Laser Physics-I (PHYC/ECE 464), *Fall 2022*

Homework #7, Due Wed. Oct. 19

1. Consider a pressure-broadened gaseous two-level medium with the following property:

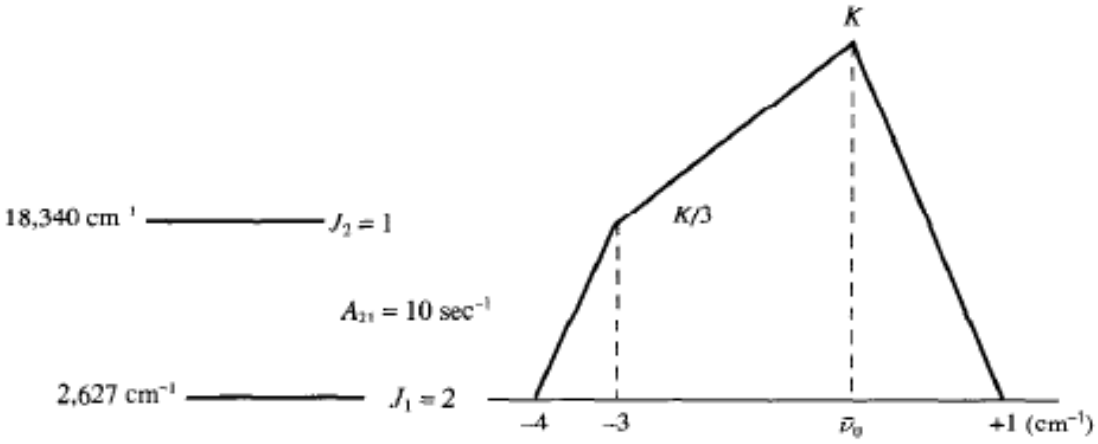
- *Spontaneous emission lifetime:* $\tau_{sp}=1\ \mu s$
- *Homogeneous linewidth* $\Delta\nu_h=1.5$ *THz*
- *Line center wavelength:* $\lambda_0= 5\ \mu m$
- *Molecular density (concentration):* $N_{total}= 2.5\times10^{19}\ cm^{-3}$
- *Non-degeneracy factors:* $g_1=5$, $g_2=1$

(a) What is the absorption coefficient $\alpha(cm^{-1})$ at the line center (5 μm) when all the molecules are in their ground state (level 1)?

(b) What fraction of the molecules needs to be excited into level 2 in order to make this gas transparent (i.e. the onset of gain) at 5 μm?

2.

7.3. The spontaneous emission profile from a certain transition can be approximated by the shape shown below.



(a) What is the stimulated emission cross section?
(b) What is the absorption cross section?

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7.5. Consider a transition of 5000 Å with a width of 1 Å, a cavity of 2 cm^3 in volume and let $n = 1$.

(a) Convert this wavelength interval (1 Å) to frequency units (i.e., GHz and cm^{-1}).

(b) How many electromagnetic modes exist in this frequency band for this cavity?

(c) Suppose that the cavity were in the form of a cylinder with a cross-sectional area of 0.1 cm^2 (and thus is 20 cm long). How many $TEM_{0,0,q}$ cavity modes would fit within the frequency band specified by this 1 Å? (Do not forget the two polarizations.)

(d) Combine the results of (b) and (c) to estimate the probability of a spontaneous photon appearing in one of the polarized $TEM_{0,0,q}$ modes.

(e) If the A coefficient for this transition is 10^7 sec^{-1}, what is the stimulated emission cross section?

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7.11. The spontaneous emission profile of a certain laser can be approximated by the triangular shape shown below. If the spontaneous lifetime were 5 nsec and the gain coefficient were 10 cm^{-1}, find

(a) The value of the line shape (in sec) at $h\nu/e = 1.476$ eV

(b) The inversion necessary to obtain that gain coefficient