Superradiance in Cold ^{85}Rb Atoms

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Outline

- Motivation
- Superradiance
- Superradiance observation
- Some features about superradiance
- Conclusion
- Acknowledgment

Motivation

Cold Rydberg atoms

- Automatically evolve into plasma
- Artificial amorphous solids

Superradiance

- Microwave source
- Leads to ionization

Quantum mechanical explanation

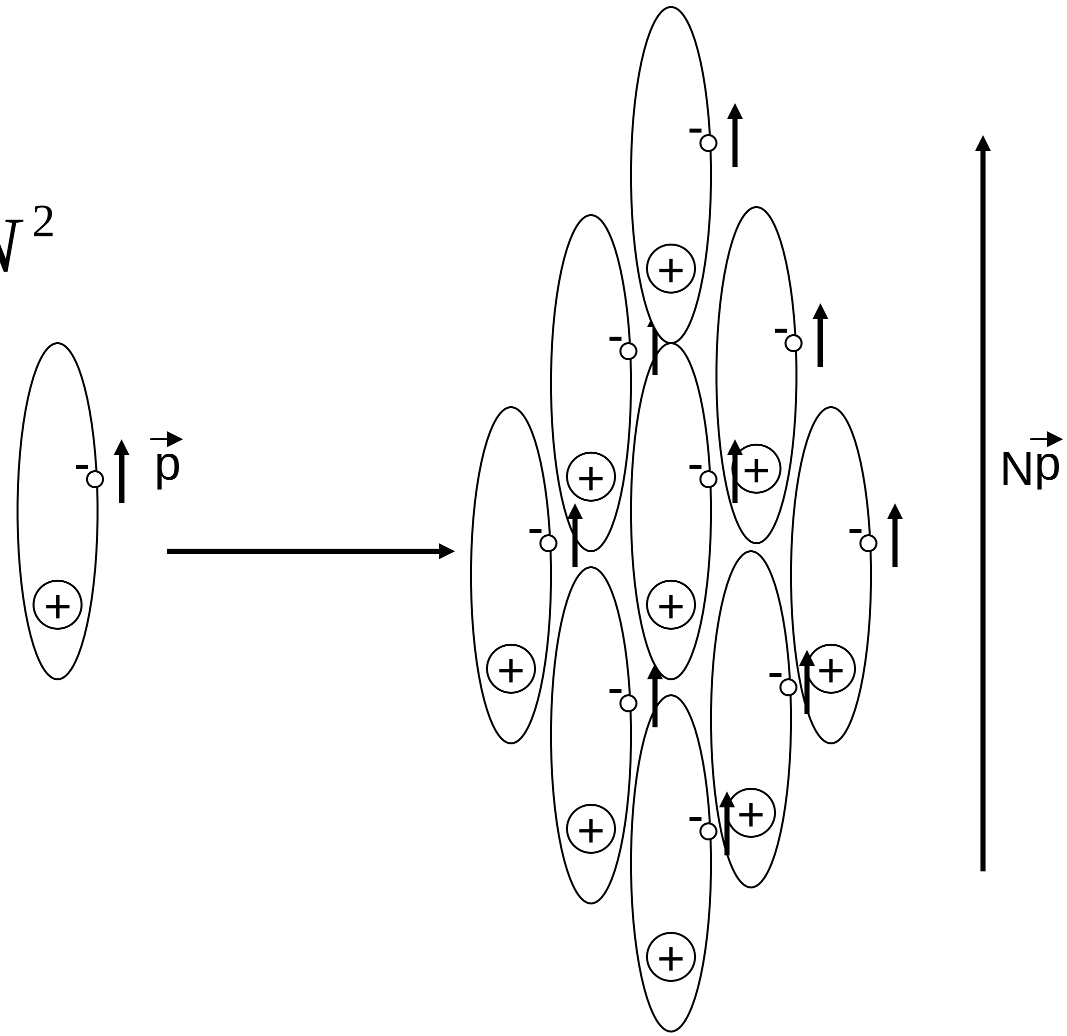
$$\Psi_1 = \psi_1 e^{-iE_1 t}$$

$$\Psi_2 = \psi_2 e^{-iE_2 t}$$

Superradiance

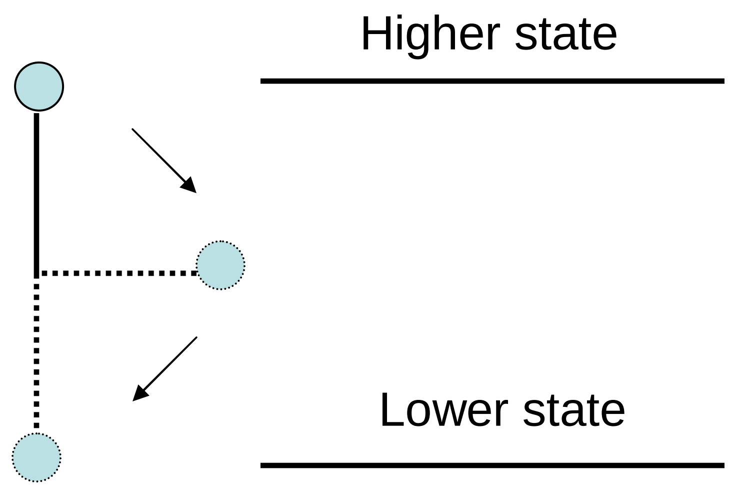
Key features:

- Peak intensity $\propto N^2$
- Threshold
- Delay



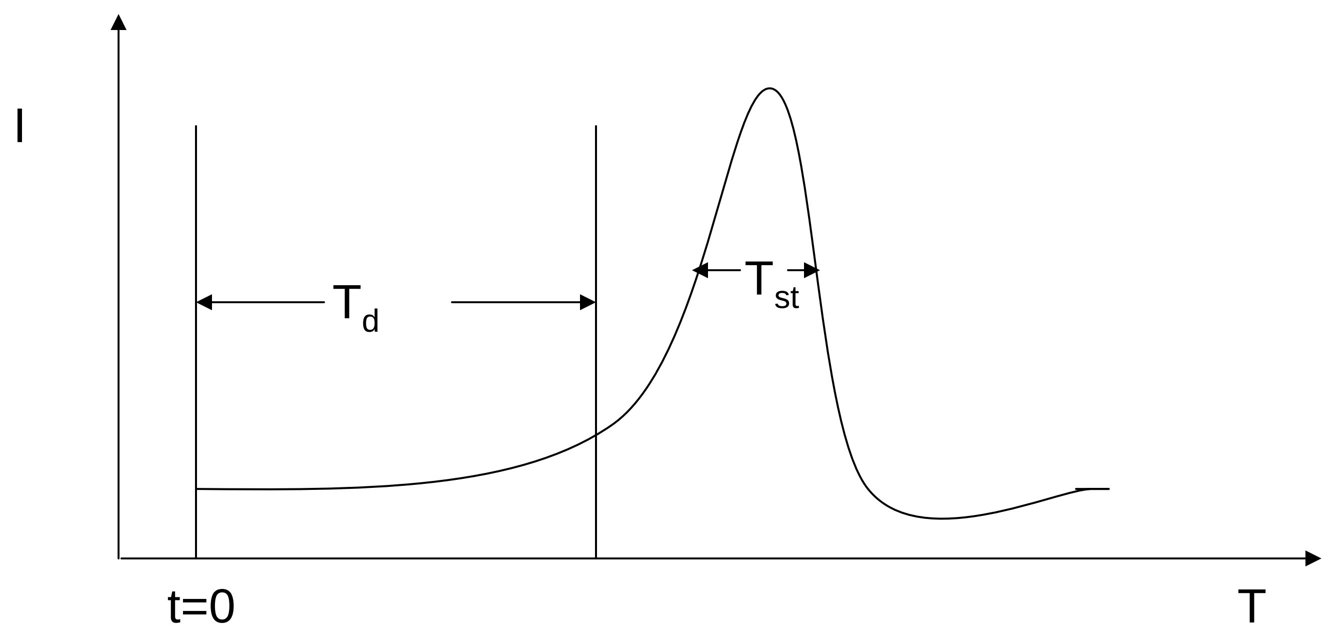
Superradiance[1]

- Inverted pendulum

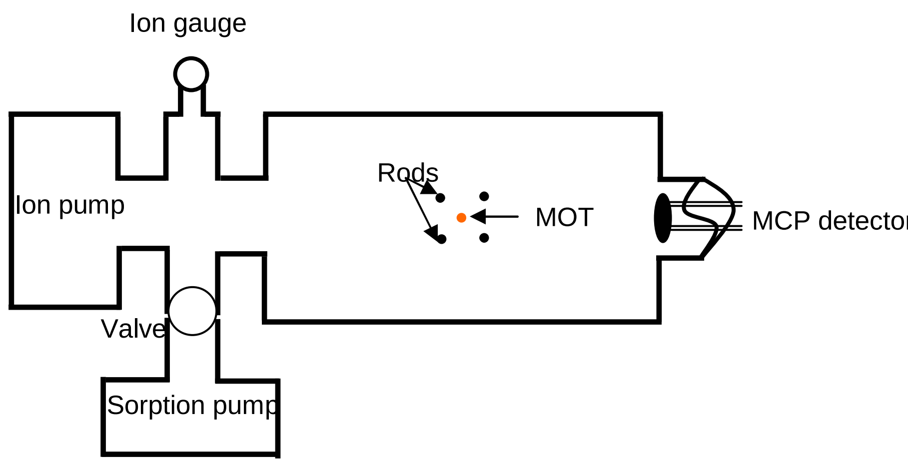


[1] Nicholas E. Rehler and Joseph H. Eberly, 3, 1735(1971).

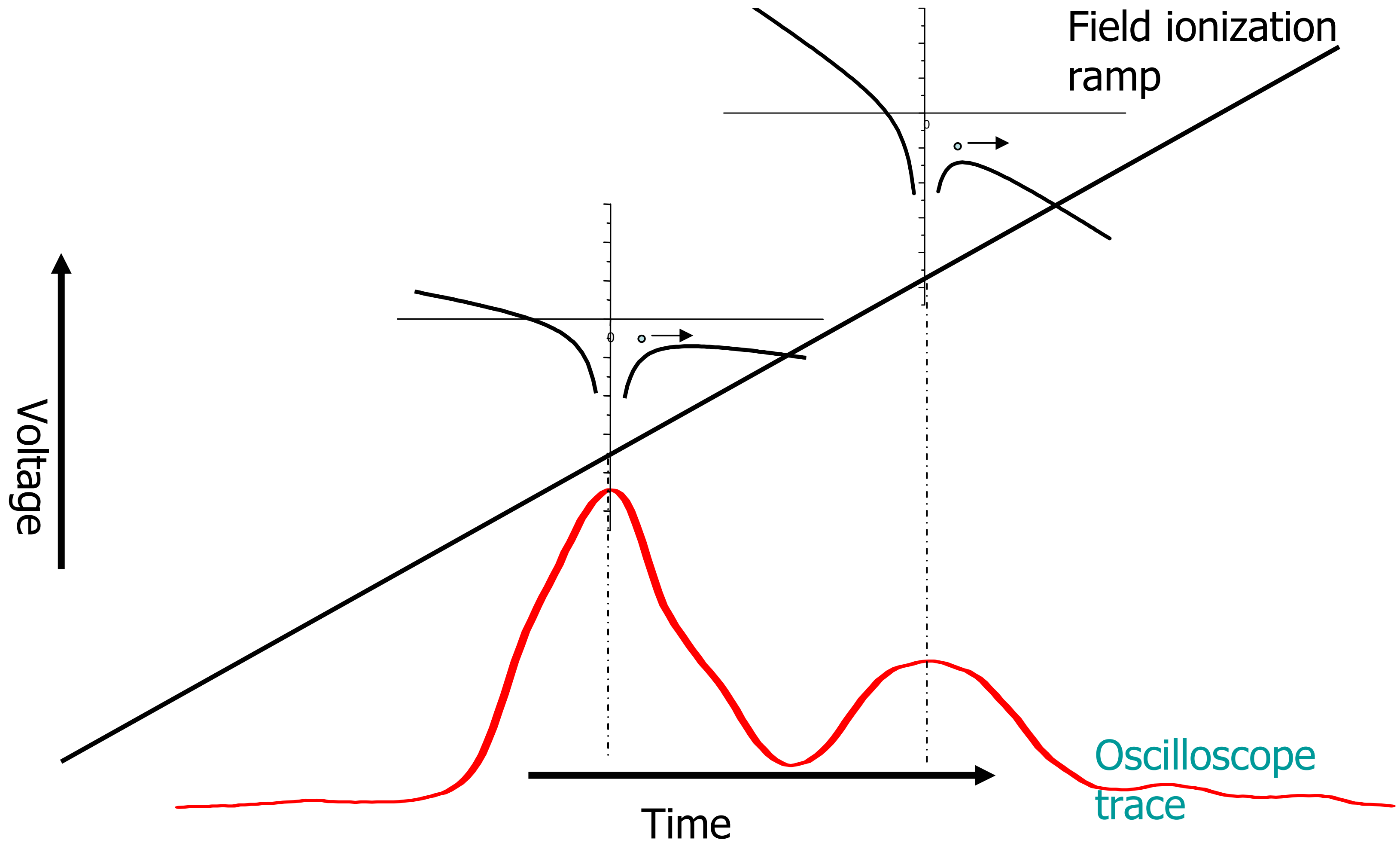
Radiation from N dipoles with spontaneous emission lifetime t



Experimental setup

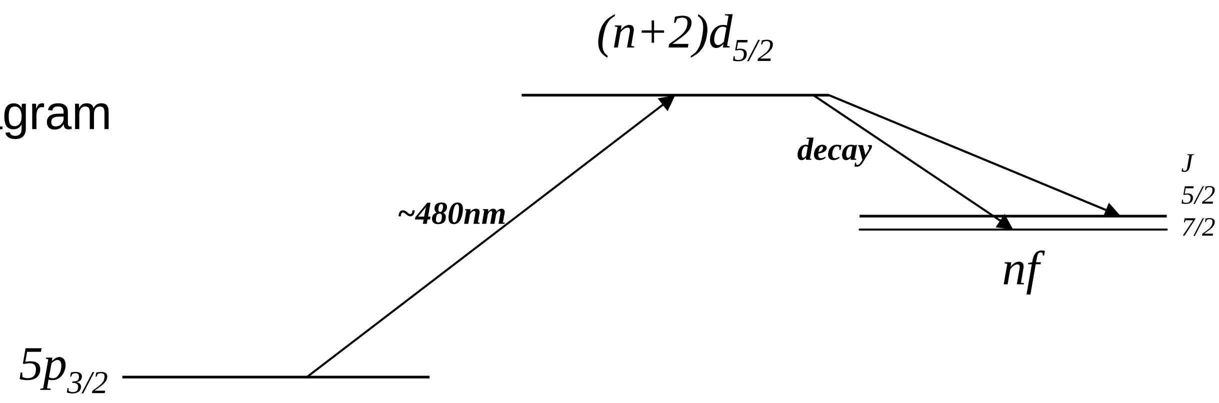


Selective Field Ionization (SFI)

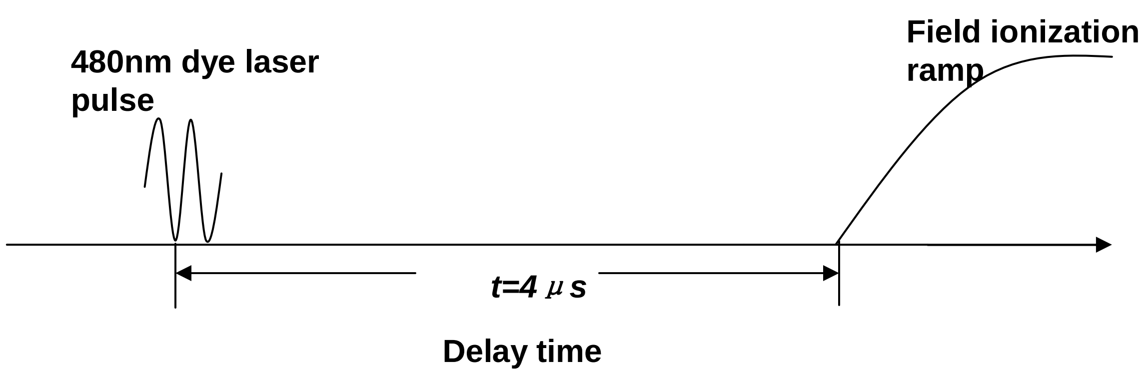


Energy diagram and Timing

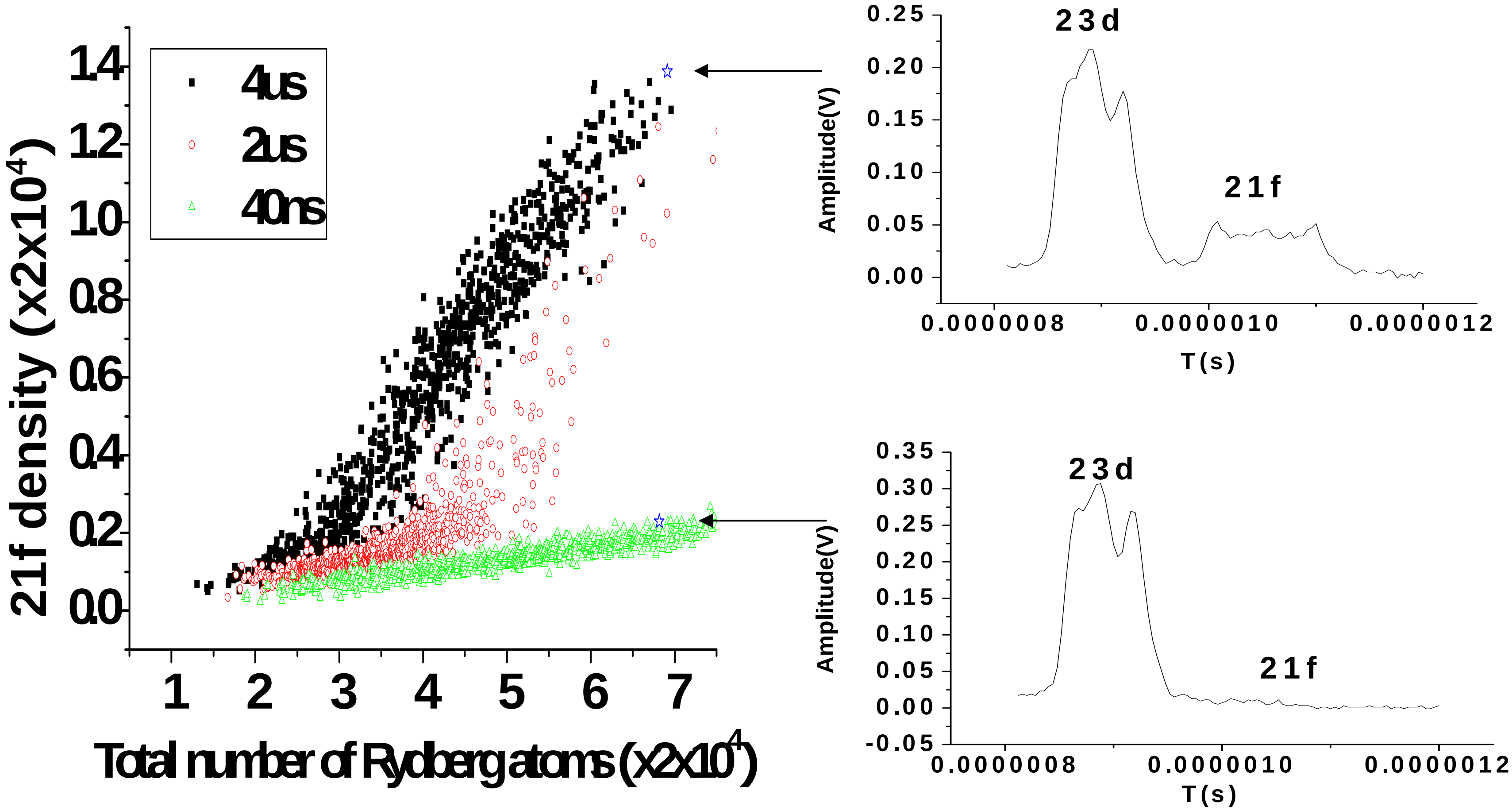
Energy diagram



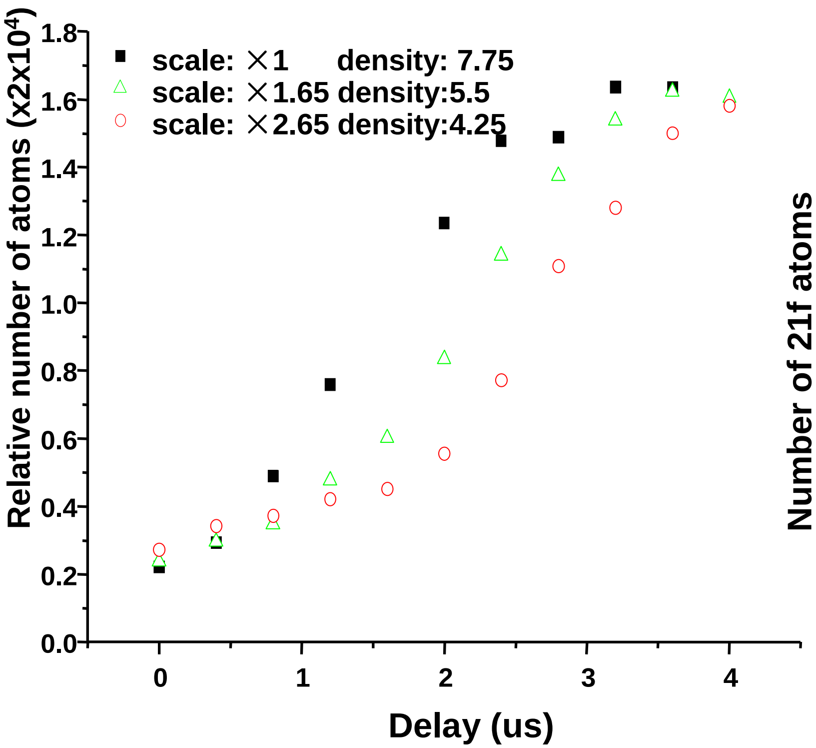
Timing

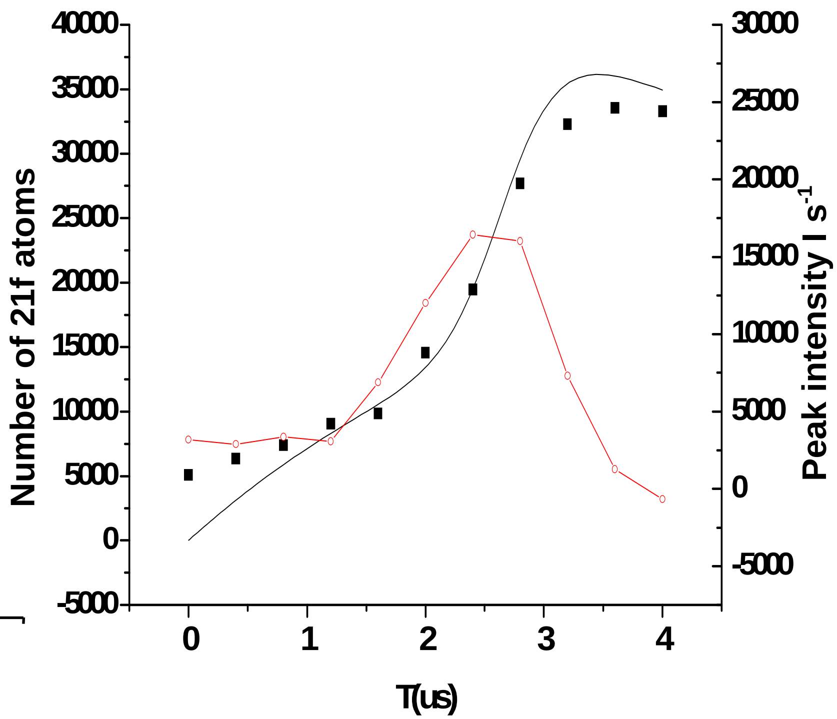


Experimental data



Data Analysis



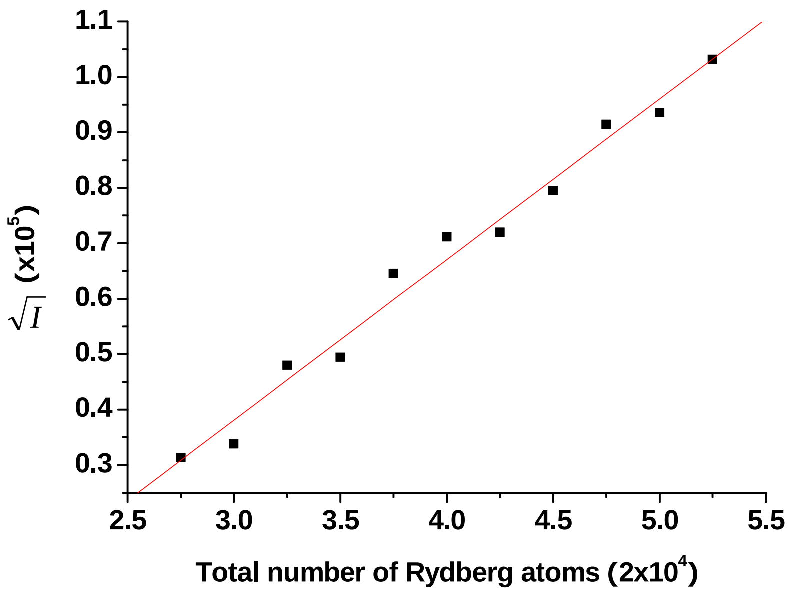


Radiation density

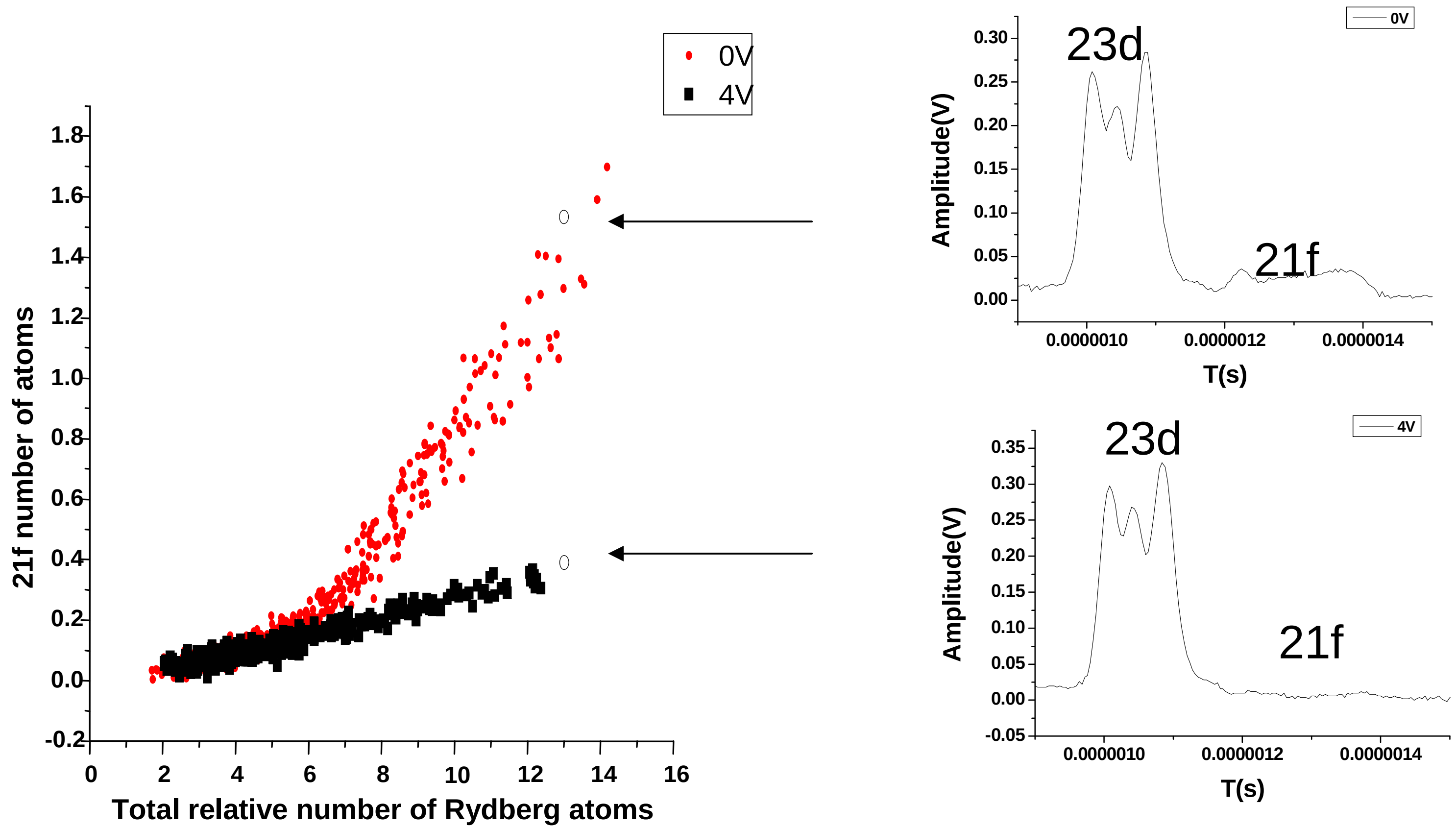
- Intensity of output radiation:

$$I \propto \frac{dN}{dt}$$

$$I \propto N^2$$

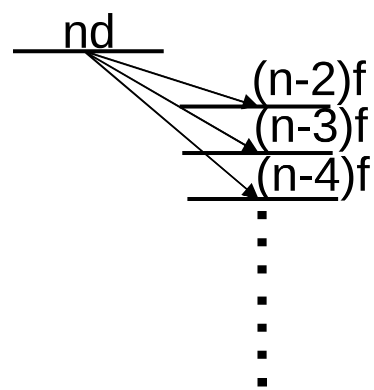


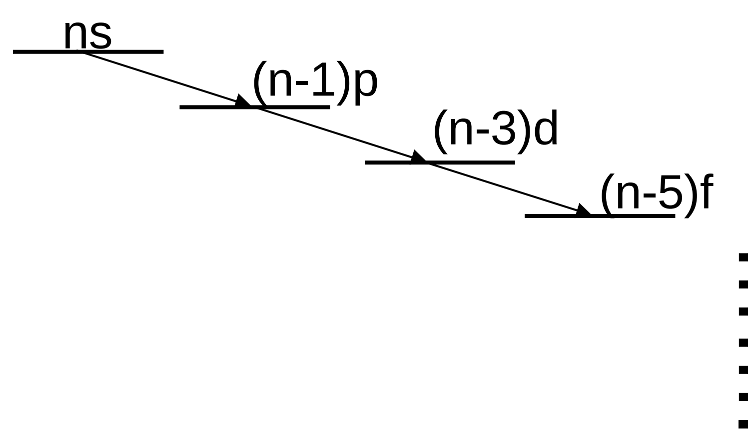
Suppression due to the electric field



Two decay channels

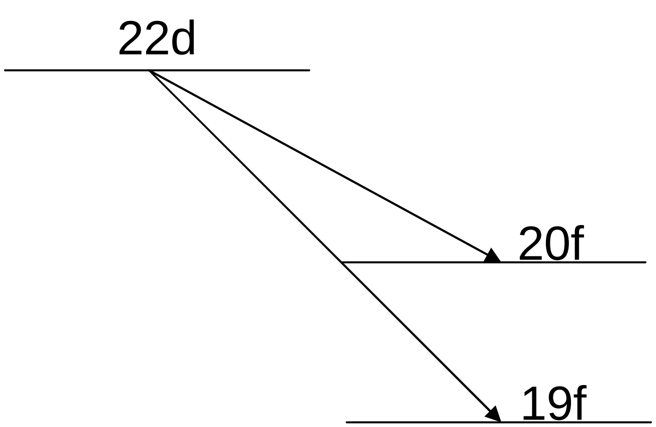
- Multimode decay: different modes have the same threshold
- Cascade decay: there is a saturation effect

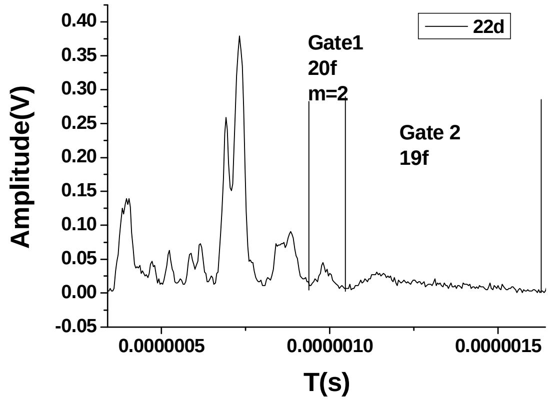


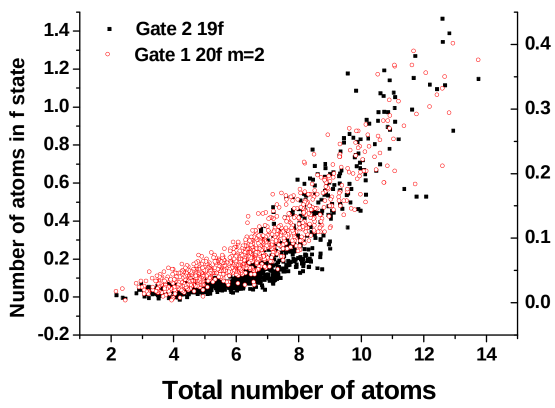


Multimode decay

- Energy levels

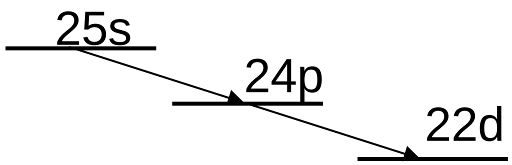


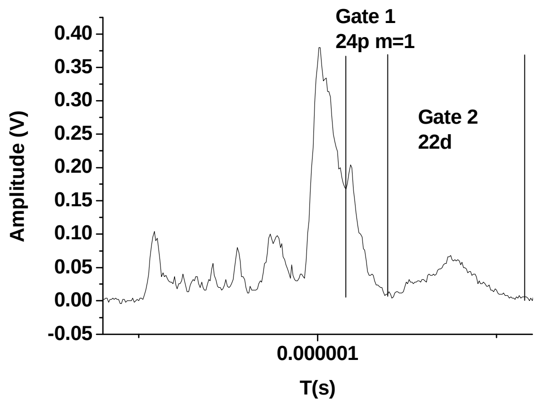


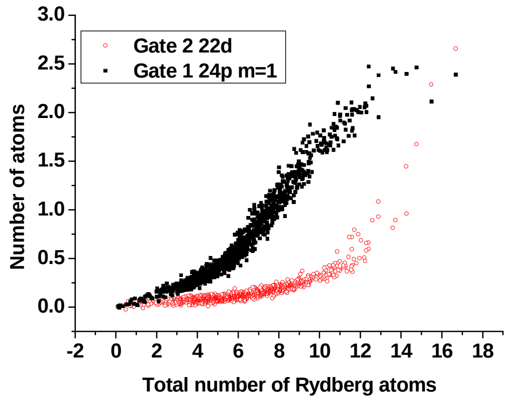


Cascade decay

- Energy levels



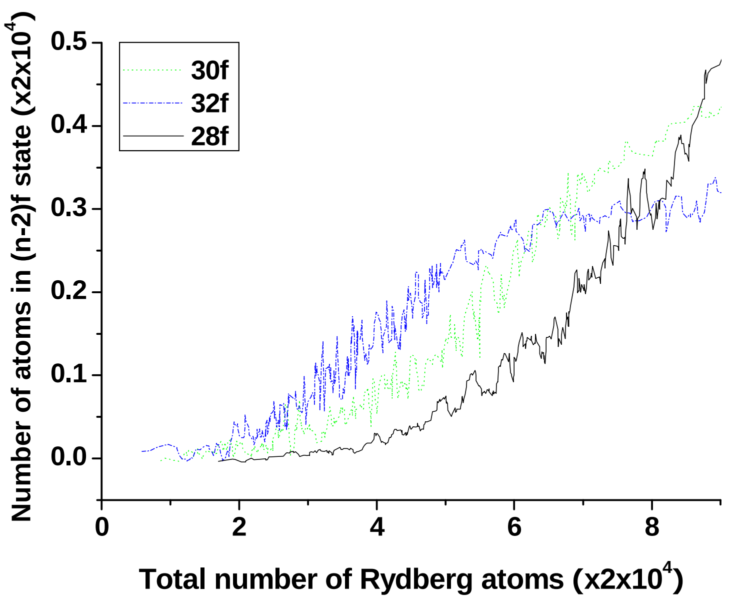




Principle quantum number n dependence

- Superradiance threshold density decrease with n
- Higher n states, superradiance occurs earlier
- The amount of superradiance decreases.

Delay: 2us



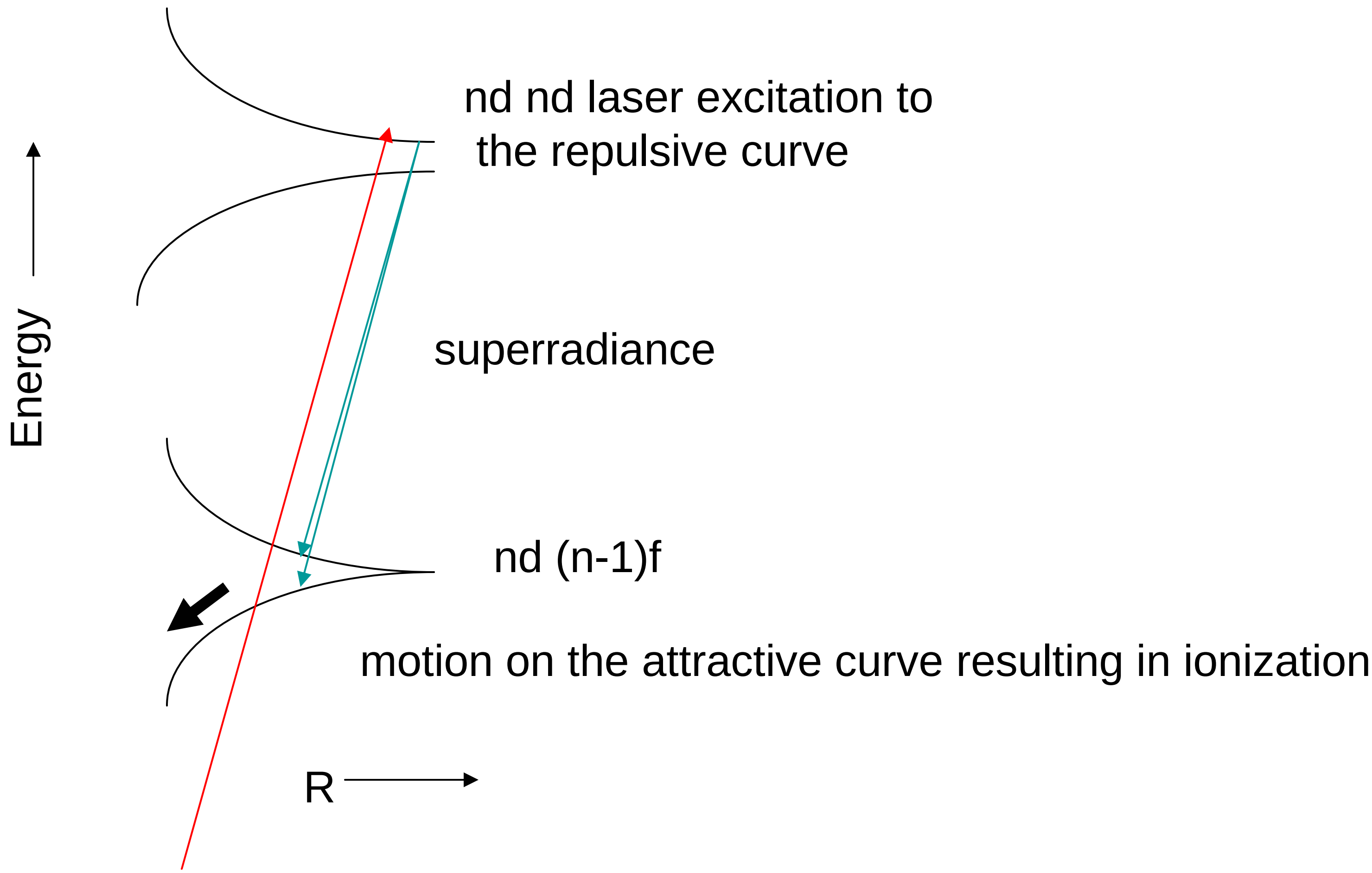
Why does Superradiance decline at high n?

Decrease in the radiative rate $$1/\tau = \mu^2\omega^3 \propto 1/n^5$$

Dipole-dipole interaction $$V_\mu = \frac{\mu}{R}\left(\frac{2\pi}{\lambda}\sin\omega t + \frac{1}{R}\cos\omega t\right)$$

23d-21f λ =2.3 mm
34d-32f λ =0.6 mm

Superradiance and Ionization



Conclusion

- Superradiance is observed in cold Rydberg atoms
- Superradiance is an effective way to transfer the atoms from low angular momentum states to high angular momentum states.

Acknowledgment

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