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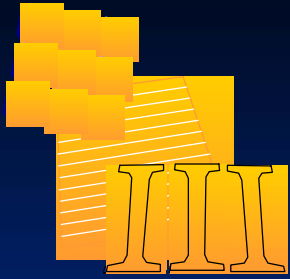
Centre of Excellence for  
Advanced Silicon Photovoltaics and Photonics\*

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# *“Third Generation Photovoltaics”*

*Martin A. Green*  
*University of New South Wales*  
*Sydney, Australia*

*\* Supported by the Australian Research Council*



# First Generation Wafers/Ribbons



## Strengths

- . *reliable, durable, etc.*

## Weaknesses

- . *material intensive*
- . *< US\$1/Wp unlikely*
- . *energy payback only 4yr*

**BUT**

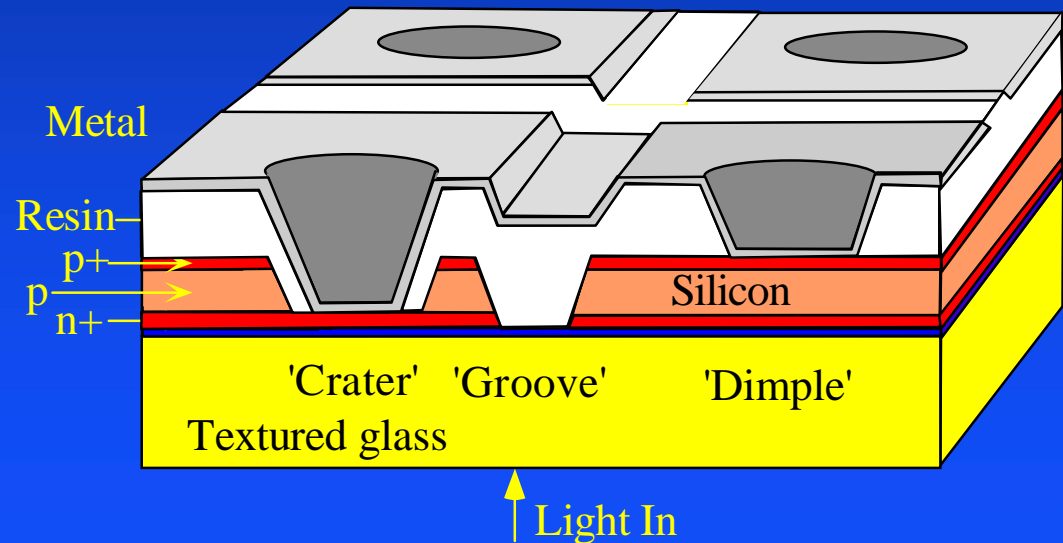
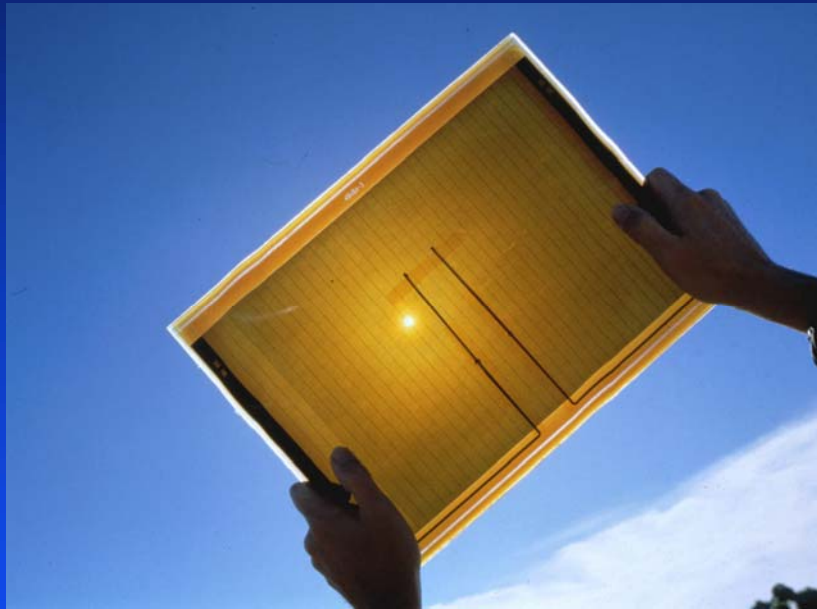
*zero energy if growth > 25%/yr*  
(Lysen, PV in Europe)



# Second Generation (thin-film)

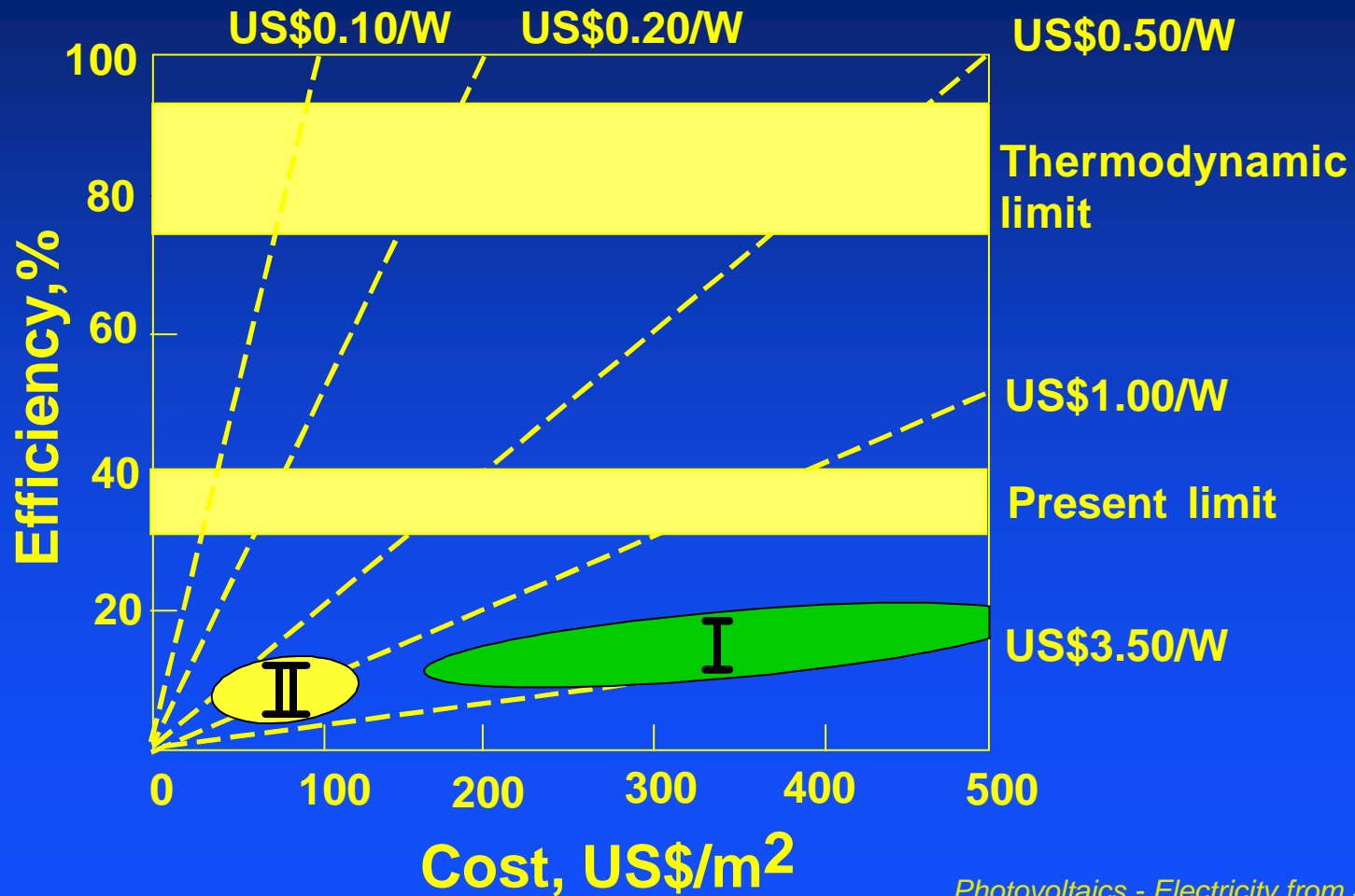
## Crystalline Silicon on Glass (CSG)

*Pacific Solar >> CSG Solar  
first products 2006*



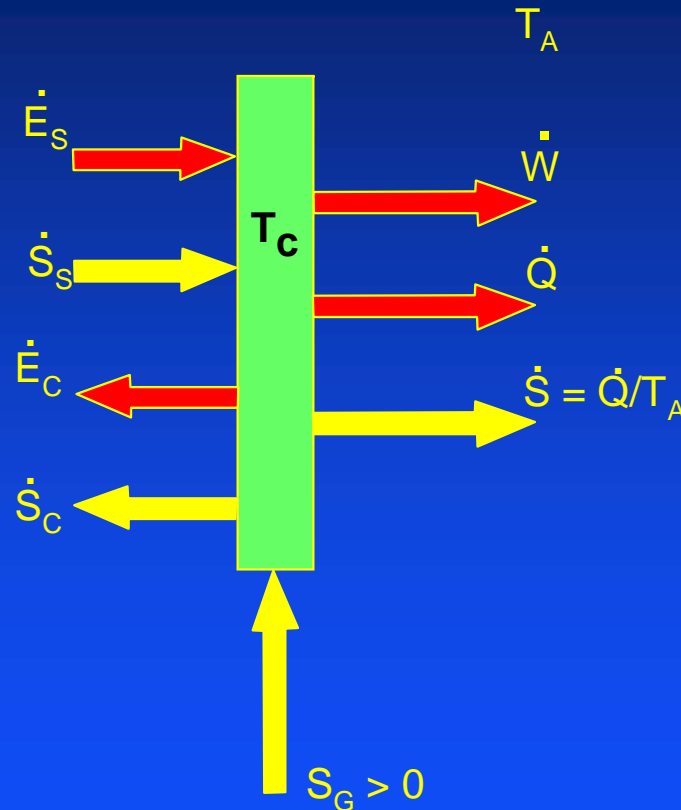


## II. Efficiency/cost





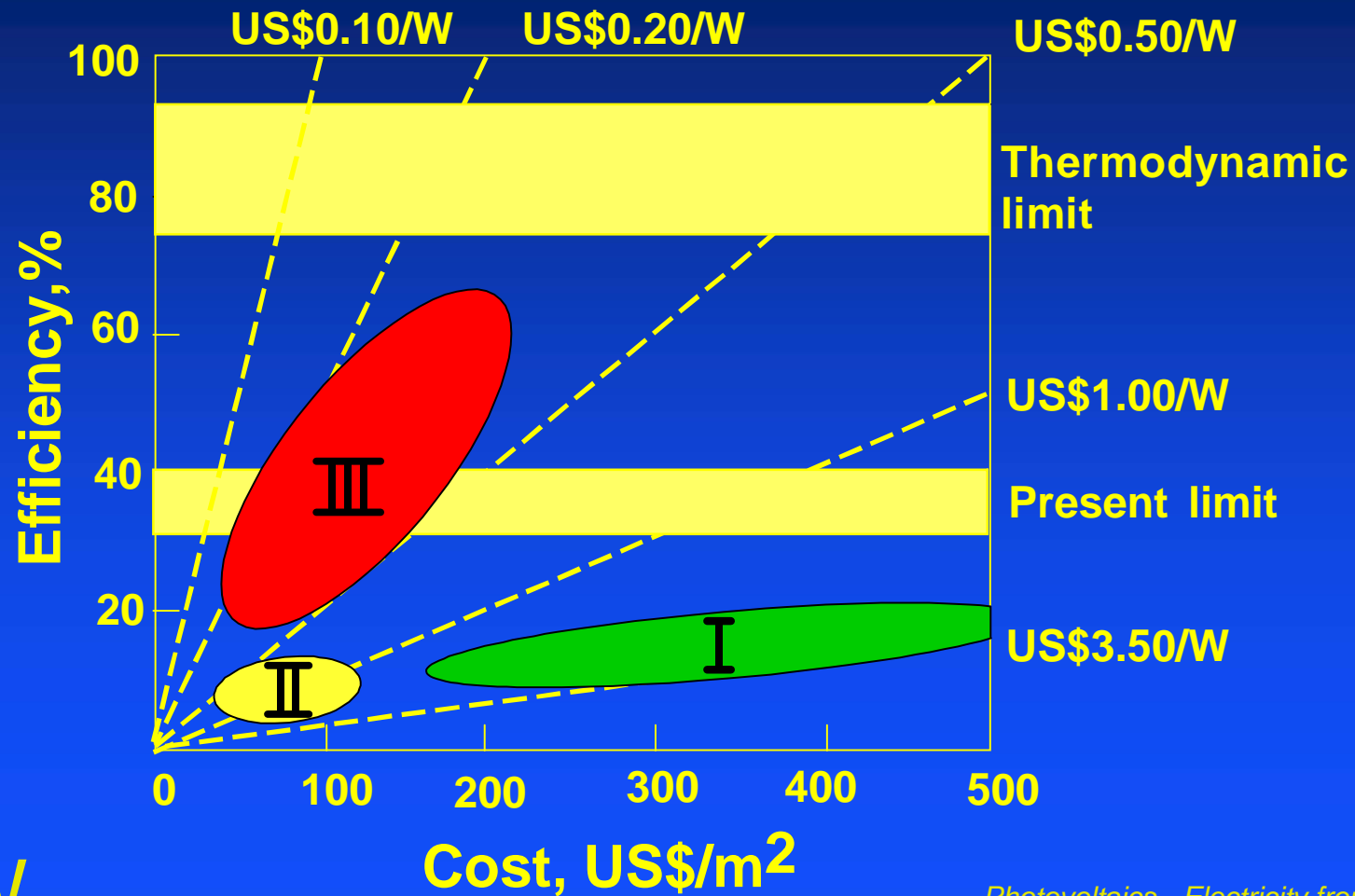
# Efficiency Limits



$$\eta \leq (1 - T_A S_s / E_s) = 93.3\% \text{ (direct)} = 73.7\% \text{ (global)}$$



# III. Efficiency/cost





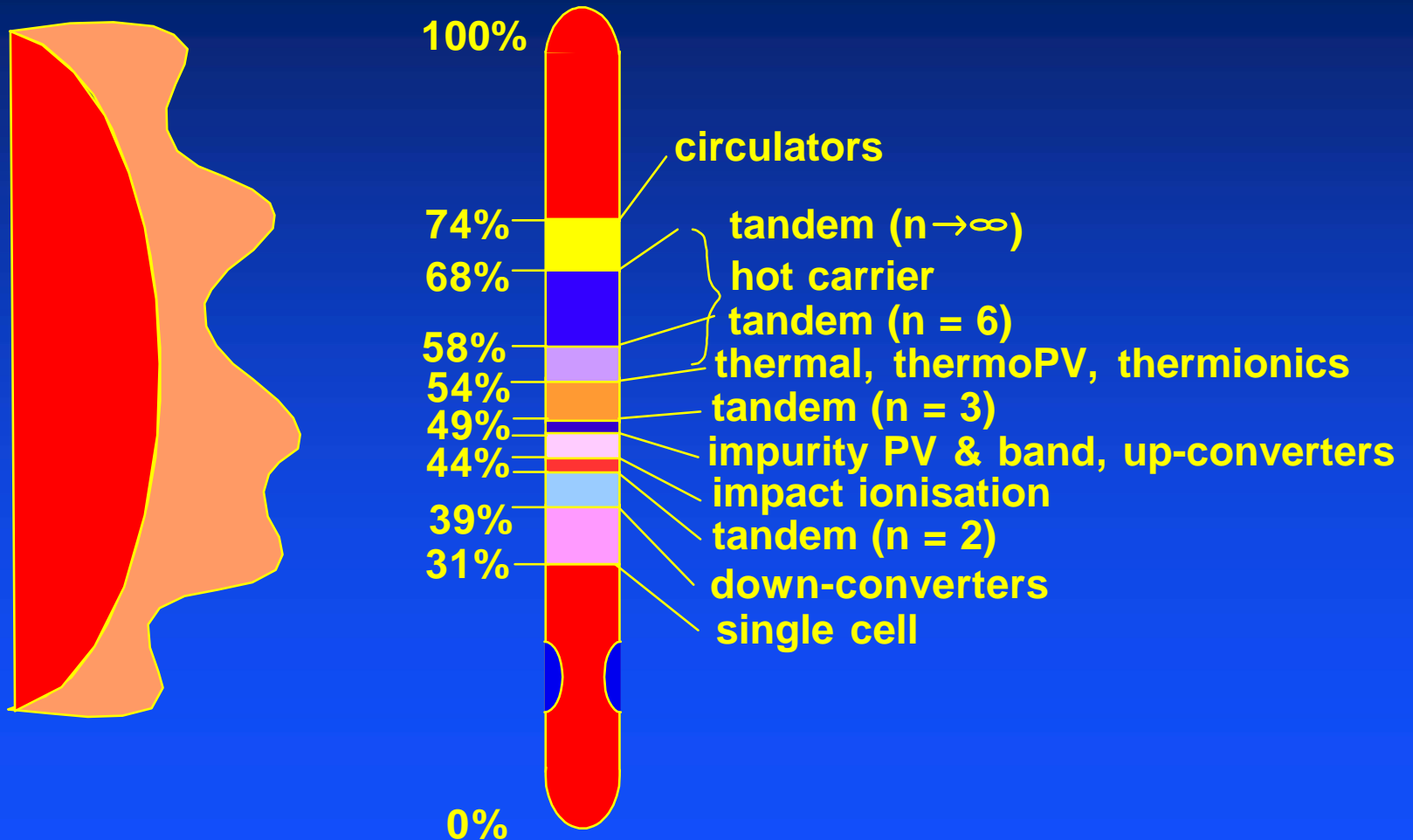
# Third Generation



- . thin-film
- . high efficiency  
( $>$  single junction)
- . abundant materials
- . non-toxic
- . stable, durable

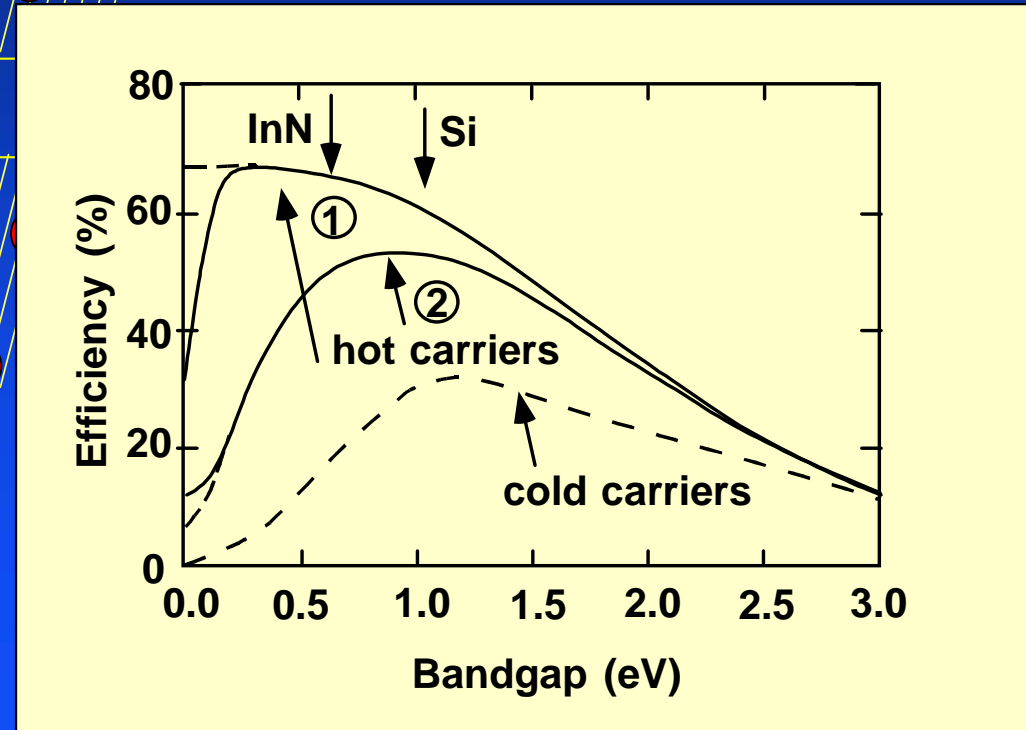
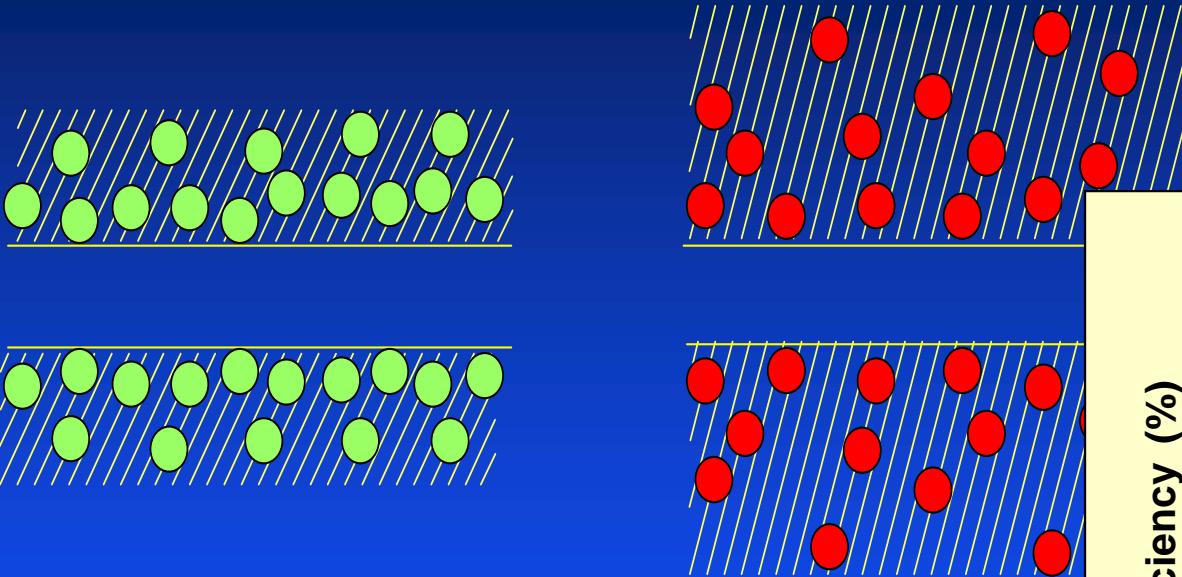


# Options/Limits



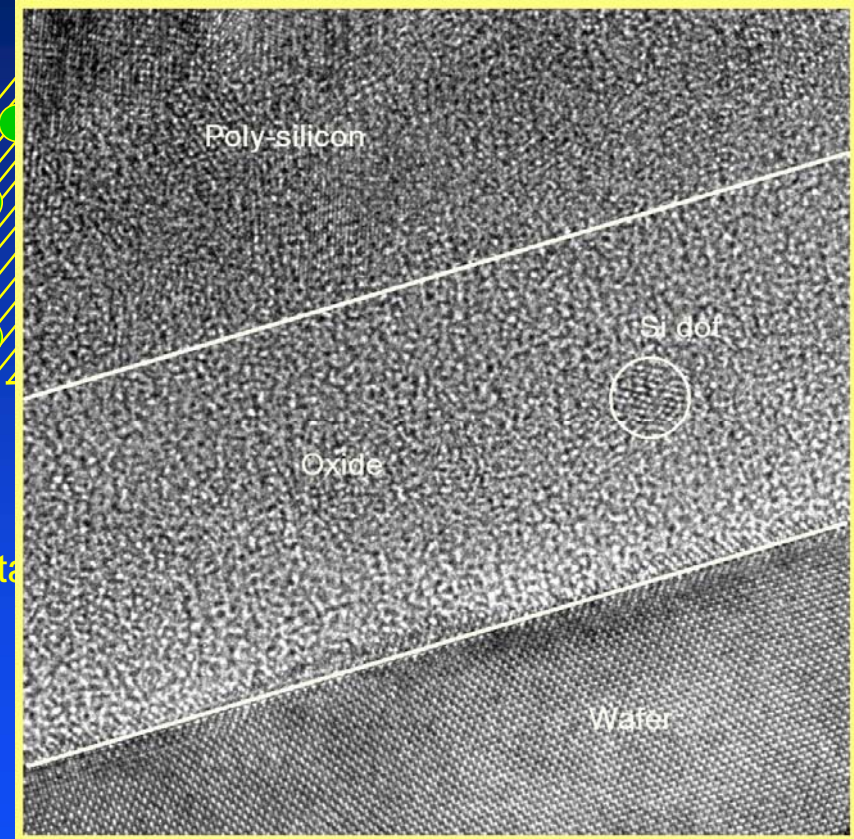
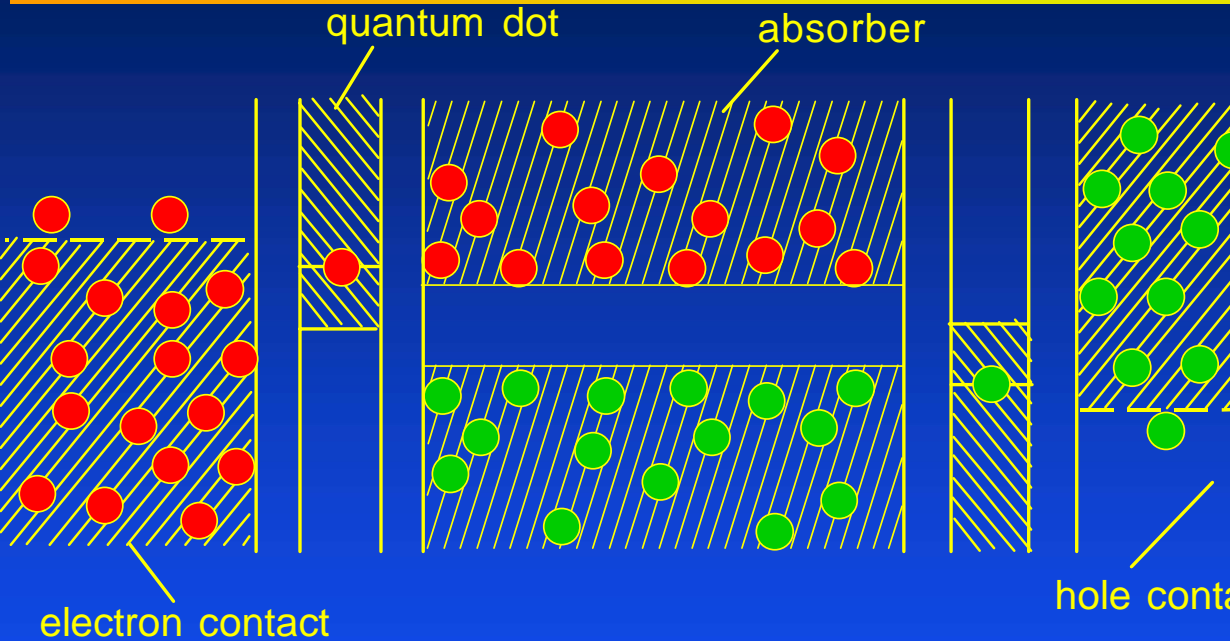


# Hot Carrier Cells



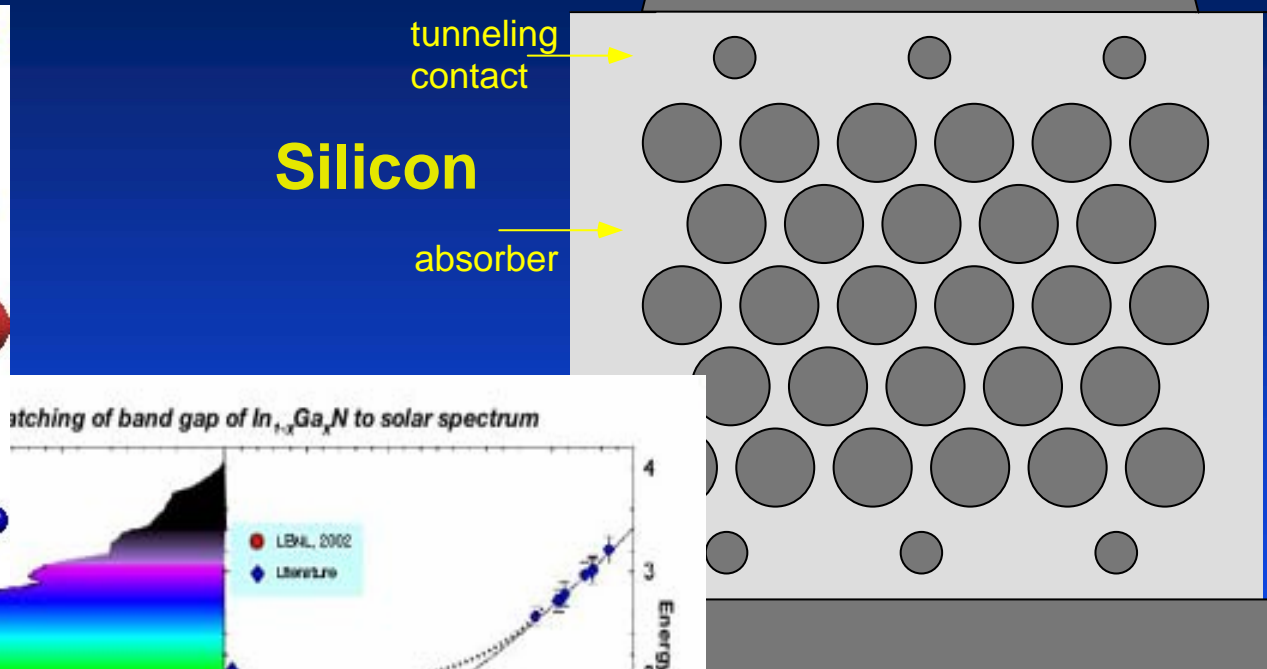
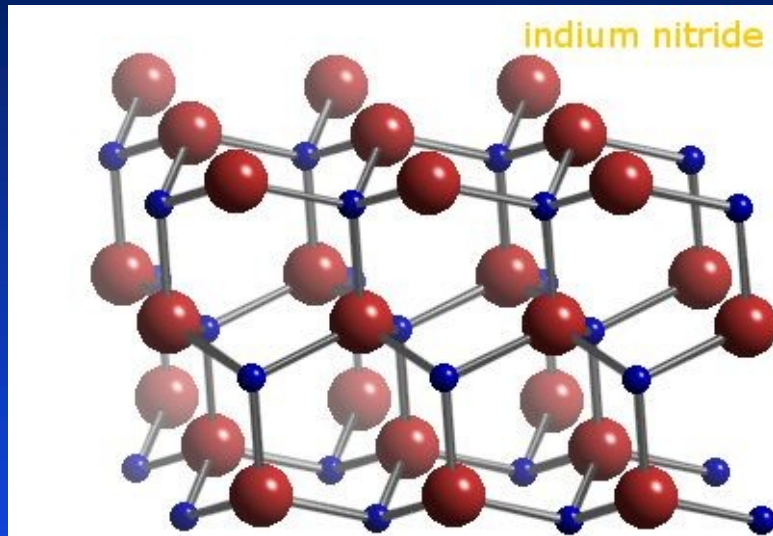
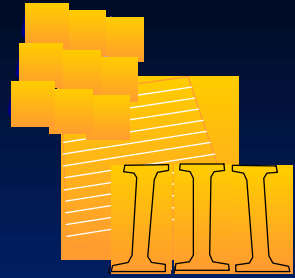


# Hot Carrier Cells

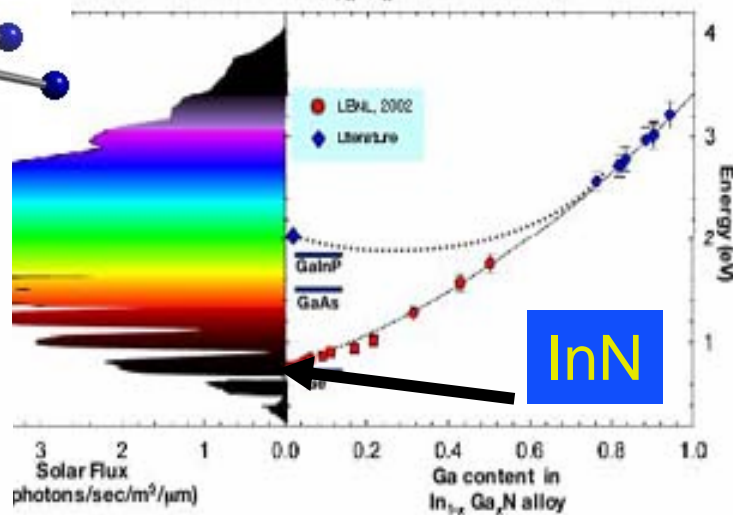


1. *Energy relaxation: radiative ~ phonon*
2. *Energy selective contacts*

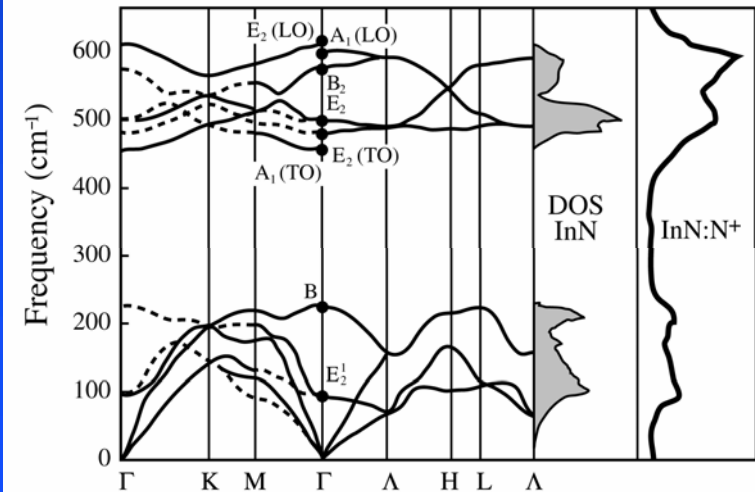
# "Hot Phonons"/Phononic Bandgaps



Matching of band gap of  $In_{1-x}Ga_xN$  to solar spectrum

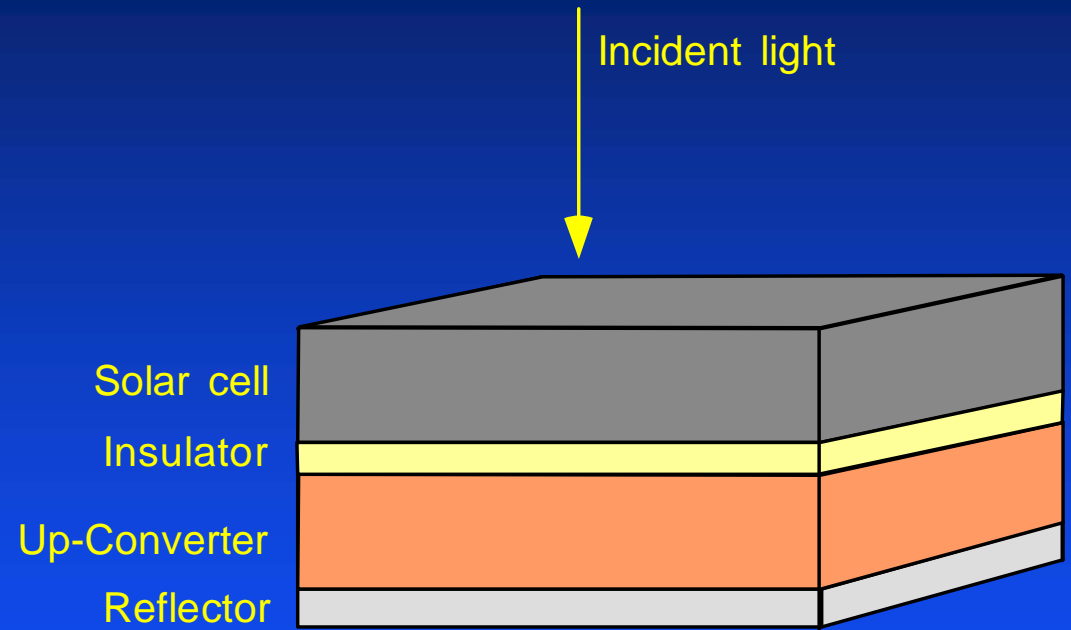
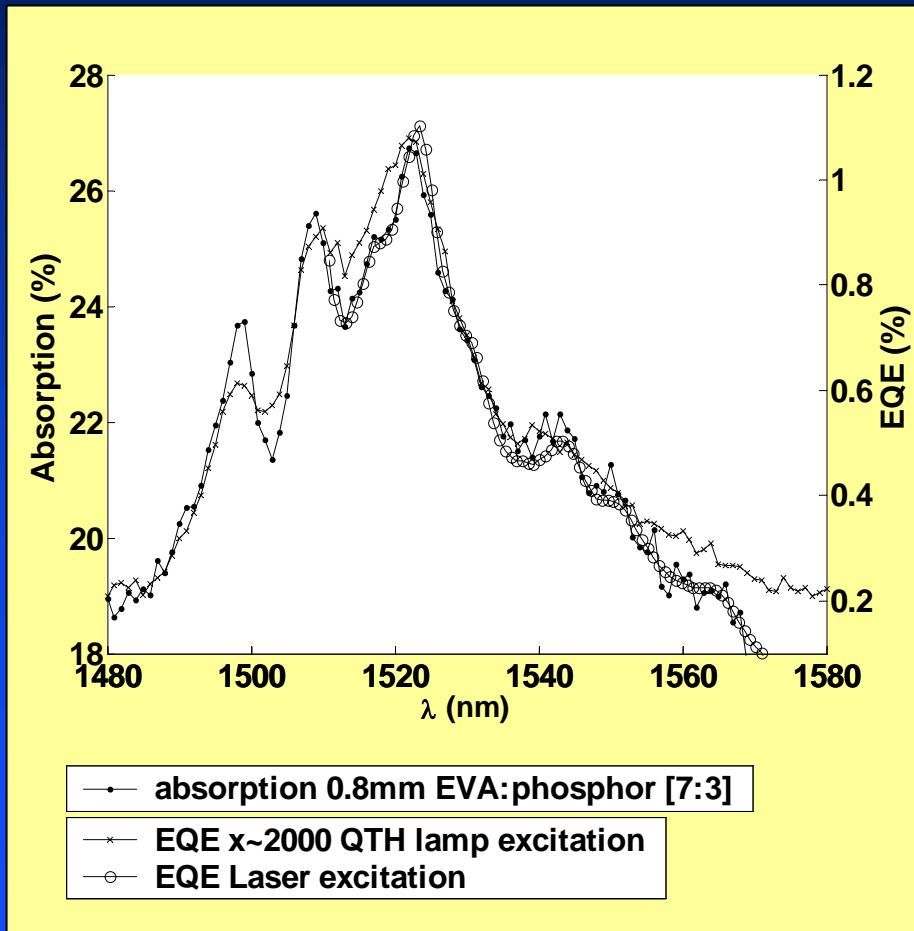


InN



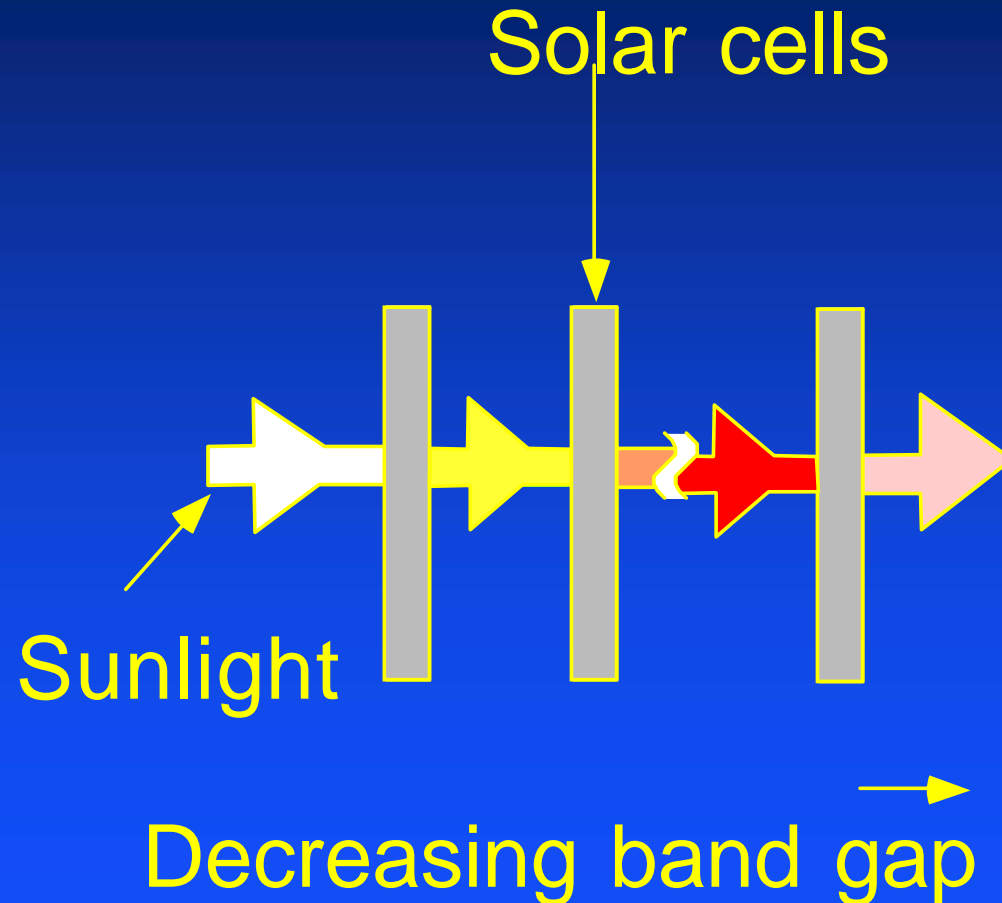


# Up-Conversion



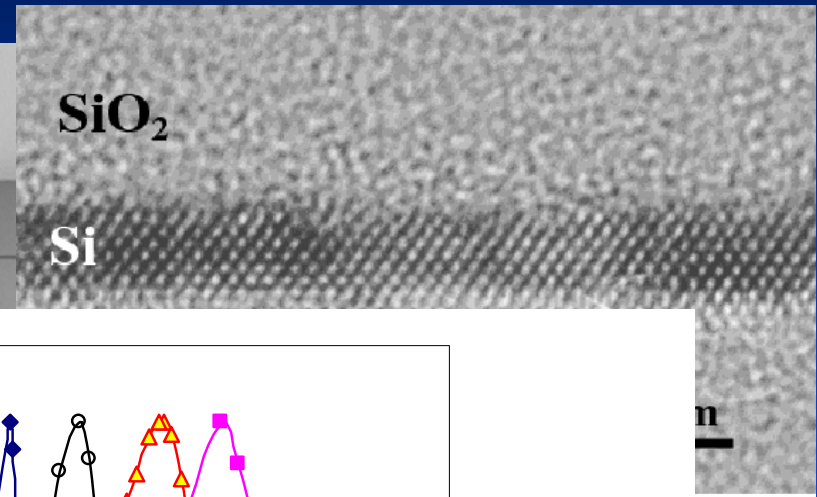


# Tandems

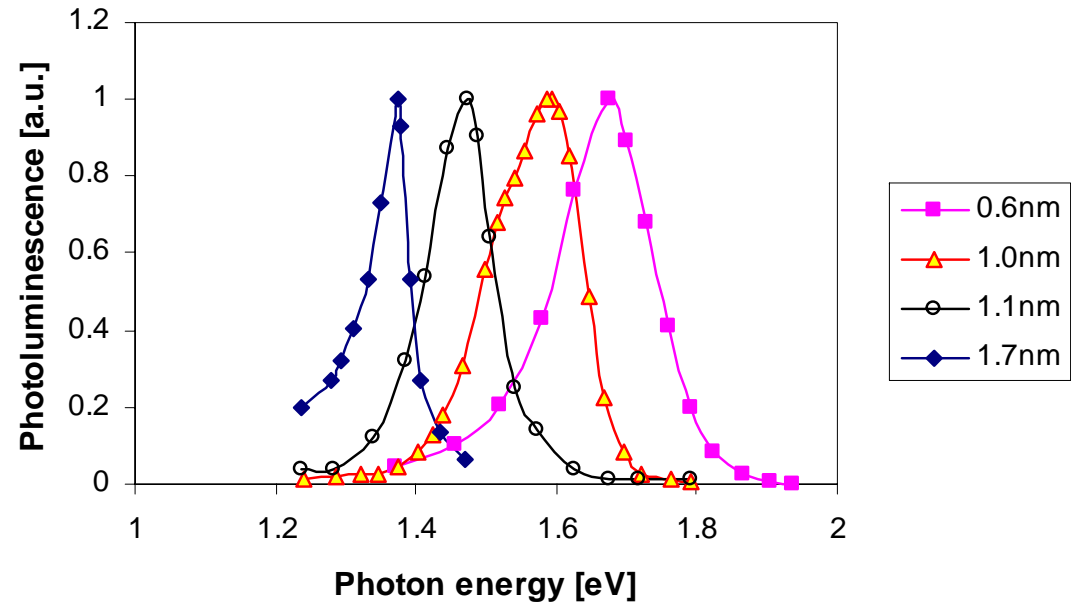




# 2D/3D Silicon



*Appl. Phys. Lett.* **84**, 2286, 2004



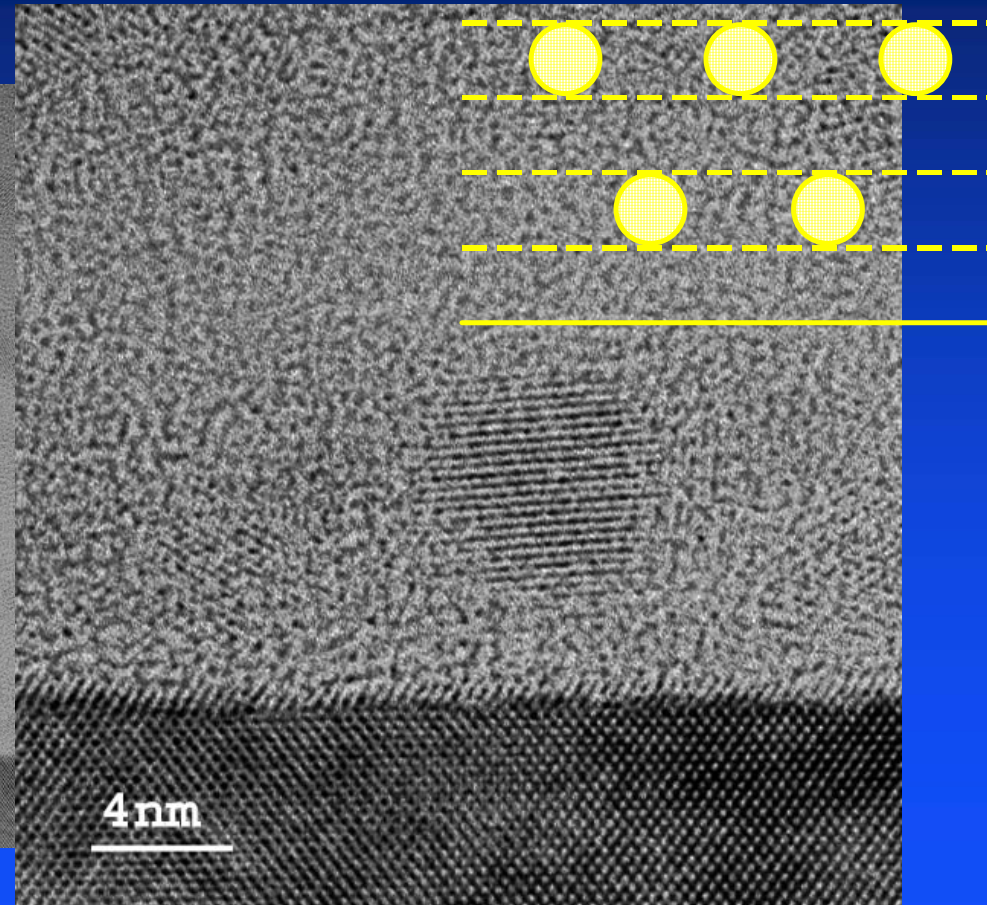


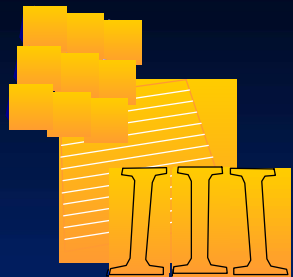
# 0D/3D Silicon



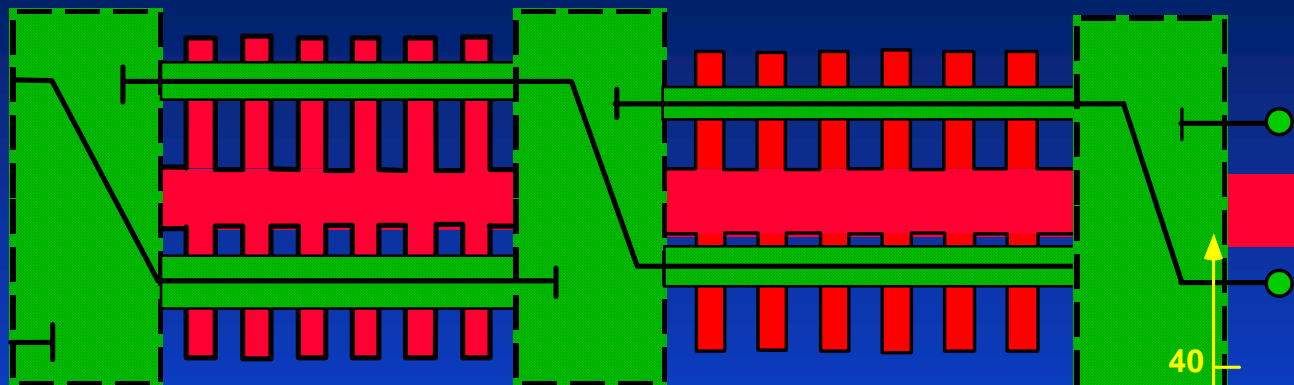
—  $\text{SiO}_x$ ,  $\text{Si}_y\text{N}_x$ ,  $\text{SiC}_x$

—  $\text{SiO}_2$ ,  $\text{Si}_3\text{N}_4$ ,  $\text{SiC}$

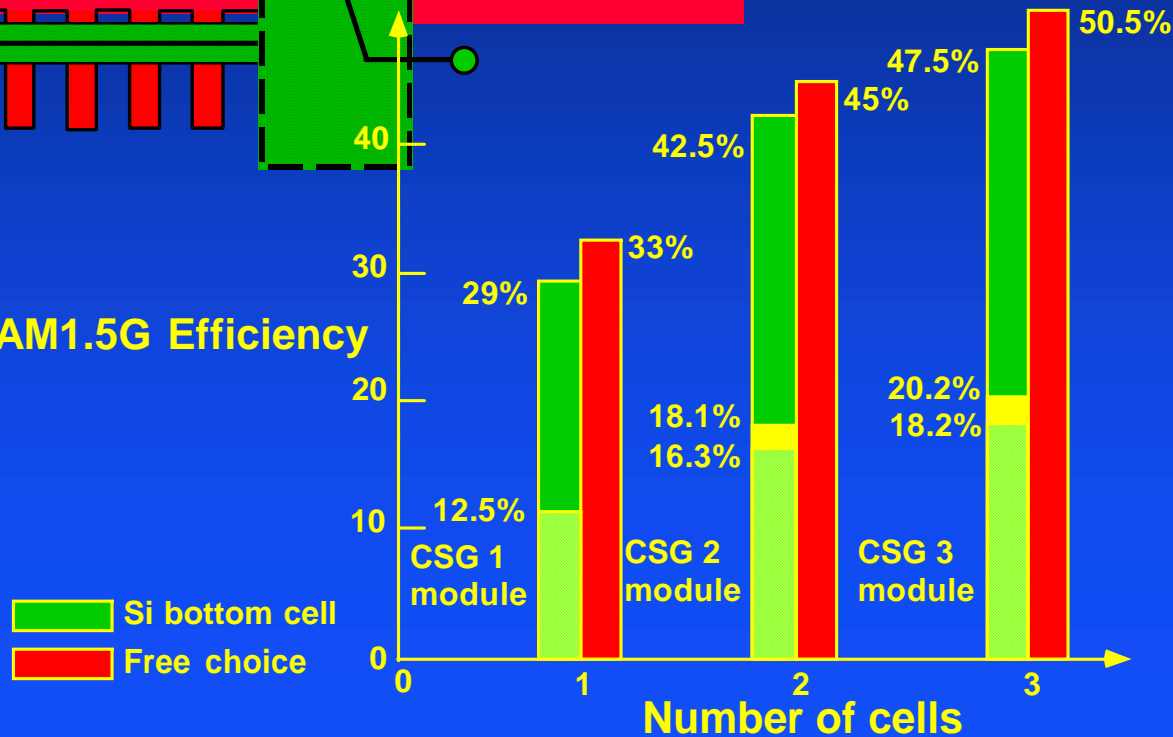




# Si Quantum Dot Tandem (SQOT)

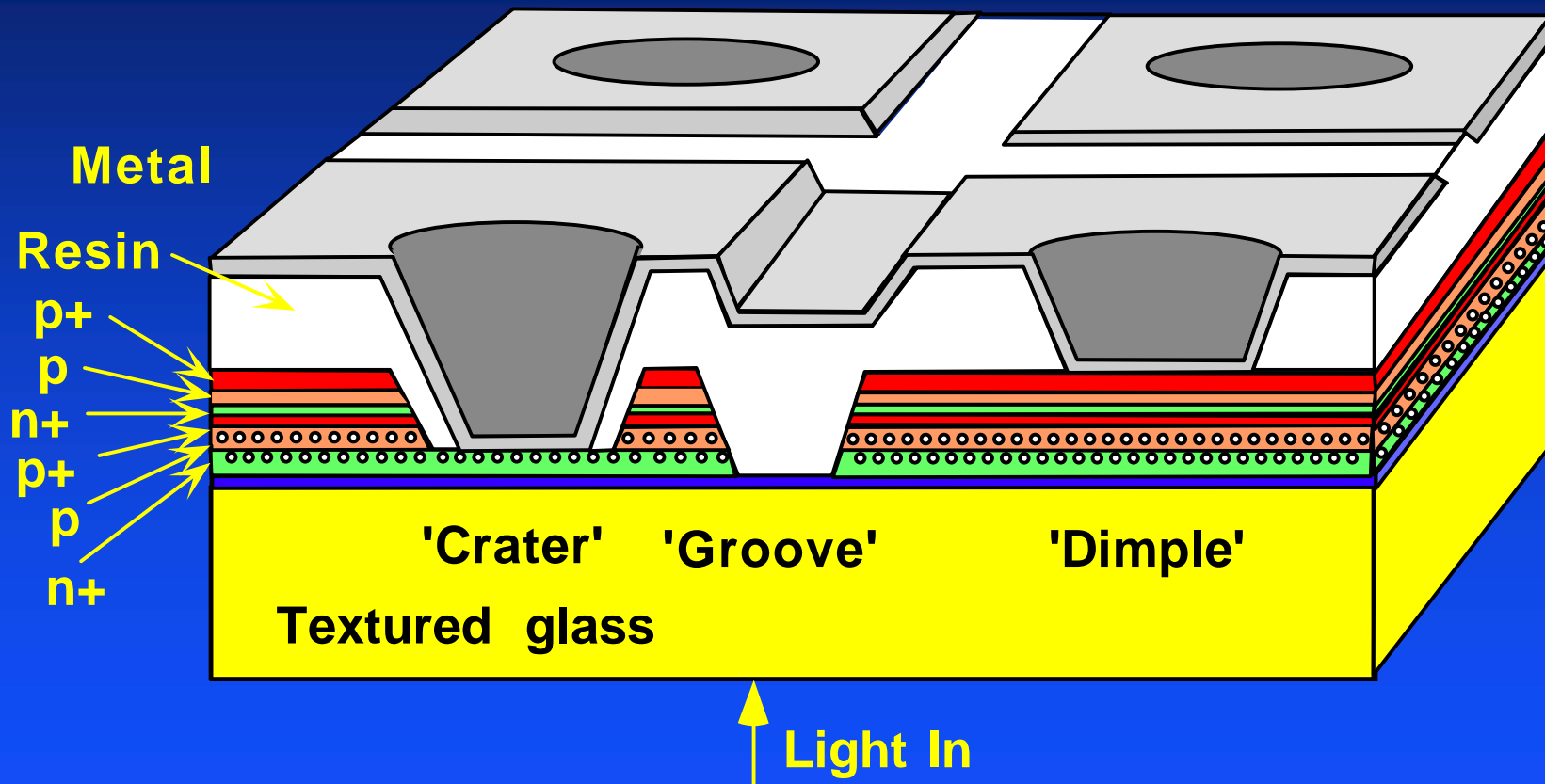


AM1.5G Efficiency





# Al-Si CSG Tandem





# Conclusions

- . *innovation needed for PV to reach full potential*
- . **hot carrier:**
  - resonant tunneling, phononic engineering*
- . **multiple step:**
  - rear up-converter*
- . **tandems:**
  - all c-Si quantum dot tandems (SQOTs)*