

# MICRO-523: Optical Detectors

Week Five: Photodiodes – Exercises

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Based on MICRO-523, P.-A. Besse, 2023

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The logo of the École polytechnique fédérale de Lausanne (EPFL), consisting of the letters 'EPFL' in a bold, red, sans-serif font.

# Outline

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5.1 High-speed photodiodes and BER

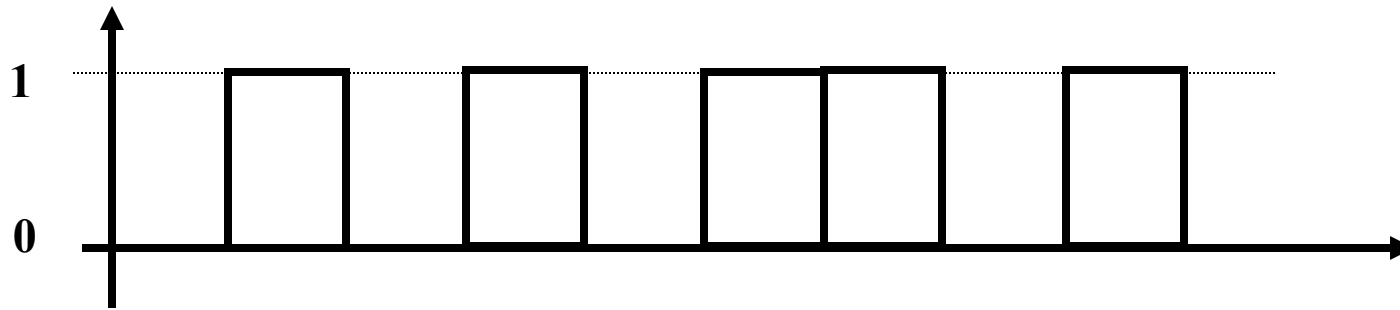
5.2 PIN Heterostructure Photodiode

Homework 5.1: Maximum Efficiency of Solar Cells

## Exercise 5.1: High-speed photodiodes and BER

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- On-off keying system: bits “0” and “1”

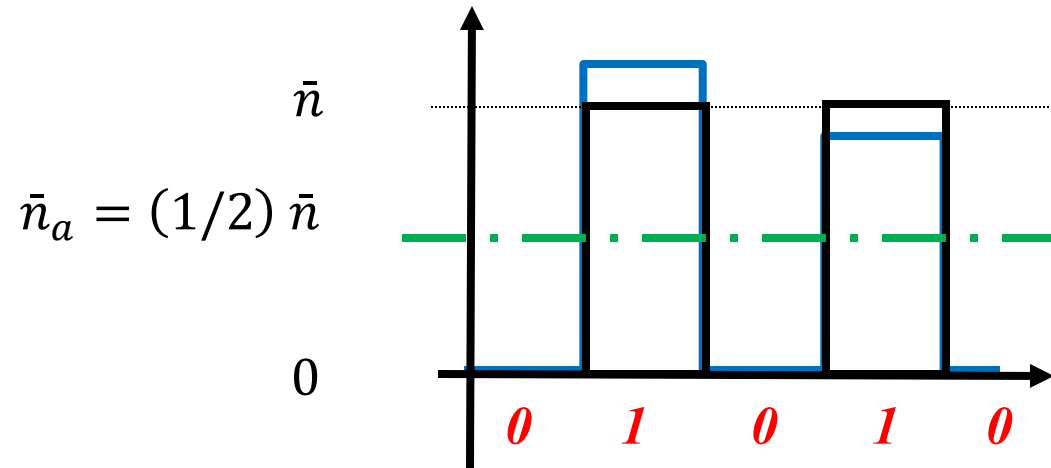


- BER: probability of error per bit
- If  $p_0$  = probability of mistaking a “0” for a “1”  
&  $p_1$  = probability of mistaking a “1” for a “0”, then

$$\text{BER} = p_0 / 2 + p_1 / 2 \quad (\text{BER definition})$$

# Exercise 5.1: High-speed photodiodes and BER

Ideal = limited by the optical signal shot noise



- If an average of  $\bar{n}$  photons is transmitted by a laser diode, the probability of detecting  $n$  photons is given by:

$$p(n) = \bar{n}^n \frac{\exp(-\bar{n})}{n!}$$

→ How many photons per “1” bit are needed to guarantee a BER of  $10^{-9}$ ?

# Outline

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# Exercise 5.2: PIN Heterostructure Photodiode

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## **In<sub>1-x</sub>Ga<sub>x</sub>As<sub>y</sub>P<sub>1-y</sub> system on an InP substrate**

a) To grow a monocrystal, we have to preserve the lattice of the InP substrate.  
This involves satisfying the following relationship:

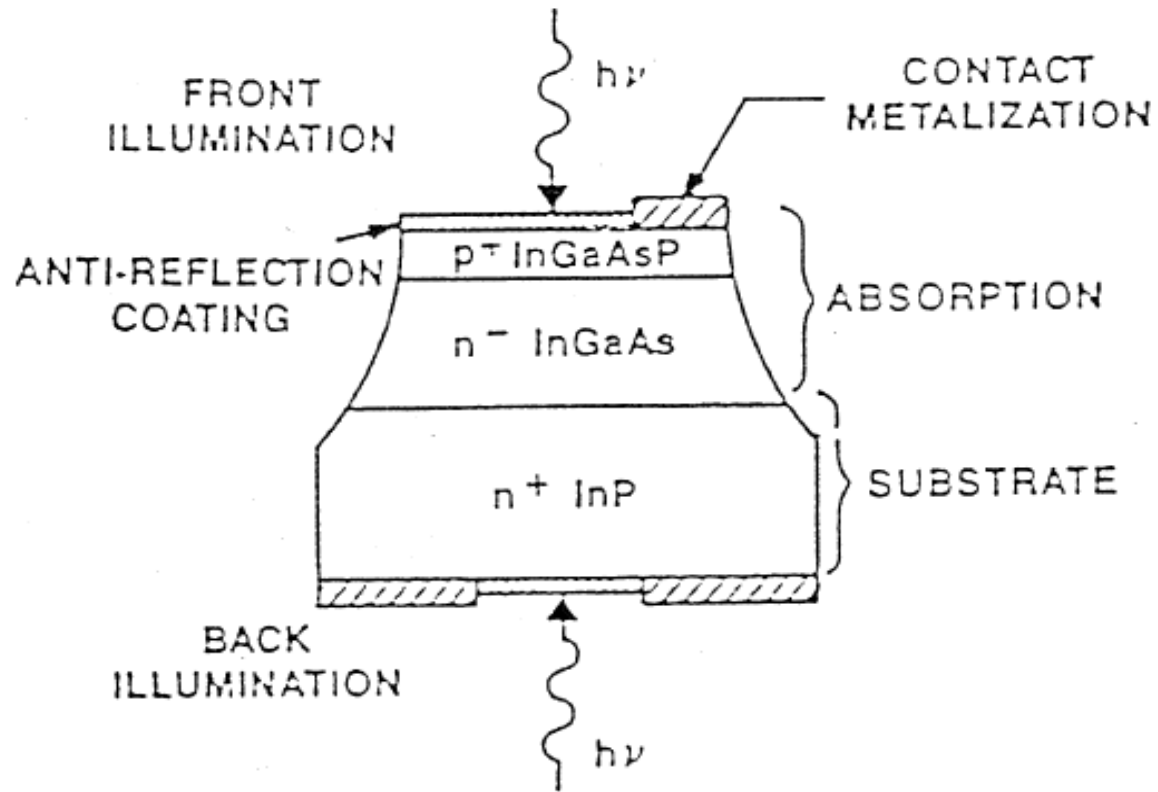
$$x = \frac{0.4562 \cdot y}{1 - 0.031 \cdot y}$$

b) In this case (“lattice matched to InP”) the bandgap can be changed according to:

$$E_g(y) = 1.35 - 0.72 \cdot y + 0.12 \cdot y^2 \quad [eV]$$

# Exercise 5.2: PIN Heterostructure Photodiode

Consider the PIN photodiode depicted below:



## Exercise 5.2: PIN Heterostructure Photodiode

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This type of photodiode was designed for optical telecommunications and has to work at wavelengths between  $1.50 \mu\text{m}$  and  $1.60 \mu\text{m}$ . Its diameter is  $10 \mu\text{m}$ , corresponding to that of a single mode fiber optic cable.

A) Considering a superficial layer with the following composition:  $\text{In}_{1-x}\text{Ga}_x\text{As}_y\text{P}_{1-y}$ , with  $y=0.84$ .

Sketch the quantum efficiency for front and back illumination. What is the main difference?

B) Estimate the width  $W$  of the intrinsic InGaAs region to optimize the bandwidth using a load resistance of  $R_L = 50 \Omega$ .

(use  $\epsilon = 12$  and  $v_{\text{sat}} = 10^5 \text{ m/s}$ )

Does the diode have to be polarized, and if so, why?

# Outline

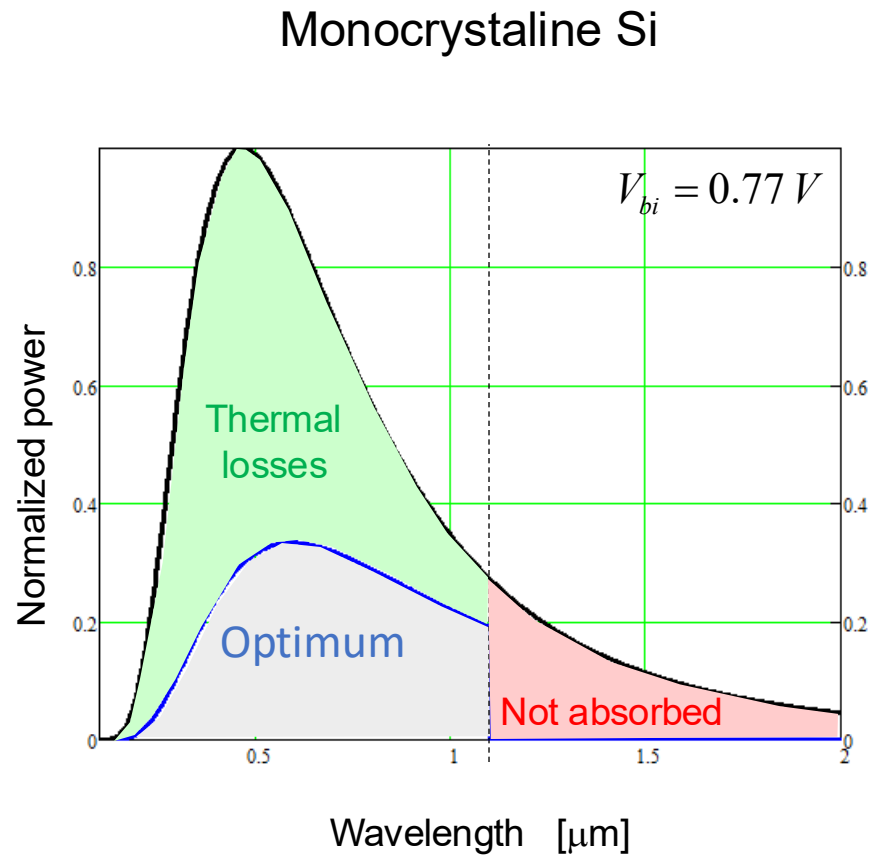
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5.1 High-speed photodiodes and BER

5.2 PIN Heterostructure Photodiode

Homework 5.1: Maximum Efficiency of Solar Cells

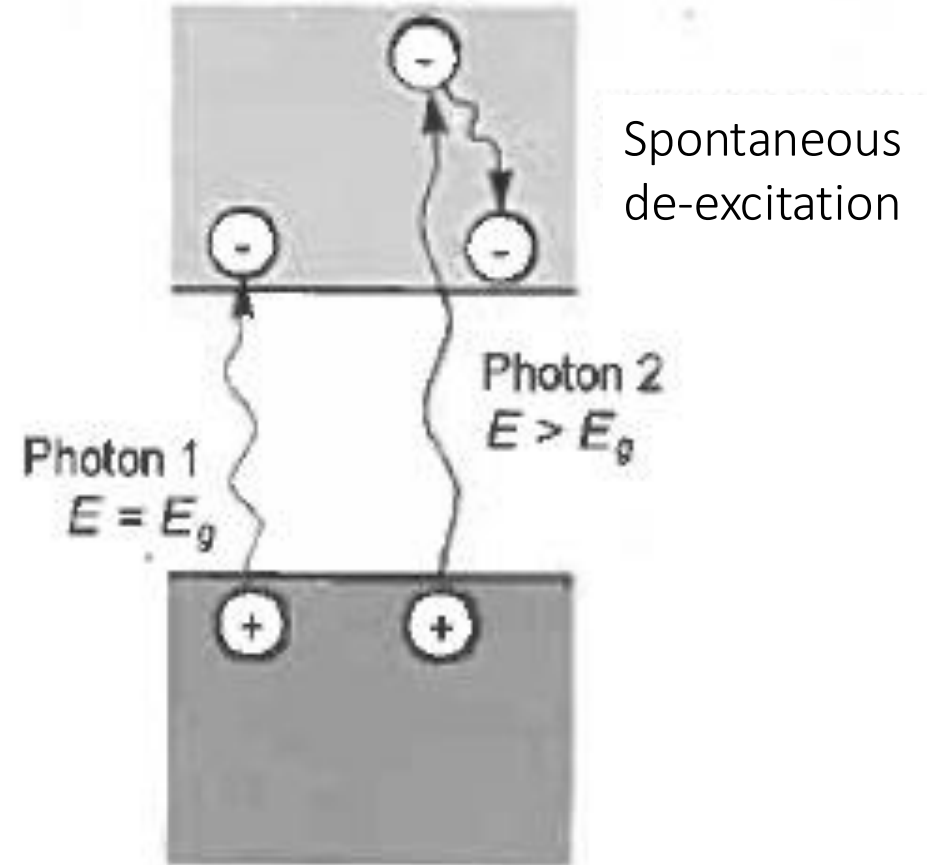
# A5.2 Maximum Efficiency of Solar Cells: *which is its origin?*



$\eta_{\text{tot}} = 31 \%$

( $E_g = 1.1 \text{ eV}$ )

Thermal losses: we generate «only»  
the bandgap energy



A. Labouret, M. Viloz,  
« installations photovoltaïques »,  
Dunod, 2012