

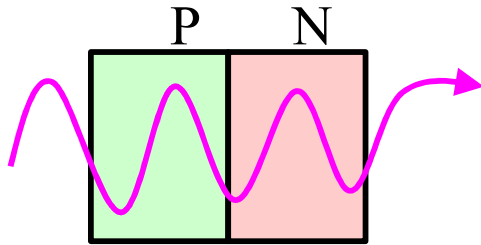
**Estimez l'efficacité électrique maximale
d'une cellule solaire en silicium monocristallin ?**

Modèle «sur le pouce»:

- **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.**

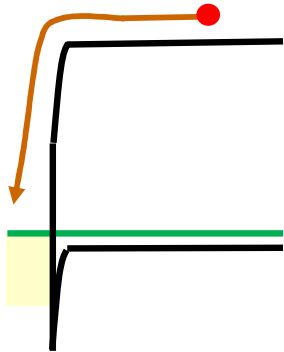
Résumé des pertes d'efficiency électriques

1) transparence



⇒ Petit bandgap

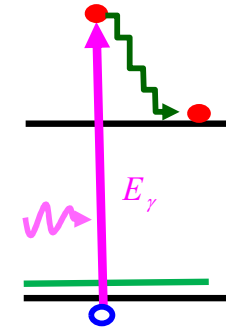
3) Pertes aux contacts



2/3

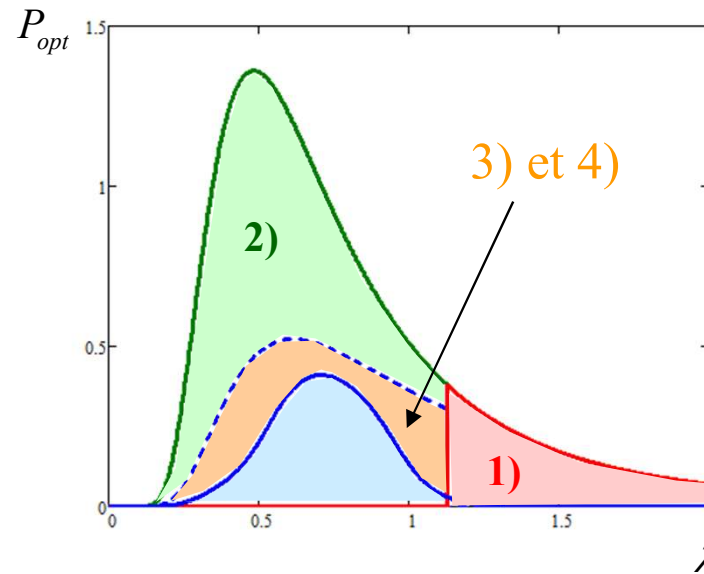
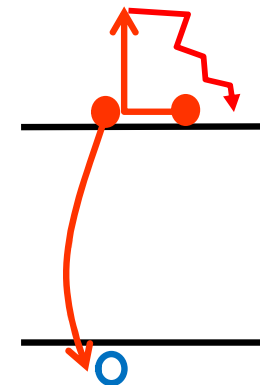


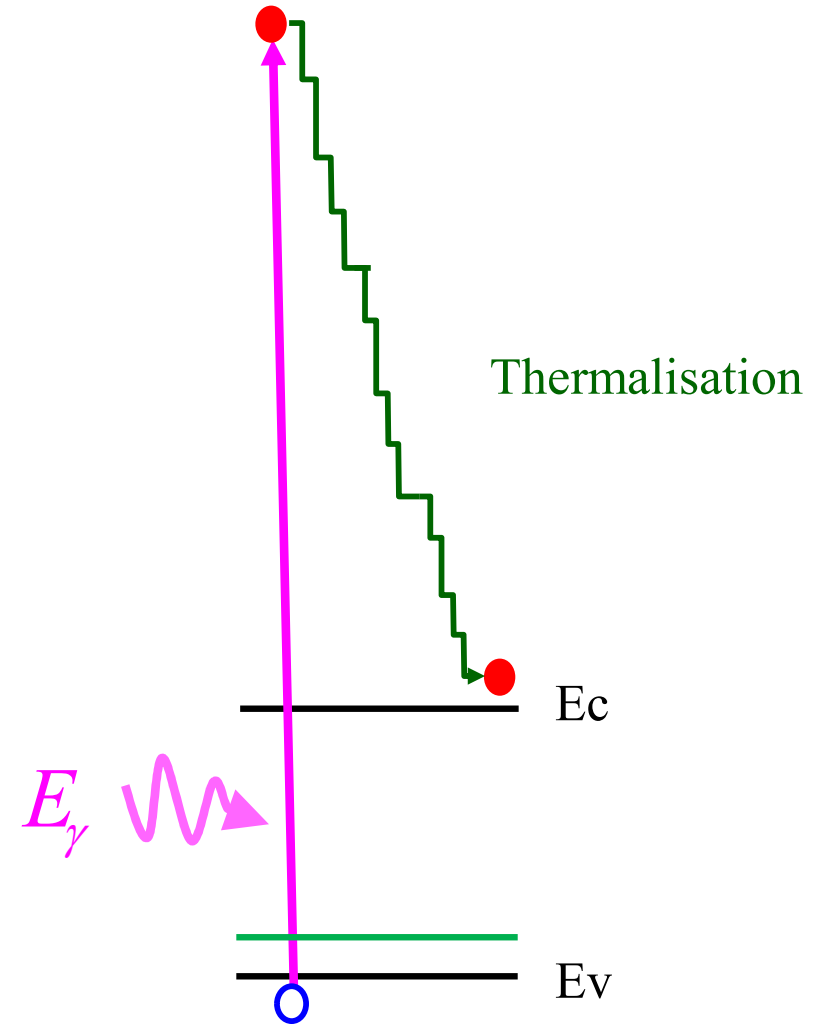
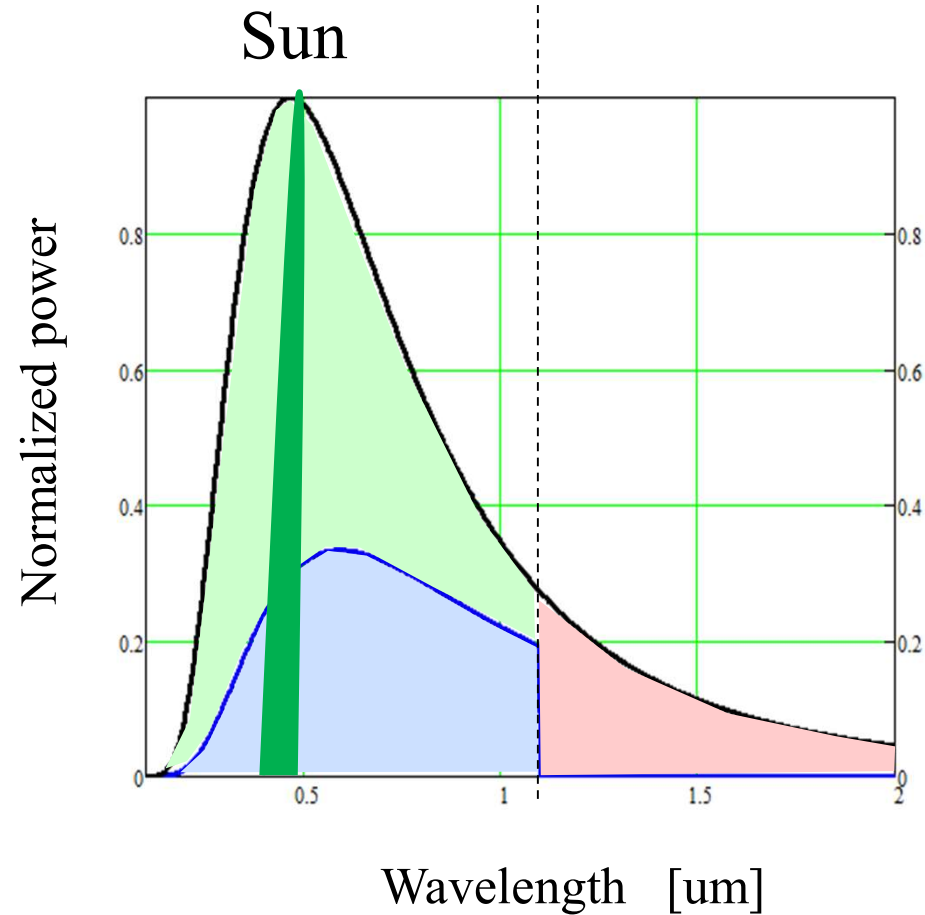
2) thermalisation



⇒ Grand bandgap

4) Recombinaisons internes





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 → $\lambda = 550\text{ nm}$

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

Silicium monocristallin → $V_{bi} = 0.7\text{ V}$

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

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

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

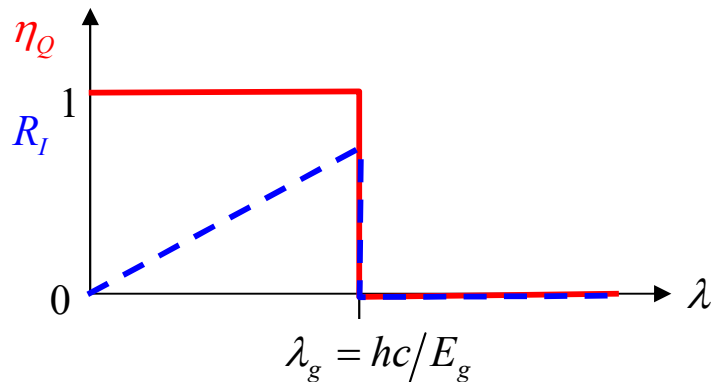
Efficiency quantique

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

Responsivity

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

Cas idéal en semiconducteur



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

Efficiency 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/spectral-response>

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

$$V_{cell} \cong V_{bi}$$

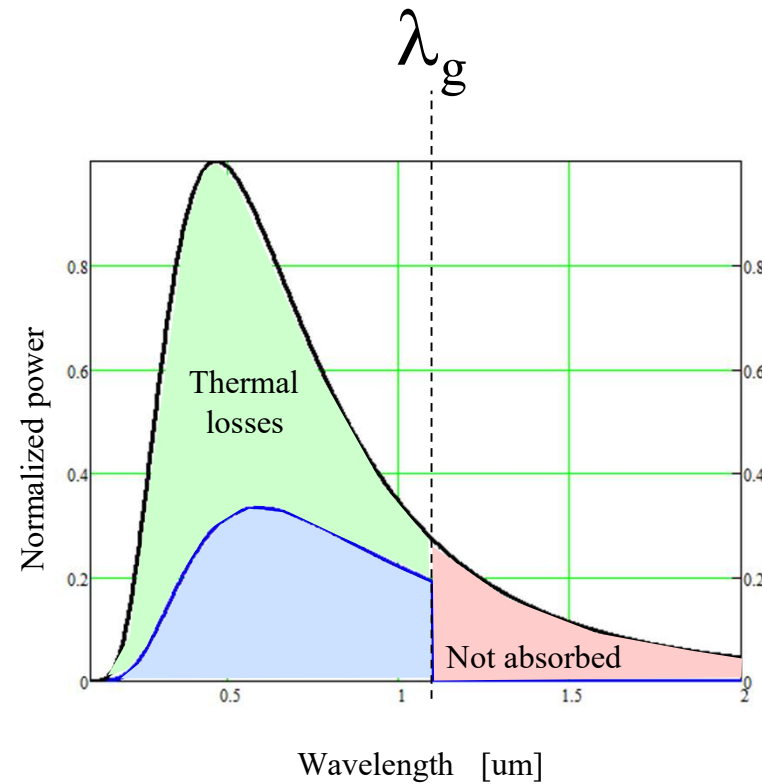
$$E_g \equiv \frac{hc}{\lambda_g}$$



$$\eta_{el} = \frac{\frac{V_{bi}}{(E_g/q)} \cdot \int_0^{\lambda_g} \eta_Q \cdot \frac{\lambda}{\lambda_g} \cdot P_{opt} \cdot d\lambda}{\int_0^{\infty} P_{opt} \cdot d\lambda}$$

$$\eta_{el} = \frac{\frac{V_{bi}}{(E_g/q)} \cdot \int_0^{\lambda_g} \eta_Q \cdot \frac{\lambda}{\lambda_g} \cdot P_{opt} \cdot d\lambda}{\int_0^{\infty} P_{opt} \cdot d\lambda}$$

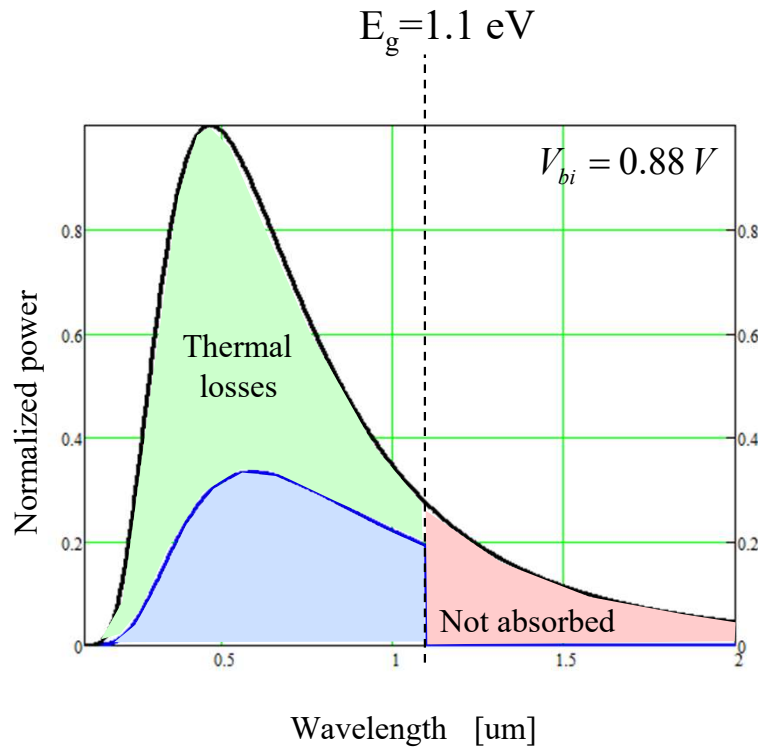
80% → 100%



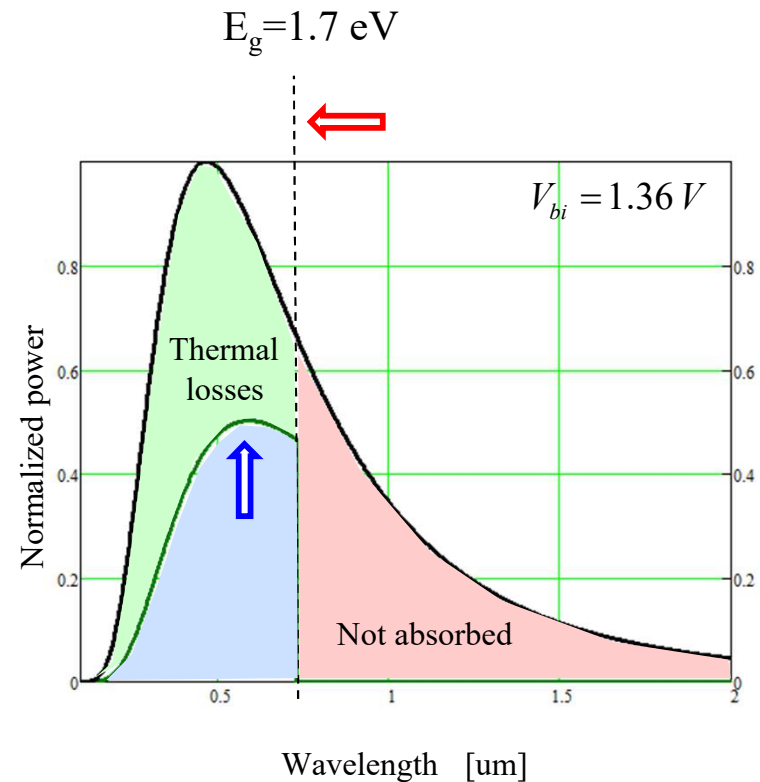
Transparence

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

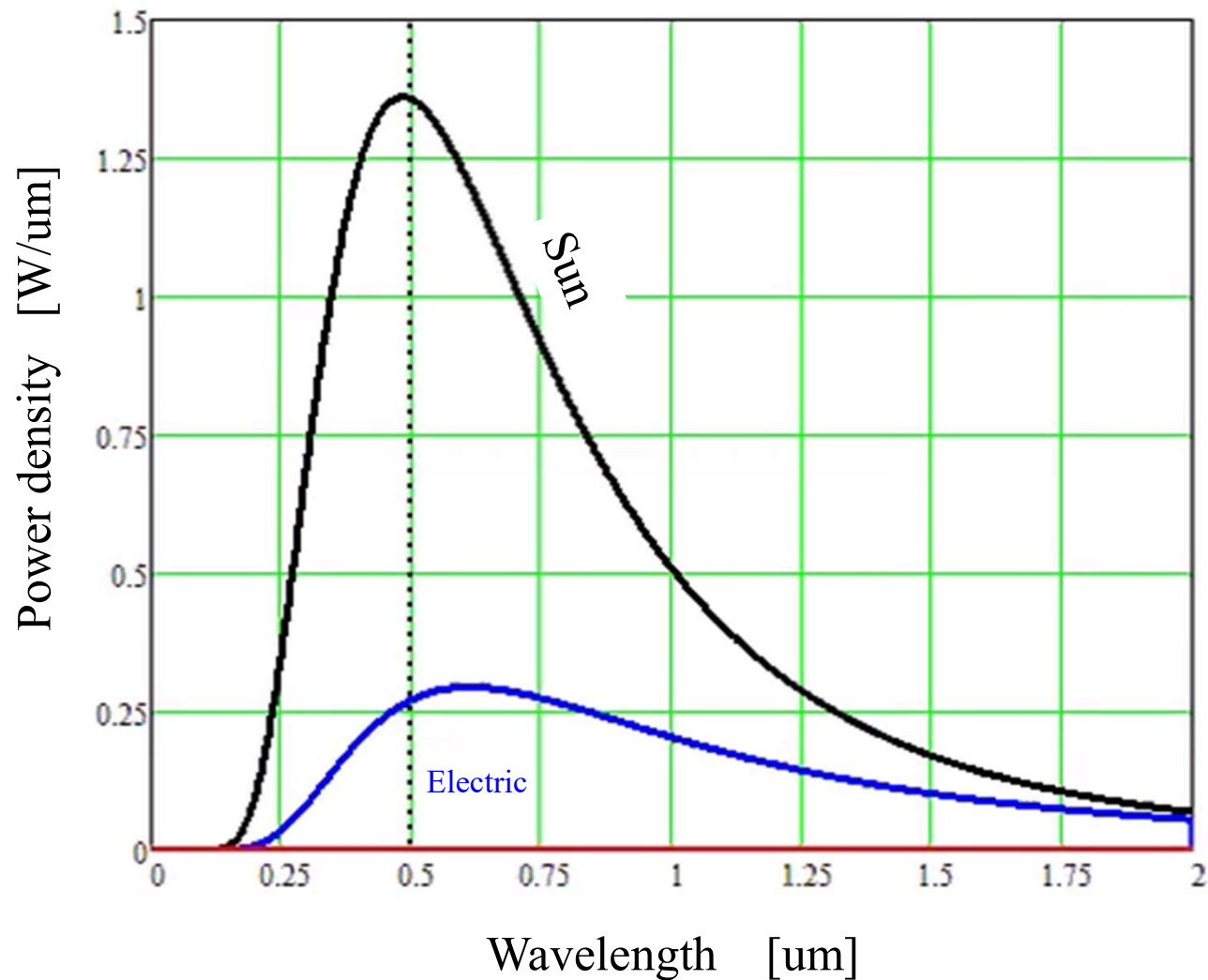
Monocrystalline Si



Amorphous Si

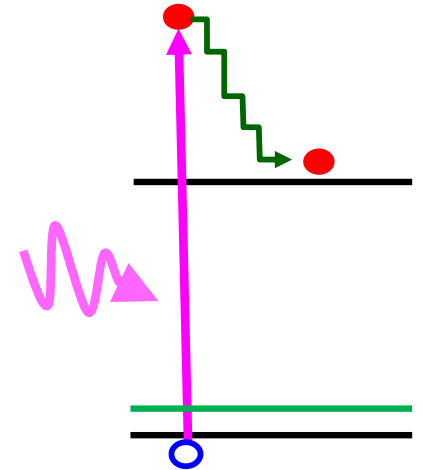
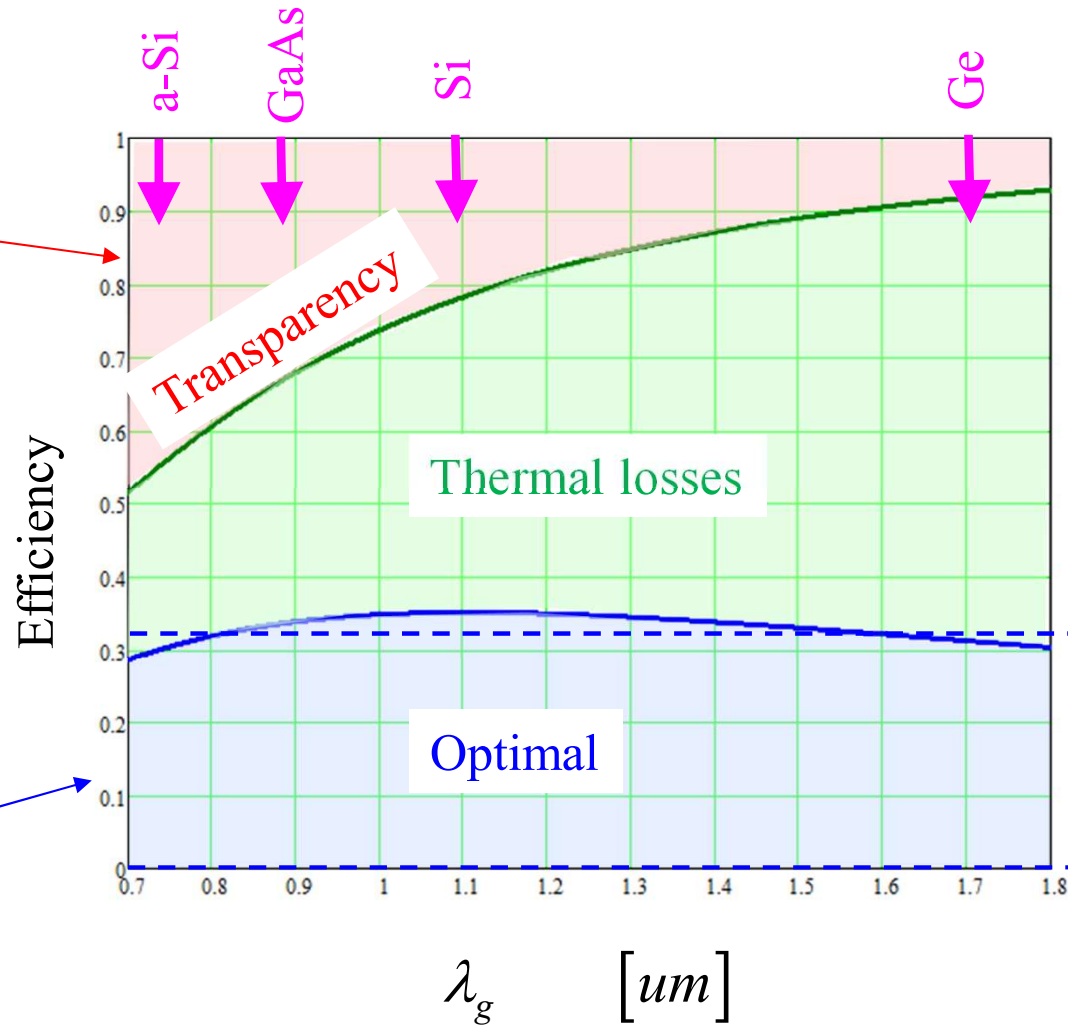


Influence de l'énergie de gap du matériel de la cellule solaire single junction



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

$$\frac{\frac{qV_{bi}}{E_g} \int_0^{\lambda_g} \eta_Q \frac{\lambda}{\lambda_g} P_{sun}(\lambda) d\lambda}{\int_0^{\infty} P_{sun}(\lambda) d\lambda}$$



1/3