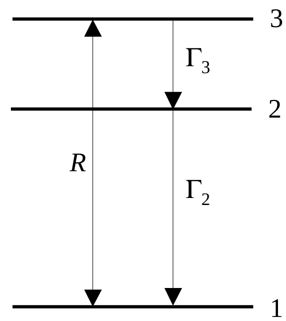
Phys 532 Assignment 5 Due February 21

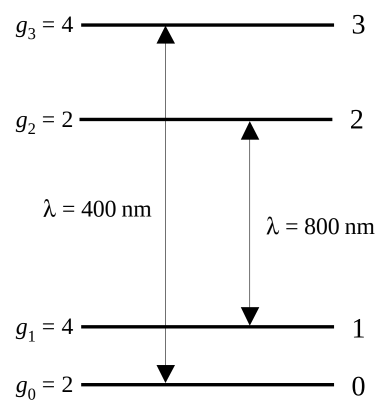
1. An ideal "three-level" laser has a level structure shown below. A reversible pumping mechanism with rate R per molecule populates state 3, which decays irreversibly to state 2 at a rate Γ_3. State 2 decays back to state 1 at a rate Γ_2. The lasing transition occurs between states 1 and 2. What pumping rate R is required to induce a population inversion? (You may assume that all levels are equally degenerate.)



2. Consider a laser medium consisting of a glass matrix doped with an ion having the level structure shown. (The wavelengths shown are the vacuum values.) You are given the following data:

- Level 3 decays radiatively to level 1 with a 10 ns lifetime
- Level 3 decays nonradiatively to level 2 at a rate of 10^9 s^{-1}
- Level 3 has a spectral linewidth of 100 GHz
- Level 2 decays radiatively to level 1 with a 30 ns lifetime
- The 1 $\leftrightarrow$ 2 transition is inhomogeneously broadened to 10 GHz linewidth
- Level 1 decays to level 0 with a lifetime of 5 ns

The ion doping concentration is 10^{17} cm^{-3}, and the index of refraction of the glass is 1.5. If the 0 $\rightarrow$ 3 transition is pumped by light of intensity 100 W/m^2, what is the small-signal gain coefficient at $\lambda = 800$ nm?



3. Suppose a gas laser operating at 514 nm has a small signal gain of 0.2 m^{-1}. The dominant decay channel for the upper laser level is spontaneous emmission to the lower level, with a lifetime of 2×10^{-8} s. The gas is in a tube 20 cm long, which is enclosed in a linear cavity with 30 cm between the two mirrors. One of the mirrors is flat, with nearly 100% reflectance. The other mirror has a radius of curvature of 2 m and a transmission of 4%. In addition, there is a distributed power loss of 1% per pass (= 2% per round trip).

(a) Estimate the output power produced by this laser.

(b) What value of the transmission of the output coupler would give the maximum output power, and how much higher would it be?

822 students only:

4. On pages 187-189, Yariv discusses "frequency pulling" effects in a laser, which are caused by the variation of the real index of refraction of the gain medium near resonance. Similar effects occur for absorbing rather than amplifying media. To investigate this, consider a Fabry-Perot cavity of length ℓ and longitudinal mode spacing $\Delta\nu_L = c/2\ell$. Suppose the cavity is filled with a gas having peak absorption coefficient α_0 at resonant frequency ν_0, and a homogeneously broadened linewidth $\Delta\nu \gg c/2\ell$. You can assume that the total absorption $\alpha_0\ell \ll 1$.

We can expect the gas to modify $\Delta\nu_L$ near the resonance. If the length ℓ is tuned such that a cavity mode lies exactly at ν_0, the neighboring modes frequencies $\nu_0 \pm \delta$. Calculate δ to leading order in $\Delta\nu_L/\Delta\nu$. Would you call the effect frequency "pulling" in this case?