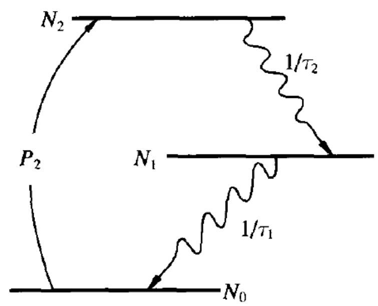
Laser Physics I (PHYS/ECE 464), Fall 2022

Homework #8, Due Monday Nov. 7

7.10. In the diagram shown below, the pump P_2 (i.e., electrons, flash lamp, another laser, etc.) excites atoms from state 0 to state 2, nothing to state 1. To make the problem simple and tractable, assume state 0 is not depleted to any significant extent for any time (i.e., $dN_0/dt = 0$); use the simple decay route indicated; neglect stimulated emission; assume $\tau_2 = 1\ \mu s$ and $\tau_1 = 2\ \mu s$; and let $P_2 = 10^{20}\ \mathrm{cm^{-3}\ s^{-1}}$. Use symbols for (a) and (b) and find numerical values for (c) and (d).



(a) What are the rate equations for states 2 and 1?
(b) Give an expression for the densities $N_{2,1}$ as a function of time.
(c) Over what time interval, δt, is the population difference $N_2 - N_1 > 0$?
(d) What are the steady-state populations in 2 and 1?

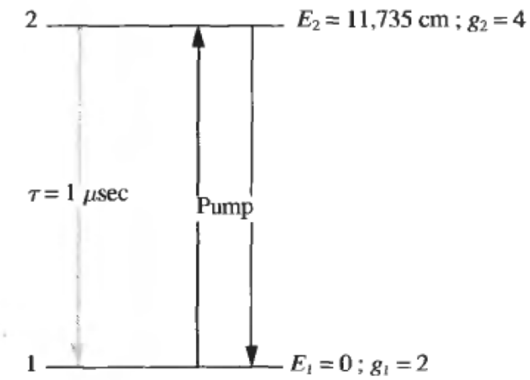
7.13. Consider the atomic system shown below being irradiated by an external wave tuned to the center of the $2 \rightarrow 1$ transition with 1 being the ground state. The wave pumps the atoms from 1 to 2 and also stimulates the atoms back to 1 from 2. In addition, the atoms in state 2 decay back to 1 by spontaneous emission and/or by other processes with a rate given by $(\tau)^{-1}$. The total density of atoms is $[N]$. Assume $\sigma = 10^{-14}\ \mathrm{cm}^2$

(a) Formulate the rate equations for the two states in terms of the intensity of the external wave, the stimulated emission cross section, the frequency $h\nu = E_2 - E_1$, τ, and the degeneracies of the states (g_2, g_1).

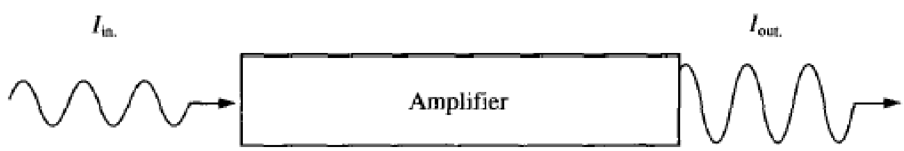
(b) What would be the population *ratio* N_2/N_1 if the intensity of the external wave were infinite?

(c) What must be the intensity to make the population ratio N_2/N_1 equal to $1/2$?

(d) If the ambient temperature were such that $kT = 208\ \text{cm}^{-1}$ and the intensity were zero, what is the steady state population ratio N_2/N_1?



8.2. An experiment involving a homogeneously broadened optical amplifier is depicted in the diagram below. For an input intensity of $1\,W/\text{cm}^2$, the gain (output/input) is 10 dB. If the input intensity is doubled to $2\,W/\text{cm}^2$, the gain is reduced to 9 dB.



(a) What is the small-signal gain (i.e., $I_{in} \rightarrow 0$) of this amplifier (in dB)?

(b) What is the saturation intensity?

(c) What is the maximum power (per unit area) that can be extracted from this amplifier (in limit of large input intensity)?

(d) What must be the input intensity to extract 50% of this maximum?

Note: dB (gain)= $10 \log_{10}(P_{out}/P_{in})$ or $10 \log_{10}(I_{out}/I_{in})$