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"Advanced Photon Management"

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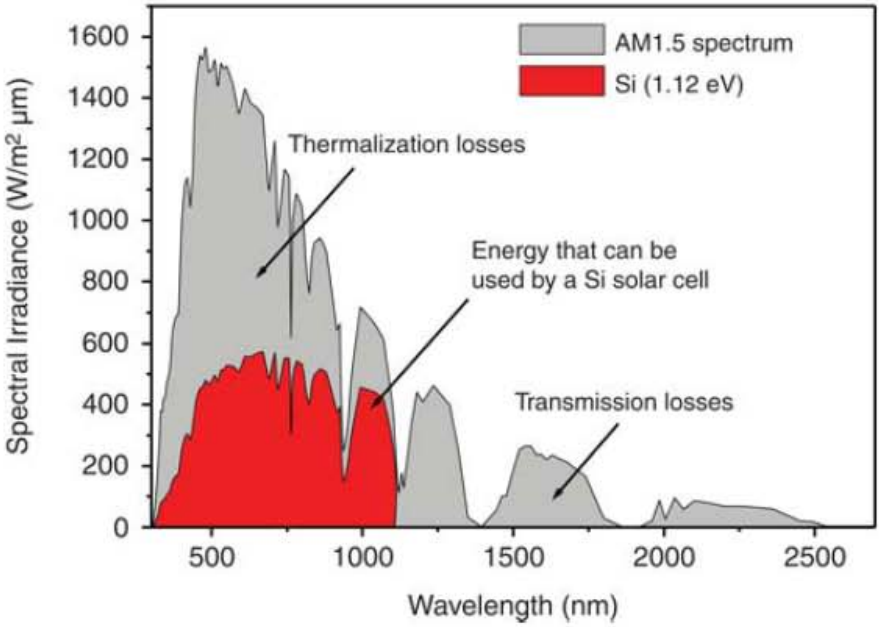
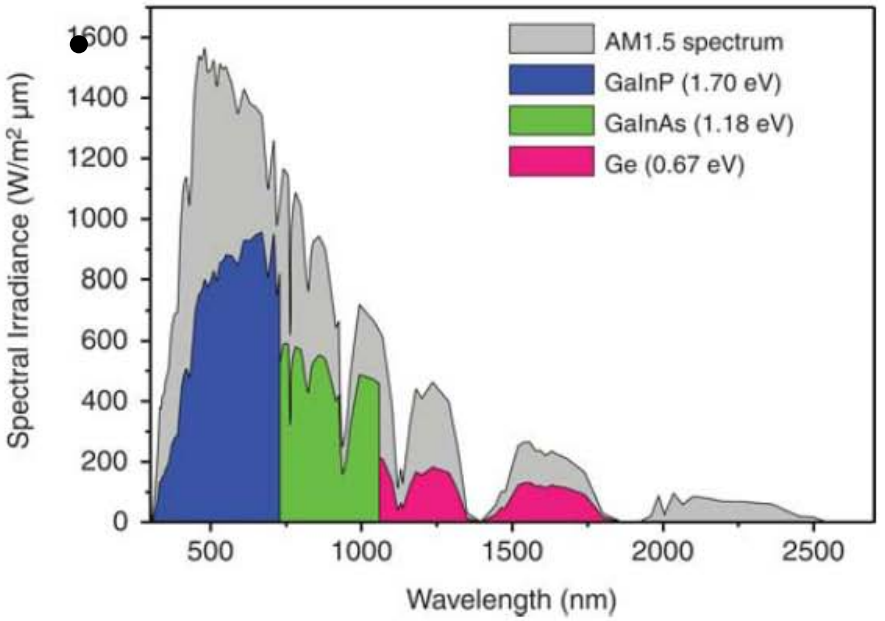
Outline

- Importance of photon management
- Where and why photons are lost
- Opportunities for light management in the blue
  - Downconversion/downshifting
- Opportunities for light management in the red
- Broad opportunities for light management
  - Waveguiding/low power concentration

Why is light management important?





Kurtz, MRS Bulletin (2007)

- Single gap cells are limited by cell architecture and bandgap to a portion of the solar spectrum
- Multijunction approaches to take better advantage of solar spectrum but are typically expensive
- Photon management offers opportunities to make better use of the photons, both inside and outside the single junction window

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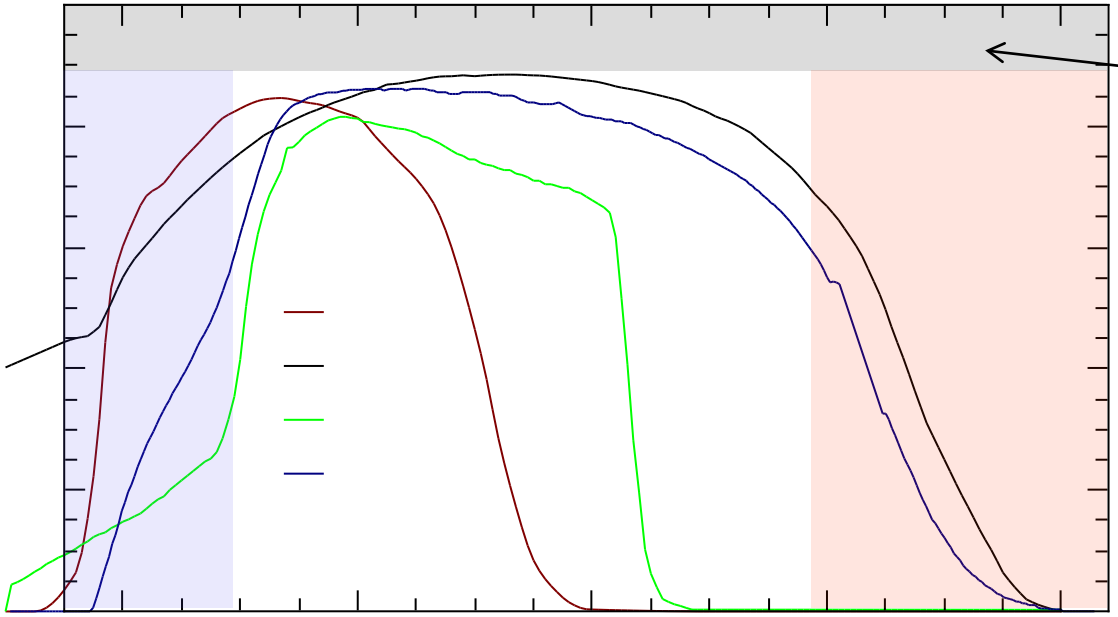
Where and why are photons lost



Reasons for general photon losses:
- Single layer AR coating
- Imperfect texturization
- bulk recombination

Reasons for losses in the blue
- front surface recombination
- window layers

Reasons for losses in the red
- thin active material
- bandgap of material
- rear surface recombination
- Imperfect rear reflector

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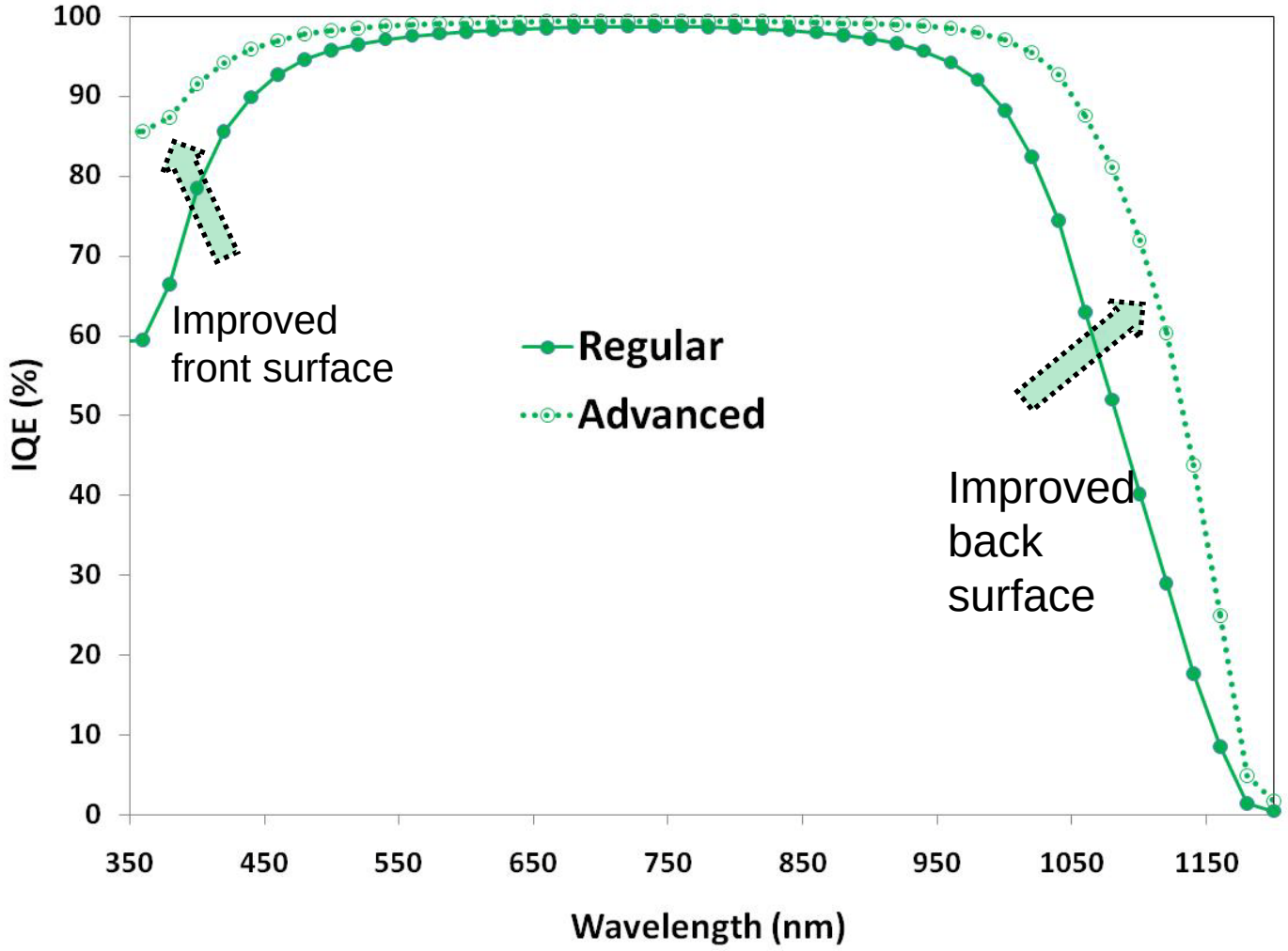
Si cells: Improved blue and red response through electrical and optical confinement



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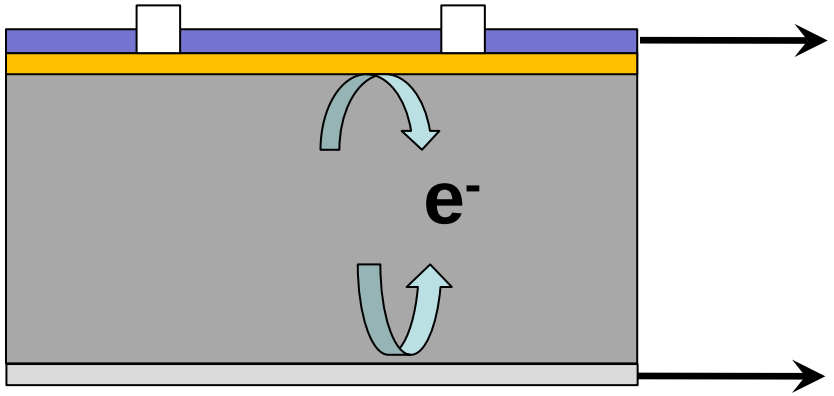
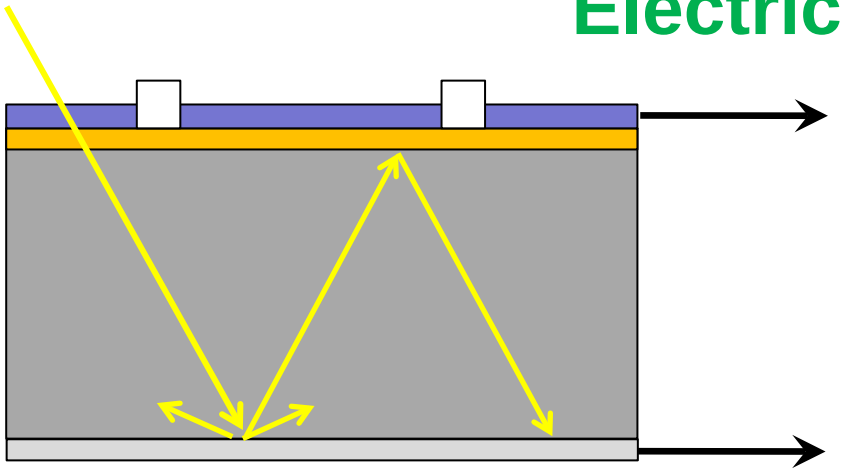
Traditional opportunities for blue and red enhancement in Si



- Reduce front surface recombination
- Thinner emitter
- Selective emitter

- Reduce rear surface recombination

Electrical



- Improve texturization (random, honeycomb, inverted, laser)
- DLAR coating

- Improve back surface reflection

Optical

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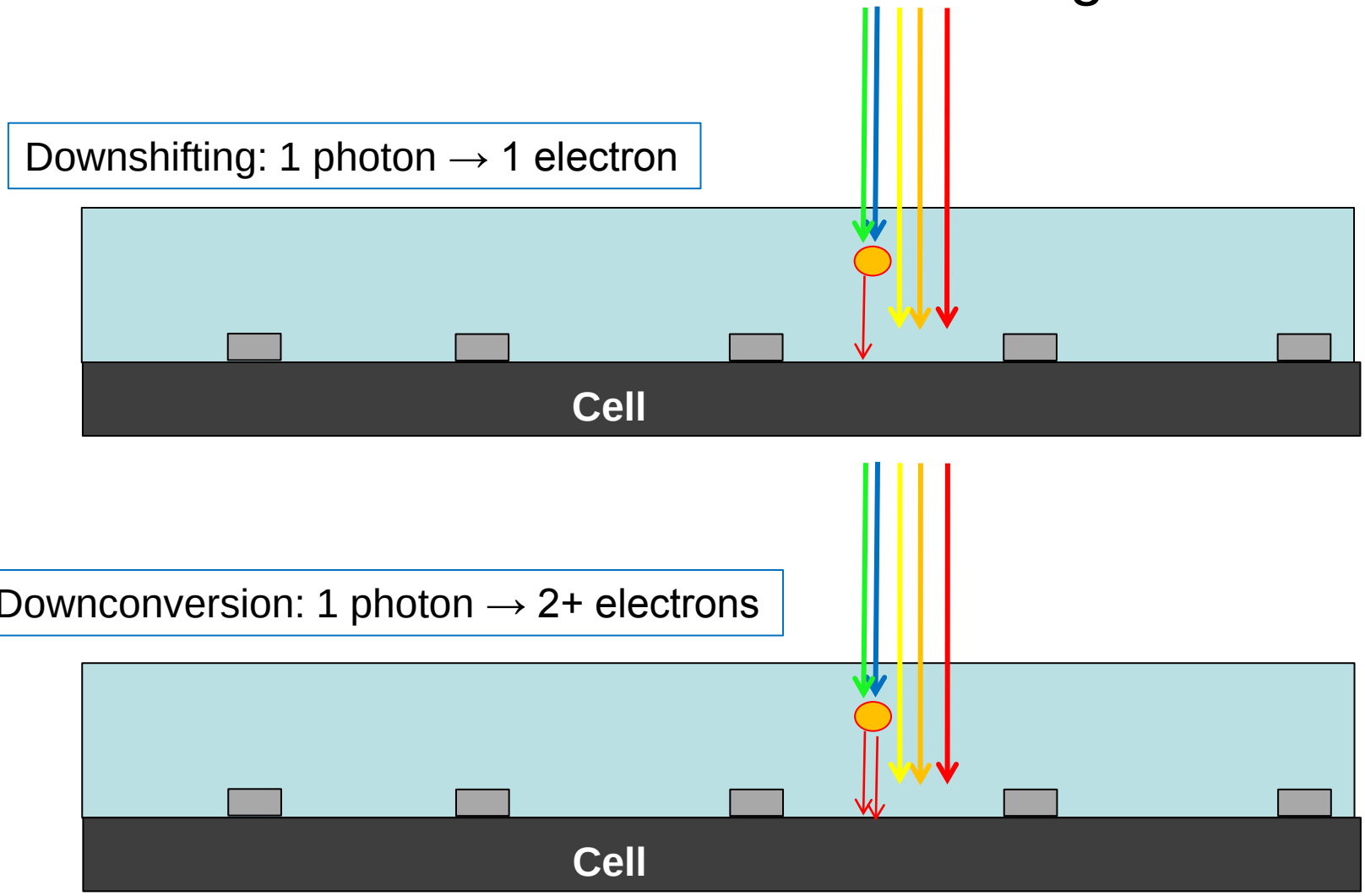
General opportunities for gaining photons in the blue: Downconversion/downshifting



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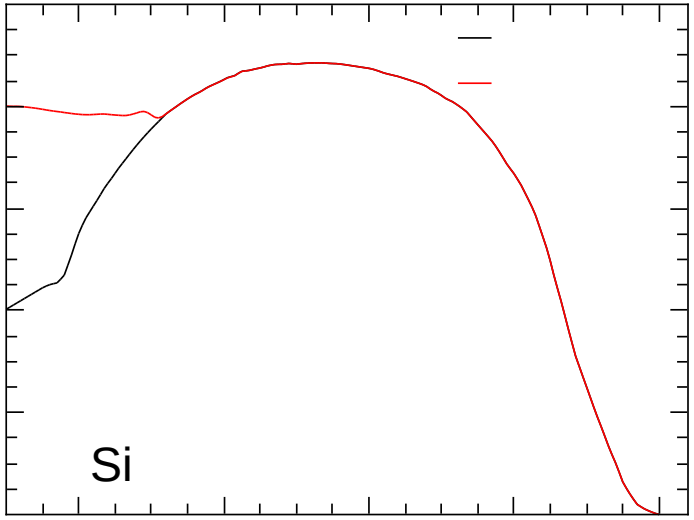
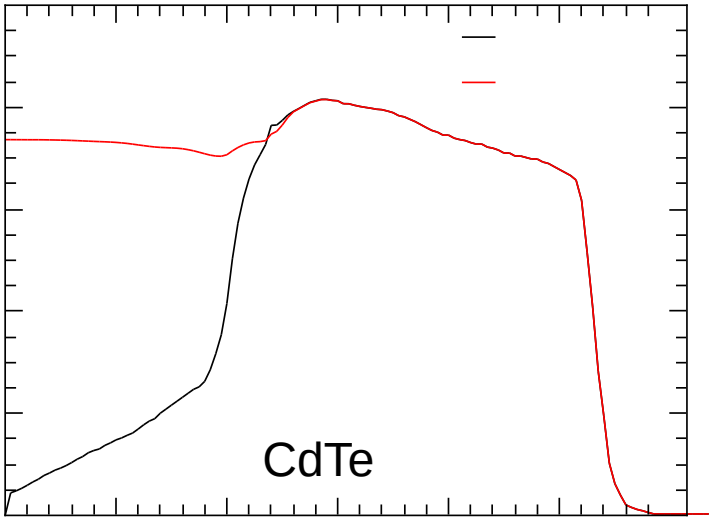
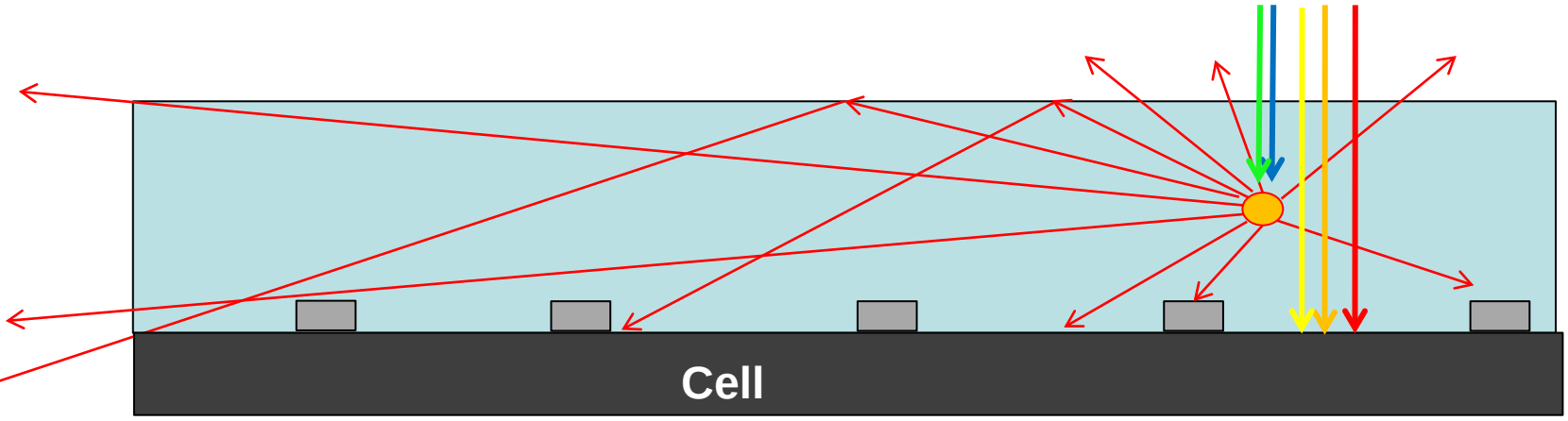
Downshifting on multiple technologies







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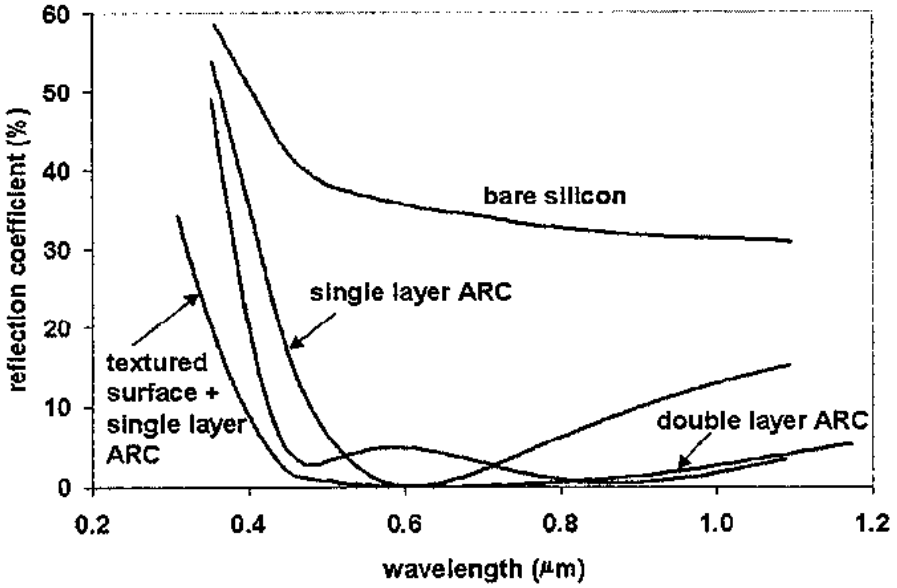
Opportunities for light management in the red

- Better rear reflectors
- Increased lifetimes
- Upconversion
- Intermediate band gap

Broad opportunities for light management

- Multiple layer AR coating
  - Graded index AR coating
- Better texturization
- Waveguiding
- Luminescent concentration/lateral concentration



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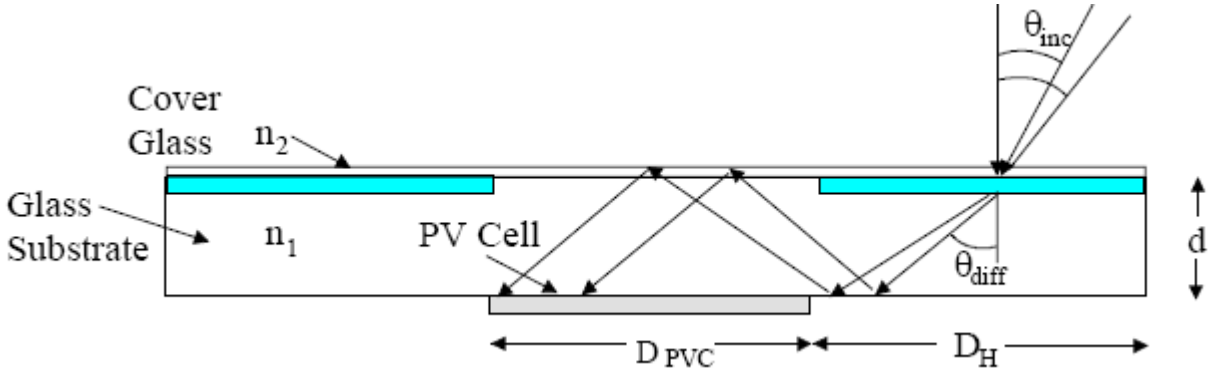
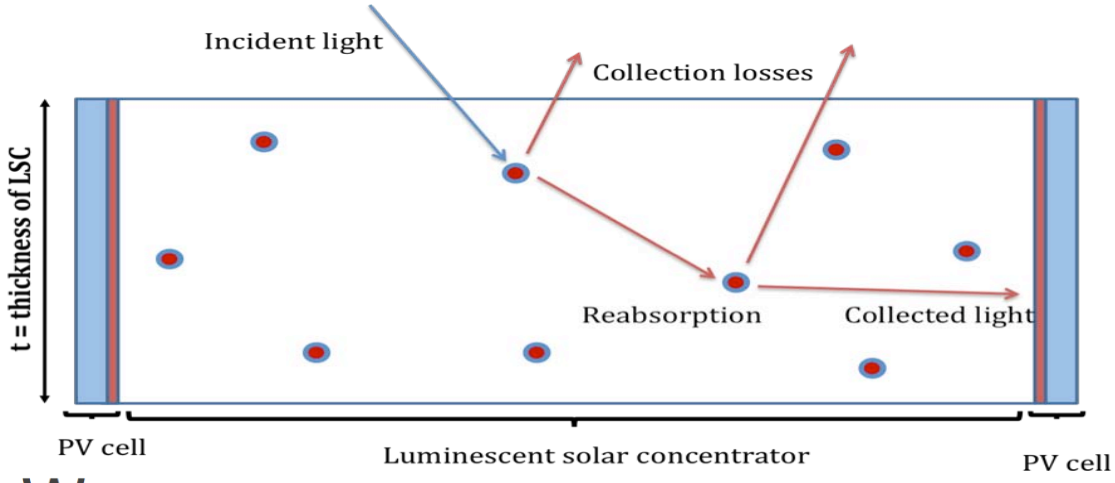
Waveguiding/Lateral concentration

- Diffraction gratings



- Luminescent concentrators



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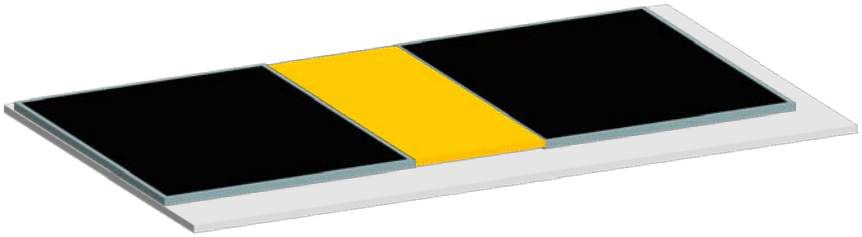
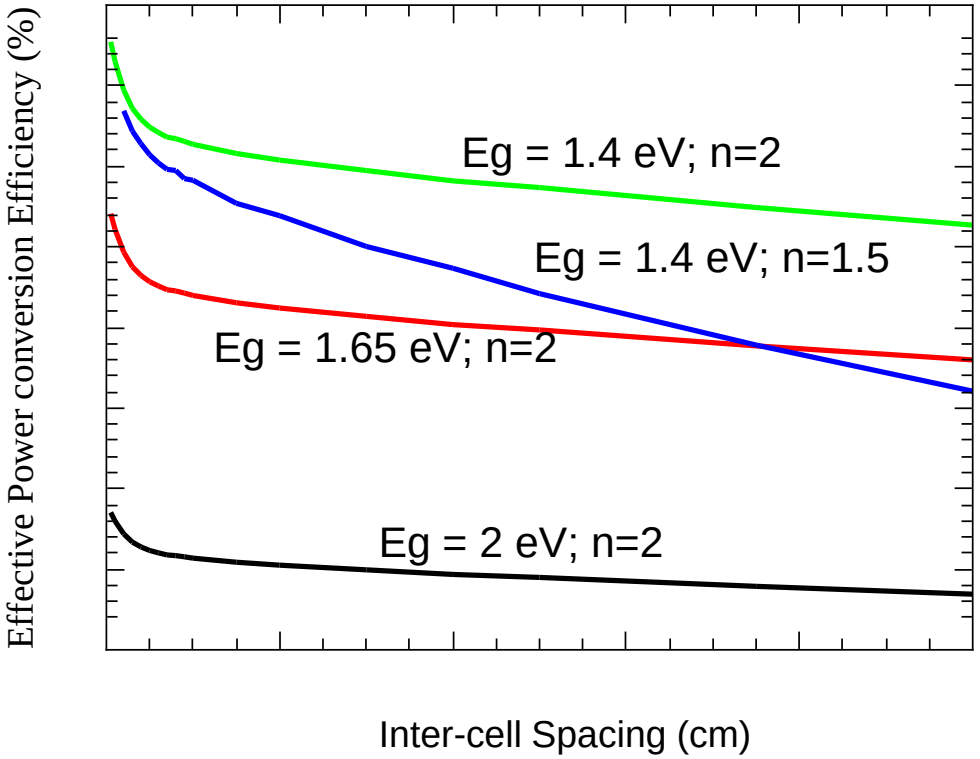
Lateral luminescent concentrators



Requirements for inter-cell material:

- Highly luminescent (95% PLQY)
- Controllable absorption/emission (tailored to cell); low self-absorption
- Tunable bandgap
- Stable



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Summary

- Conventional photon management techniques such as improving surface recombination, better texturization, better rear reflectors, etc are a clear way to advance toward higher efficiencies
- Advanced photon management such as up/downconversion, downshifting, and waveguiding are heavily materials-dependent, but could lead to a non-monolithic “multijunction” technology