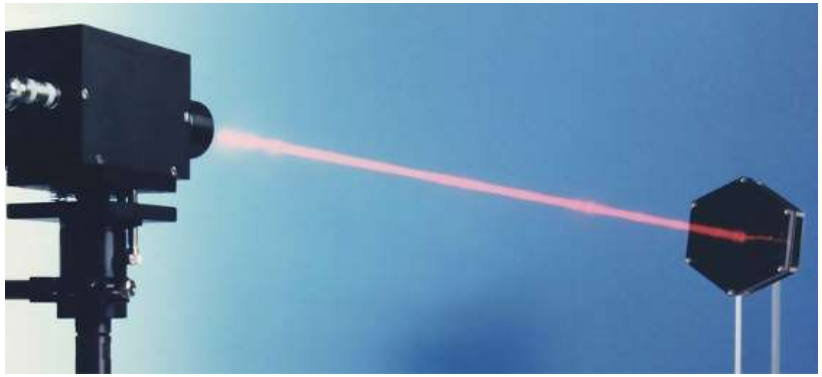
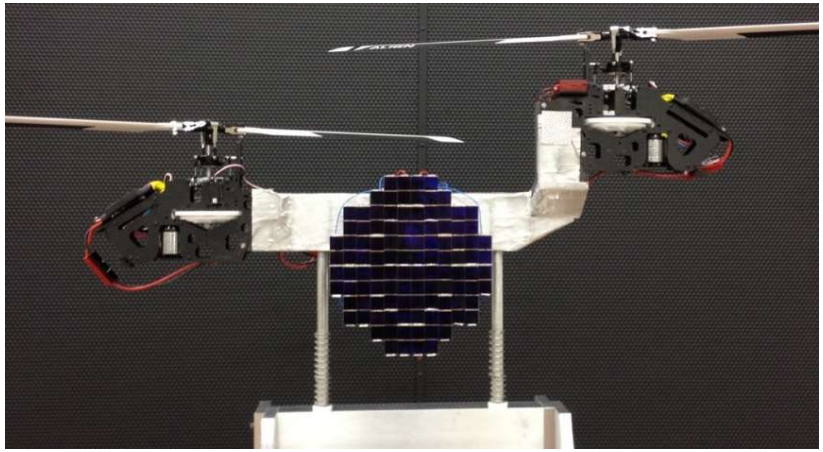
Exercice 8.3: Laser Power Converter (LPC)

Un laser est utilisé pour alimenter en énergie une batterie.
Discutez le design des cellules photovoltaiques (Laser Power Converter).



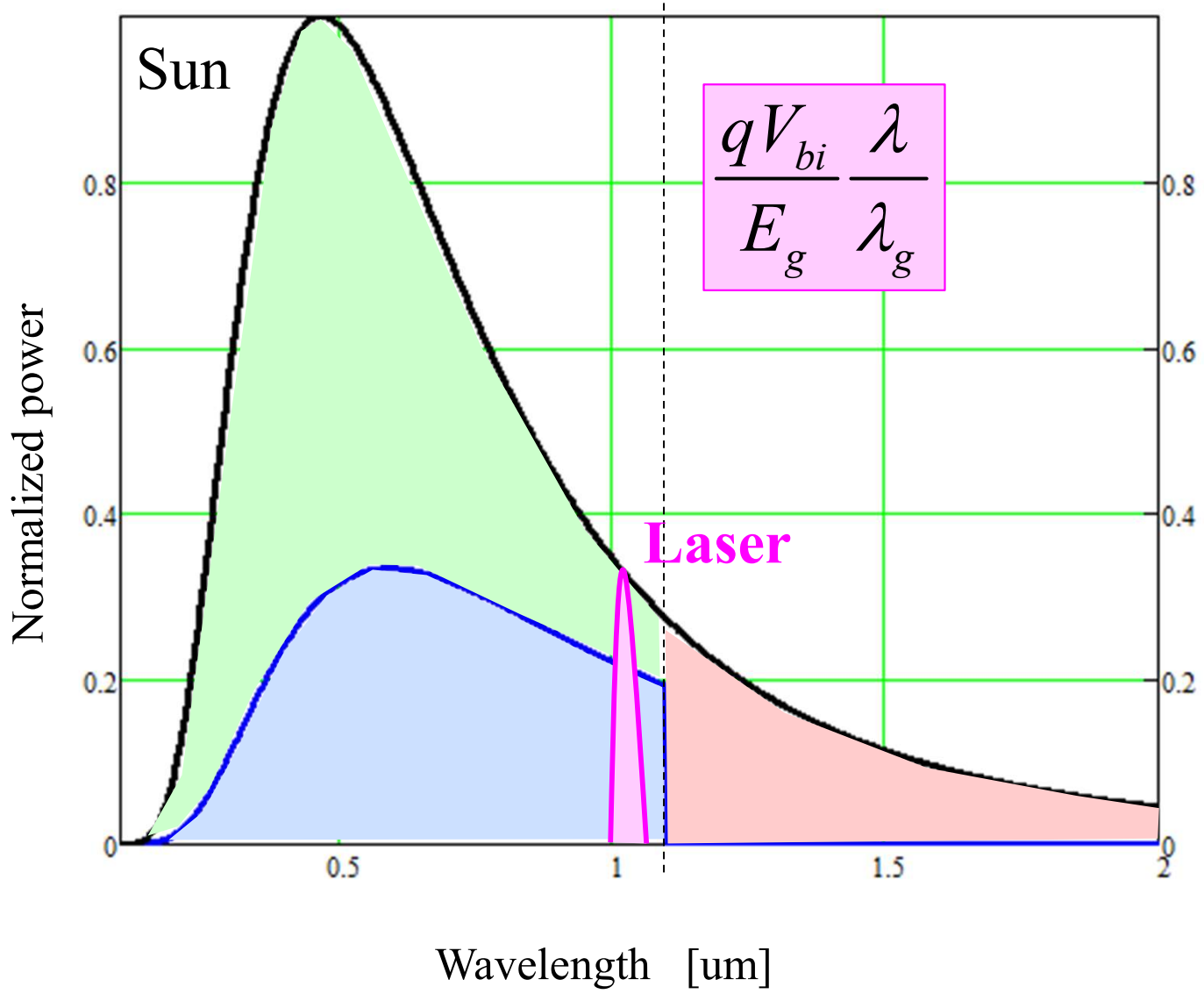


Le laser émet:
- **une lumière monochromatique**
- de puissance constante

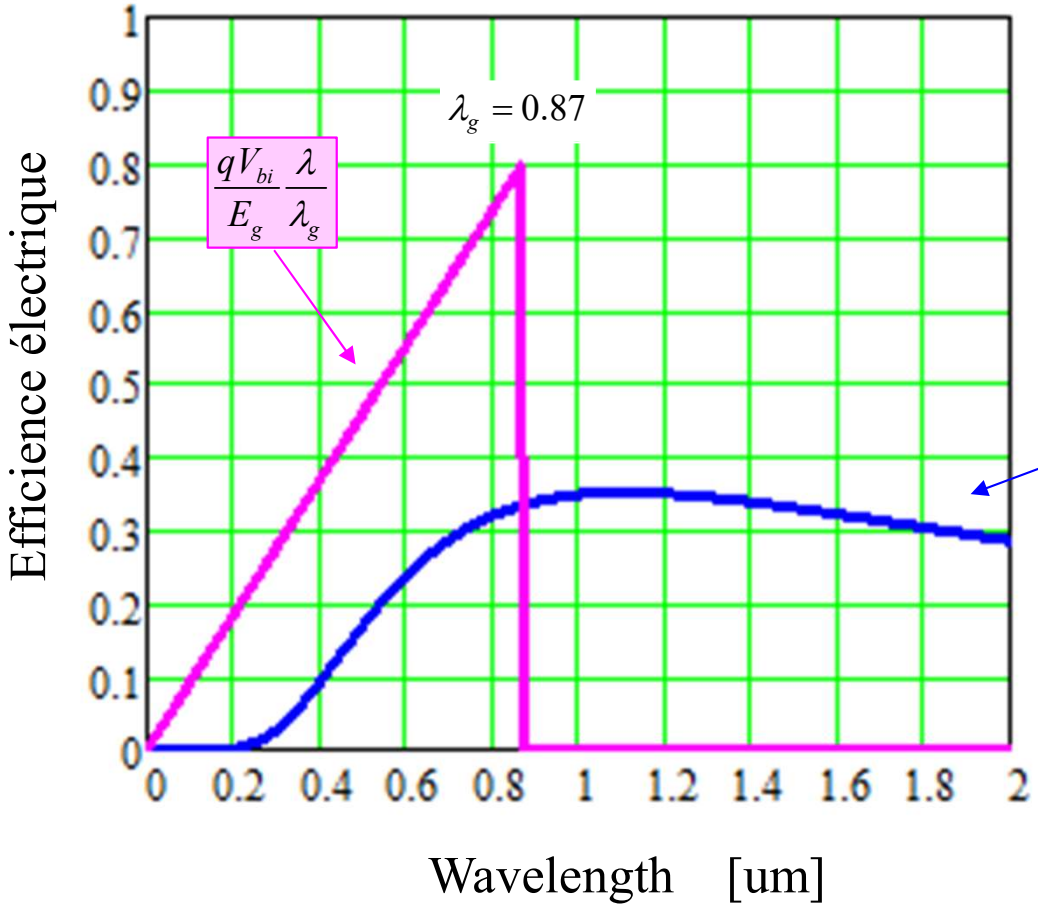
1) Enoncez des lignes directrices pour le design de la cellule PV

2) Quels seraient les avantages d'une cellule photovoltaïque (PV) multi-jonction pour cette application ?

Efficience électrique «monochromatique»



Comparaison pour une illumination solaire ou monochromatique



Efficience électrique optimale pour:

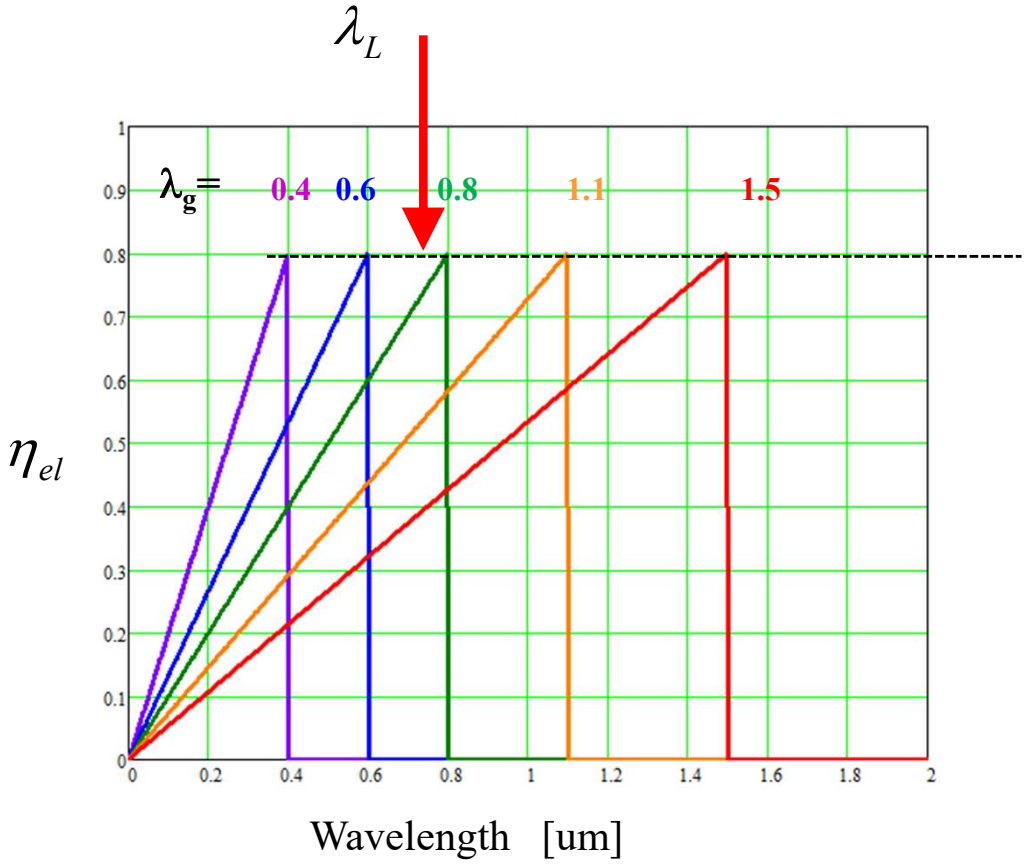
Une illumination solaire
en fonction du gap du matériel

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

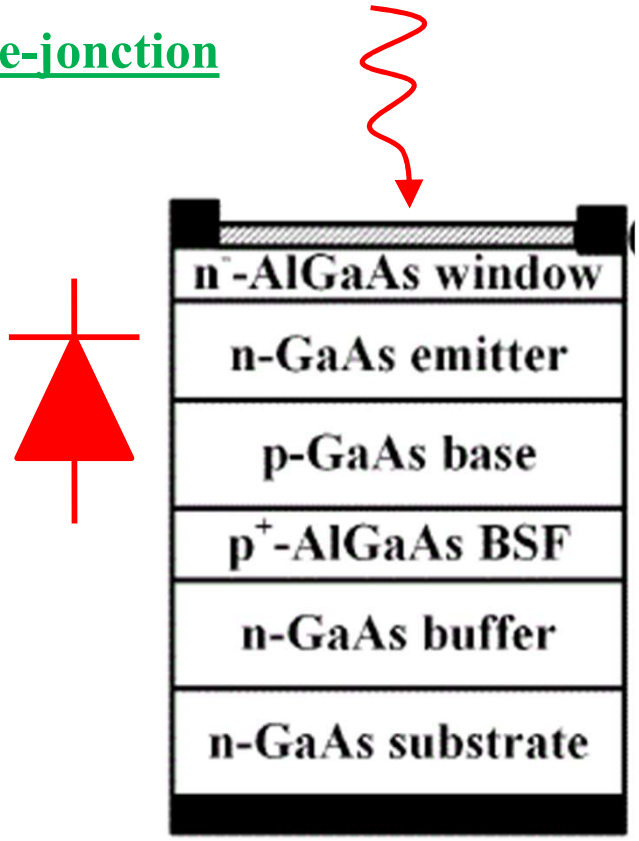
$$\frac{qV_{bi}}{E_g} \cong 0.8$$

Une cellule en GaAs
en fonction de la longueur d'onde
de la lumière monochromatique

Exercice: Laser Power Converter (LPC)



Single-jonction

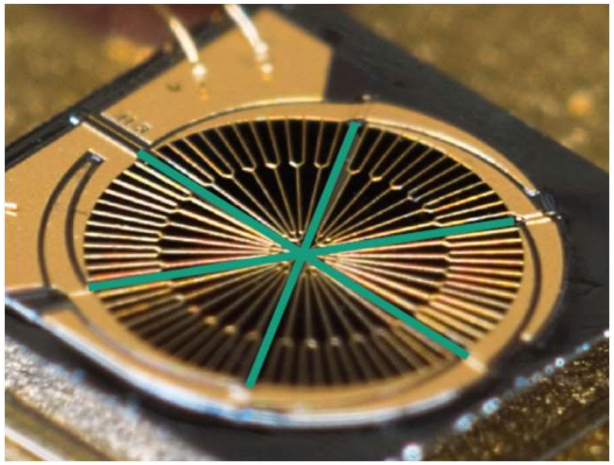


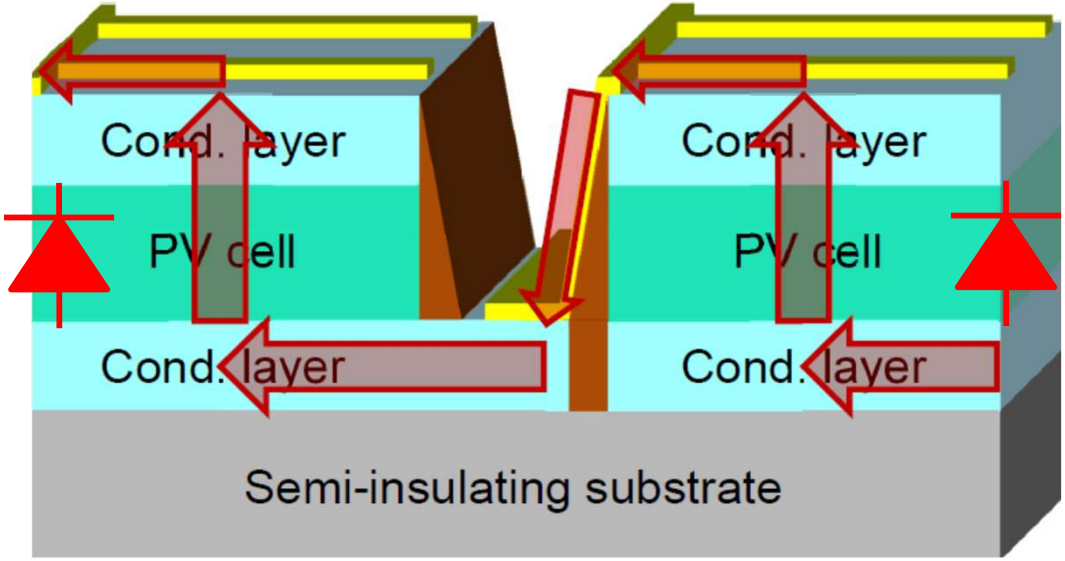
$$\eta_{el} \cong \frac{q \cdot V_{bi}}{E_g} \cdot \eta_{opt} \cdot \frac{\lambda}{\lambda_g}$$

- **Jonction unique**
- **Choisir le matériel avec λ_g juste supérieur à λ_L**
- Évitez les recombinaisons dans le matériel
- Interfaces réflectifs aux contacts

Multi-jonction pour augmenter la tension

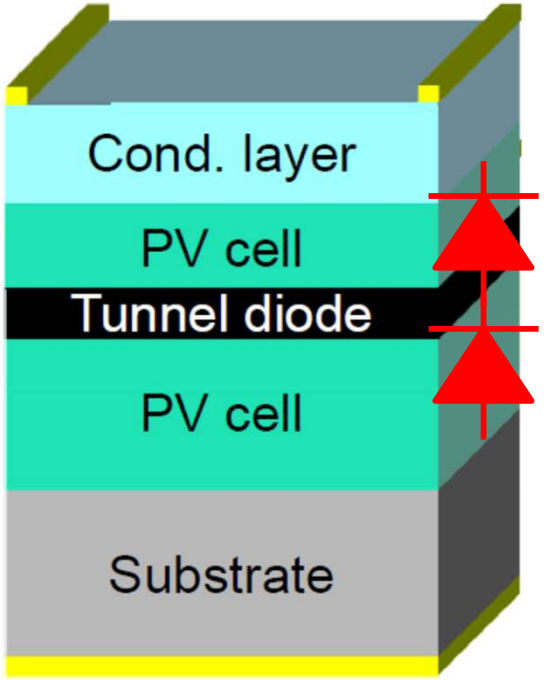
Pie-shaped





Current matching

Vertically-stacked



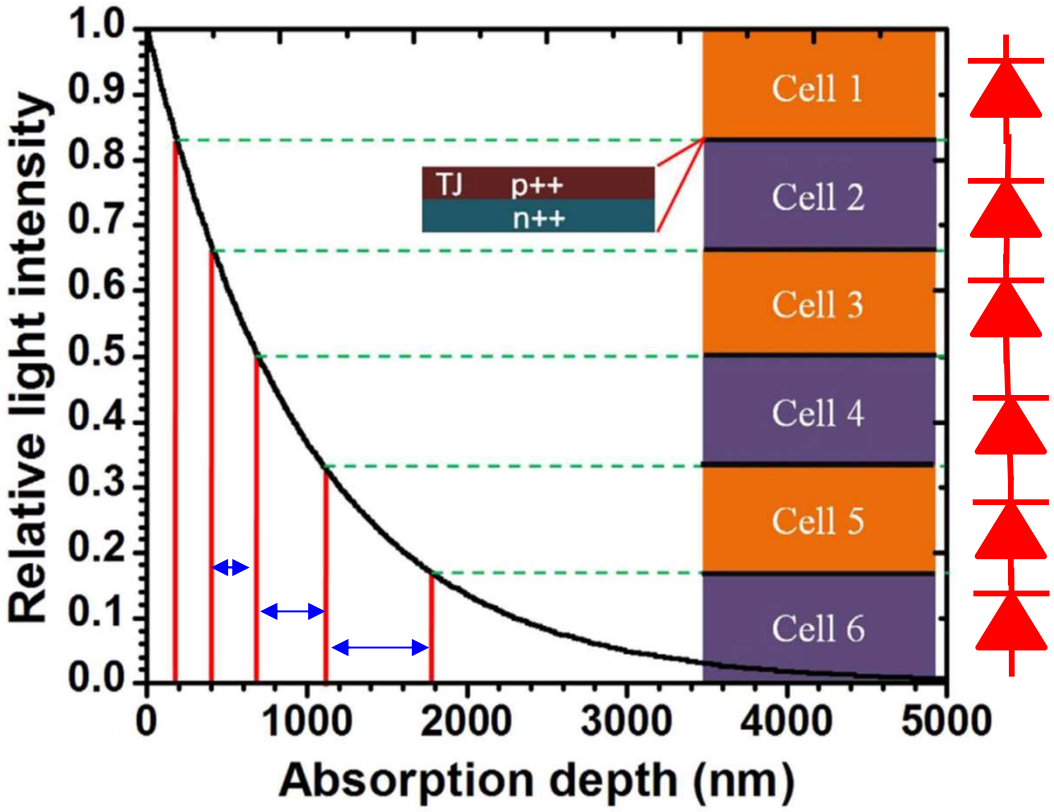
H Helmers,K. Reichmuth, Photovoltaic cells for optical power and data transmission, 2014

LPC: 6-layer design

Type	Voltage (V)	Incident energy	Illumination wavelength (nm)	Efficiency(%)
GaAs	1	5 W/cm^2	808	52.2[1]
GaAs	1	36.5 W/cm^2	810	54.9[15]
GaAs	1		809	~60[33]
GaAs	1	43 W/cm^2	810	53.4[34]
GaAs	1	0.522 W	835	56[17]
Vertically-stacked	2	100 W/cm^2	810	41[34]
Pie-shaped	2	15 W/cm^2	810	~47.5[14]
Pie-shaped	4	0.8 W	830	~47[35]
Pie-shaped	4	8.5 W/cm^2	810	55.1[14]
Pie-shaped	4	0.17 W	808	45.4[36]
Pie-shaped	5	2 W/cm^2	793	50.4[5]
Vertically-stacked	5	11 W/cm^2	835	60[3]
Pie-shaped	6	17 W/cm^2	810	43[34]
Pie-shaped	6	22 W/cm^2	810	42.7[14]
Pie-shaped	6	~0.25 W	808	~43.5[36]
Vertically-stacked	6	2.6 W/cm^2	808	50.2*

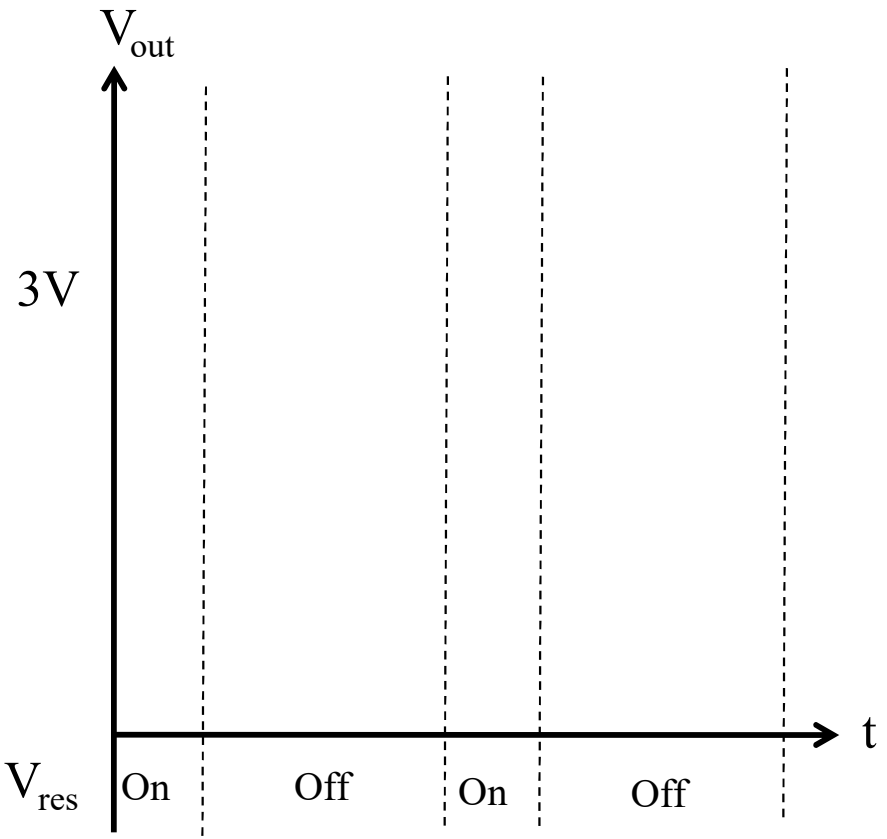
Y. Zhao et al., «Design and fabrication of sixvolt vertically-stacked GaAs photovoltaic power converter» Scientific Reports | 6:38044 | DOI: 10.1038/srep38044

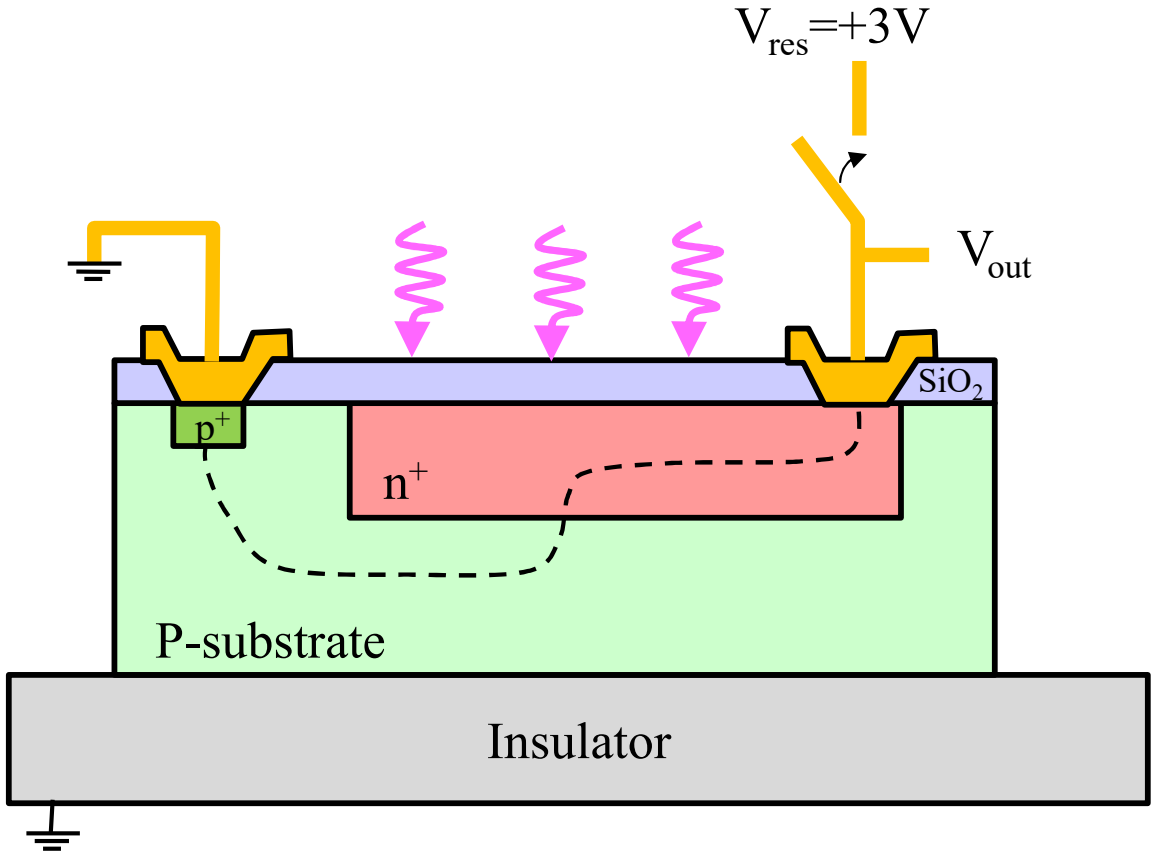
TJ= tunnel junction between cells



Current matching

Exercise 8.4: CMOS Camera (Pixel)

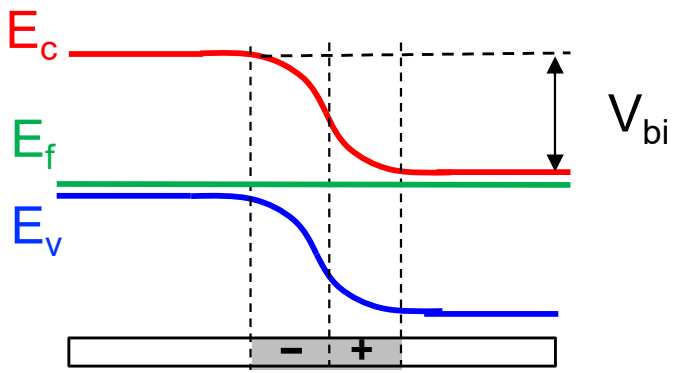




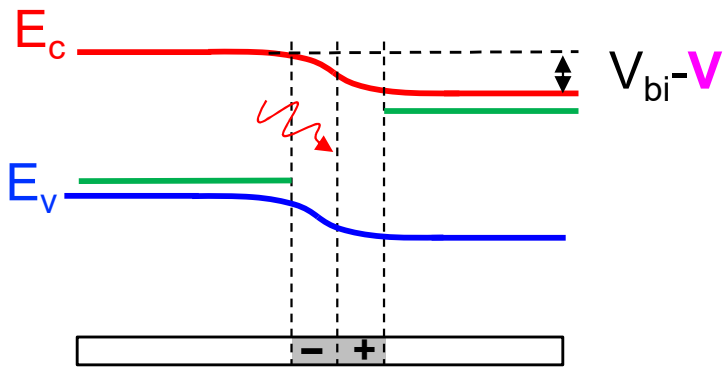
- Draw the band diagram and the electrical charges along the dotted line and and analyze their temporal behavior when the pixel is illuminated.
- Plot the output voltage with and without light.

Solar cell – CMOS pixel

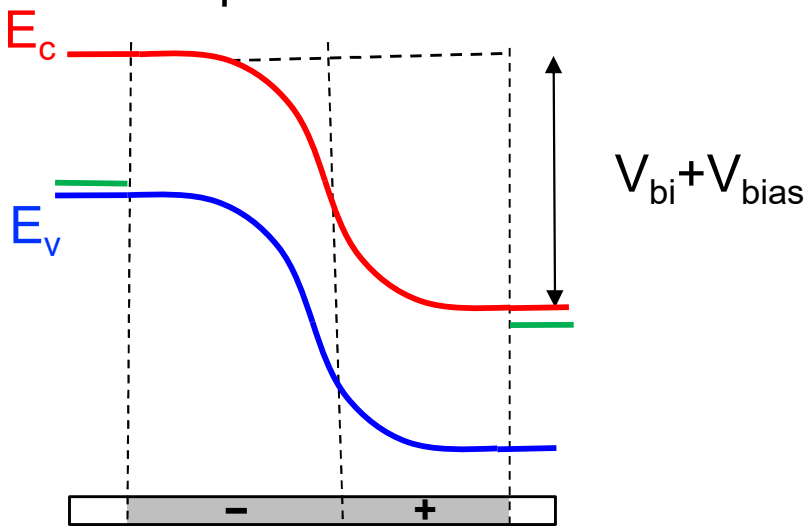
Solar cell: no illumination



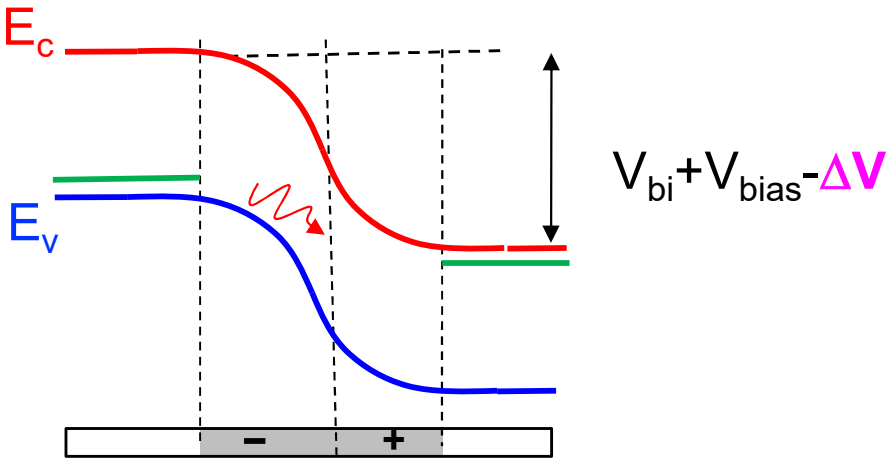
Solar cell: with illumination



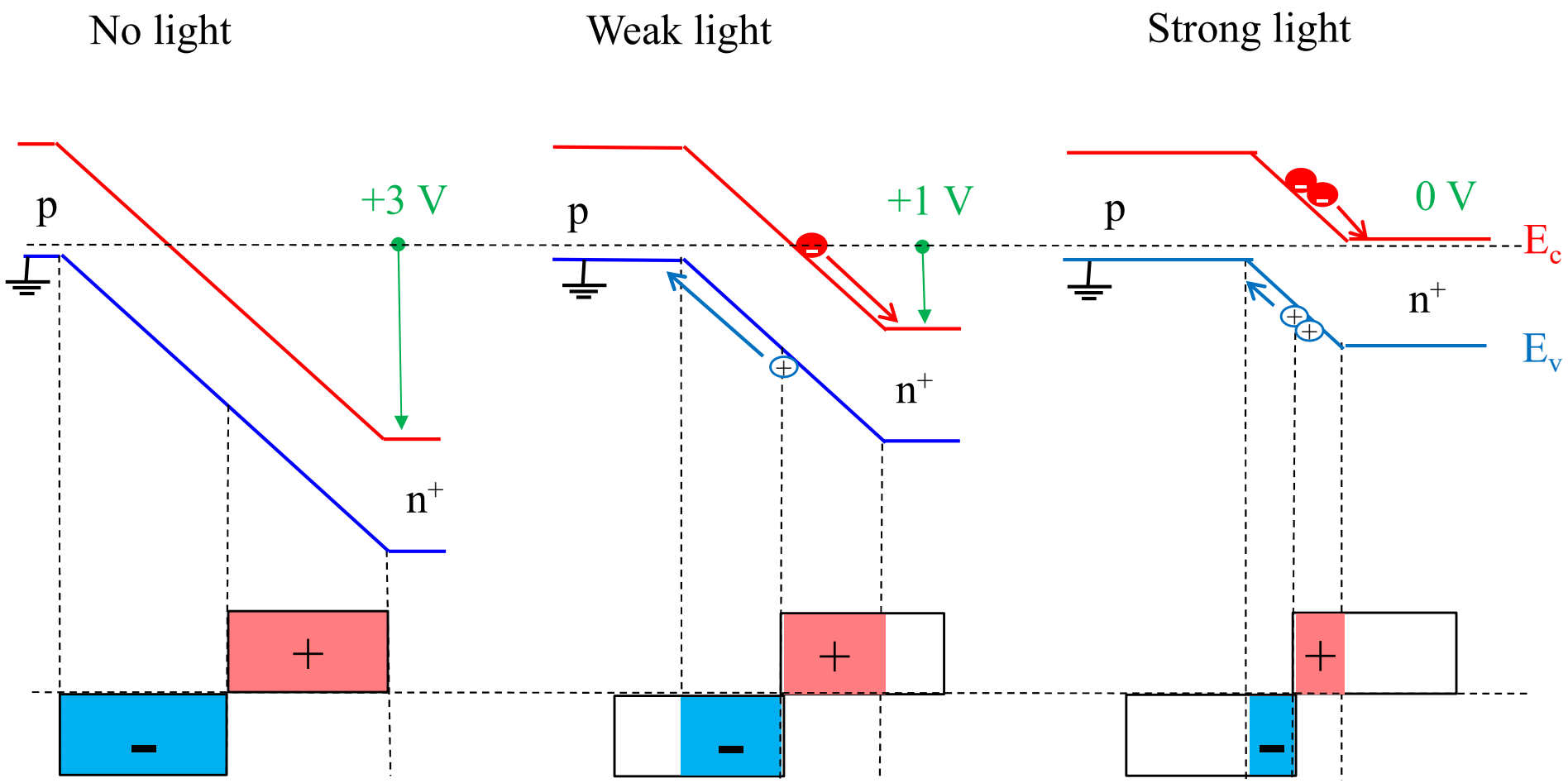
CMOS pixel before illumination



CMOS pixel under illumination



A CMOS Camera: Pixel (1)

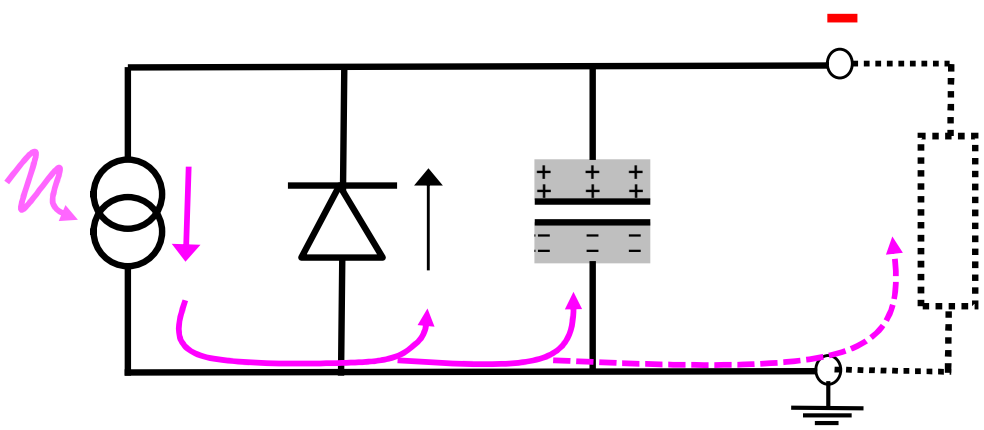


- With no light, the depletion capacity contains the maximum of charges
- The carriers that are produced by the illumnation reduce the charges in the depletion region

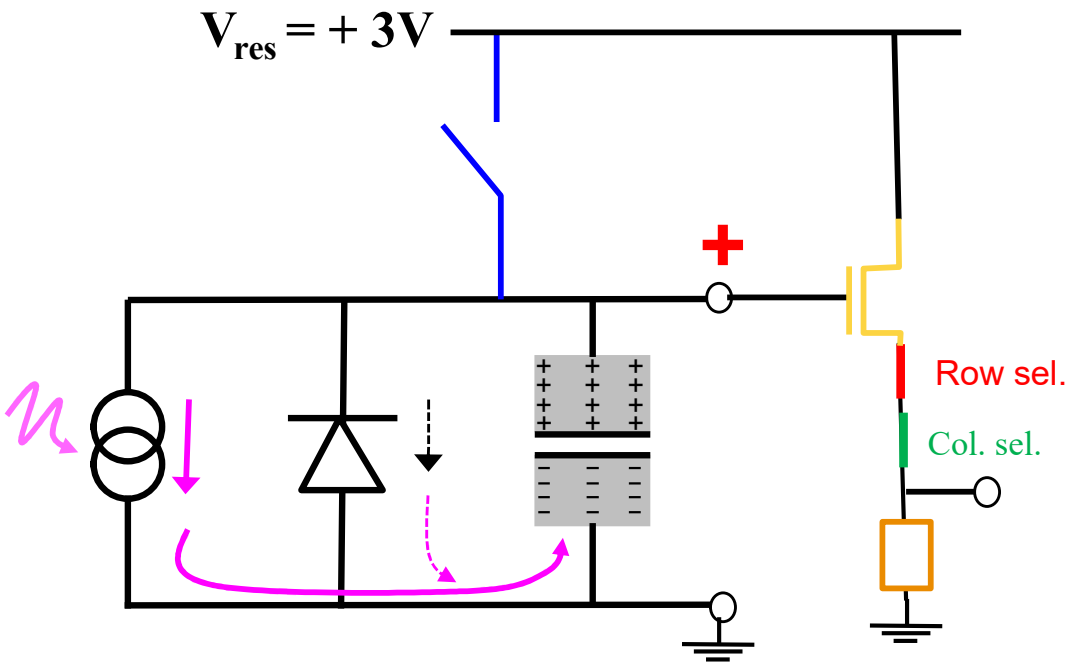
→ The depletion capacity integrates the generated charges.

Solar cell – CMOS pixel

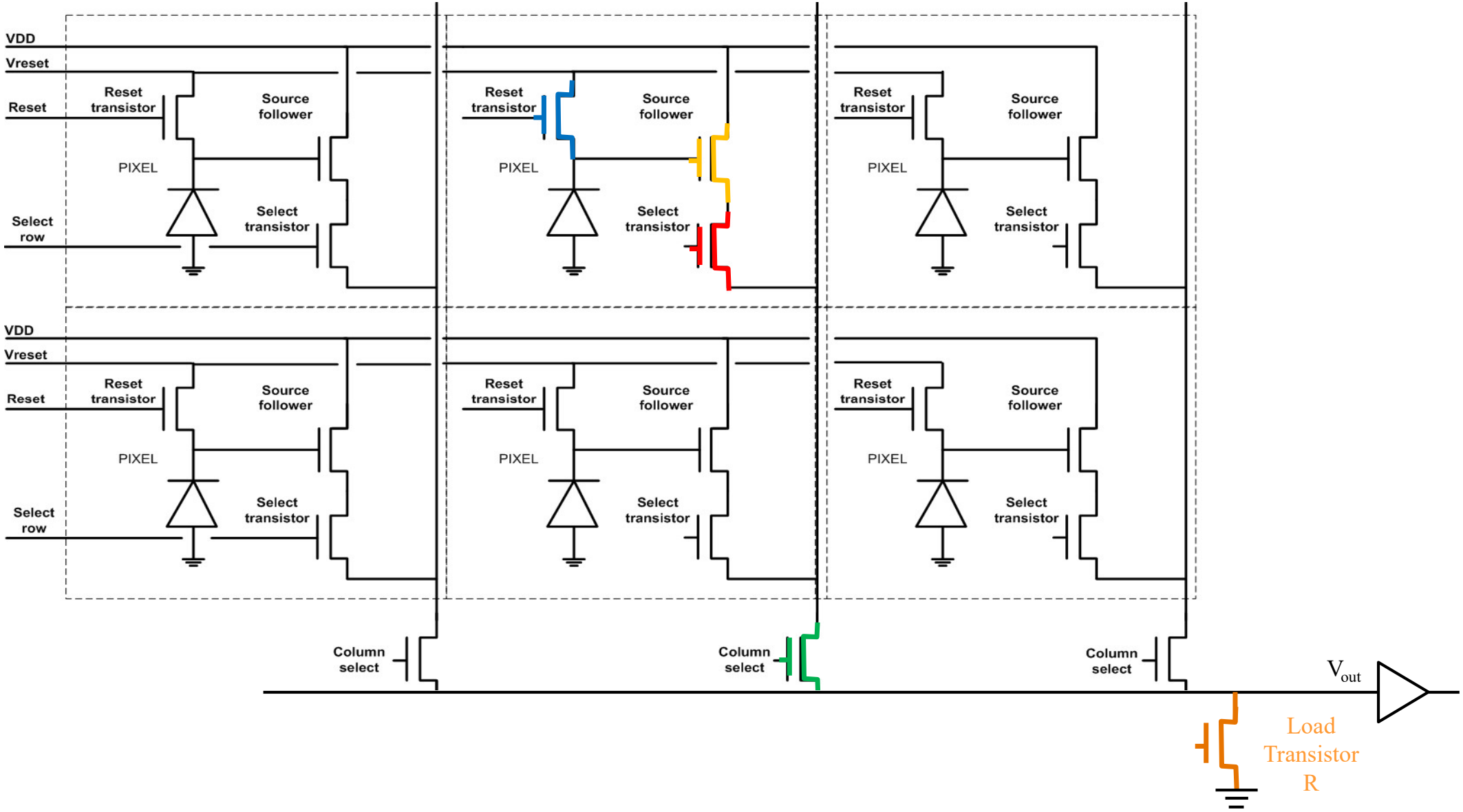
Solar cell



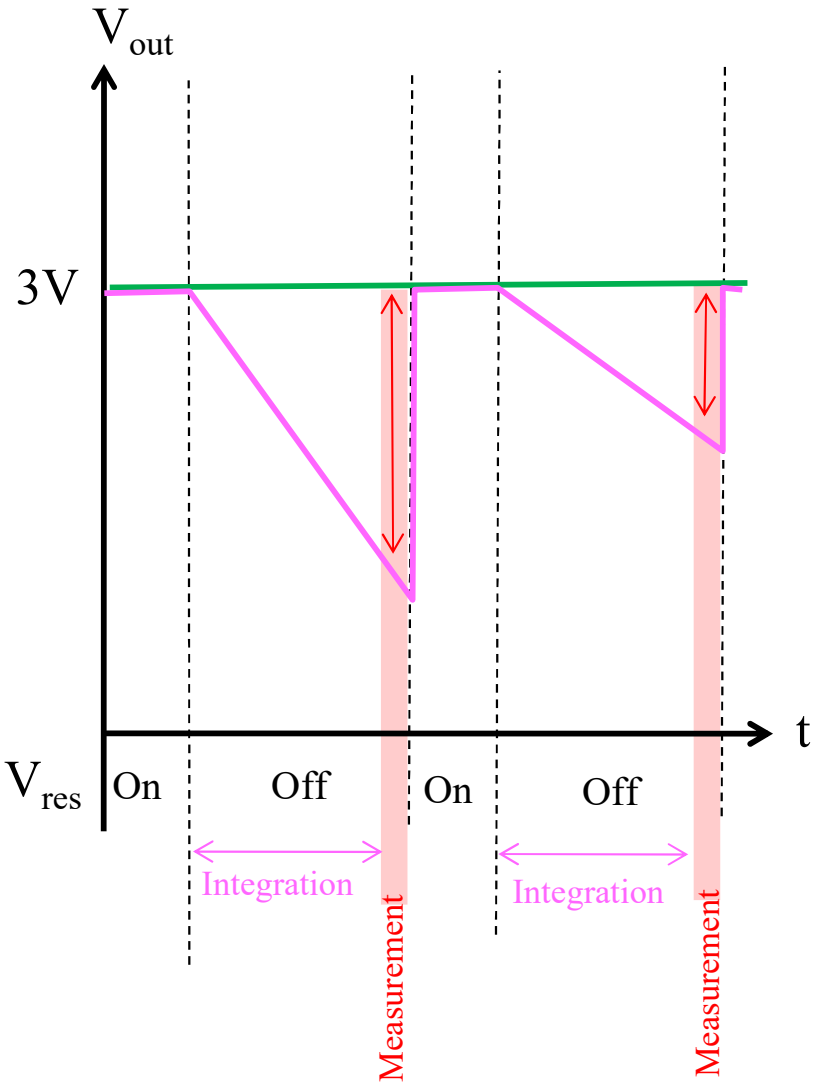
CMOS pixel: Photodiode

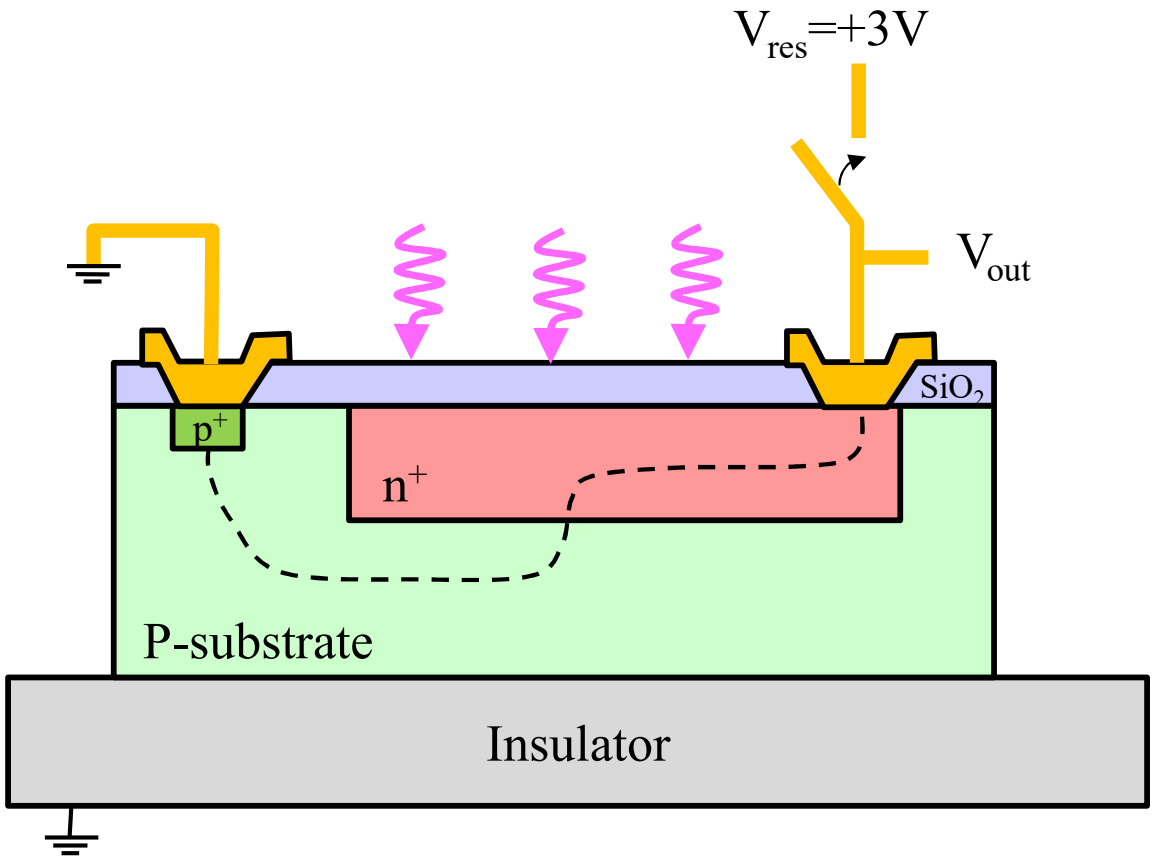


Caméra Standard 3T Pixel



CMOS Camera: Pixel (2)

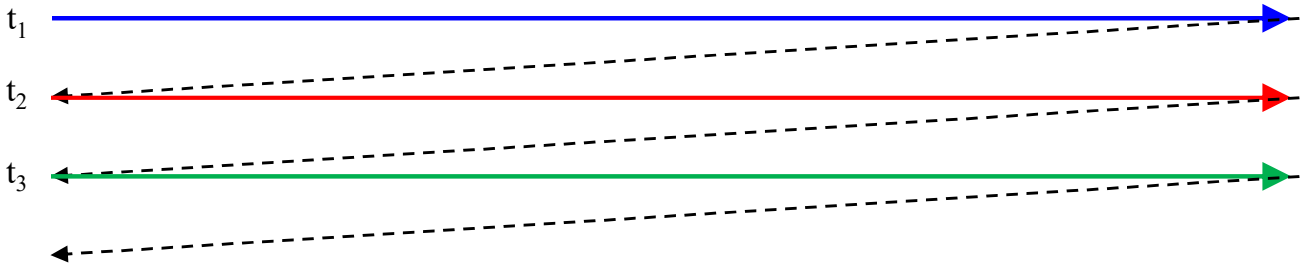


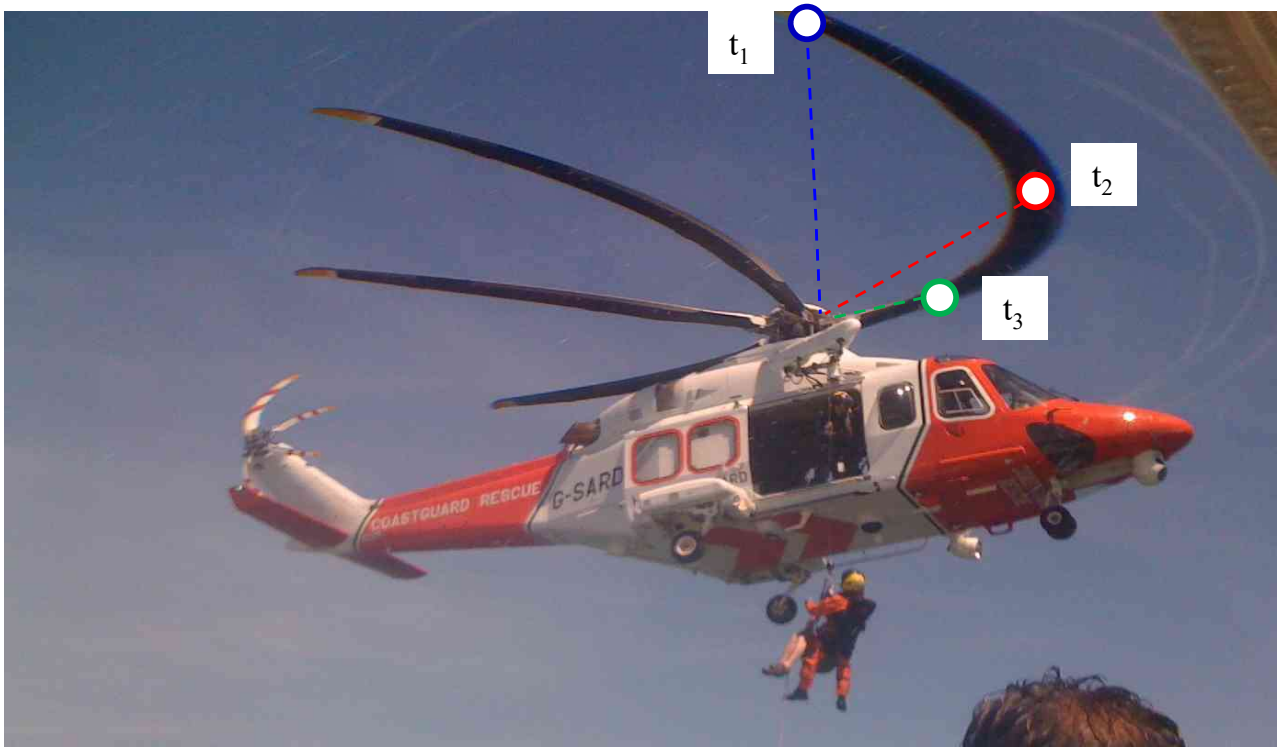


- "Long" integration time: *1/(frame-rate)*
- "Very short" measurement time: *1/(frame-rate)*(Nb.pixels)*

→ Optimal for a camera

Pixels lus à des temps différents: rolling shutter





⇨ Introduction du global shutter …