PHYC 564, Laser Physics II

Homework #5, Due April 19, 2021

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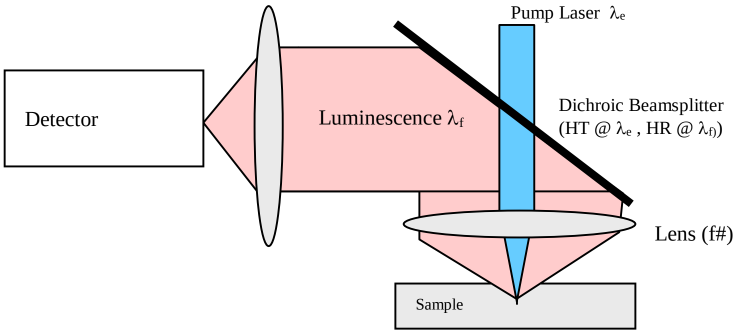
You are asked to perform a photo-luminescence experiment where a pump laser at wavelength λ_p is incident through a dichroic beam splitter and is focused onto the sample with a lens with known f# (=f/D). The luminescence (centered at $\lambda_f > \lambda_p$) is then collected with the same lens and is imaged into a detector or monochrometer for analysis. All lenses are AR coated.



a) Knowing the internal PL power P_f, calculate the collected (external) PL power (P_{ex}) at the detector. Write $P_{ex} = \eta_e P_f$ and show that η_e (the extraction efficiency) can be approximated as

$$\eta_e \approx \frac{1}{4n(n+1)^2} \times \frac{1}{(f\#)^2},$$

where n is refractive index of the sample. *Hint: This is the fraction of solid angle (inside the sample) subtended by the lens after exiting. Ignore the reflection of the fluorescence from the bottom surface.*

b) The detector system can be characterized by the following parameters: load resistance (R_L), capacitance (C), quantum efficiency η_q and gain $\bar{G}$. The dominant noise is the Johnson noise of the load resistor at temperature T. Write the SNR of the system in terms of P_f, η_q, η_i, η_e, R, C, and other known parameters and constants.

c) Consider now that the sample under study is bulk GaAs at T=300 K (E_g=1.42 eV, n=3.6). Assume an internal luminescence power of 10 μW. Assume the mean luminescence frequency is $\nu_f \approx \nu_g = E_g/\hbar$. The *f#* of the lens is 4.

i) What is the SNR if we use a regular photodiode (PD) η_q=1, $\bar{G}$ =1 terminating into an oscilloscope with R_L=1 MΩ, C=5 pF at T=300 K?

ii) What is the SNR in (ii) if we replace the PD with an APD with $\bar{G}$ =100 and excess noise factor of 10? What gain is necessary for making the detection shot-noise limited?