

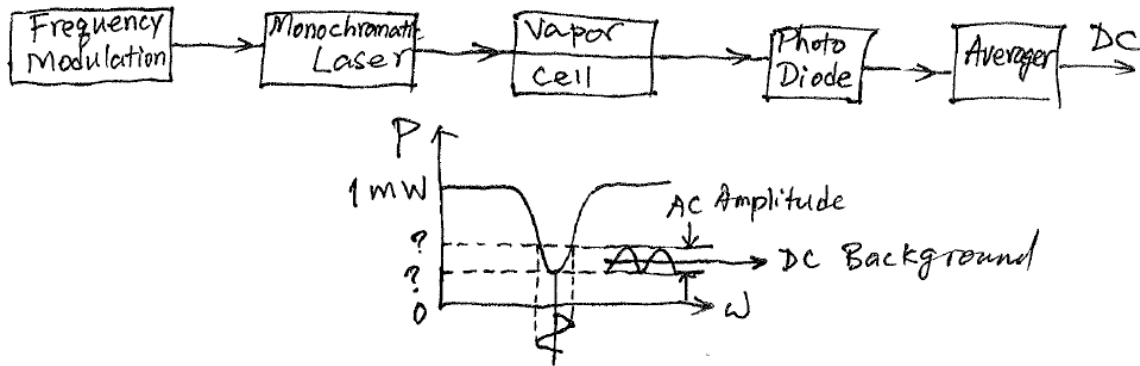
## Fundamentals of Spectroscopy for (Optical) Remote Sensing Homework #9

1. (Textbook Problem 6.3)

A monochromatic laser beam with power  $P = 1 \text{ mW}$  is sent through a 1-m long sample cell filled with absorbing molecules. The absorbing transition has the Doppler width  $\Delta\omega_D = 2\pi \times 10^9 \text{ Hz}$  and a peak absorption coefficient  $\alpha(\omega_0) = 10^{-8} \text{ cm}^{-1}$ , where  $\omega_0$  is the resonance frequency of the molecule. The laser frequency is modulated while it is tuned to the molecular resonance frequency  $\omega_0$ , i.e.,  $\omega_L = \omega_0 + \Delta\omega \cos 2\pi ft$ , where  $\Delta\omega = 2\pi \times 10 \text{ MHz}$ .

(1) Calculate the maximum AC amplitude of the detector output signal for a detector with a sensitivity of  $1 \text{ V/mW}$ .

(2) How large is the DC background signal if the detector output is averaged over time?



2. (Textbook Problem 7.1)

(1) A collimated sodium beam is crossed by a single-mode cw dye laser, tuned to the  $D_1$  transition  $3^2S_{1/2} \rightarrow 3^2P_{1/2}$  of Na. Calculate the saturation intensity  $I_S$  if the flux of sodium atoms is  $N = n \cdot \bar{v} = 10^{15} \text{ atoms / cm}^2 / \text{s}$ . The lifetime  $\tau_K$  of the upper level is  $\tau_K = 16 \text{ ns}$ .

(2) How large is  $I_S$  in a sodium cell at  $P_{\text{Na}} = 10^{-6} \text{ mbar}$  with  $P_{\text{Ar}} = 10 \text{ mbar}$  additional argon pressure? The pressure broadening is  $25 \text{ MHz/mbar}$  for Na-Ar collisions.

3. (Textbook Problem 7.3)

In an experiment on polarization spectroscopy, the circularly polarized pump laser causes a change  $\Delta\alpha = \alpha^+ - \alpha^- = 10^{-2}\alpha_0$  of the absorption coefficient. By which angle is the plane of polarization of the linearly polarized probe laser beam at  $\lambda = 600 \text{ nm}$  tuned after passing through the pumped region with length  $L$ , if the absorption without pump laser  $\alpha_0 L = 5 \times 10^{-2}$ ?

4. (Textbook Problem 6.1 with corrections)

A monochromatic laser beam is sent through a sample of diatomic molecules. The laser wavelength is tuned to a vibration-rotation transition  $(v'', J'') \rightarrow (v', J')$  with an absorption cross section of  $\sigma_{ik} = 10^{-18} \text{ cm}^2$ .  $(v'' = 0, J'' = 20) \rightarrow (v' = 1, J' = 21)$

(1) Estimate the fraction  $n_i/n$  of molecules in the level  $(v_i'' = 0, J_i'' = 20)$  at  $T = 300 \text{ K}$  (vibrational constant  $\tilde{\nu}_e = 2000 \text{ cm}^{-1}$ , rotational constant  $B_e = 1.5 \text{ cm}^{-1}$ ).

(2) Calculate the absorption coefficient for a total gas pressure of 10 mbar.

(3) What is the transmitted laser power  $P_t$  behind an absorption path length of 1 m for an incident power  $P_0 = 100 \text{ mW}$ ?

5. Choose one of the following spectroscopy methods to describe its principle, experimental setup, required detectors, and applications: photoacoustic spectroscopy, optothermal spectroscopy, ionization spectroscopy, and optogalvanic spectroscopy.