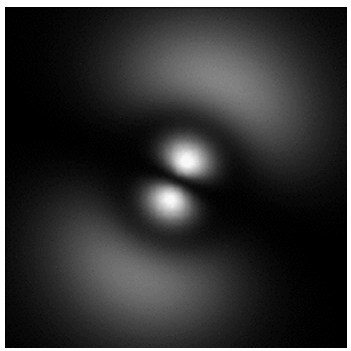
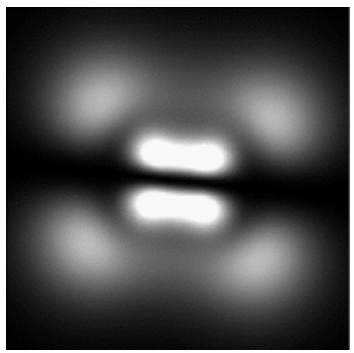


3p



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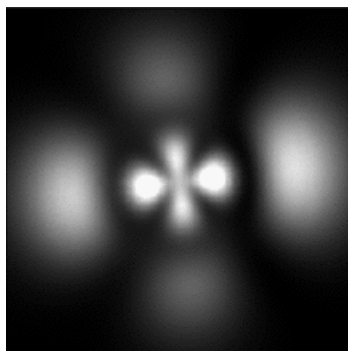
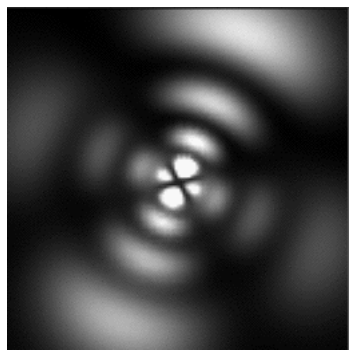


4d



6s