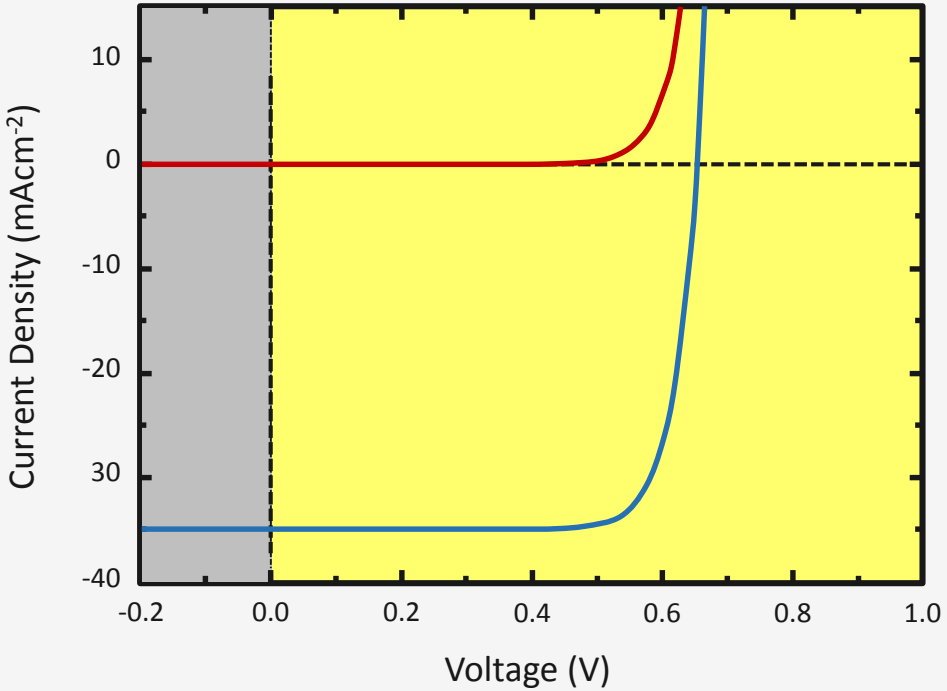
Solar Cell Operation, Performance and Design Rules

External Parameters of an Ideal Solar Cell

Week 3.2.1

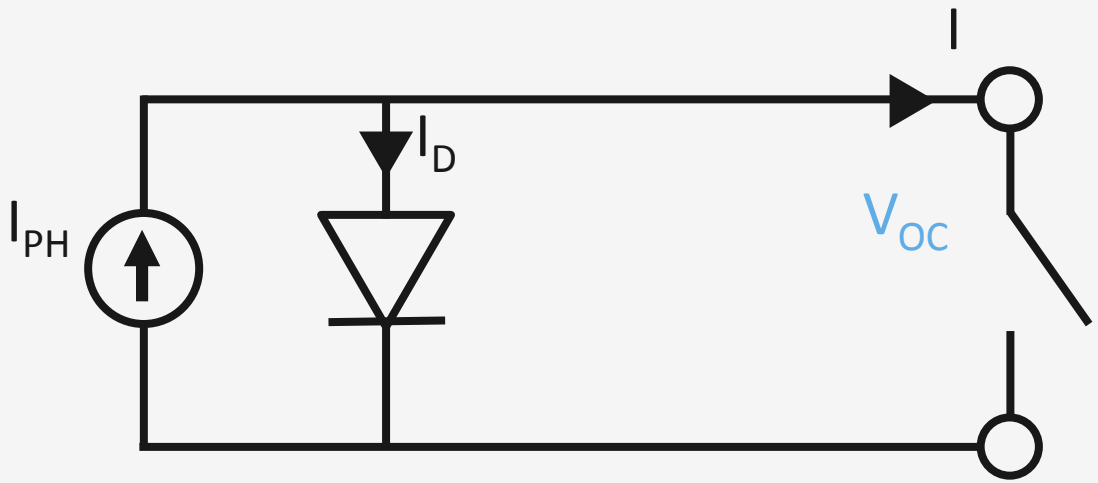
Arno Smets

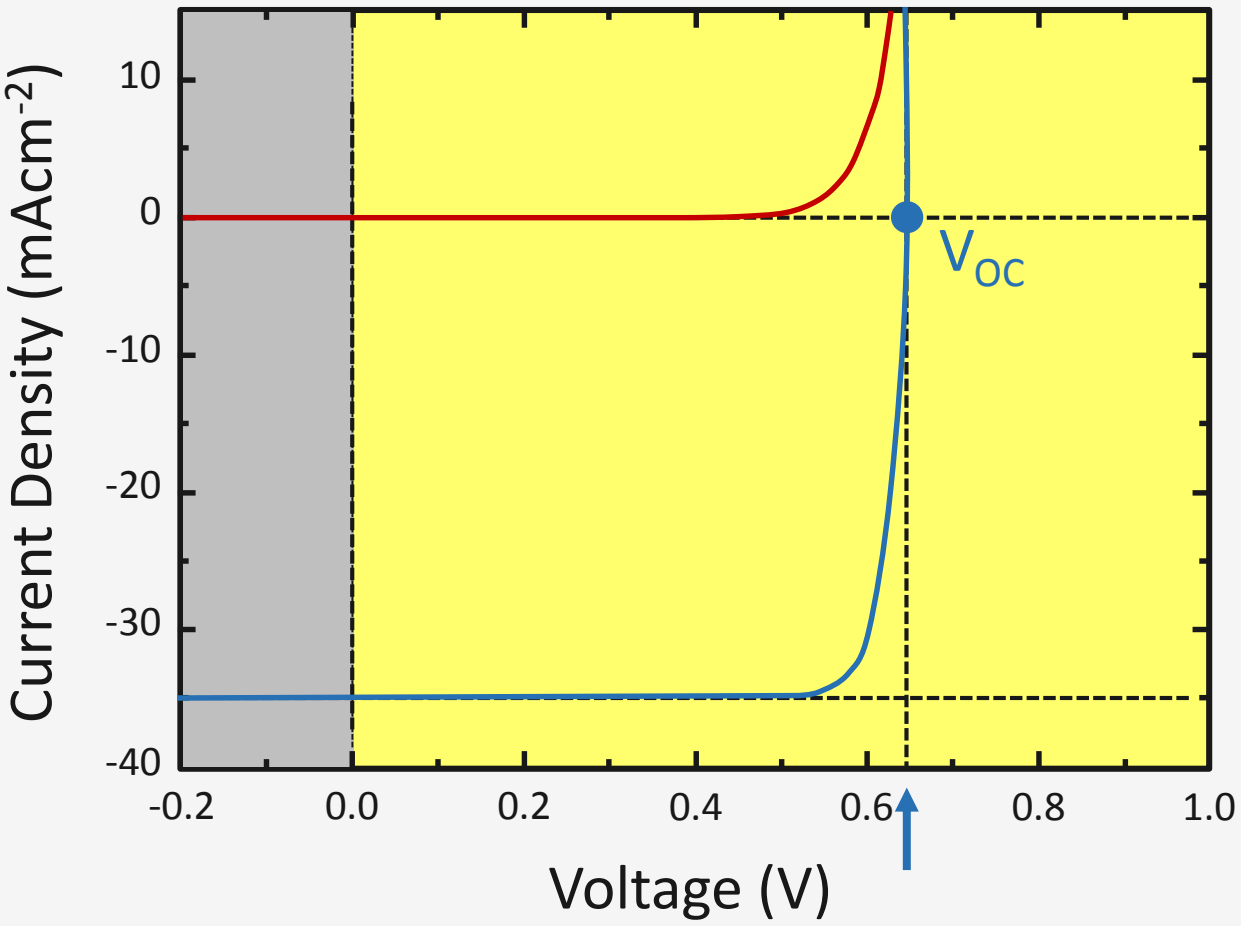
JV-Curve


Current Density (mAcm-2)
10
0
-10
-20
30
-40
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
Voltage (V)

JV-Characteristic: the external parameters

Open circuit voltage V_{OC}




Current Density (mAcm-2)
10
0
-10
-20
-30
-40
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
Voltage (V)
VOC

$$J = J_{PH} - J_0 \left(\exp\left(\frac{qV_{OC}}{k_B T} \right) - 1 \right) = 0$$

$$J = 0$$

$$V_{OC} = \frac{k_B T}{q} \ln\left(\frac{J_{PH}}{J_0} + 1 \right)$$

Open Circuit Voltage

$$V_{OC} = \frac{n\,k_B T}{q} \ln\left(\frac{J_{PH}}{J_0} + 1\right)$$

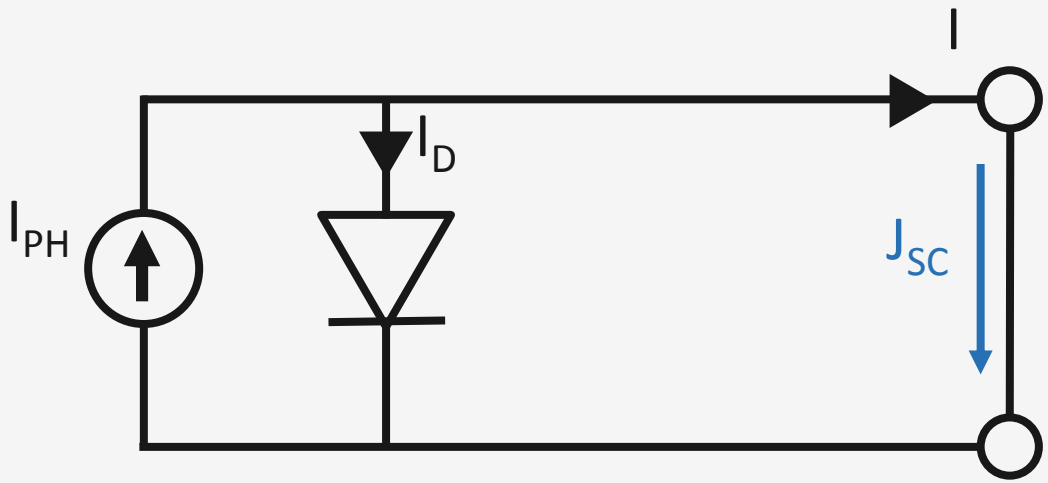
Temperature

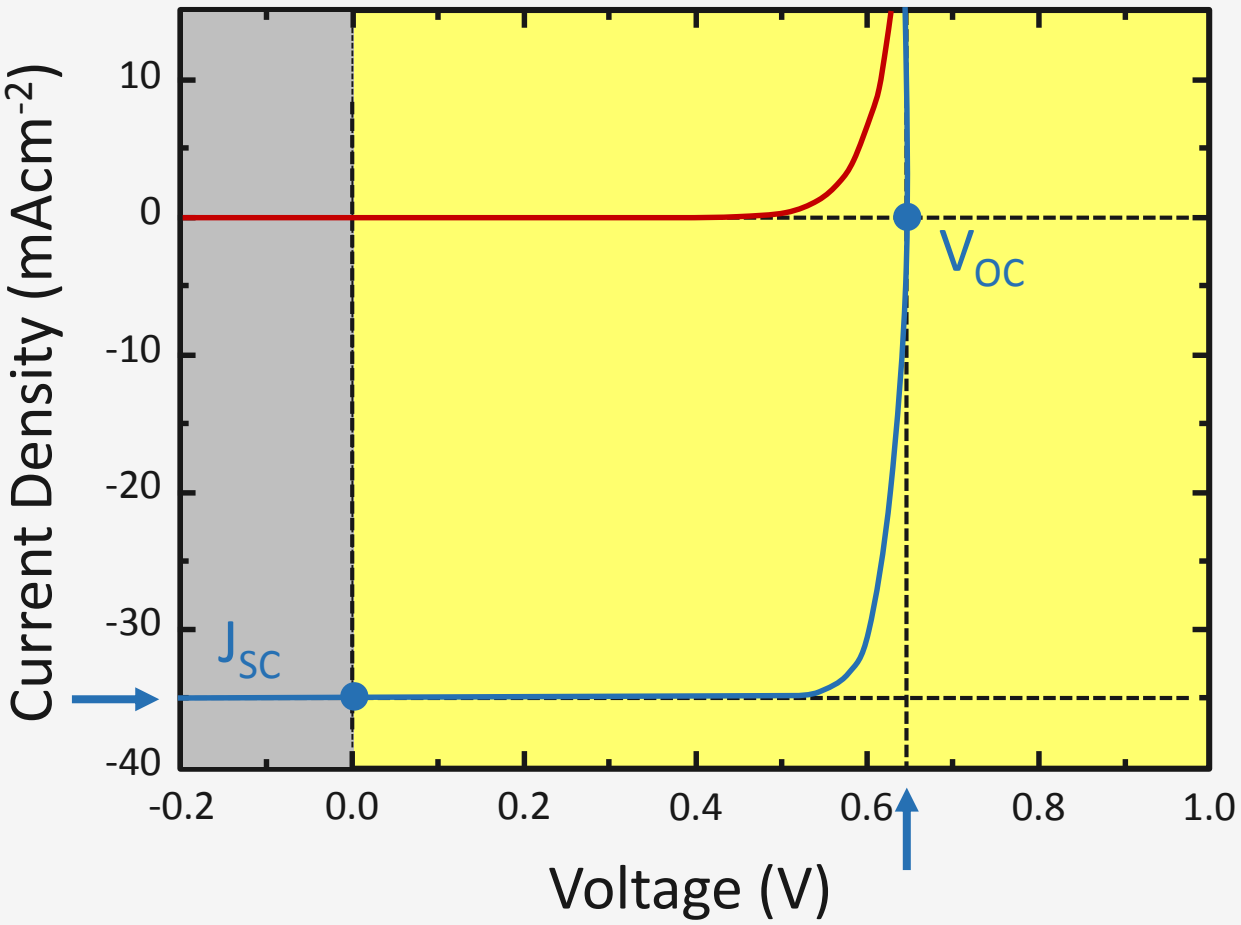
Open circuit voltage

- The band gap of the absorber material
- The amount of doping of the doped layers
- The quality of the material
- The light generated current density
- Temperature

JV-Characteristic: the external parameters

Short circuit current J_{sc}




Current Density (mAcm-2)
10
0
-10
-20
-30
-40
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
Voltage (V)
Jsc
Voc

$$J = J_{PH} - J_0 \left[\exp\left(\frac{qV}{k_B T} \right) - 1 \right]$$

$$J_{SC} \quad \text{Þ} \quad V = 0$$

$$J_{SC} = J_{PH}$$

Short circuit current

- Incident light intensity (number of photons)
- The spectrum of the incident light
- The optical properties (absorption coefficient)
- The collection probability

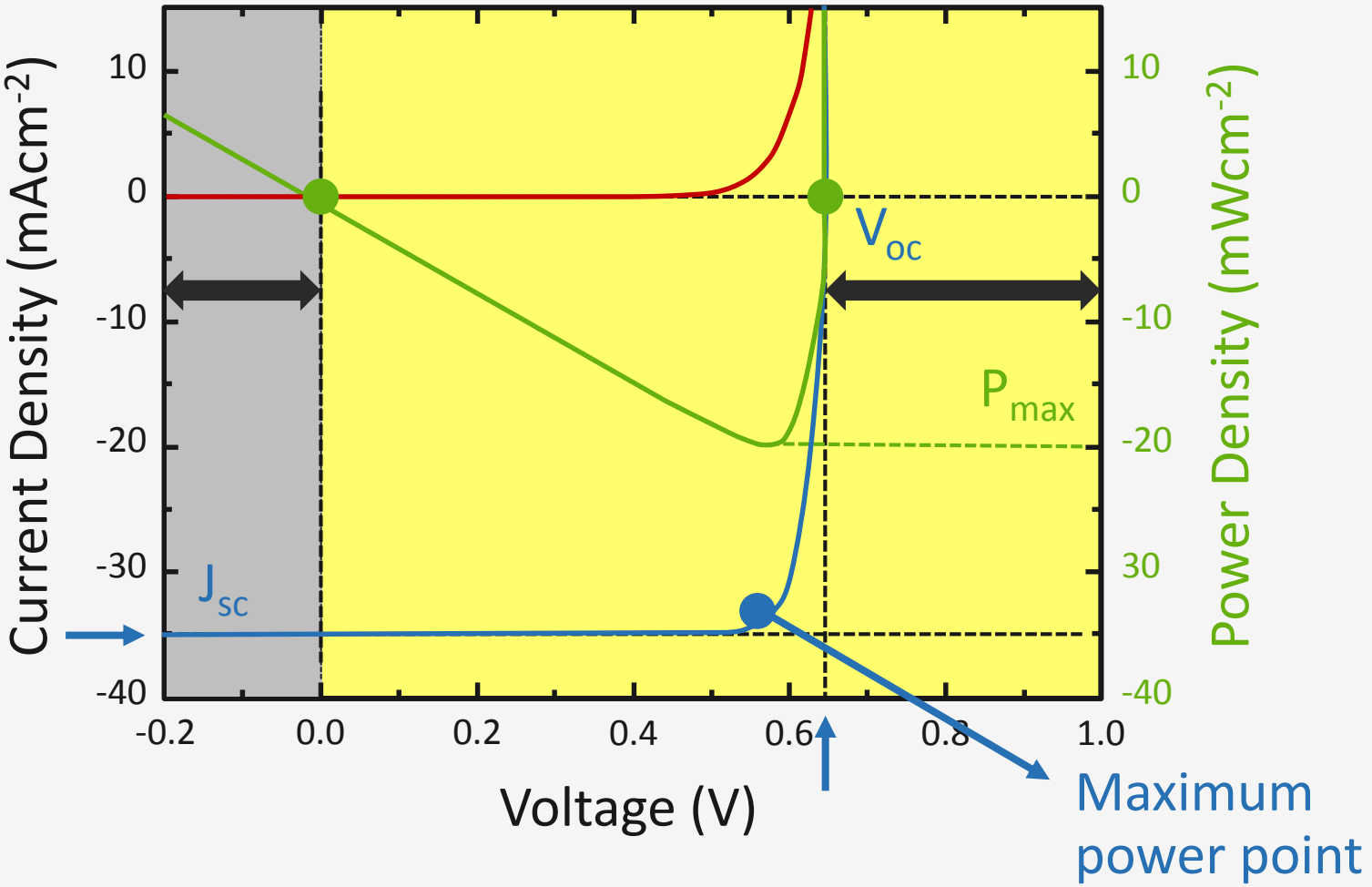
JV-Characteristic: the external parameters

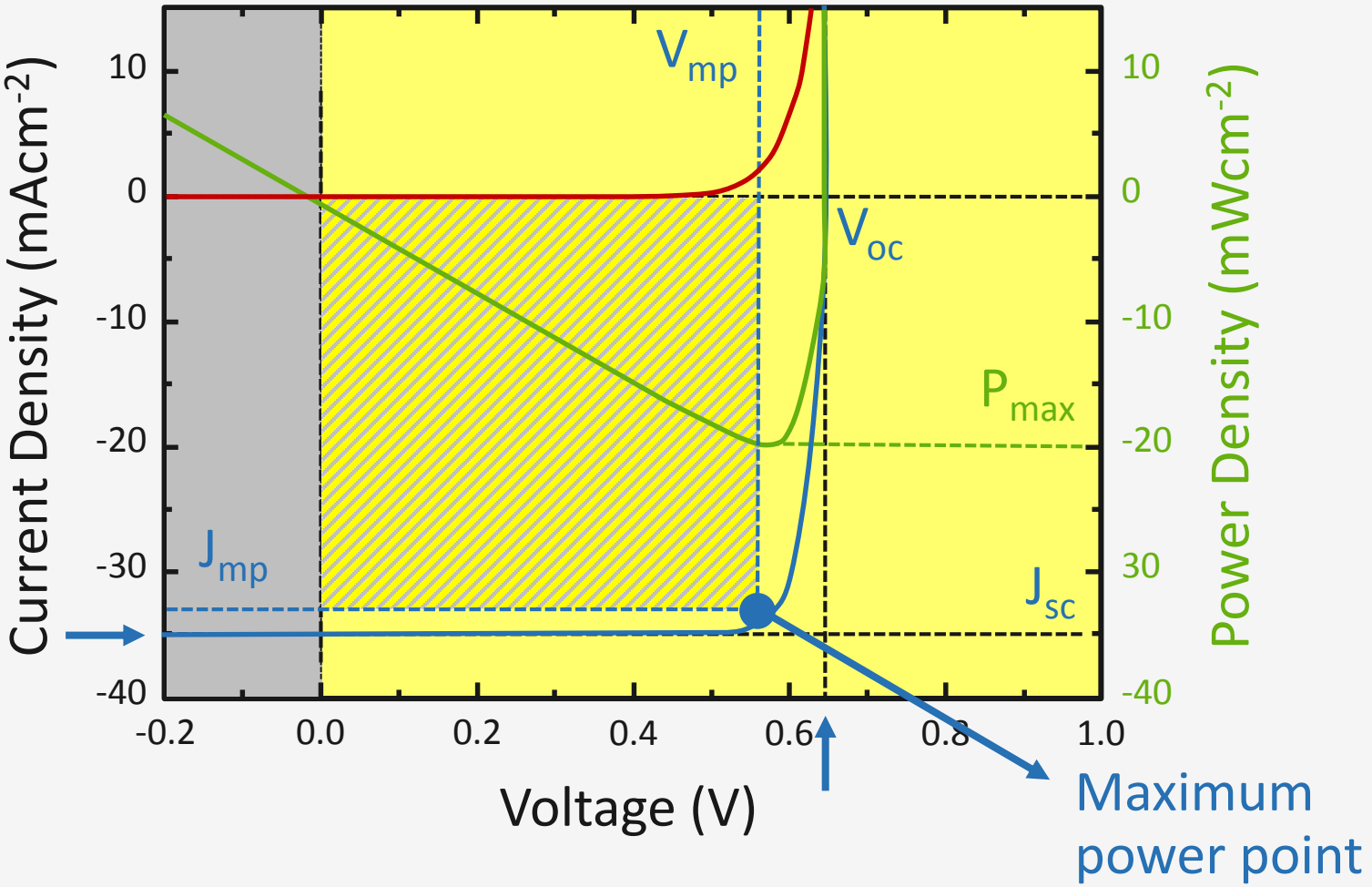
Power density :

power = current ⍰ voltage

Watt = Ampere ⍰ Volt

$W/m^2 = A/m^2$ ⍰ V

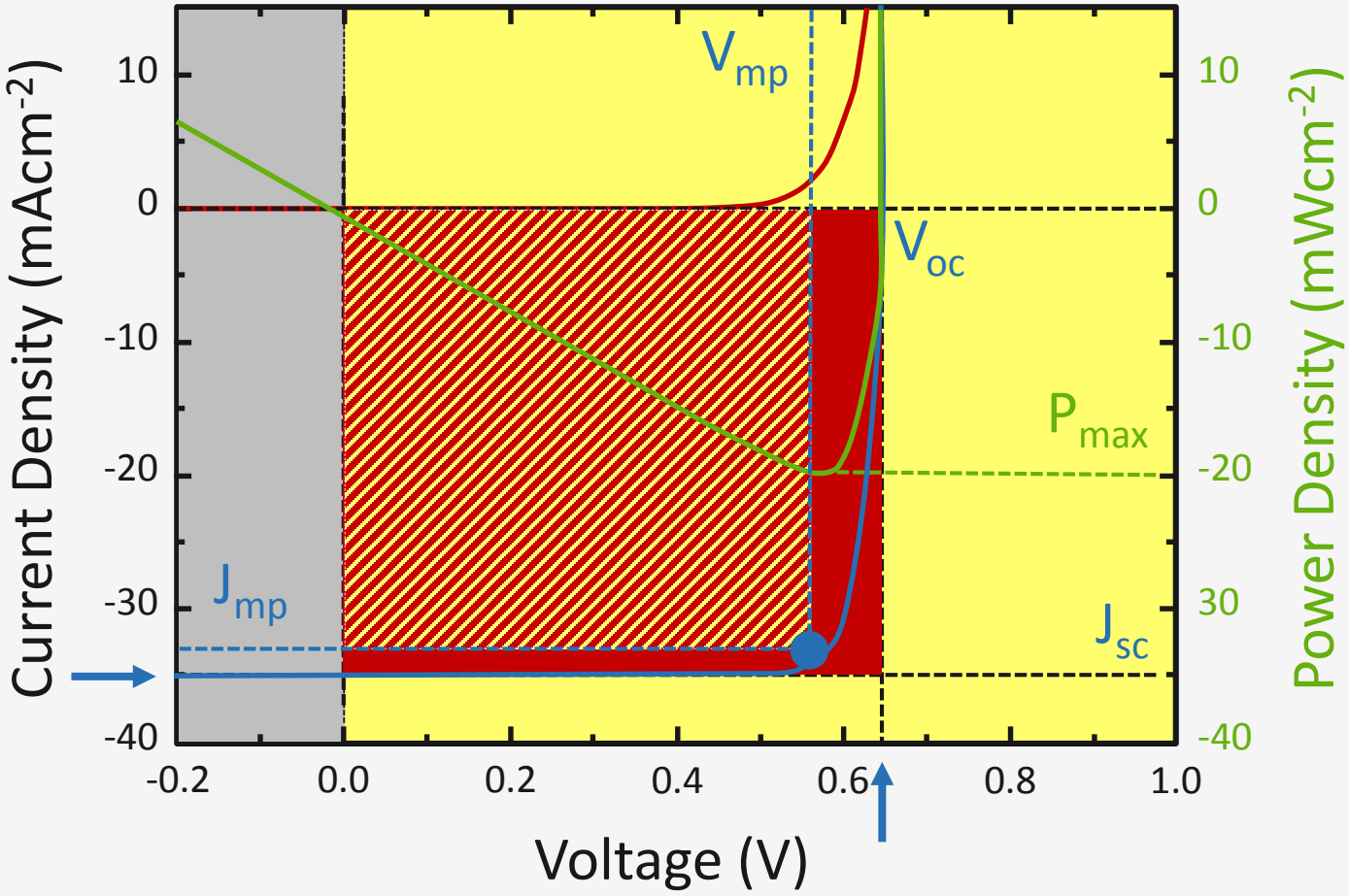

Current Density (mAcm-2)
Power Density (mWcm-2)
Voltage (V)
10
0
-10
-20
-30
-40
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
Voc
Pmax
Jsc
Maximum
power point


Current Density (mAcm-2)
Power Density (mWcm-2)
Voltage (V)
10
0
-10
-20
-30
-40
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
Vmp
Voc
Pmax
Jmp
Jsc
Maximum
power point

JV-Characteristic: the Fill Factor

$$FF = \frac{P_{max}}{J_{sc} V_{oc}} = \frac{J_{mp} V_{mp}}{J_{sc} V_{oc}}$$

$FF=$


Current Density (mAcm-2)
Power Density (mWcm-2)
Voltage (V)
Vmp
Voc
Pmax
Jmp
Jsc
10
0
-10
-20
-30
-40
30
-0.2
0.0
0.2
0.4
0.6
0.8
1.0

Efficiency ?

$$h = \frac{P_{out}}{P_{in}} = \frac{P_{max}}{P_{in}} = \frac{J_{mp} \times V_{mp}}{P_{in}} = \frac{J_{sc} \times V_{oc} \times FF}{P_{in}}$$

$$J_{mp} V_{mp} = J_{sc} V_{oc} FF$$

efficiency is expressed in all external parameters!

η, V_{oc}, J_{SC}, FF

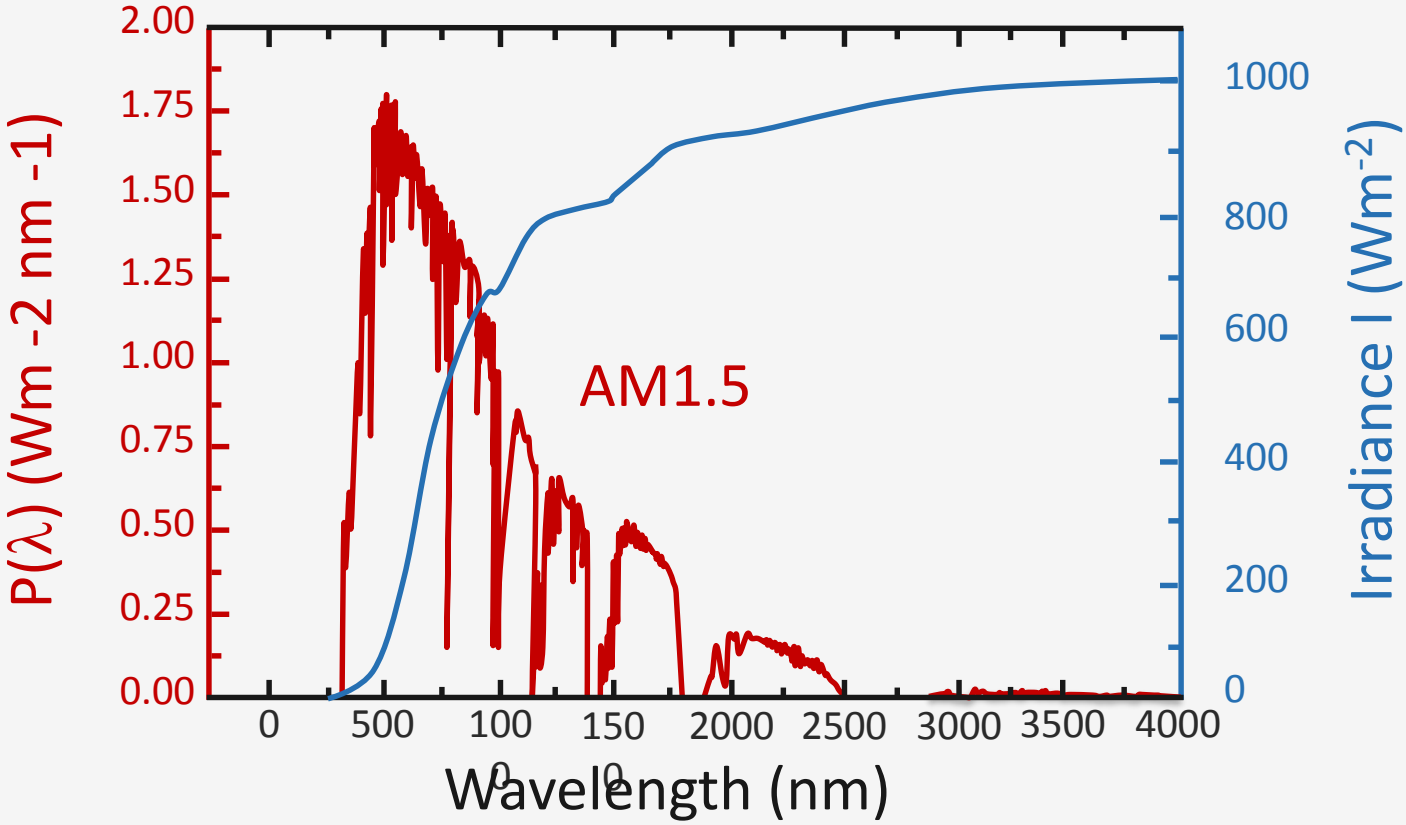
Efficiency ?

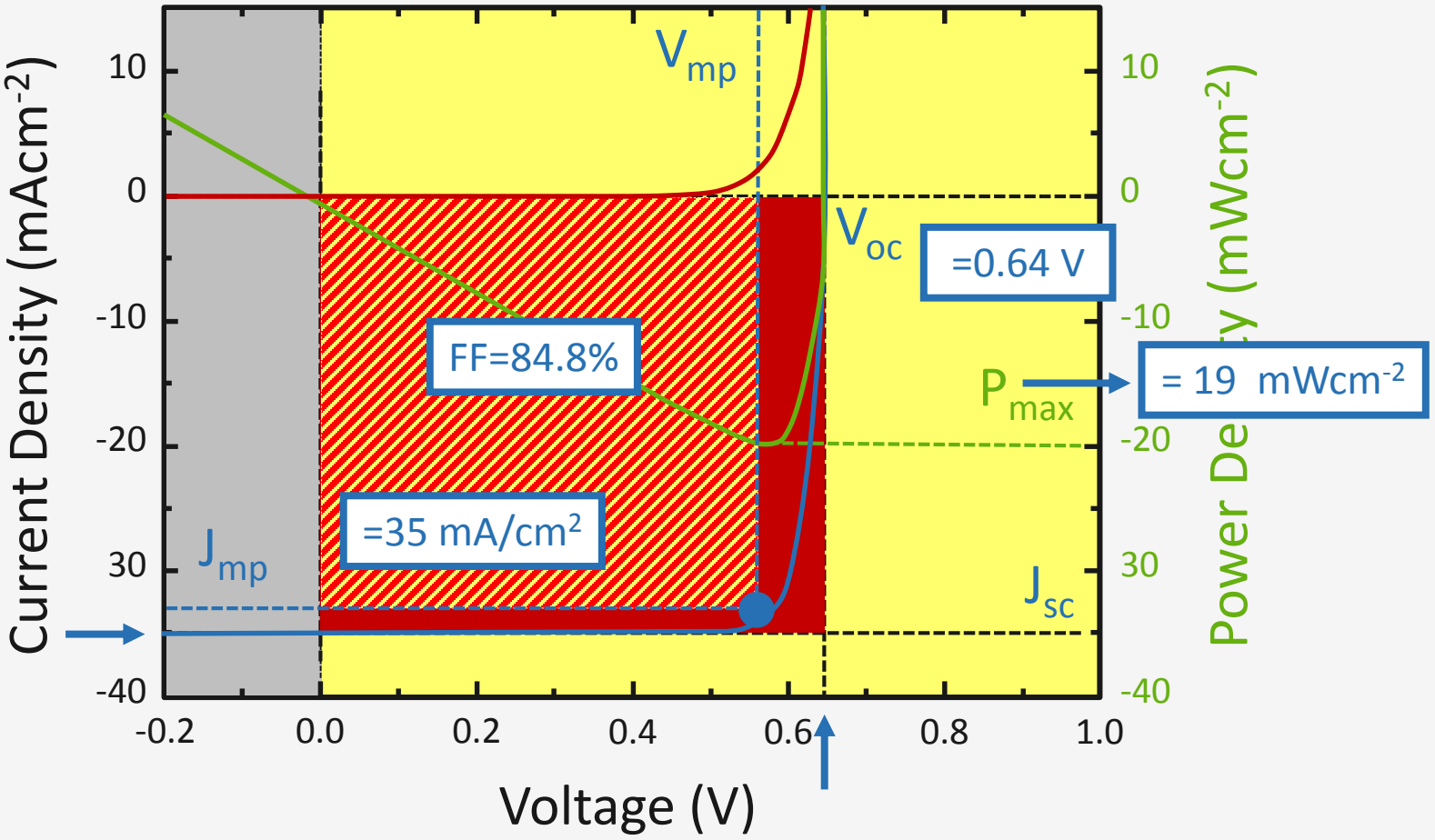
$$\eta = \frac{P_{out}}{P_{in}} = \frac{P_{max}}{P_{in}} = \frac{V_{mp} \times I_{mp}}{P_{in}} = \frac{V_{oc} \times I_{sc} \times FF}{P_{in}}$$

Standard test conditions

$P_{in} = 1000\ Wm^{-2}$ $T = 25°C$ $AM1.5$

AM1.5 Spectrum




Current Density (mAcm-2)
Power Density (mWcm-2)
Voltage (V)
10
0
-10
-20
30
-40
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
Vmp
Voc
=0.64 V
FF=84.8%
Pmax
= 19 mWcm-2
=35 mA/cm2
Jmp
Jsc

Thank you for your attention!

Thank you for your attention!