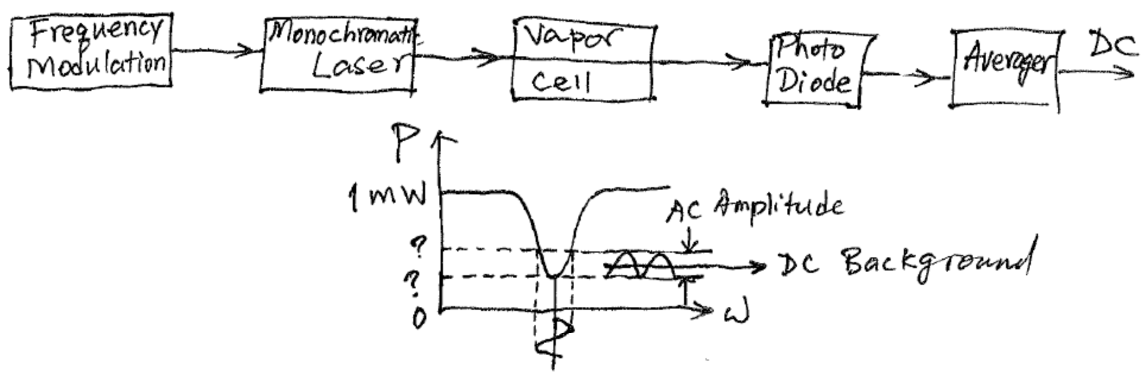
**Fundamentals of Spectroscopy for (Optical) Remote Sensing**
**Homework #9**

1. (Textbook Problem 6.3)
A monochromatic laser beam with power P = 1 mW is sent through a 1-m long sample cell filled with absorbing molecules. The absorbing transition has the Doppler width $\Delta\omega_D = 2\pi \times 10^9$ Hz and a peak absorption coefficient $\alpha(\omega_0) = 10^{-8}$ $cm^{-1}$, 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 $\Delta\omega = 2\pi \times 10$ MHz.
(1) Calculate the maximum AC amplitude of the detector output signal for a detector with a sensitivity of 1 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 $N = n \cdot \bar{v} = 10^{15} atoms / cm^2 / s$. The lifetime $\tau_K$ of the upper level is $\tau_K$ = 16 ns.
(2) How large is $I_S$ in a sodium cell at $P_{Na} = 10^{-6}$ mbar with $P_{Ar}$ = 10 mbar additional argon pressure? The pressure broadening is 25 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 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 $\sigma_{ik} = 10^{-18} cm^2$. $(v'' = 0, J'' = 20) \rightarrow (v'' = 1, J'' = 21)$

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