MICRO-523: Optical Detectors

Week Three: Detector Formalism and Noise

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Outline

Exercise 3.1: Quantum Efficiency and Detectivity

Consider a semiconductor photodiode with a band gap E_g and an ideal quantum efficiency.

Sketch:

- its quantum efficiency η and
- its responsivity R_I

as a function of the wavelength of the incident photons.

Consider the noise N to be independent of wavelength.

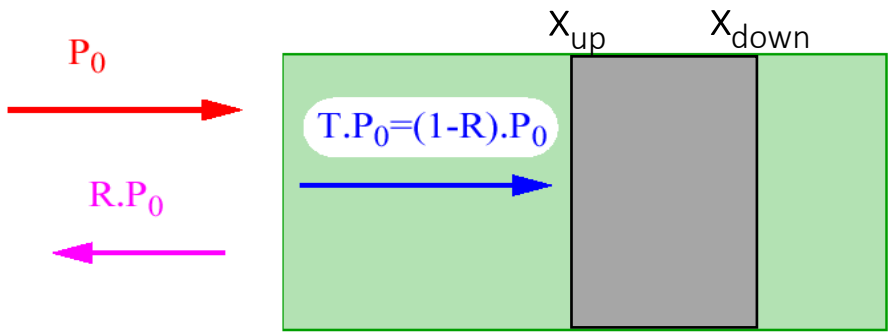
Sketch its detectivity as a function of its wavelength.

Exercise 3.2: Responsivity and Depth

The absorption coefficient of silicon can be approximated as $\alpha_{cm^{-1}}(\lambda_{\mu m}) \cong 10^{7.2-5.5\lambda}$

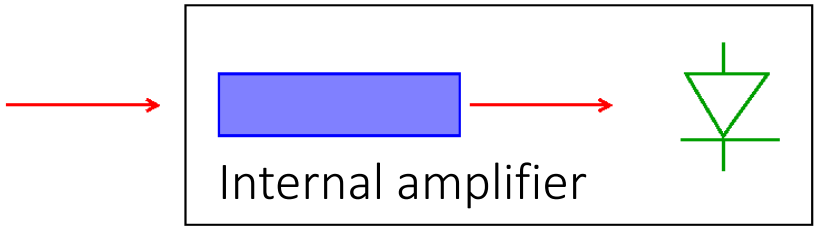
Consider two detectors and two wavelengths (λ=450nm and λ =600nm).
The first detector is sensitive between x_{1up} = 0.05µm and x_{1down} = 0.3µm.
The second detector is sensitive between x_{2up} = 0.9µm and x_{2down} = 4µm.
The reflection coefficient is 10%.

Calculate the responsivity R_I and the quantum efficiency of both detectors at the abovementioned wavelenghts.



Exercise 3.3: Optimal Internal Gain

We would like to detect an optical signal with P_0=25 pW
using a detector with a variable internal gain G
(for example an avalanche photodiode).
Its responsivity is R_I=0.4 A/W,
its bandwidth is Δf=1 MHz,
and its excess noise factor is $F=G^{0.3}$.



Determine as a function of its gain G:

a) The amplified photocurrent $I_{sig}(G)$.
b) The shot noise of this current.

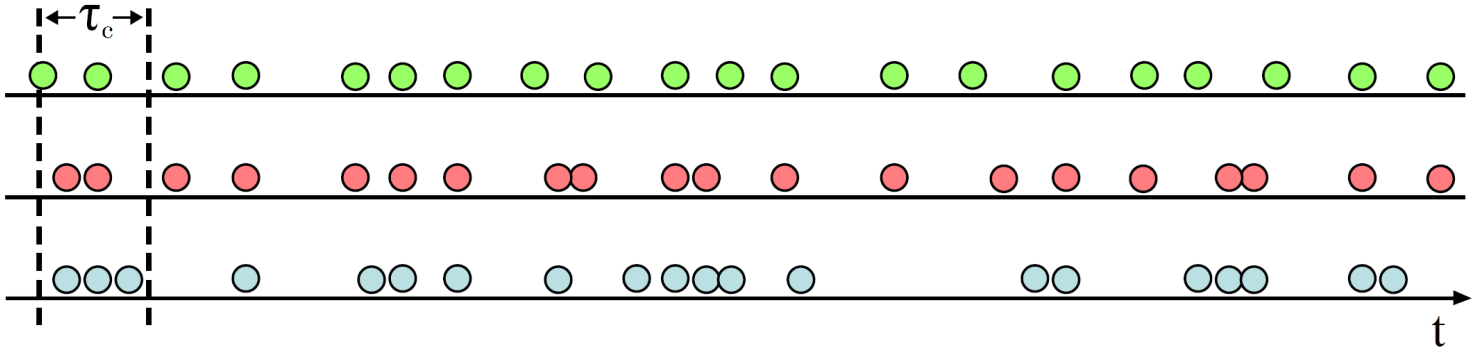
The electronics generate an rms noise of ΔI_{el}=100 pA.

c) Calculate the total noise Δi_{tot} as a function of the gain.
d) Determine the signal to noise ratio as a function of gain.
e) What is the optimal gain G_{opt}?

Exercise 3.4: Light sources statistics

Questions

- Which kind of light sources exist?
- How are their statistical emission properties?



Photon detections as function of time for a) antibunched, b) random, and c) bunched light

By Ajbura - Vectorised version of File:Photon bunching.png, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=73299604