Phys 4061— Lecture Two

Outline of Lecture

Review of Terms

- Intensity, I
- Energy Density, ρ
- Spectral Density, ρ_ν
- Line Shape, $g(\nu)$

2 Level Atoms in Thermal Equilibrium

- Rate equation for population density
- Relationship between B_{12} and B_{21}
- Relationship between A_{21} and B_{21}

Interaction of Light and Matter (Dilute Atomic Gases) – Review of Operational Terms

1. Intensity

$$\text{Intensity} = \frac{\text{Energy}}{\text{Area Time}}$$

2. Poynting Vector

$$S_{avg} = I_{avg} = \tfrac{1}{2}\,\varepsilon_o\, c\, E_o^{\,2}$$

3. Energy Density

$$\rho_{avg} = \frac{\text{Energy}}{\text{Volume}} = \tfrac{1}{2}\,\varepsilon_o\, E_o^{\,2}$$

4. Radiation Pressure

$$P_{rad} = \frac{F}{A} = (Rate\ of\ Change\ of\ Momentum)\left(\frac{1}{A}\right)$$

$$P_{rad} = \frac{\text{Energy}}{(\text{Time})(\text{Area})(c)} = \frac{\text{Intensity}}{c}$$

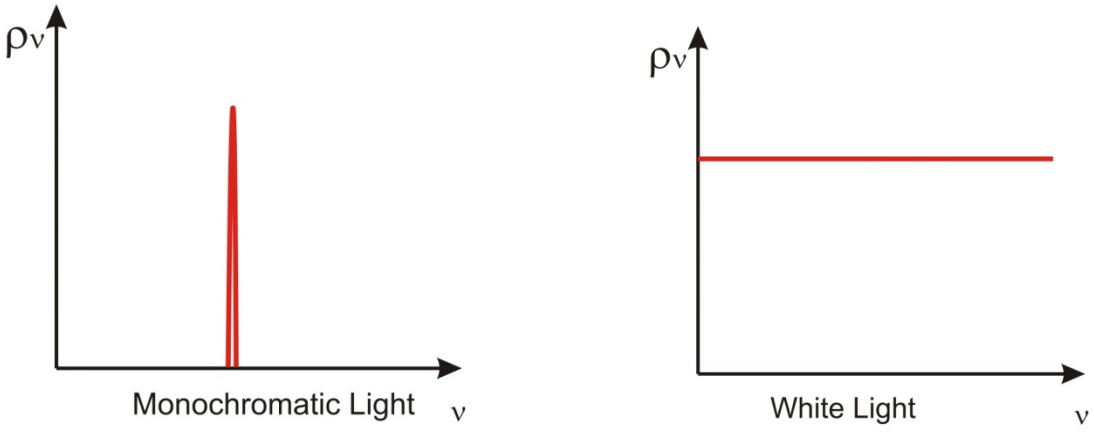
$$P_{rad(avg)} = \tfrac{1}{2}\,\varepsilon_o\, E_o^{\,2}$$

$$P_{rad(ang)} = \rho_{avg}$$

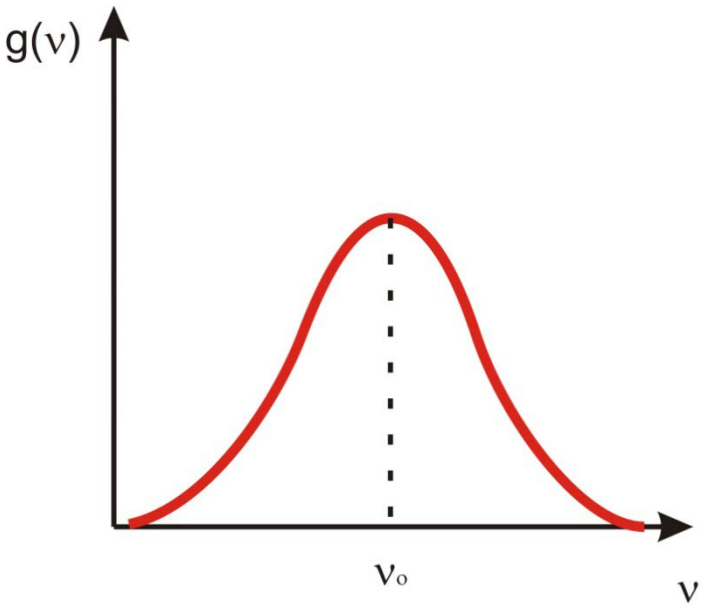
5. Spectral Density
   - energy density per unit frequency interval

$$\rho_\nu = \frac{\rho}{\Delta\nu} = \frac{I_\nu}{c}$$

   - where I_ν is the Spectral intensity (intensity per unit frequency interval)



6. Line Shape Function g(ν)
    - Energy range of absorbed/emitted light

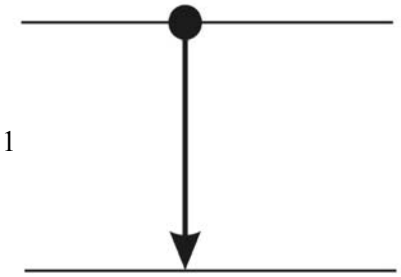


- Probability of absorption/emission in range ν to ν + dν
- Lineshape is generally Lorentzian or Gaussian for atomic gases

Spontaneous Emission – Gas of two level atoms

2

1



$$dn_2/dt = -n_2A_{21}$$

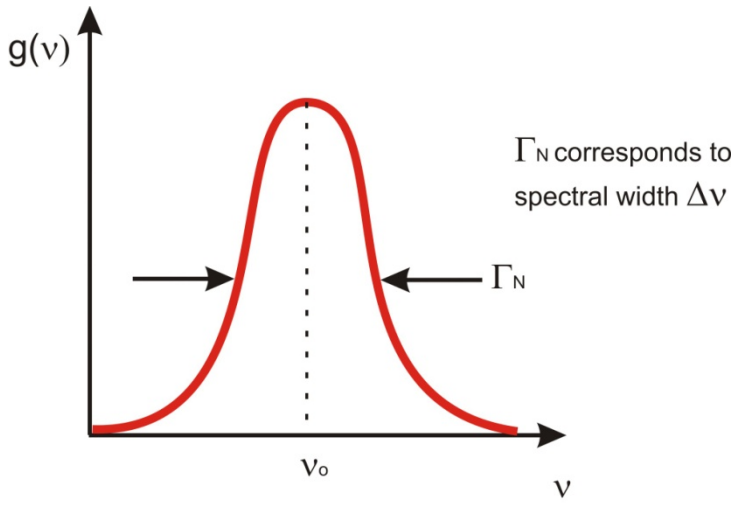
- A_{21} is the Einstein A Coefficient
    - probability of transition from 2 → 1
    - A_{21} is a rate [s^{-1}]

$$n_2(t) = n_2(t=0)\exp[-A_{21}t]$$

- n_2 and n_1 are the atoms per unit volume in levels 2 and 1 respectively
- Natural lifetime of level 2, $\tau_2 = 1/A_{21} = 1/\Gamma$

Spectral Width

- corresponding spectral lineshape is Lorentzian
- Γ_N is the natural line width



$$\Gamma_N = A_{21}/2\pi = \Gamma/2\pi$$

- $E_L = h\nu_L$
  - Spread due to the source line width
- $E_{21} = h\nu_o$
  - Spread about resonant energy (intrinsic atomic line width)
- Atomic linewidth is associated with lifetime τ_2 = uncertainty in emission time
  - $\Delta E = h/\tau_2$
  - Spread ΔE due to uncertainty principle