Superradiance in Cold $^{85}\text{Rb}$ 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

Radiation from $N$ dipoles with spontaneous emission lifetime $t$
Experimental setup

Ion gauge
Ion pump
Valve
Sorption pump
Rods
MOT
MCP detector
Selective Field Ionization (SFI)
Energy diagram and Timing

Energy diagram

- $5p_{3/2}$
- $\sim 480\text{nm}$
- $(n+2)d_{5/2}$
- $n^f$
- $j = 5/2\rightarrow 7/2$
- Decay

Timing

- 480nm dye laser pulse
- Field ionization ramp
- Delay time $t = 4\mu s$
Experimental data
Data Analysis

![Graphs showing data analysis results](image-url)
Radiation density

- Intensity of output radiation:

\[ I \propto \frac{dN}{dt} \]

\[ I \propto N^2 \]
Suppression due to the electric field

![Graph showing suppression due to electric field](image)
Two decay channels

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

- Energy levels

![Graph showing energy levels and population distribution over time and total number of atoms]
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.

![Graph showing number of atoms in (n-2)f state against total number of Rydberg atoms.](image)

Delay: 2μs
Why does Superradiance decline at high n?

Decrease in the radiative rate

\[ \frac{1}{\tau} = \mu^2 \omega^3 \propto \frac{1}{n^5} \]

Dipole-dipole interaction

\[ V_\mu = \frac{\mu}{R} \left( \frac{2\pi}{\lambda} \sin \omega t + \frac{1}{R} \cos \omega t \right) \]

\[ 23d-21f \quad \lambda = 2.3 \text{ mm} \]
\[ 34d-32f \quad \lambda = 0.6 \text{ mm} \]
Superradiance and Ionization

nd nd laser excitation to the repulsive curve

superradiance

nd (n-1)f

motion on the attractive curve resulting in 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.
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