ORDRE DES INGÉNIEURS DU QUÉBEC

NOVEMBER 2011 SESSION

Open-book examination
Calculators: only authorized models
Duration: 3 hours

07–ELEC–B10 Electro-optical engineering

Problem 1 (25 points)

A manufacturer is interested in the development of double junction solar cells because they show superior performances over those involving only a single junction. These cells use junctions of distinct semiconductor materials, therefore having different bandgap energies, to enable absorption of light over a wider spectral range. He particularly wants your opinion on the problem of the method used to electrically connect the resulting diodes.

Each photodiode can be modeled using an ideal diode whose $I-V$ characteristic is defined by the following equations:

$$I = -I_{\text{sc}}, \qquad \forall V < V_{\text{oc}},$$

and

$$V = V_{\text{oc}}, \qquad \forall I > -I_{\text{sc}},$$

where V_{oc} is the open-circuit voltage and I_{sc} represents the short-circuit current.

a) (5 points) Sketch the ideal $I - V$ characteristic defined above.

b) (5 points) What is the maximum electrical power provided by such a solar cell?

c) Consider that the first junction has parameters $V_{\text{oc},1}$ and $I_{\text{sc},1}$, and that the second junction has rather parameters $V_{\text{oc},2}$ et $I_{\text{sc},2}$. Note that $V_{\text{oc},1} < V_{\text{oc},2}$ and that $I_{\text{sc},1} > I_{\text{sc},2}$.

   i) (5 points) Sketch the $I - V$ characteristic of the global component when the photodiodes are connected in serial. Be sure to identify the parameters defining it.

   ii) (5 points) Sketch the $I - V$ characteristic of the global component when the photodiodes are connected in parallel. Be sure to identify the parameters defining it.

   iii) (5 points) According to the possible values of the 4 parameters, which of these two approaches maximizes the produced electrical power? Consider all possible cases and determine the conclusions that apply.

Problem 2 (25 points)

A fast PIN photodetector is used to detect a laser pulse. The characteristics of the photodetector are:

- $-3\,\mathrm{dB}$ cutoff frequency of $47\,\mathrm{GHz}$ (first order);
- responsivity of $0.53\,\mathrm{A/W}$;
- maximum photocurrent of $32\,\mathrm{mA}$.

a) (15 points) What is the maximum pulse energy that can be supported to avoid saturation of the photocurrent? Assume that the duration of the laser pulse is much smaller than the response time of the photodetector. To simplify the problem, assume that the laser pulse has a rectangular shape.

b) (10 points) During how much time does the detection signal produced by the photodetector has an amplitude above the noise? Suppose that only shot noise is present.

Problem 3 (25 points)

A Fabry-Perot semiconductor laser has a cavity length of $100\,\mu\mathrm{m}$. The reflectivity of each of its facets is $35\,\%$. The internal losses are $15\,\mathrm{cm}^{-1}$. The effective index of the single propagating mode is 3.3.

a) (15 points) What is the photon lifetime in the cavity?

b) (10 points) What should be the reflectivity of each Bragg reflector in a VCSEL (for "Vertical-Cavity Surface-Emitting Laser") having the same photon lifetime? The reflectors are spaced apart by $2\,\mu\mathrm{m}$.

Problem 4 (25 points)

This problem is about the *eye diagram*.

a) (5 points) In which context is this measurement useful?

b) (5 points) Sketch such a diagram.

c) (8 points) What information do carry such a diagram?

d) (7 points) How do you measure this diagram?

Glossary

termes français	*English terms*
bande interdite	band gap
bruit	noise
bruit de grenaille	shot noise
cascade	serial
cavité	cavity
circuit ouvert	open-circuit
court-circuit	short-circuit
diagramme de l'œil	eye diagram
facette	facet
fréquence de coupure	cut-off frequency
impulsion laser	laser pulse
indice de réfraction	refractive index
indice effectif	effective index
largeur de bande	spectral bandwidth
laser à semi-conducteurs	semiconductor laser
mode	mode
pertes	losses
pertes internes	internal losses
photocourant	photocurrent
photodiode	photodiode
photodétecteur	photodetector
pile solaire	solar cell
puissance	power
réflectivité	reflectivity
région active	active region
réseau de Bragg	Bragg reflector
responsivité	responsivity
semi-conducteur	semiconductor
temps de vie	lifetime

— End of exam —