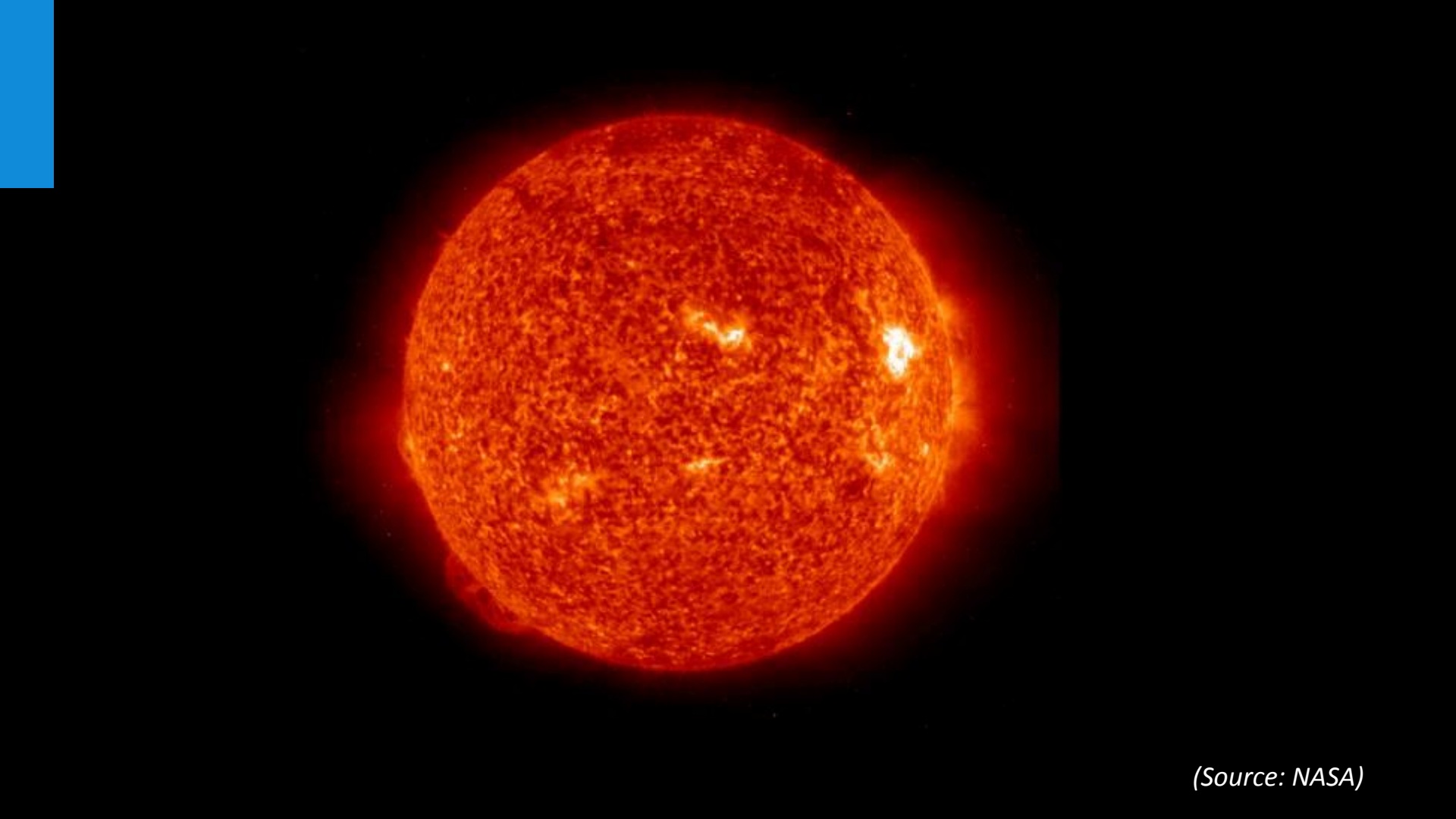
Thin-Film PV Technologies

III-V PV Technology

Week 5.1

Arno Smets



(Source: NASA)

III – V PV Technology

Semiconductor Materials

		IIIA	IVA	VA	VIA	VIIA	VIIIA
							2 He 4.0026
		5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.180
IB	IIB	13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.065	17 Cl 35.453	18 Ar 39.948
29 Cu 63.546	30 Zn 65.38	31 Ga 69.723	32 Ge 72.64	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.798
47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po [209]	85 At [210]	86 Rn [222]

III-V semiconductors:

GaAs:

GaP:

InP:

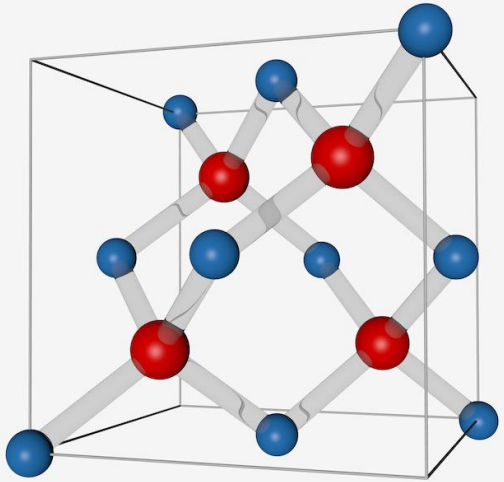
InAs:

GaInAs:

GaInP:

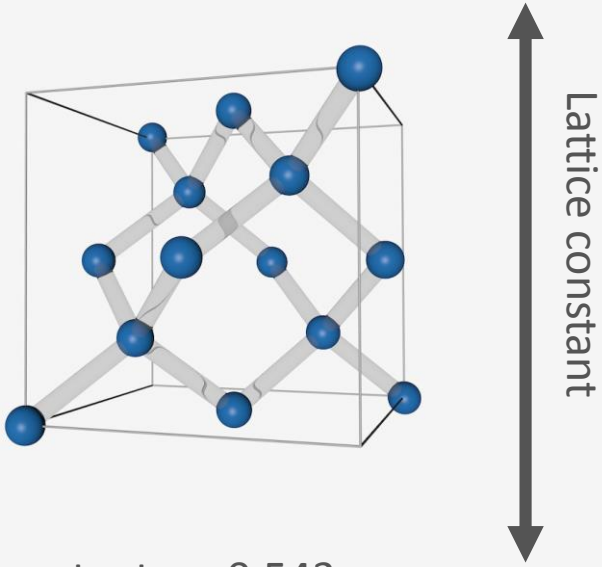
AlGaInAs:

AlGaInP:



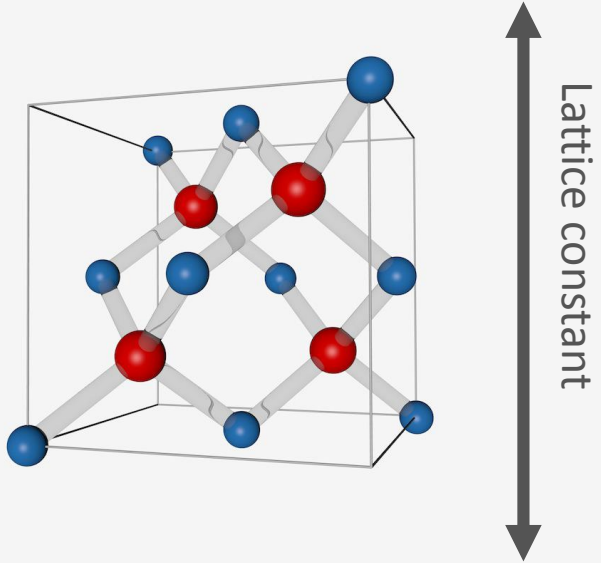
Atomic Structure

Silicon

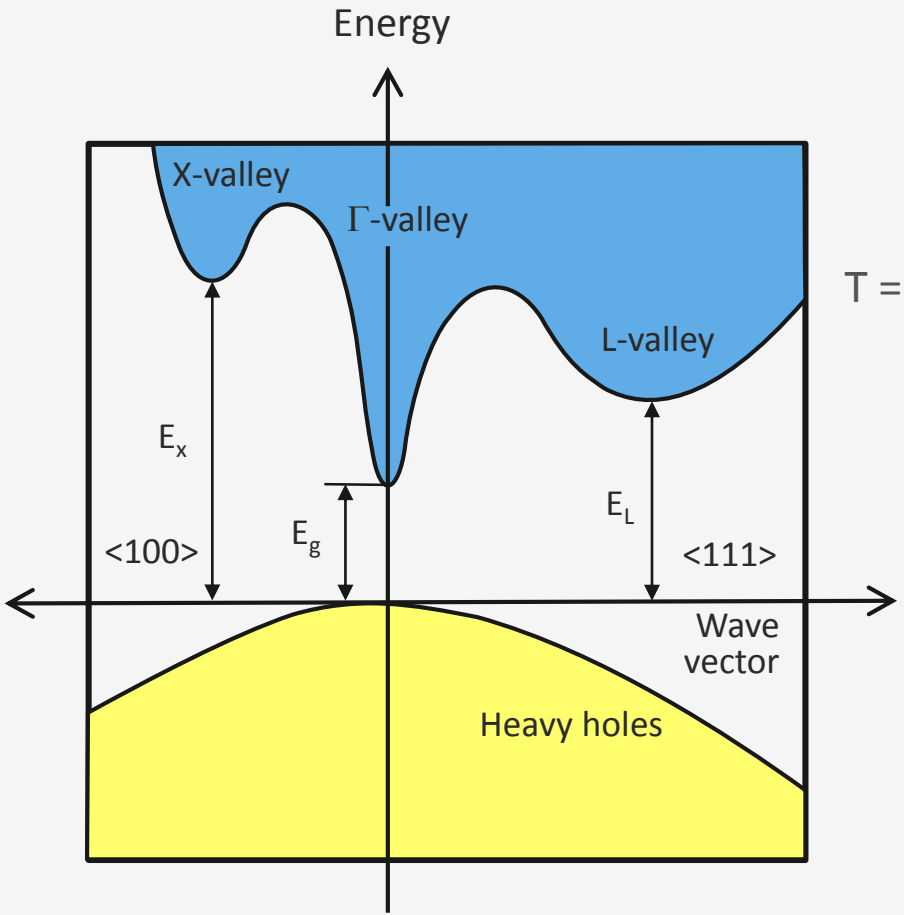


Lattice constant: 0.543 nm
Atom density: 5.0×10^{22} cm^{-3}
Density: 2.33 gcm^{-3}

GaAs



Lattice constant: 0.565 nm
Atom density: 4.42×10^{22} cm^{-3}
Density: 5.32 gcm^{-3}



T = 300K

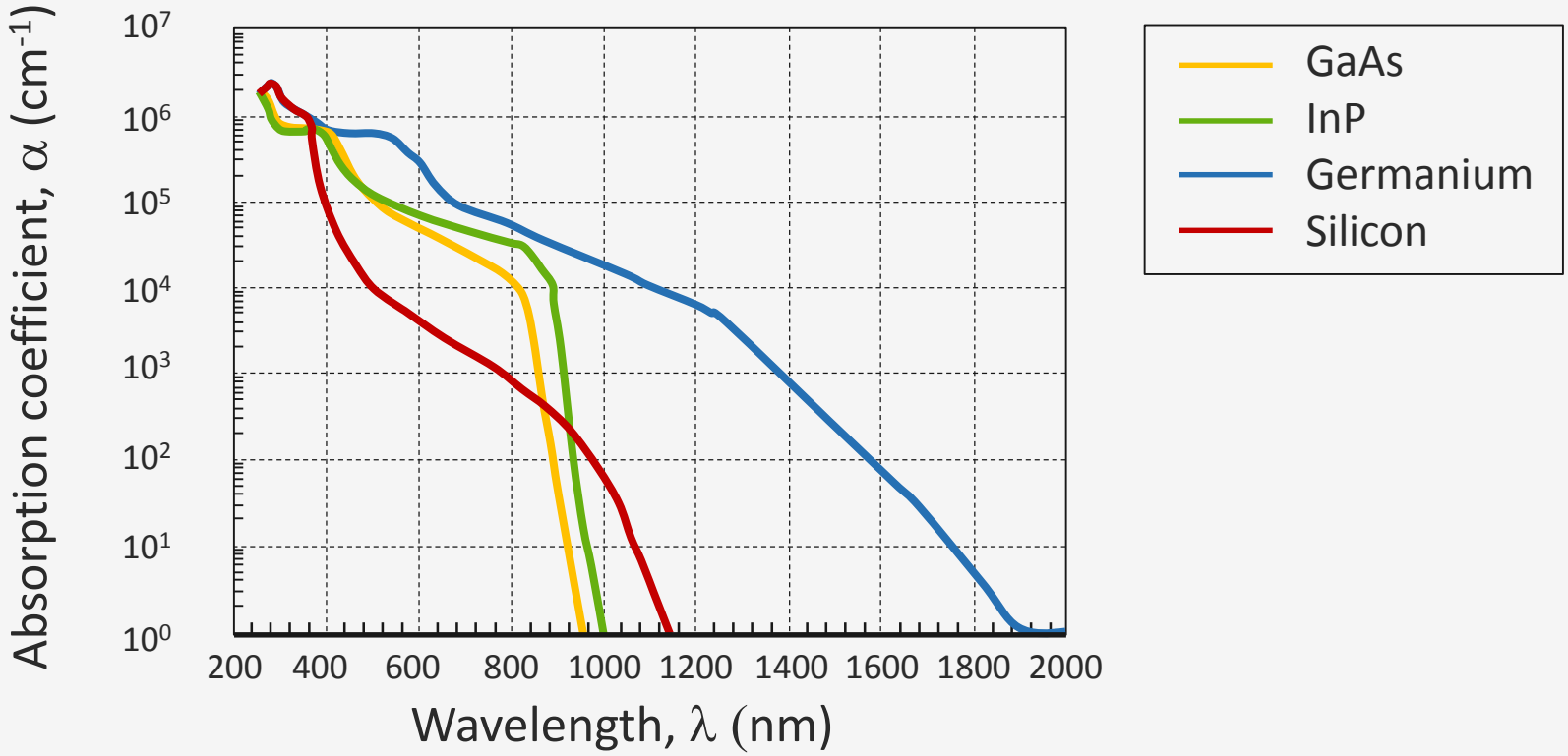
E_g = 1.42 eV

E_L = 1.71 eV

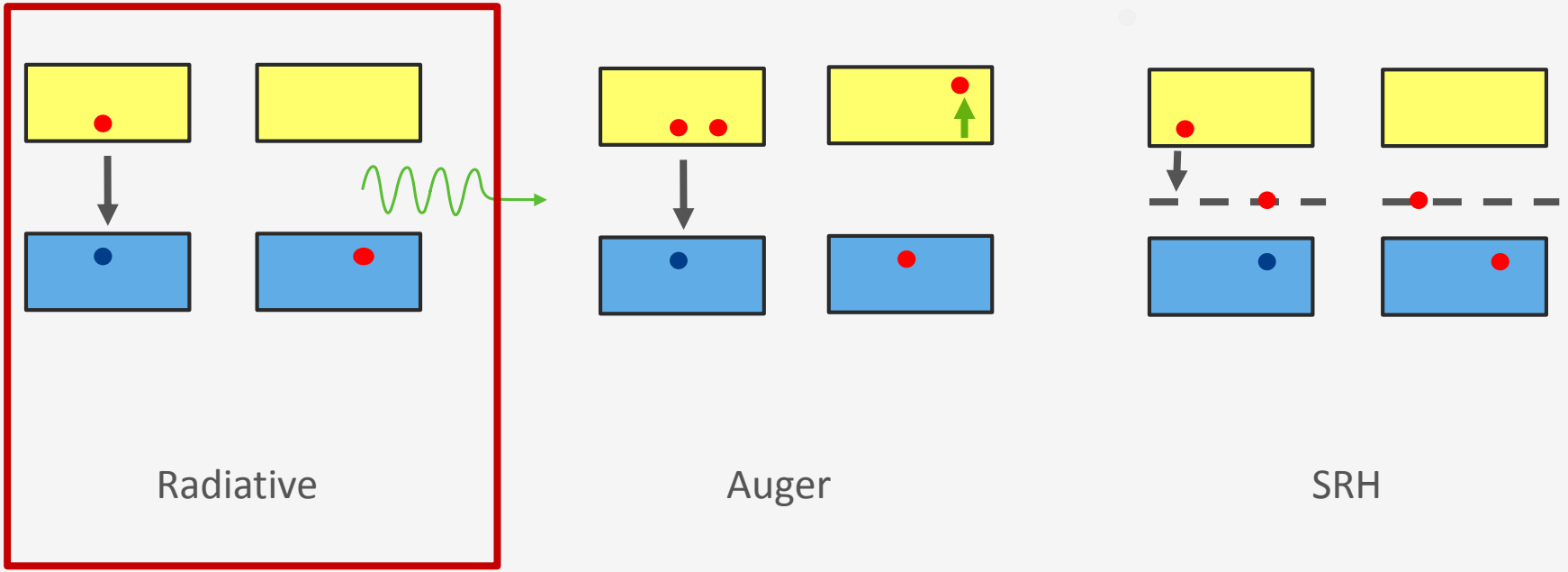
E_X = 1.90 eV

E_{90} = 0.34 eV

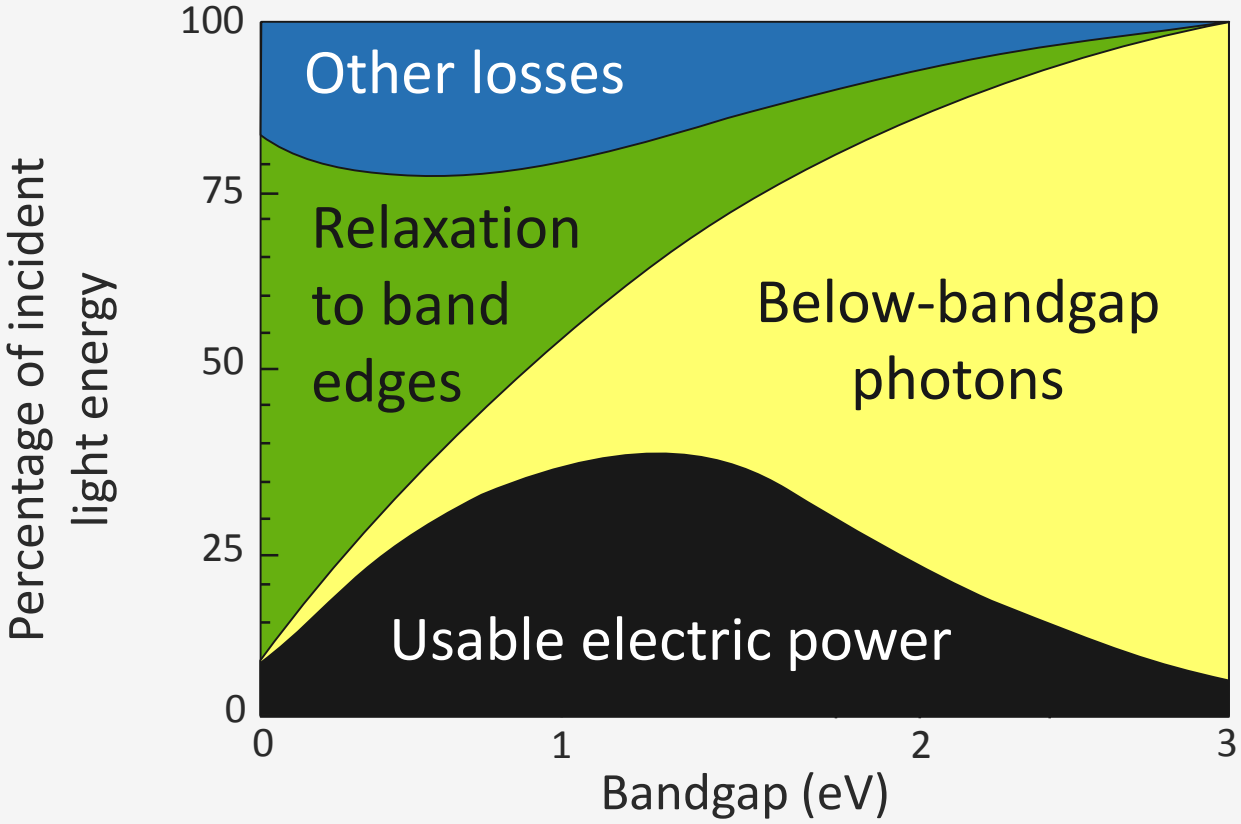
Absorption coefficient



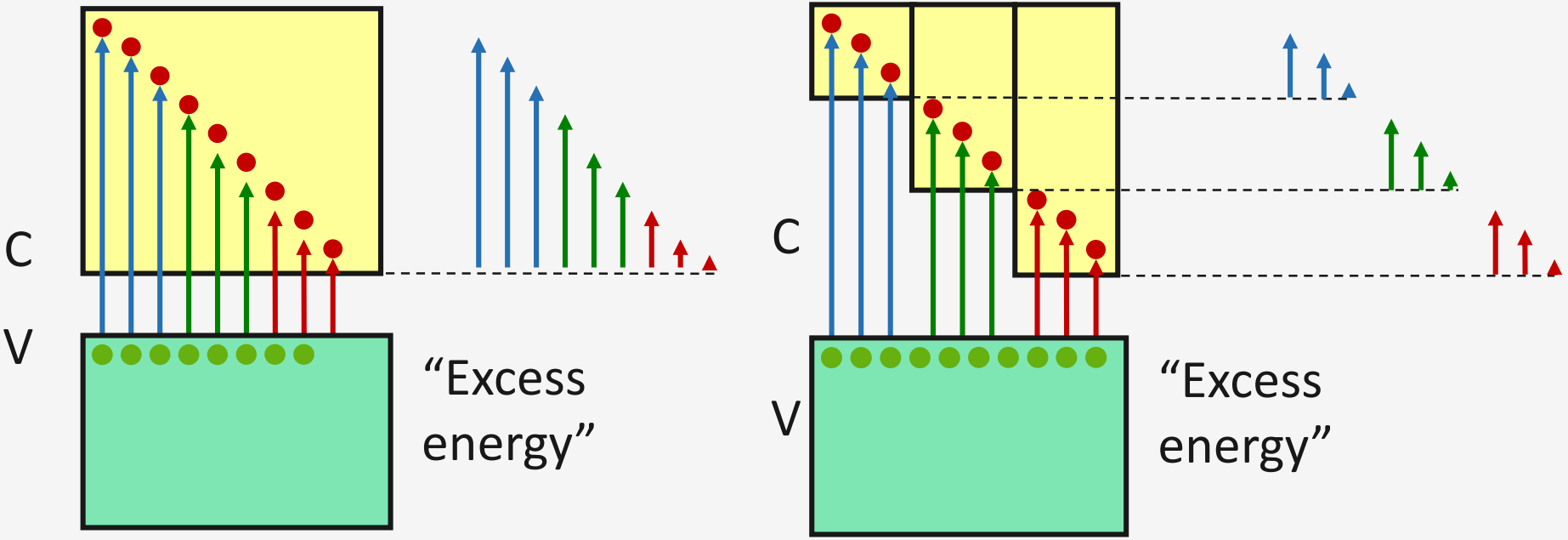
Charge Carrier Recombination



Spectral Mismatch



Multijunction



III-V Technologies

Top cell window/emitter

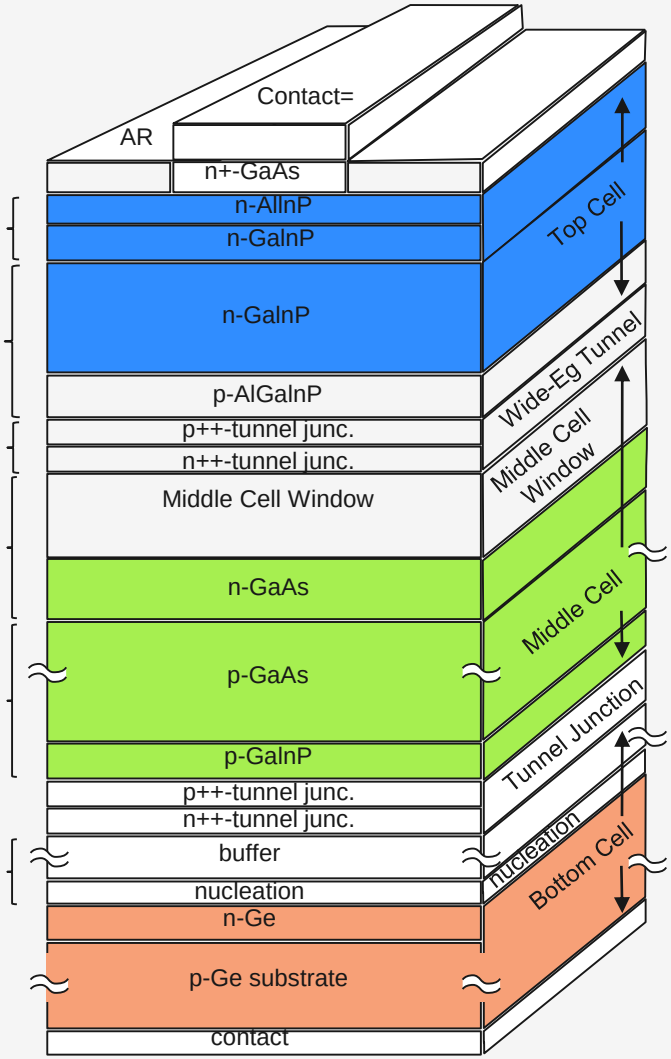
Top cell base/BSF

Wide-Eg tunnel junction

Middle cell window/emitter

Middle cell base/BSF

TC & MC crystal quality:
Nucleation, buffer,
Interface control,
Lattice-matching



Courtesy: Richard King
Spectro Labs

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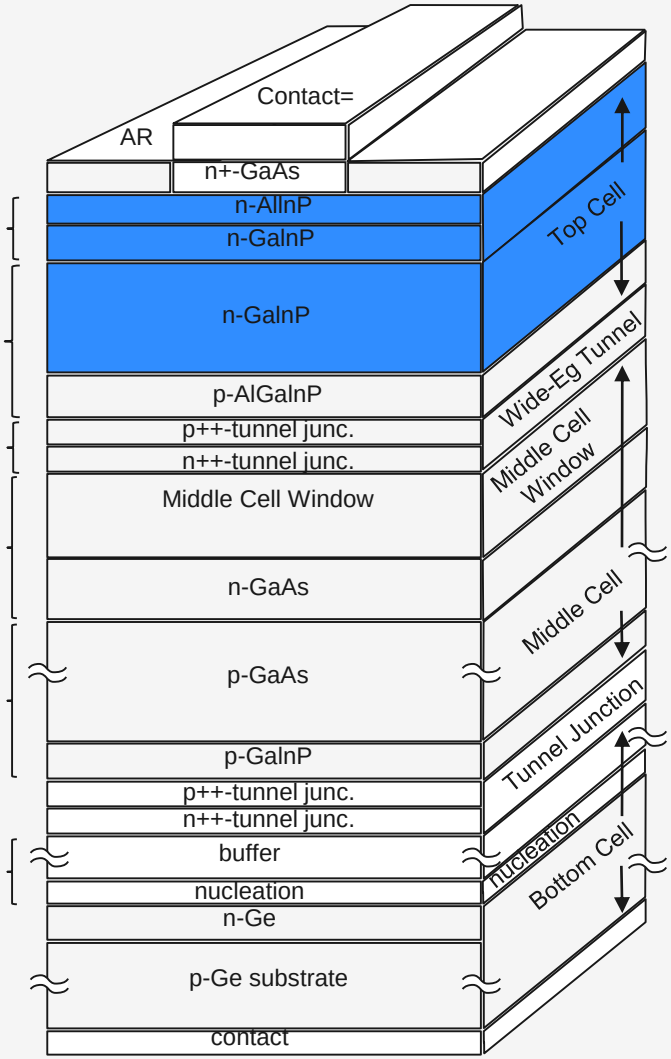

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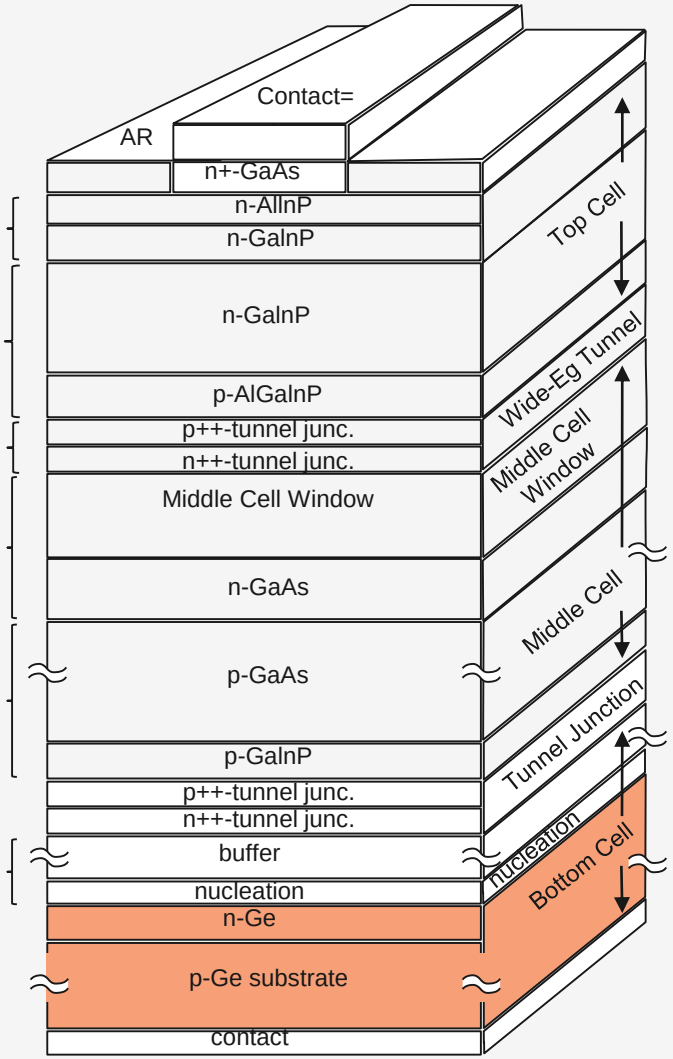
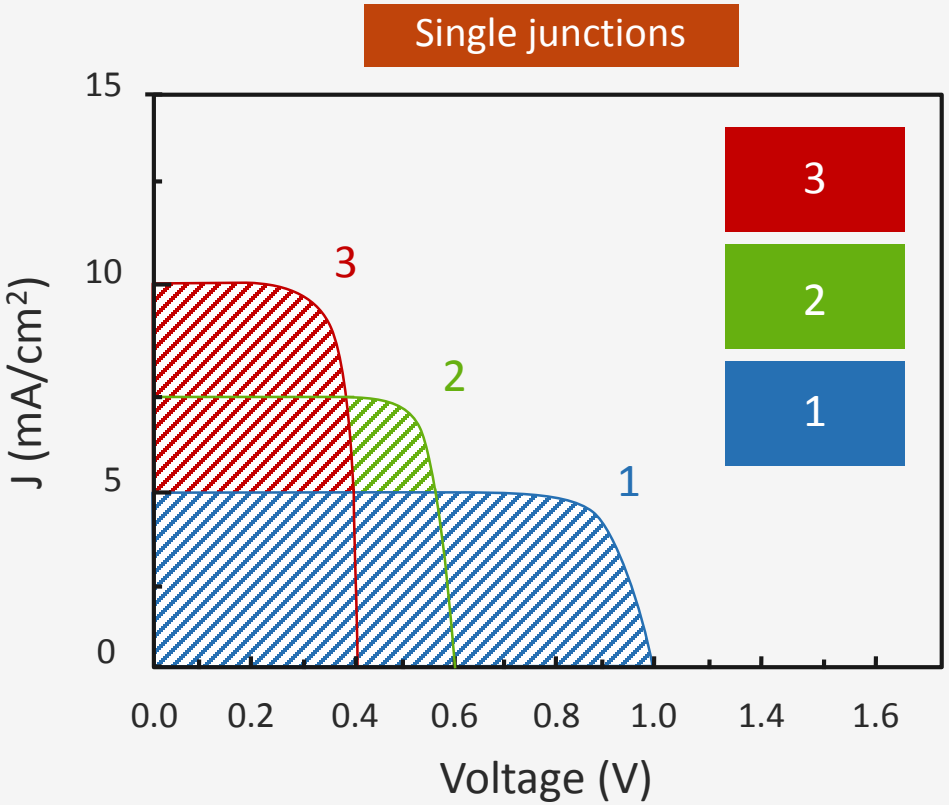
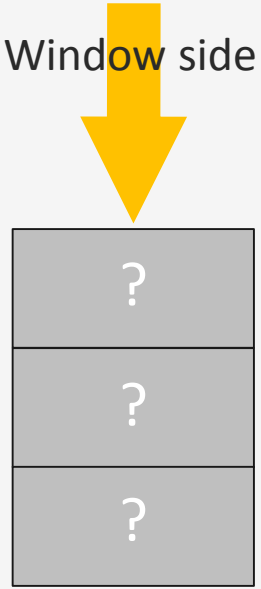


Courtesy: Richard King
Spectro Labs

Multi-junction approach





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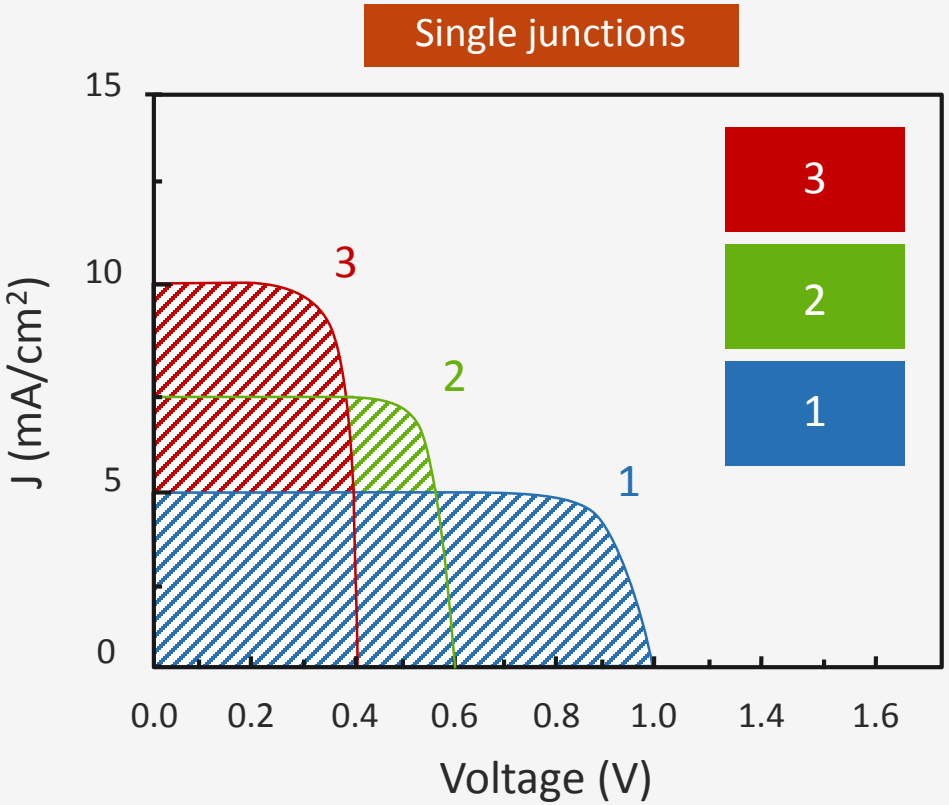

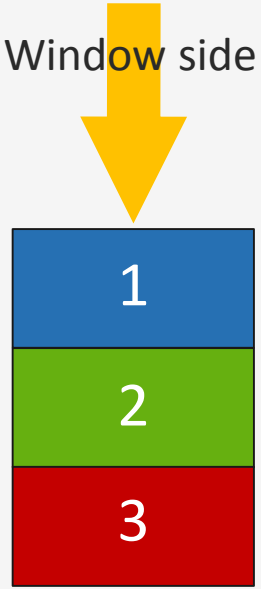

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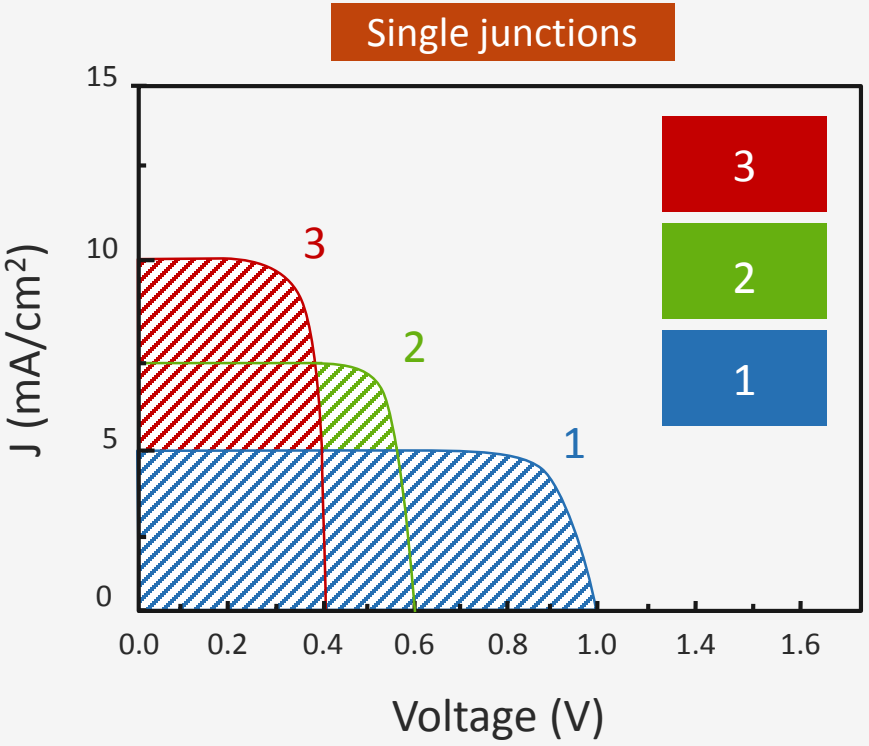
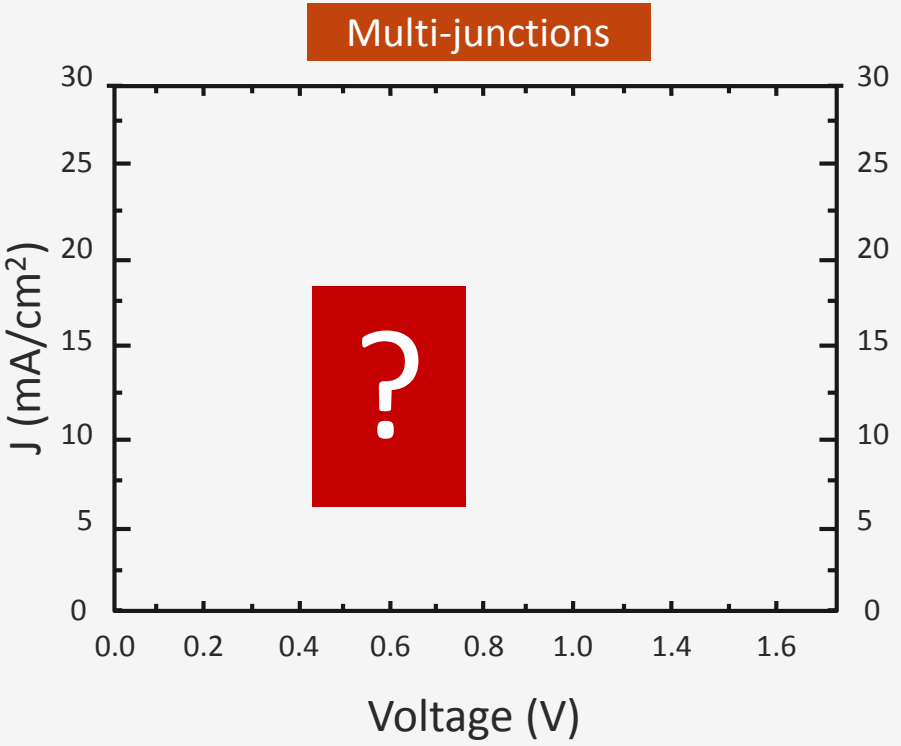
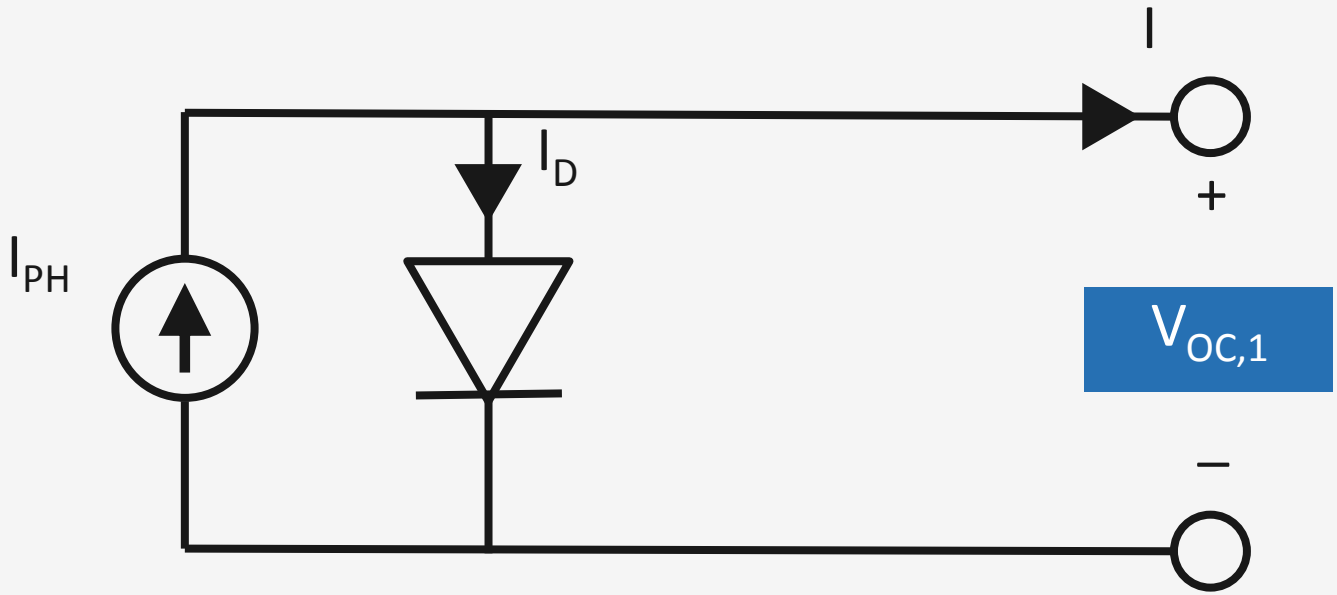
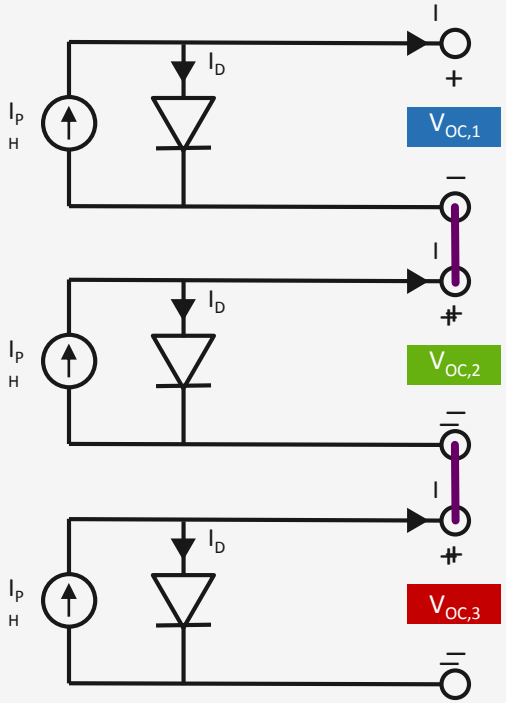




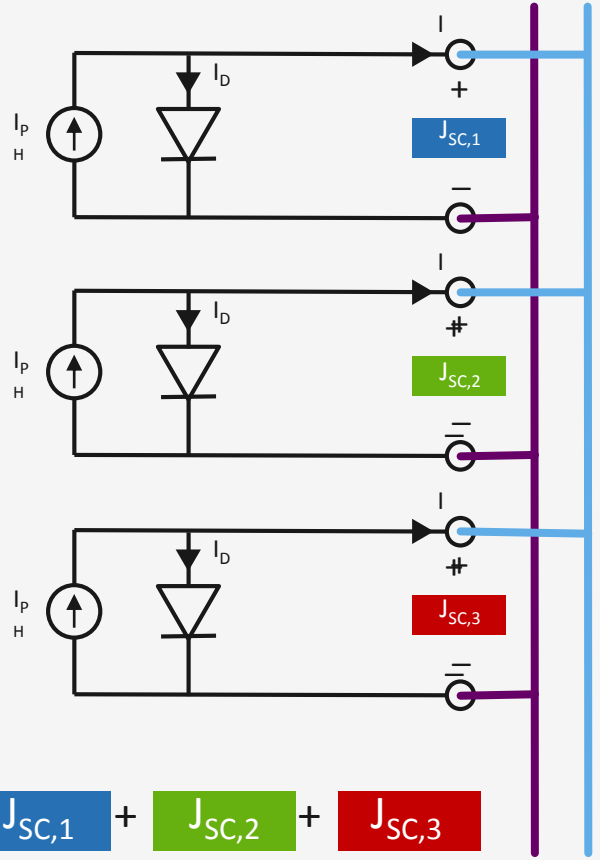
Equivalent circuit - ideal solar cell



Series or parallel?

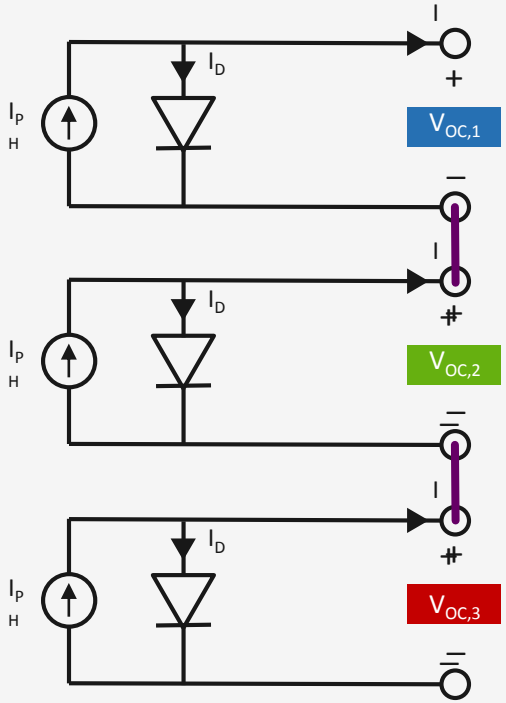


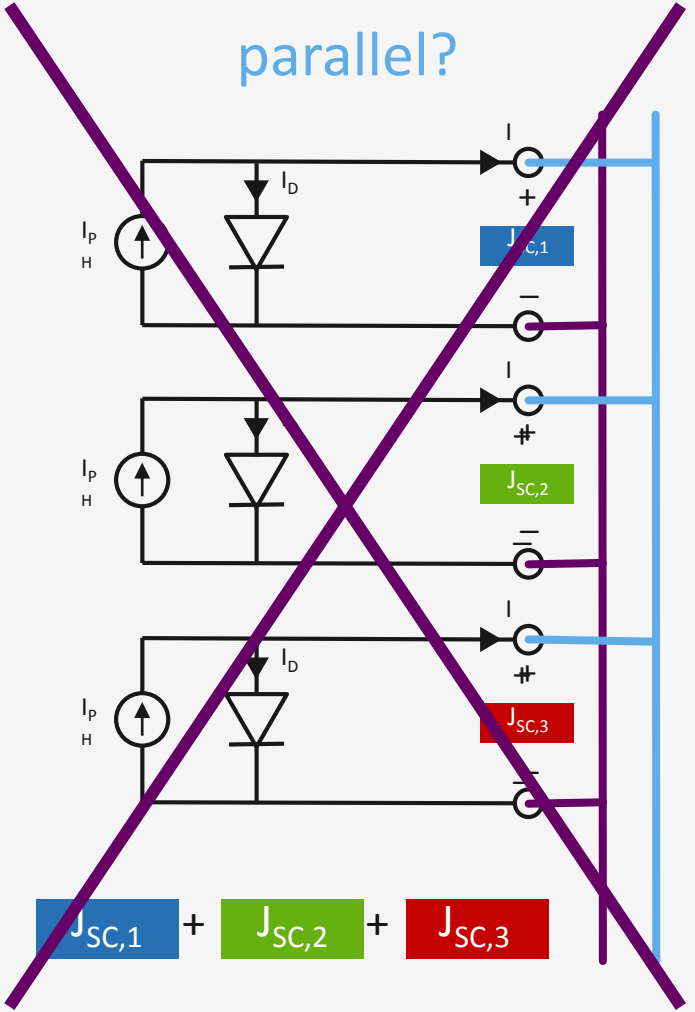
$V_{OC,1} + V_{OC,2} + V_{OC,3}$



$J_{SC,1} + J_{SC,2} + J_{SC,3}$

Series or parallel?

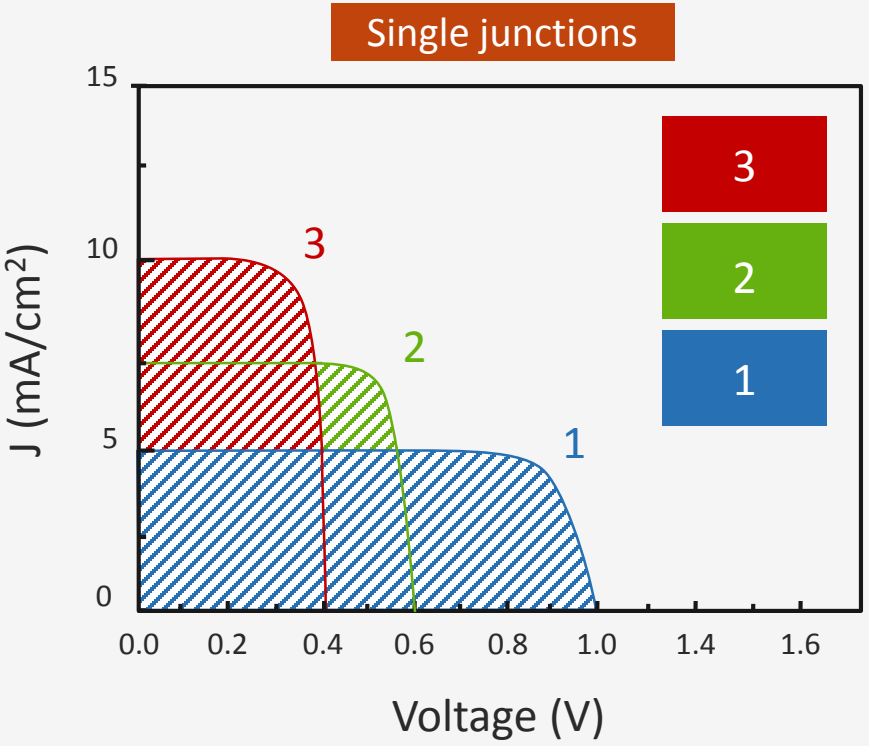


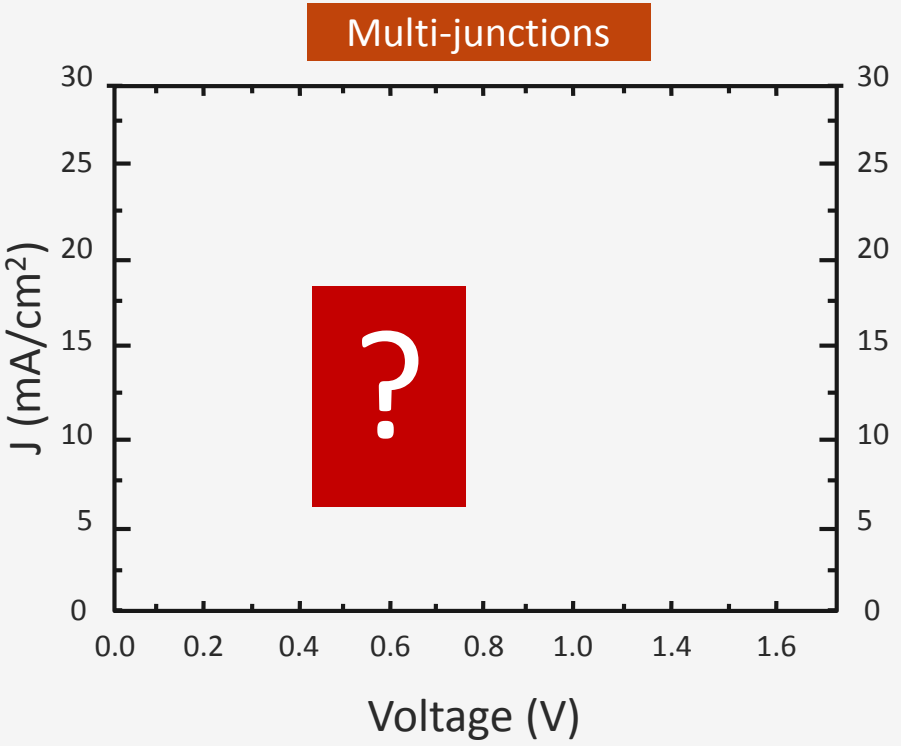


$V_{OC,1} + V_{OC,2} + V_{OC,3}$

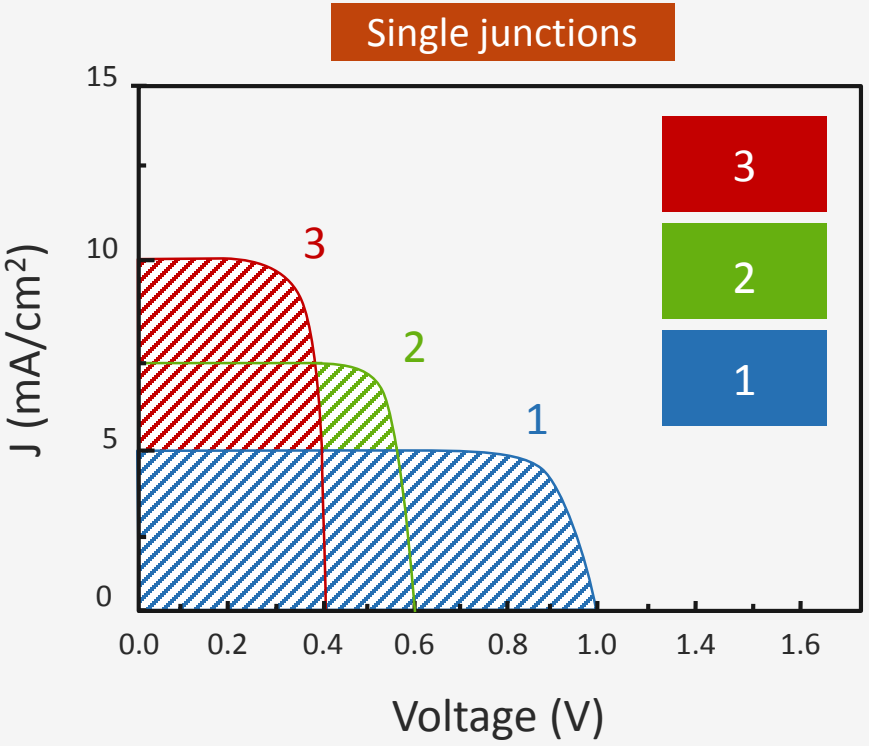
$J_{SC,1} + J_{SC,2} + J_{SC,3}$

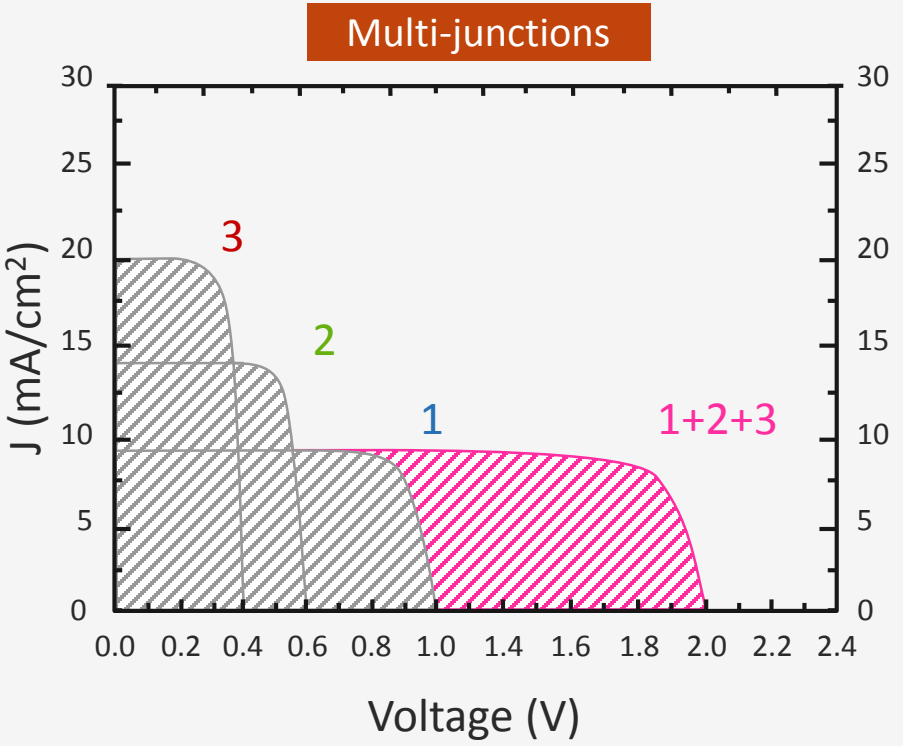
Multi-junction approach



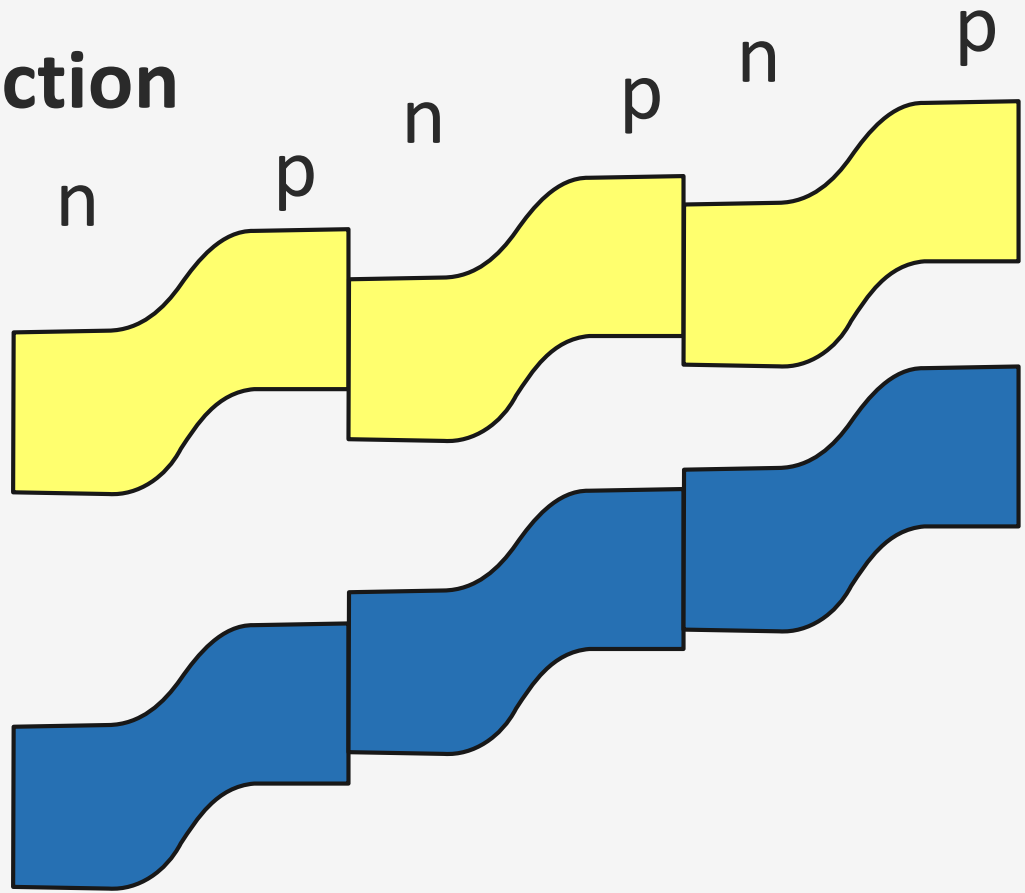


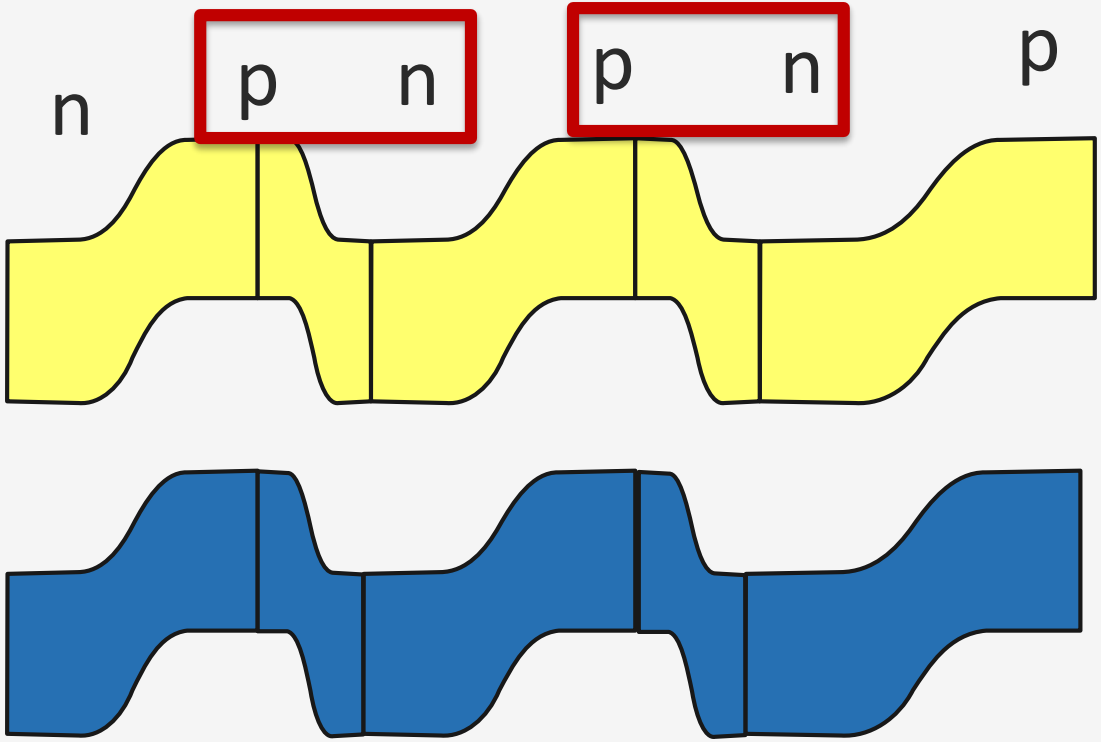
Multi-junction approach





Triple Junction




n
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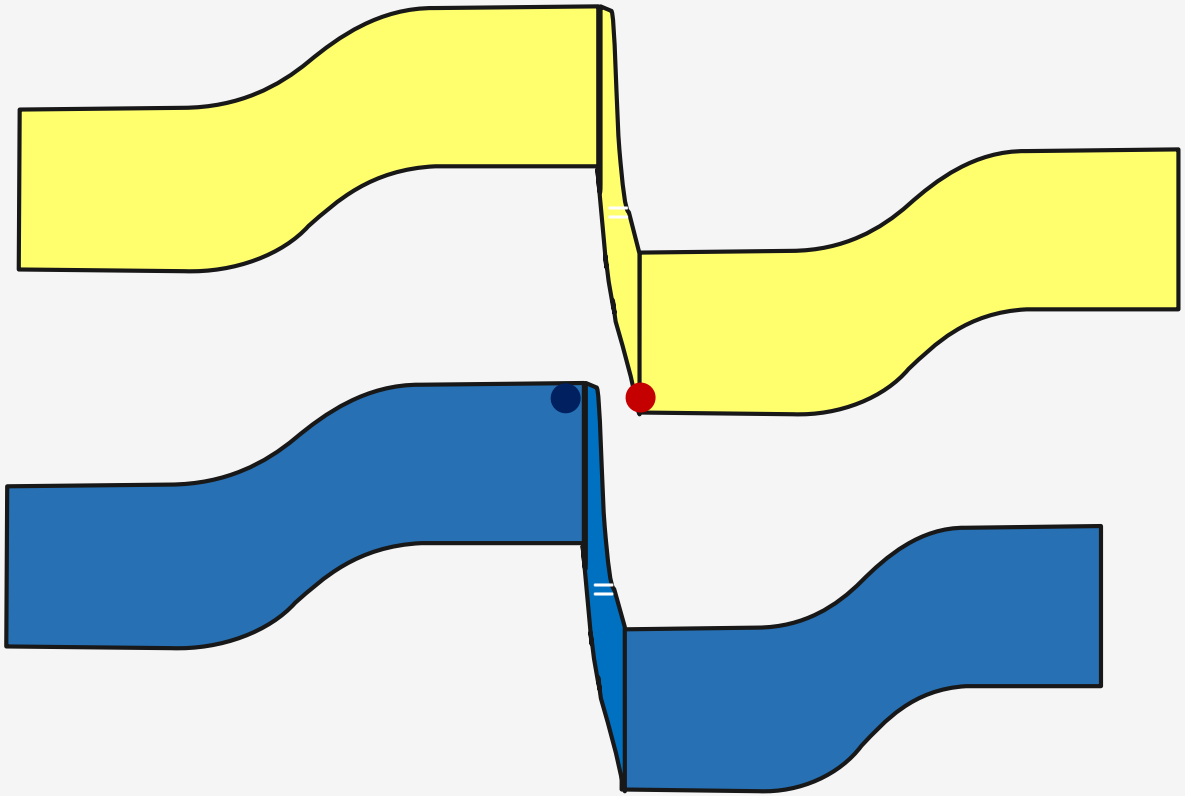
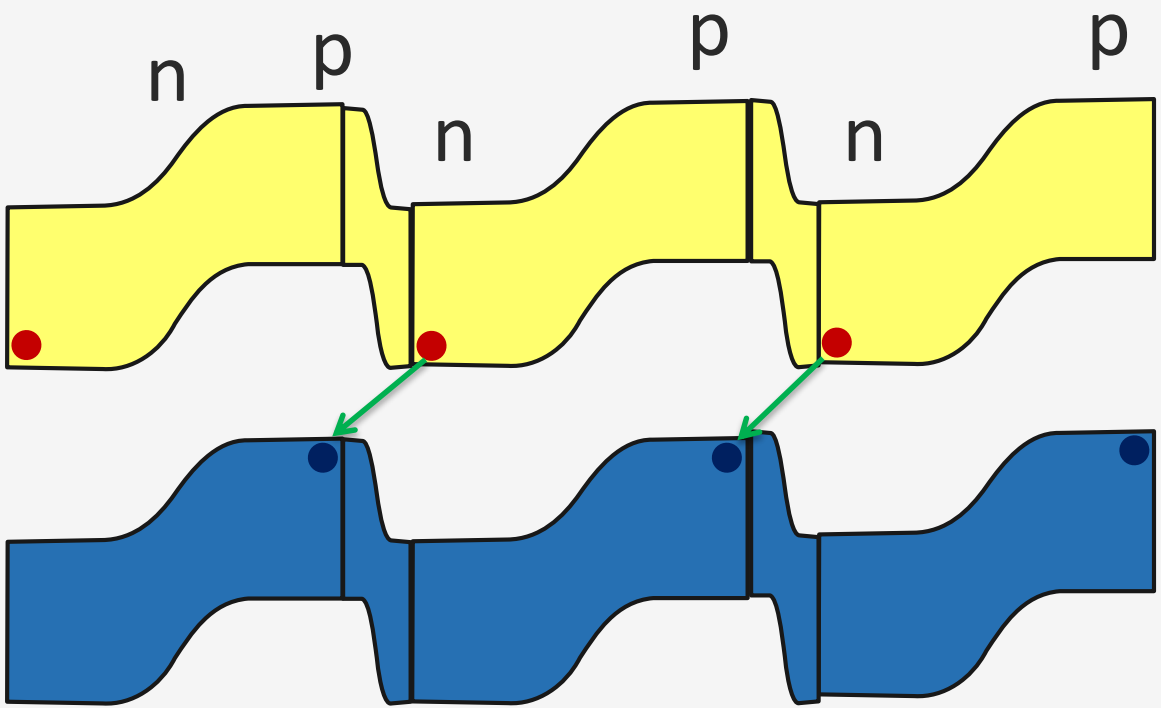
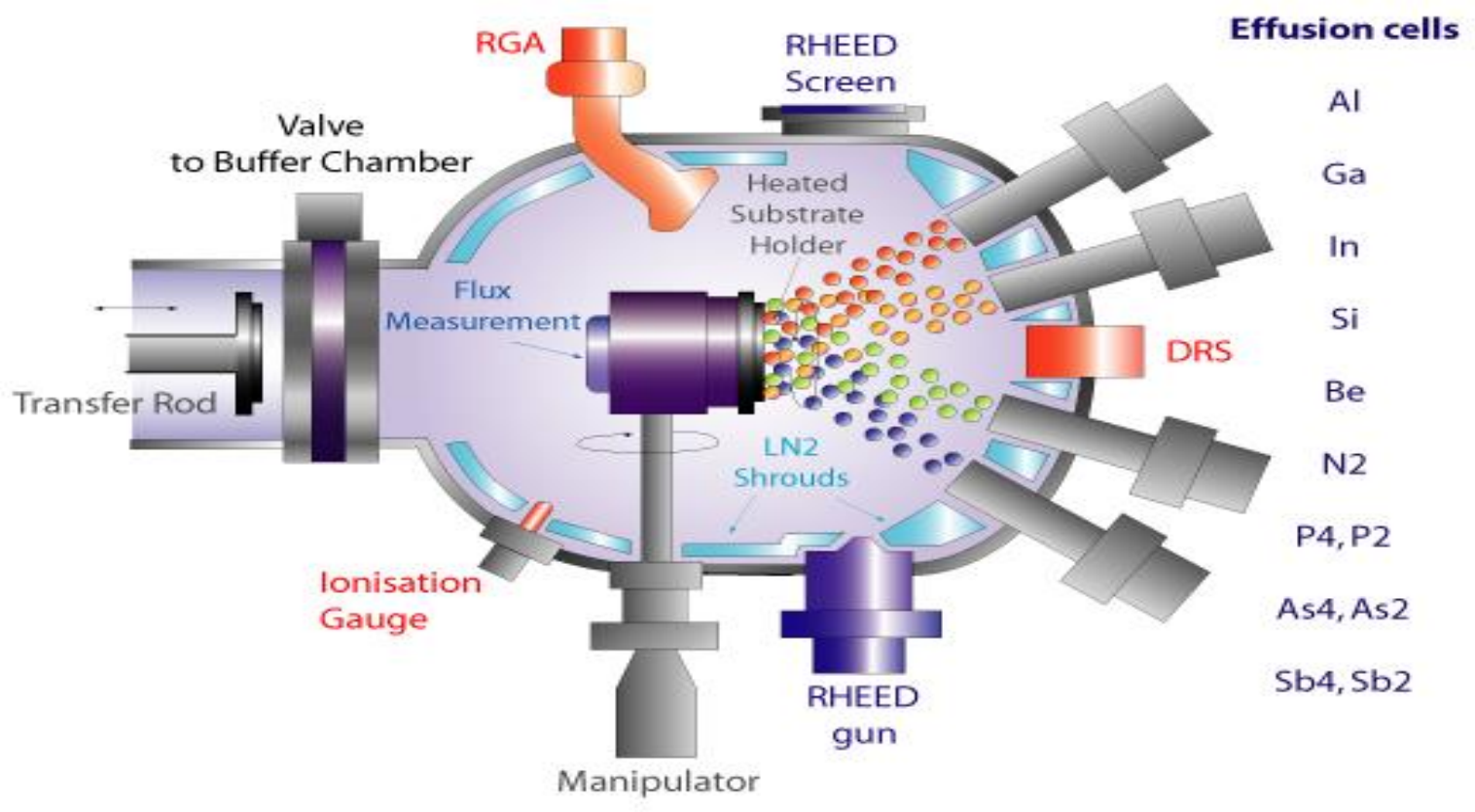


Triple Junction

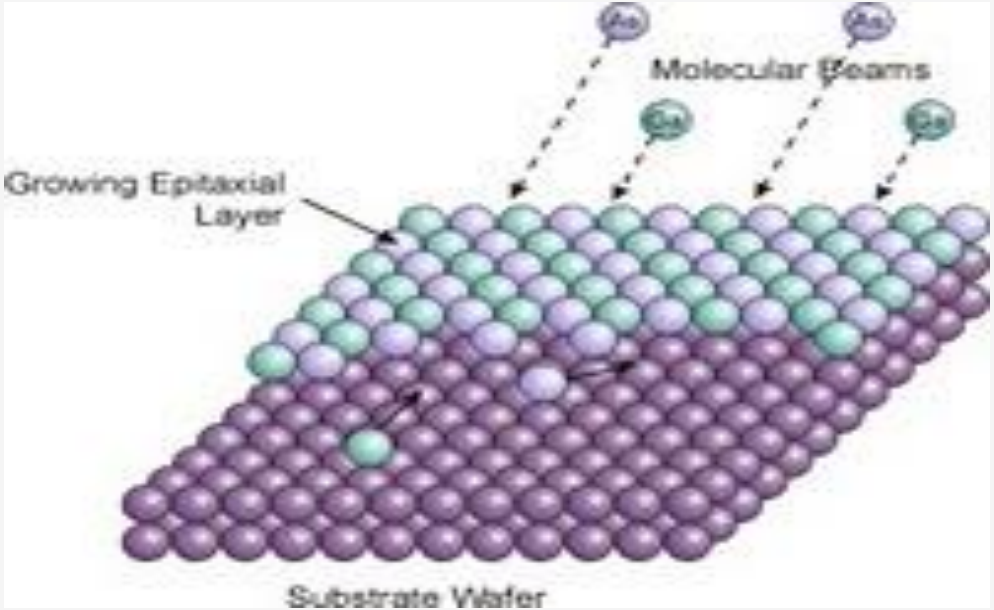


Epitaxy of III-V Materials

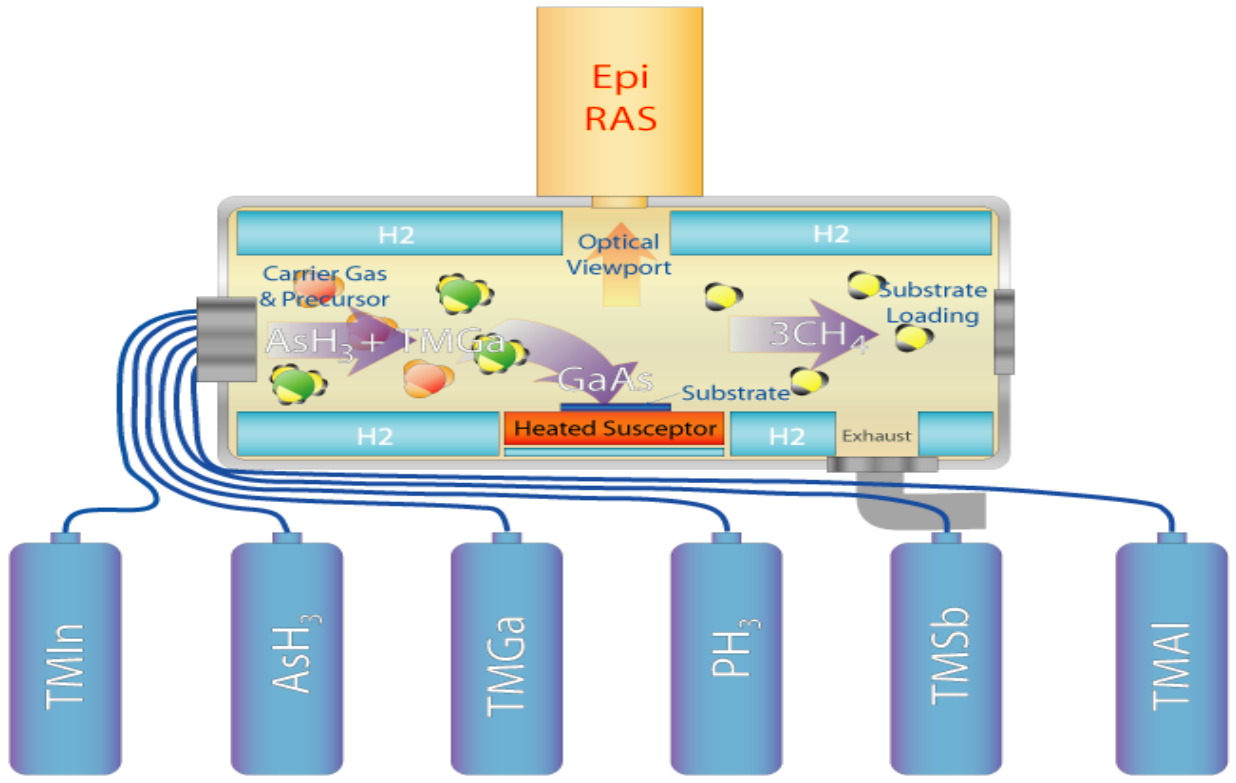


Source: http://www.photonics.ethz.ch/research/core_competences/technology/

Epitaxy of III-V Materials



Epitaxy of III-V Materials



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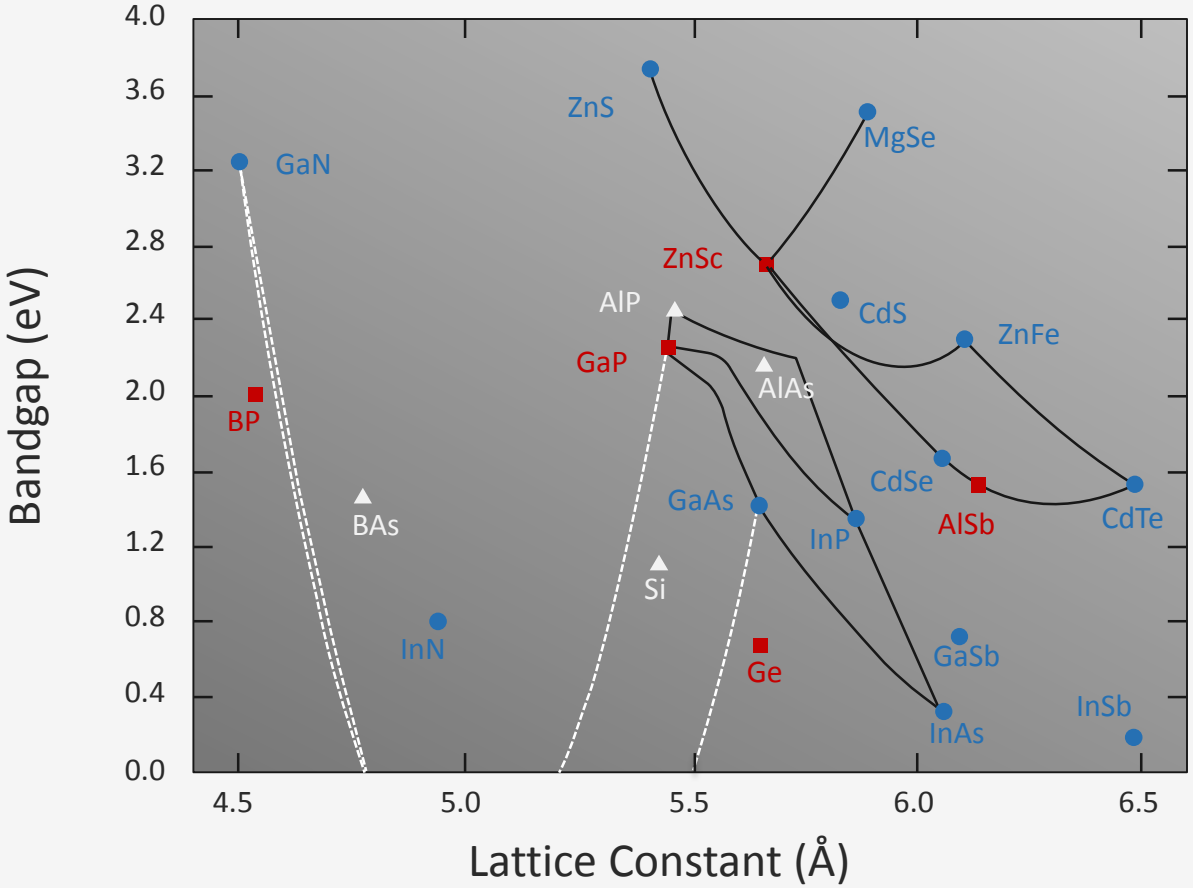
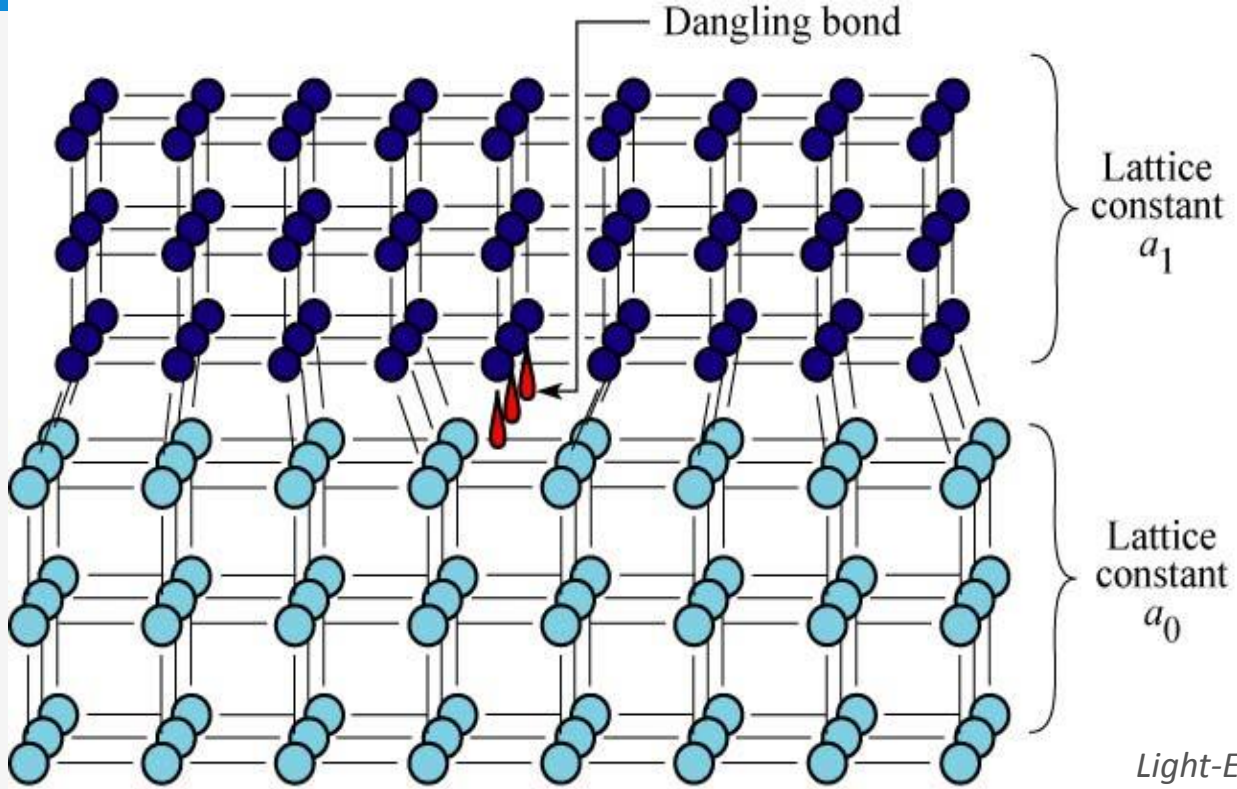
Bandgap vs. Lattice constant



Crystal mismatch: interface defects

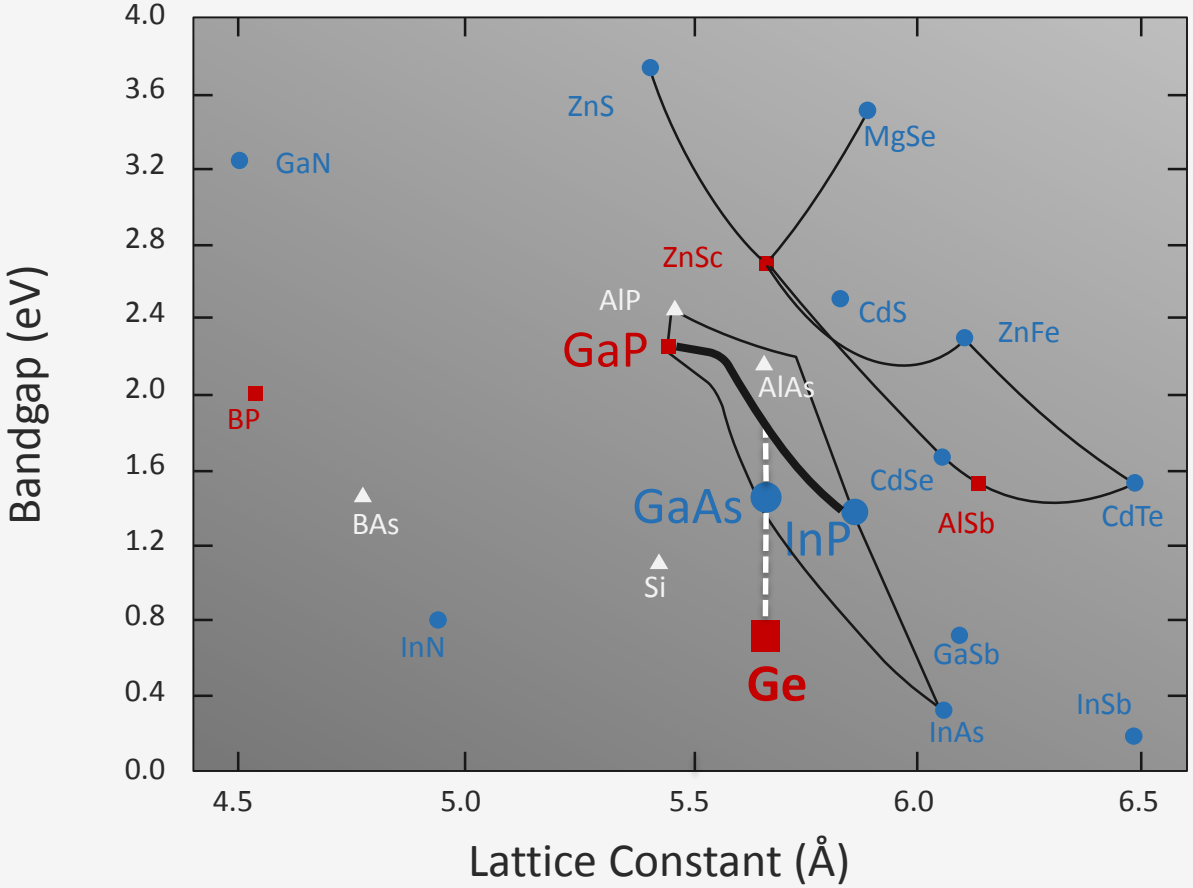


E.F. Schubert

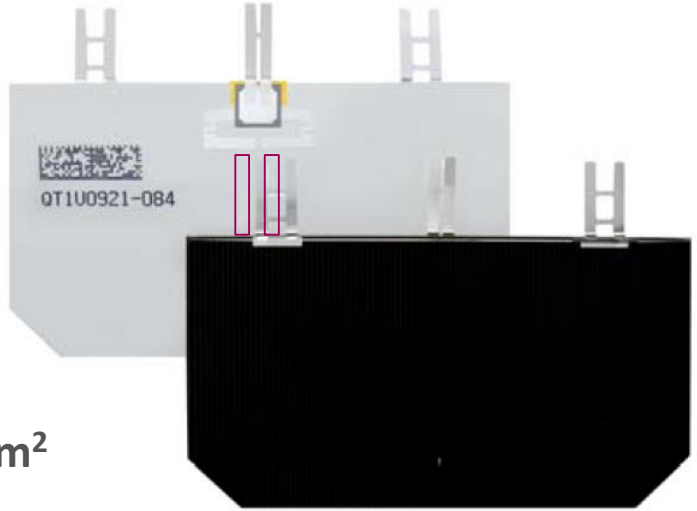
Light-Emitting Diodes (Cambridge Univ. Press)

www.LightEmittingDiodes.org

Bandgap vs. Lattice constant



29.5% NeXt Triple Junction (XTJ) Solar Cells



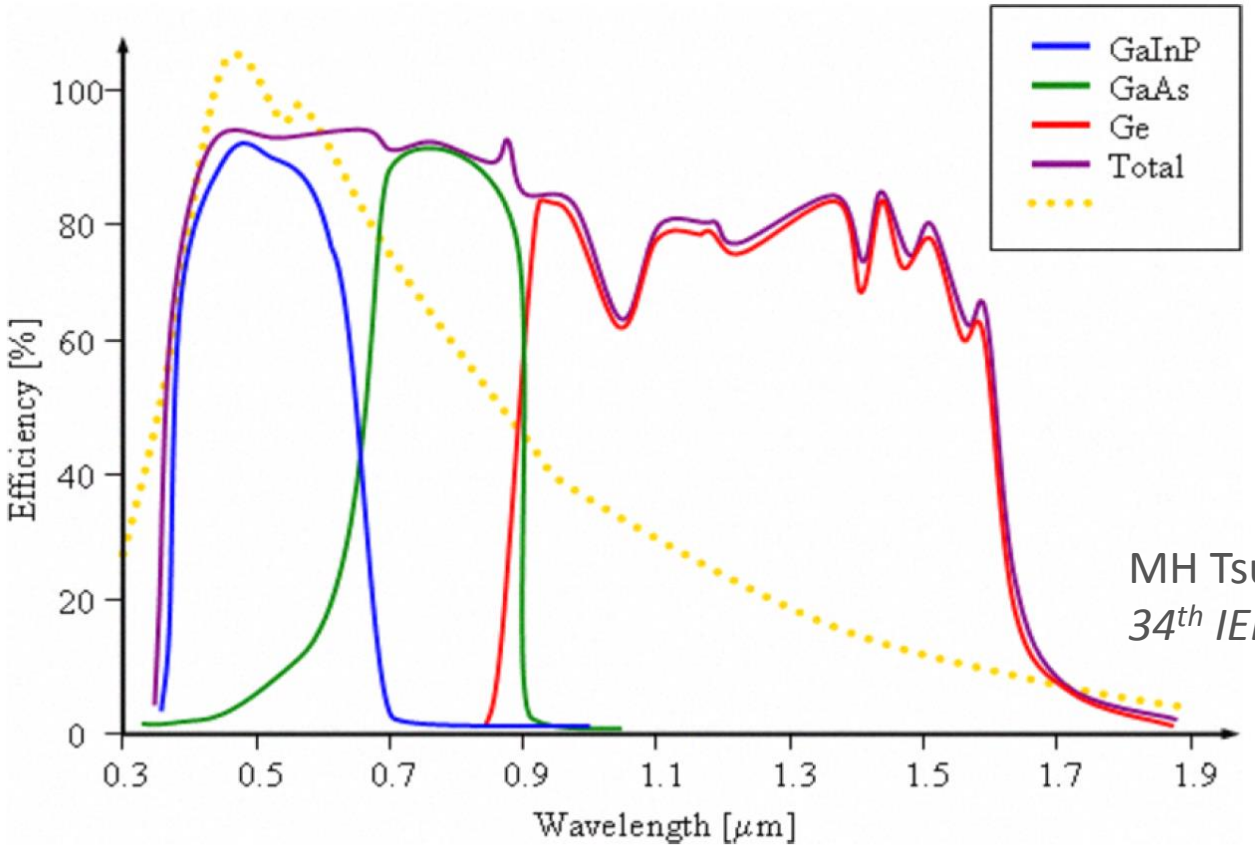
AM 0 conditions

J_{SC} = 17.76 mA/cm^2

V_{OC} = 2.633 V

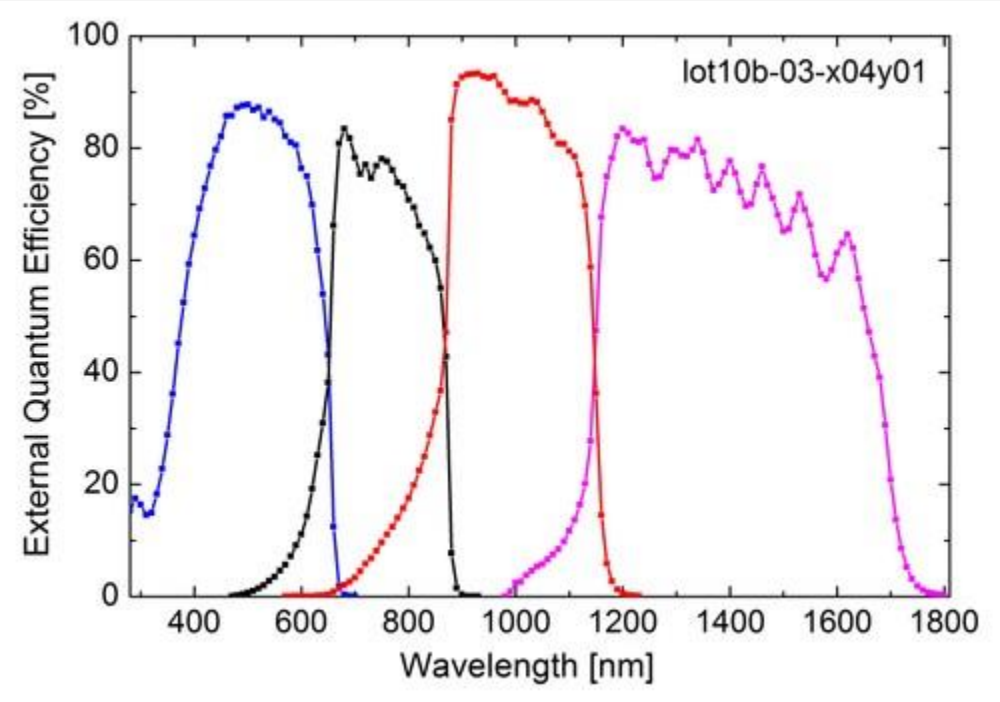
FF = 0.85

EQE spectrum of multijunction cells



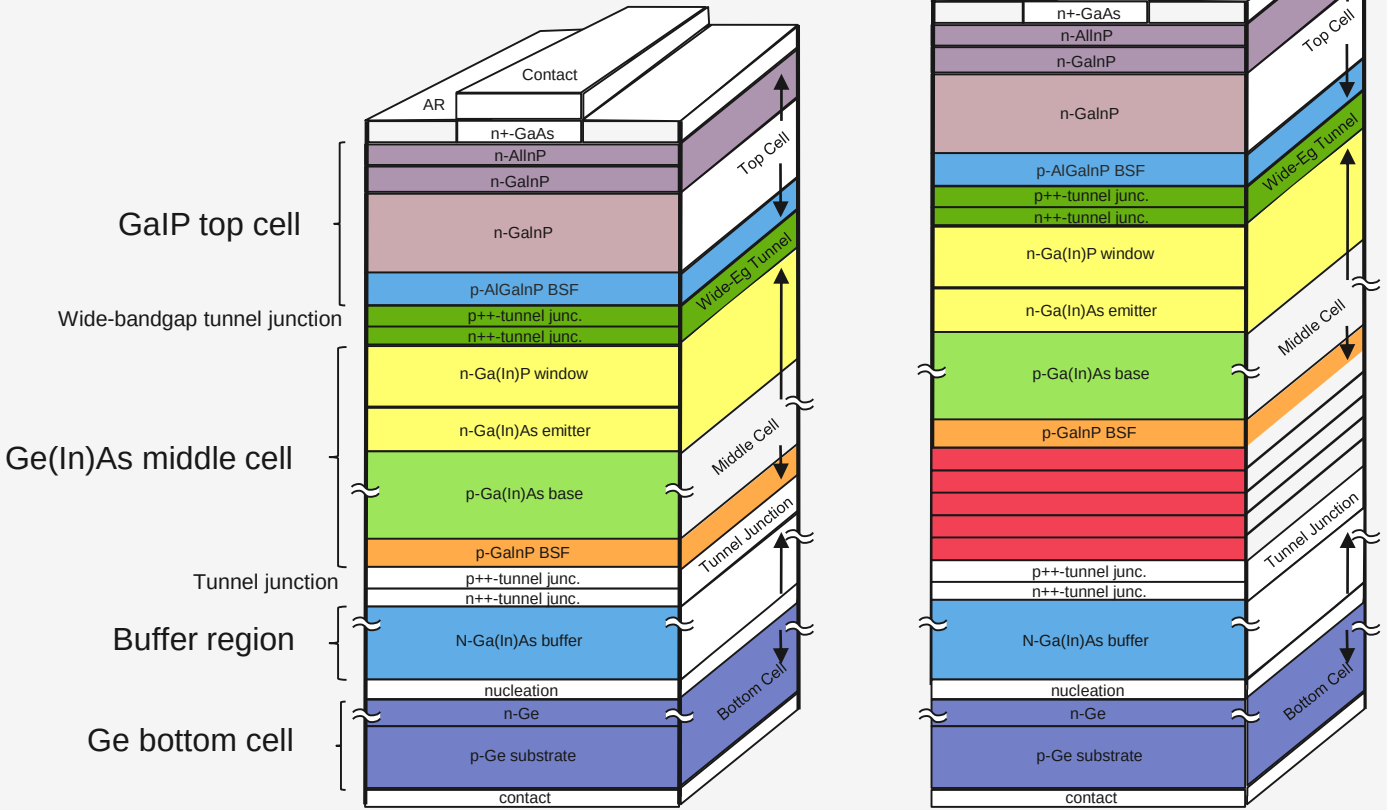
MH Tsutagawa et al.
34th IEEE PVSC pp. 1959 (2009)

EQE spectrum of 4-junction cells



http://www.ise.fraunhofer.de/en/press-and-media/press-releases/presseinformationen-2013/43.6-four-junction-solar-cell-under-concentrated-sunlight

Lattice Matched and Metamorphic 3-Junction Cell Cross-Section



Courtesy: Richard King
Spectro Labs

III – V PV Technology

Thank you for your attention!