Exercice 8.1: estimation «sur le pouce» de l'efficience électrique maximale

Estimez l'efficience électrique maximale

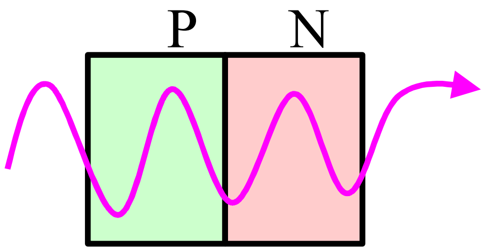
d'une cellule solaire en silicium monocristallin ?

<u>Modèle «sur le pouce»:</u>

- **Exprimez l'énergie d'un photon solaire typique en eV.**
- **Estimez le gain d'énergie d'un photo-électron en eV.**
- **Comparez les deux énergies.**

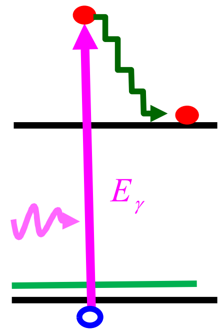
Résumé des pertes d'efficience électriques

1) transparence



⇨ Petit bandgap

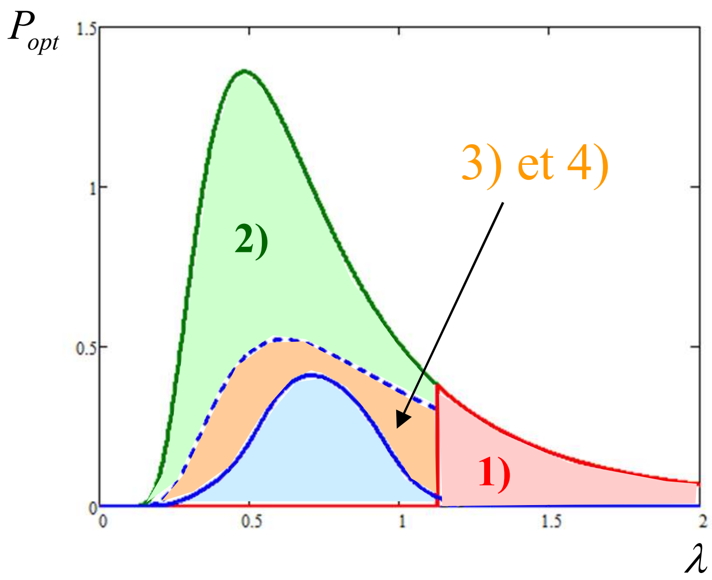
2) thermalisation



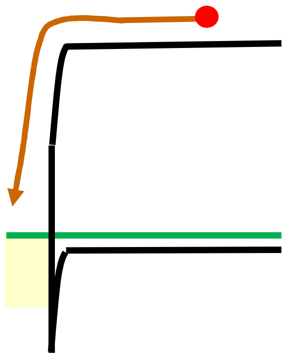
⇨ Grand bandgap

2/3

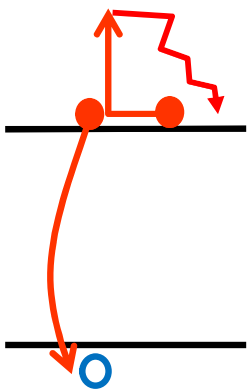
⇔



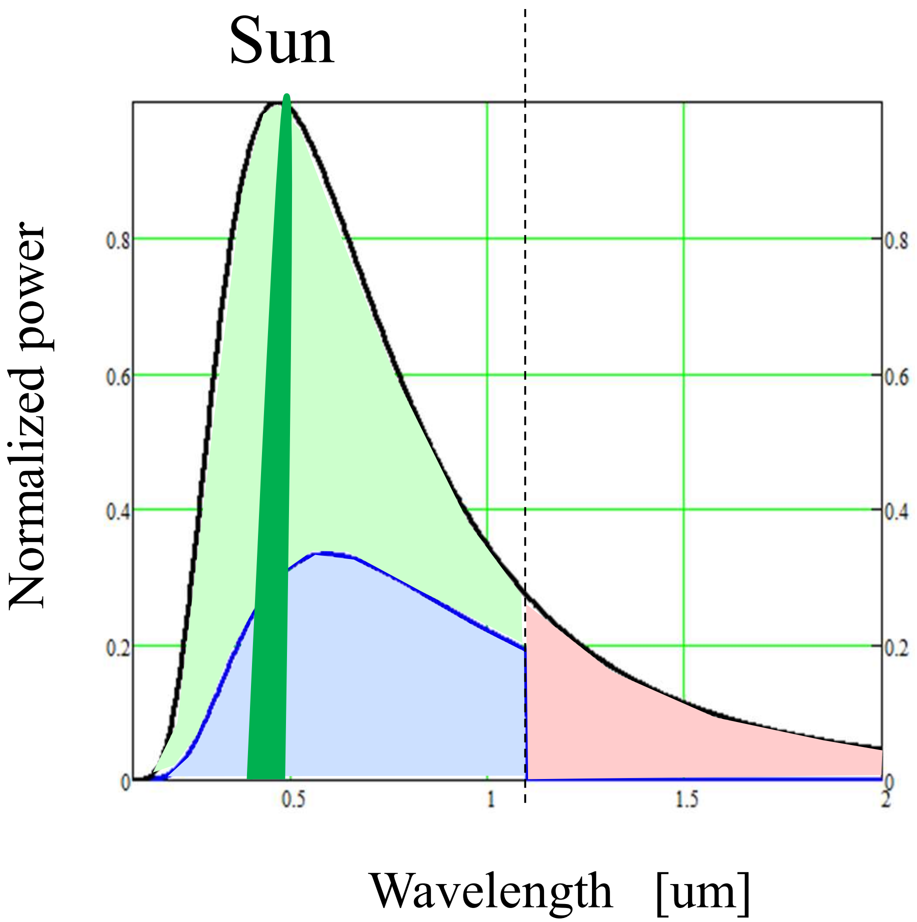
3) Pertes aux contacts

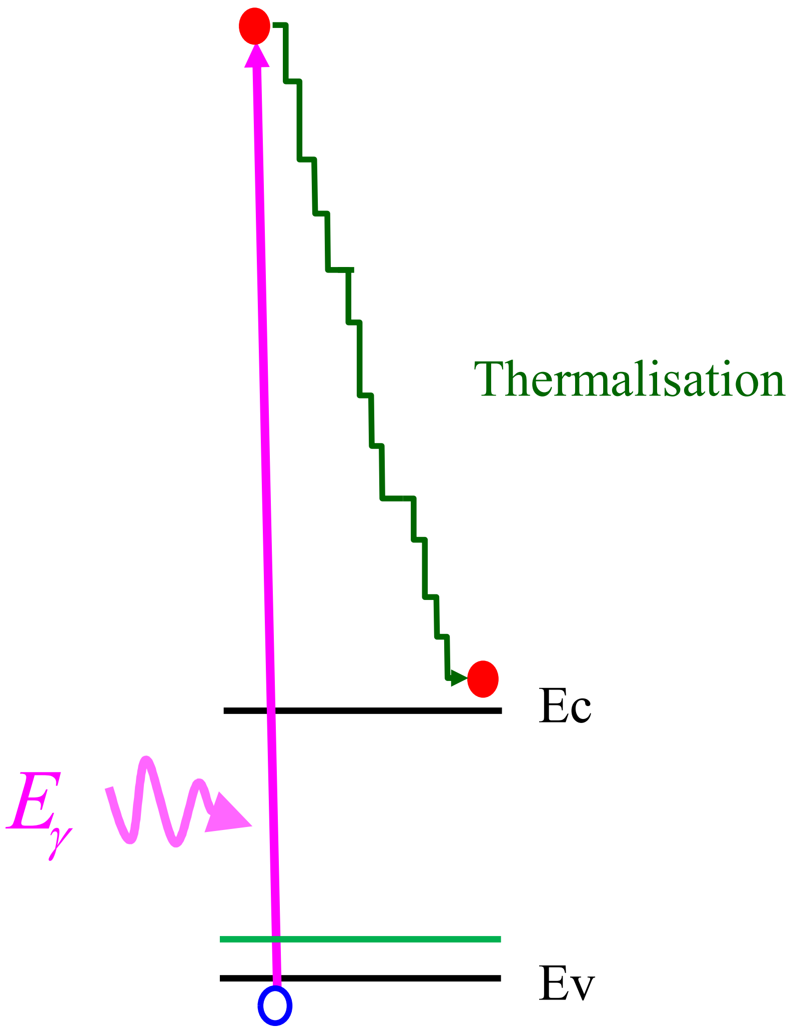


4) Recombinaisons internes



Efficience électrique «monochromatique»





Maximum Efficiency of Solar Cells

Energie d'un photon en eV

$$E_{opt\,[eV]} = \frac{h\nu}{q} = \frac{hc}{q} \cdot \frac{1}{\lambda} \cong \frac{1.24}{\lambda_{[\mu m]}}$$

Spectre solaire → photon typique en vert → λ = 550 nm

$$E_{opt} = 2.25 \quad [eV]$$

Silicium monocristallin → V_{bi} = 0.7 V

$$E_{el} = 0.7 \quad [eV]$$

$$\eta_{el} \leq 31\% \cong \frac{0.7\ eV}{2.25\ eV}$$

Exercice 8.2: influence du gap

Comparons deux cellules solaires avec des énergie de gap différentes.

- La première cellule est en silicium monocristallin avec un gap de E_g=1.1 [eV] et une tension de built-in de V_{bi}=0.88 [eV].

- La seconde cellule est en silicium amorphe avec un gap de E_g=1.7 [eV] et une tension de built-in de V_{bi}=1.36 [eV].

Comparez qualitativement les pertes par transparence et celles par thermalisation

Efficience quantique et efficience électrique

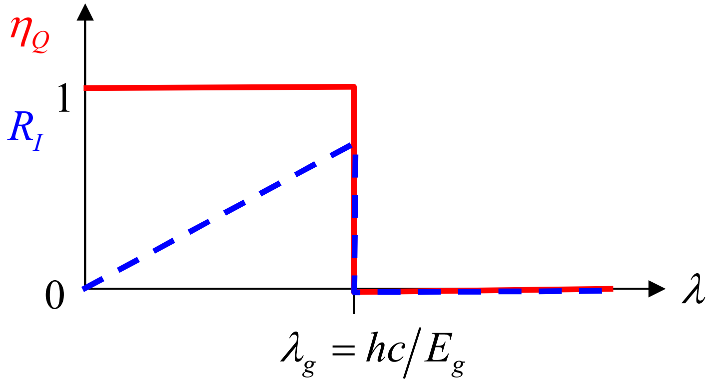
Efficience quantique

$$\eta_Q \equiv \frac{N_e}{N_\gamma} = \frac{\text{Nb. de paires electron/trou récoltées}}{\text{Nb. photons incidents}} \quad [1]$$

Responsivity

$$R_I \equiv \frac{I_{cell}}{P_{opt}} = \frac{q \cdot N_e / \tau}{\mathrm{h}\nu \cdot N_\gamma / \tau} = \eta_Q \cdot \frac{q\lambda}{hc} \quad \left[\frac{A}{W}\right]$$

Cas idéal en semiconducteur



Efficience électrique

$$\eta_{el} \equiv \frac{P_{el}}{P_{opt}} = \frac{V_{cell} \cdot \int R_I P_{opt} \cdot d\lambda}{\int P_{opt} \cdot d\lambda} \quad [1]$$

https://www.pveducation.org/pvcdrom/solar-cell-operation/quantum-efficiency

https://www.pveducation.org/pvcdrom/solar-cell-operation/spectral-response

Efficience électrique

$$\eta_{el} \equiv \frac{P_{el}}{P_{opt}} = \frac{V_{cell} \cdot \int R_I P_{opt} \cdot d\lambda}{\int P_{opt} \cdot d\lambda} = \frac{V_{cell} \cdot \int \eta_Q \frac{q}{hc} \lambda \cdot P_{opt} \cdot d\lambda}{\int P_{opt} \cdot d\lambda}$$

$$V_{cell} \cong V_{bi} \cong 0.8 \cdot E_{g_{[eV]}}$$

$$q \cdot E_{g_{[eV]}} \equiv \frac{hc}{\lambda_g}$$

$$\Downarrow$$

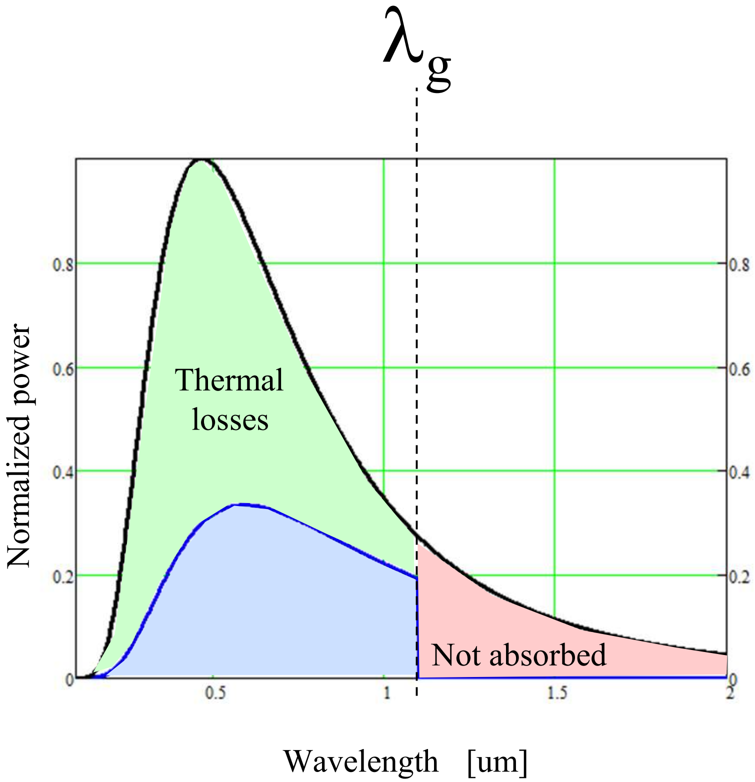
$$\eta_{el} = \frac{0.8 \cdot E_{g_{[eV]}} \cdot \int_0^{\lambda_g} \eta_Q \cdot \frac{1}{E_{g_{[eV]}} \lambda_g} \lambda \cdot P_{opt} \cdot d\lambda}{\int_0^{\infty} P_{opt} \cdot d\lambda}$$

Efficience électrique solaire: $P_{opt}=P_{sun}$

$$\lambda_{g[\mu m]} \cong \frac{1.24}{E_{g\,[eV]}}$$

80% **100%**

$$\eta_{el} = \frac{0.8 \cdot \int_0^{\lambda_g} \eta_Q \cdot \frac{\lambda}{\lambda_g} \cdot P_{sun} \cdot d\lambda}{\int_0^{\infty} P_{sun} \cdot d\lambda}$$

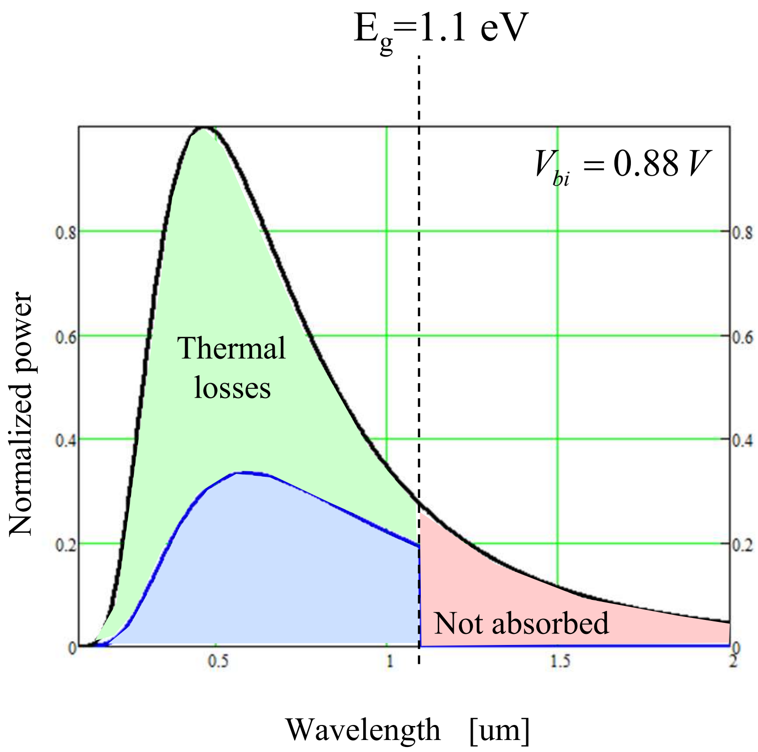


Transparence

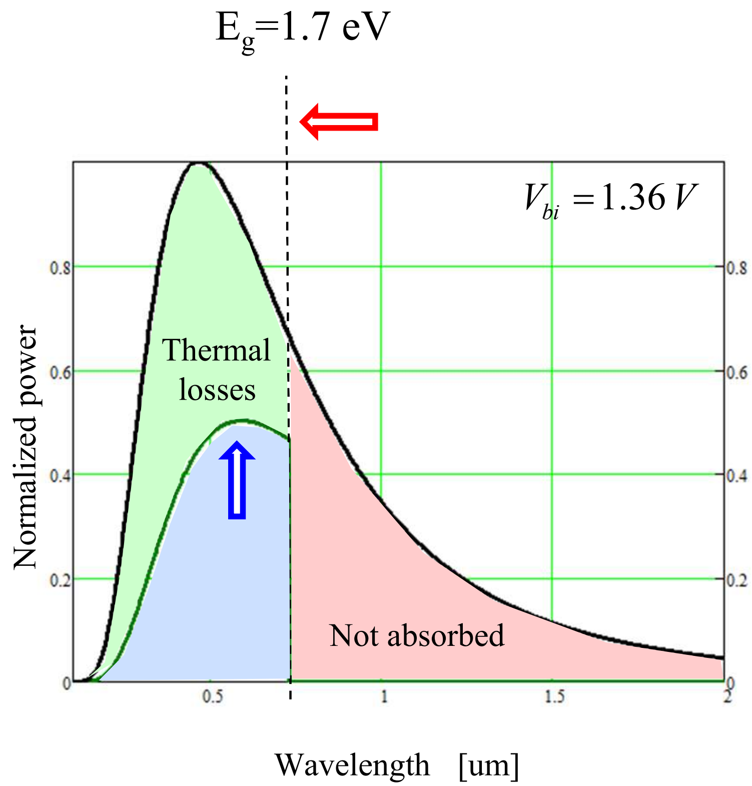
$$\frac{\int_{\lambda_g}^{\infty} P_{sun} \cdot d\lambda}{\int_0^{\infty} P_{sun} \cdot d\lambda}$$

Maximum Efficiency of Solar Cells

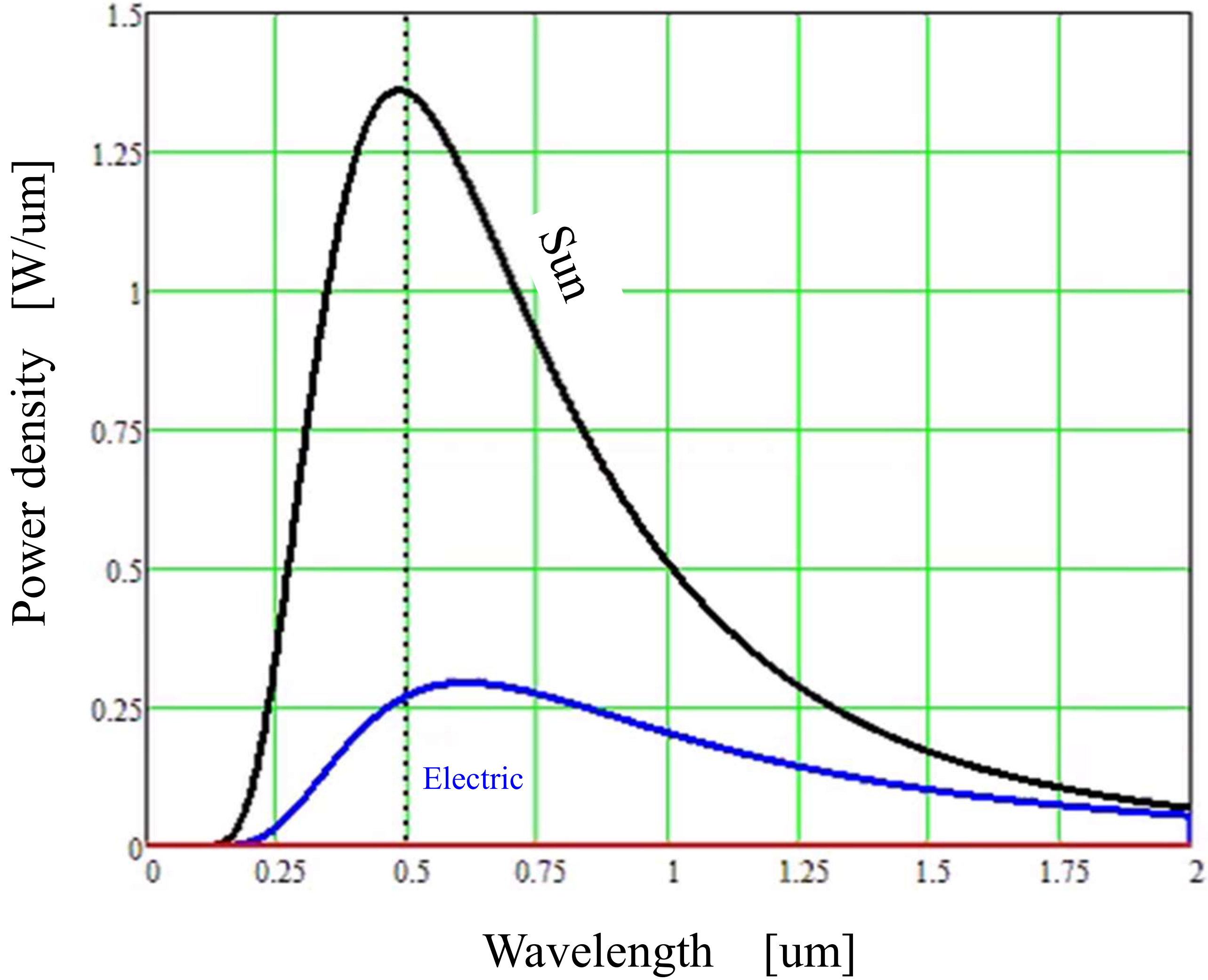
Monocrystaline Si



Amorphous Si

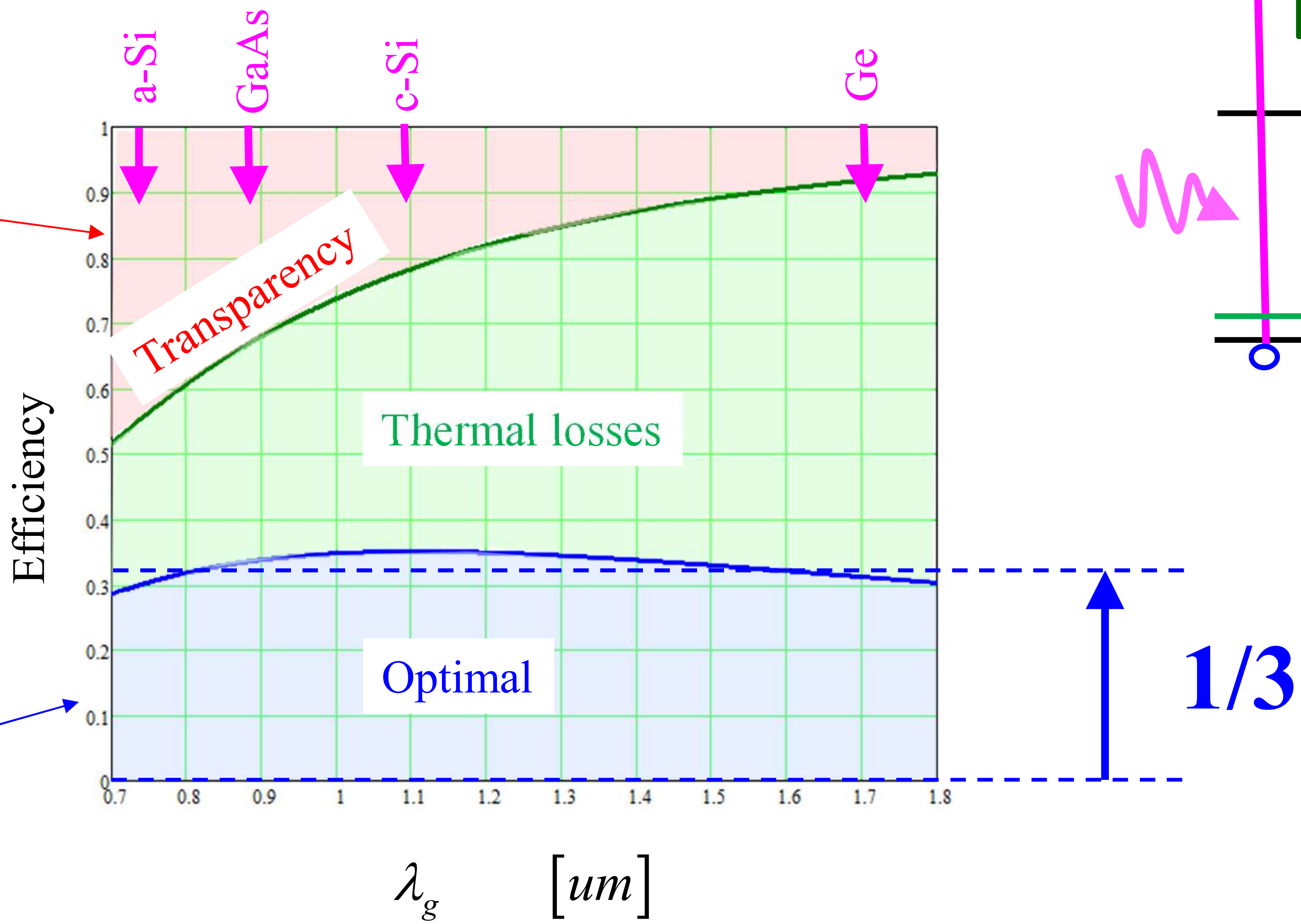


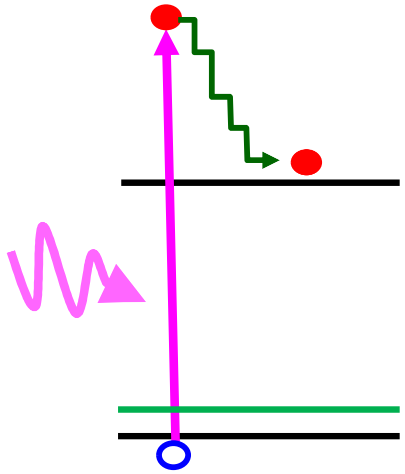
Influence de l'énergie de gap du matériel de la cellule solaire single junction



Maximum Efficiency in Standard Conditions

$$\frac{\int_{\lambda_g}^{\infty} P_{sun}(\lambda)d\lambda}{\int_{0}^{\infty} P_{sun}(\lambda)d\lambda}$$





$$\eta_{el} = \frac{0.8 \cdot \int_{0}^{\lambda_g} \eta_Q \cdot \frac{\lambda}{\lambda_g} \cdot P_{sun} \cdot d\lambda}{\int_{0}^{\infty} P_{sun} \cdot d\lambda}$$