CPV

Concentration photovoltaics

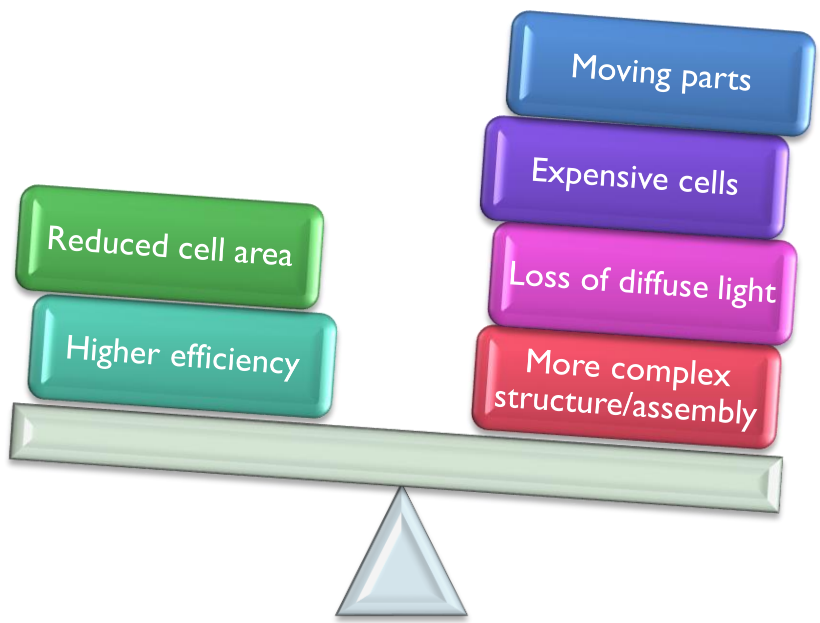
CPV – CONCENTRATION PV

- Concentration concept
- Solar cells under concentration
- Categories of concentration
  - Including luminescent concentrators
- Solar cells for concentration
  - Silicon
  - Multijunction
- What is the best CPV technology?

CPV – CONCENTRATION PV

Concentration concept

- Replace expensive solar cell by cheaper materials, e.g. mirrors and/or lenses
- 'Allows' for the use of more efficient (i.e. expensive) solar cells



CPV – CONCENTRATION PV

Concentration concept

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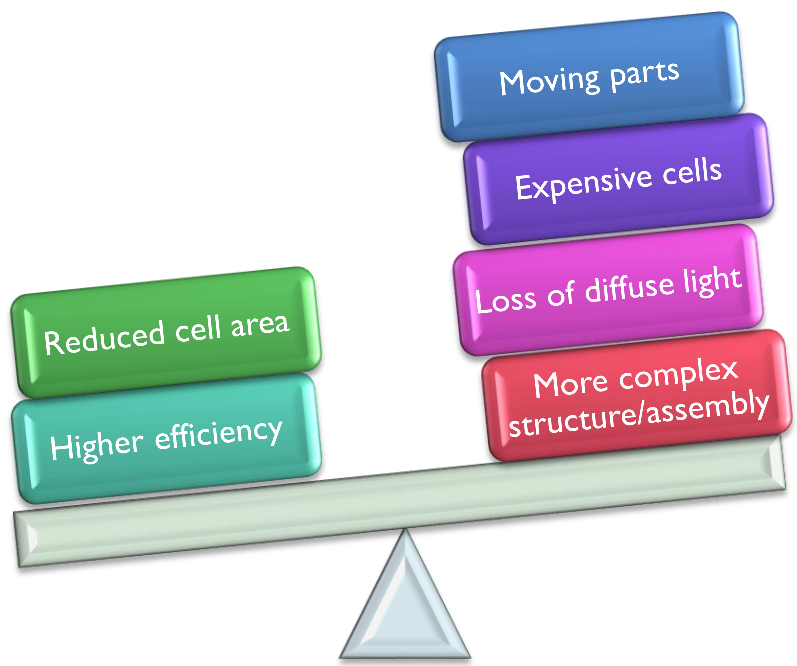

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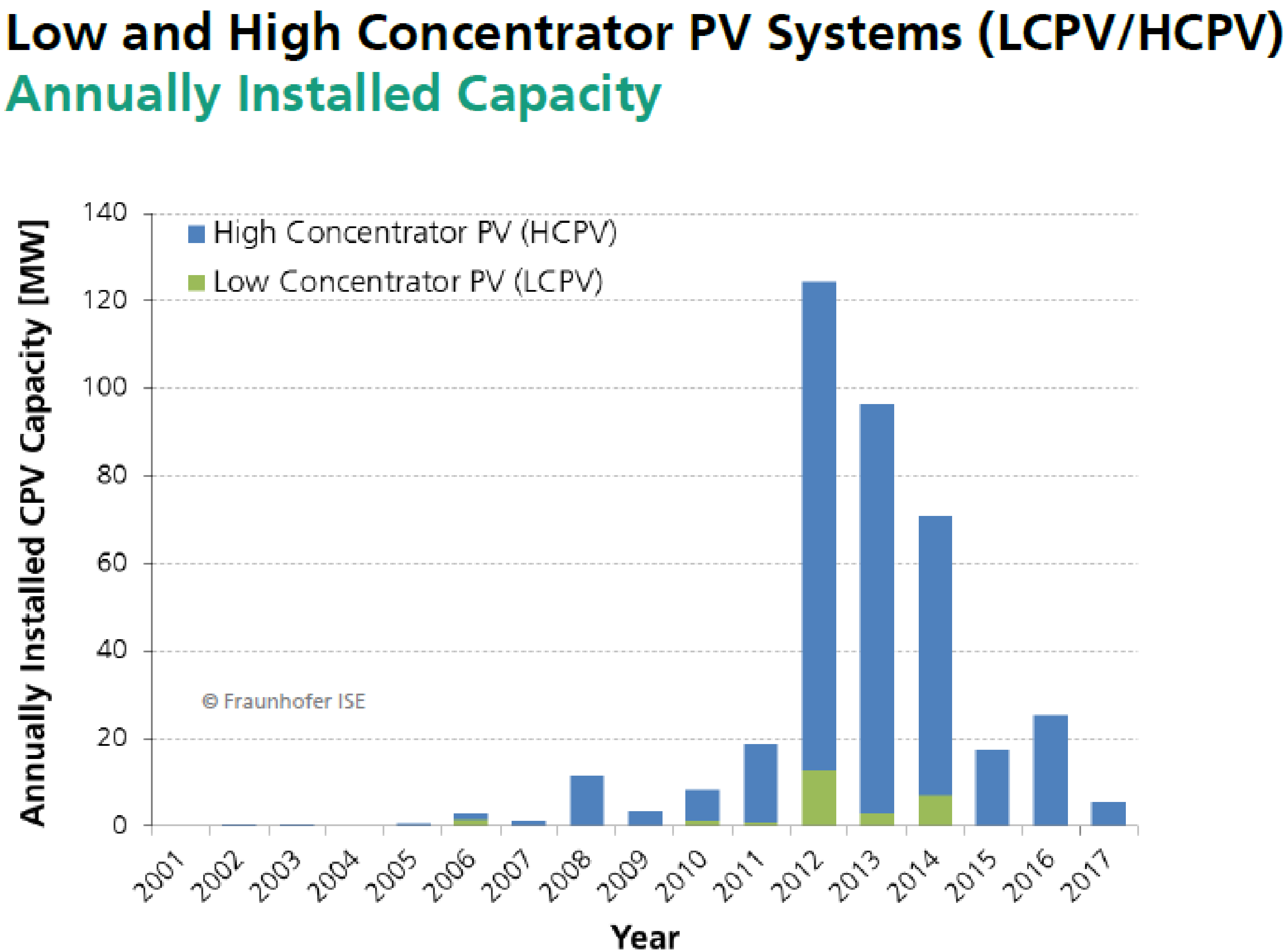

LCPV and HCPV have concentration factors below 100 suns and from 300 up to 1000 suns, respectively.

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Solar cells under concentration X

- Increased irradiance

$$G(X) \equiv XG(1)$$

- Increased current

$$\boxed{I_{sc}(X) = XI_{sc}(1)}$$

- Increased voltage

$$V_{oc}(X) = \frac{KT}{q}\ln\left(\frac{I_{sc}(X)}{I_0} + 1\right) \approx \frac{KT}{q}\ln\left(X\frac{I_{sc}}{I_0}\right)$$

$$\boxed{V_{oc}(X) = V_{oc}(1) + \frac{KT}{q}\ln(X)}$$

- Increased efficiency:

$$\eta(X) = \frac{V_{oc}(X)I_{sc}(X)FF}{G(X)}$$

$$\boxed{\eta(X)\eta(1)\left(1 + \frac{KT}{q}\frac{\ln(X)}{V_{oc}(1)}\right)}$$

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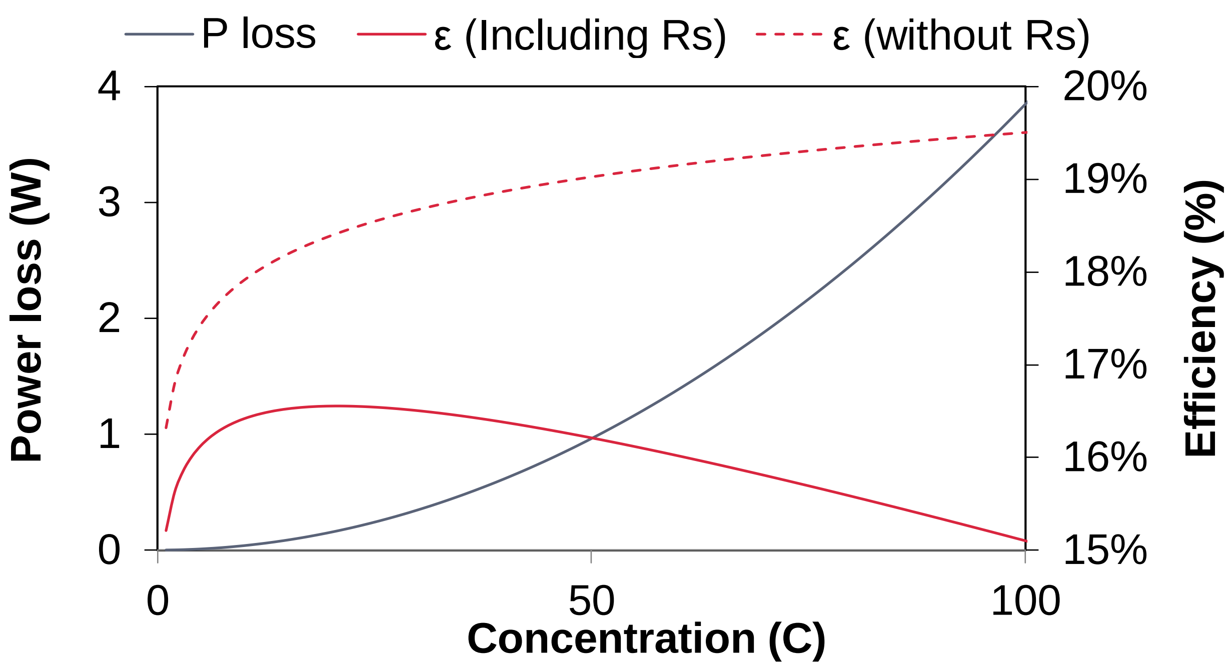
Solar cells under concentration X



- Increased series resistance loss

$$P_{loss} = I^2 R_s \cong X^2 I_{sc}(1)^2 R_s$$

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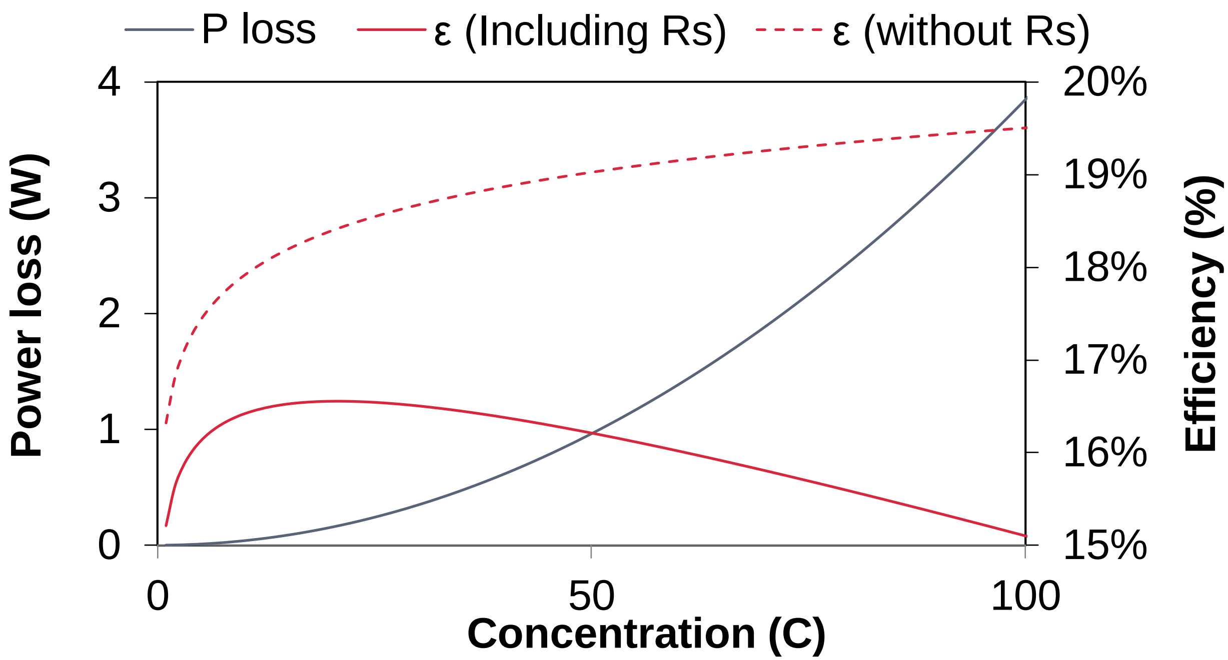
Solar cells under concentration X



- Optimum concentration for a given cell

$$X \cong \frac{KT/q}{I_{sc}(1)R_s}$$

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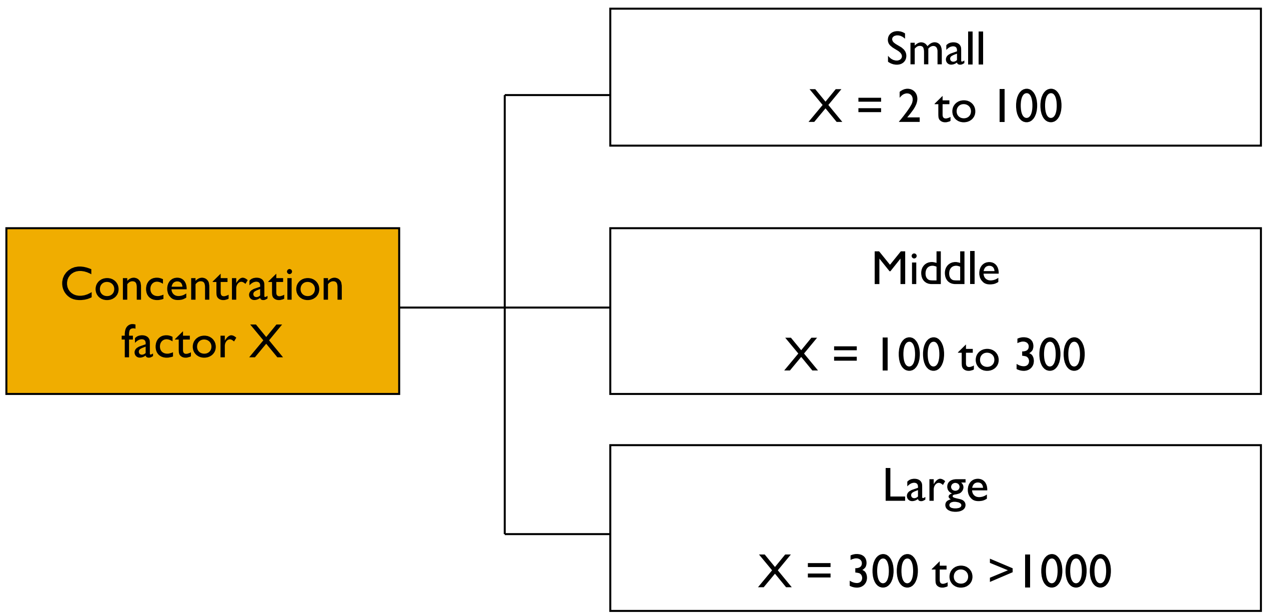
‘Possible’ classification scheme for CPV



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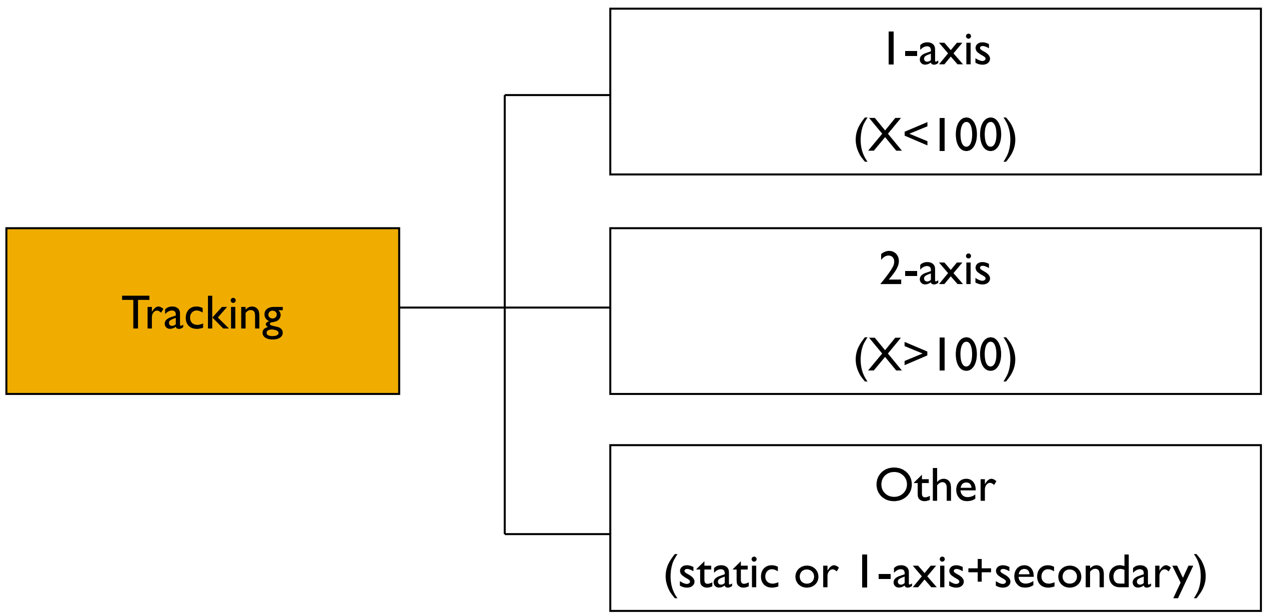
Another ‘possible’ classification scheme for CPV



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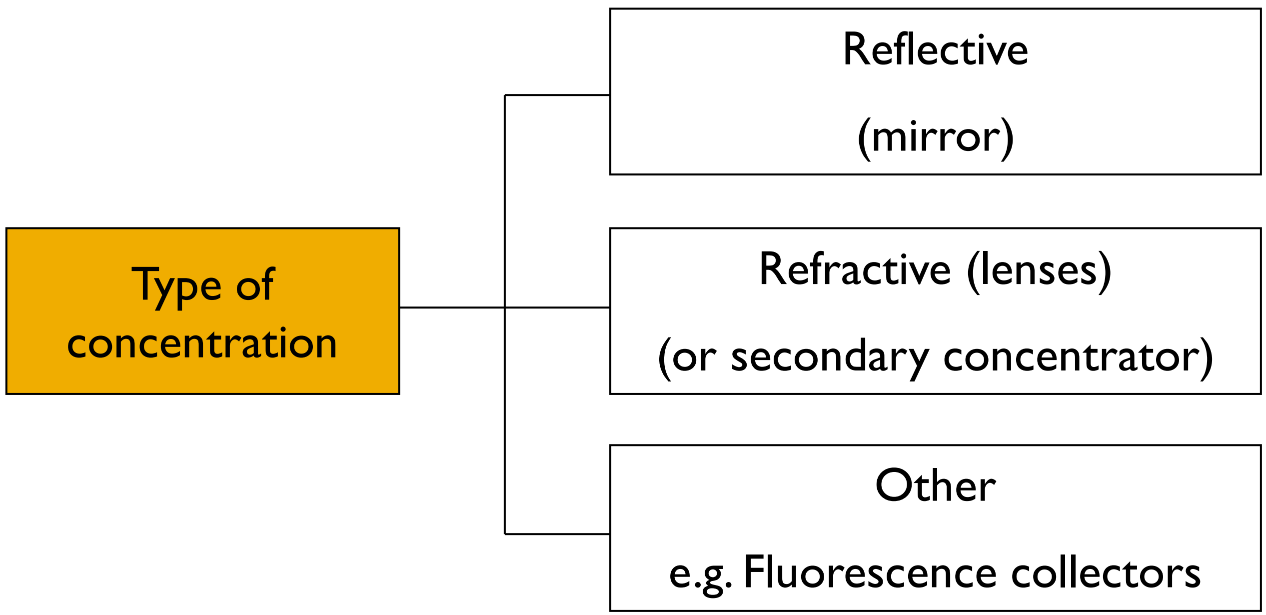
Another ‘possible’ classification scheme for CPV



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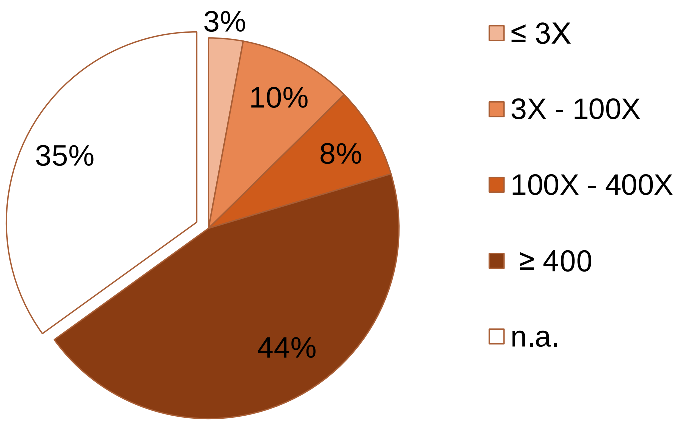
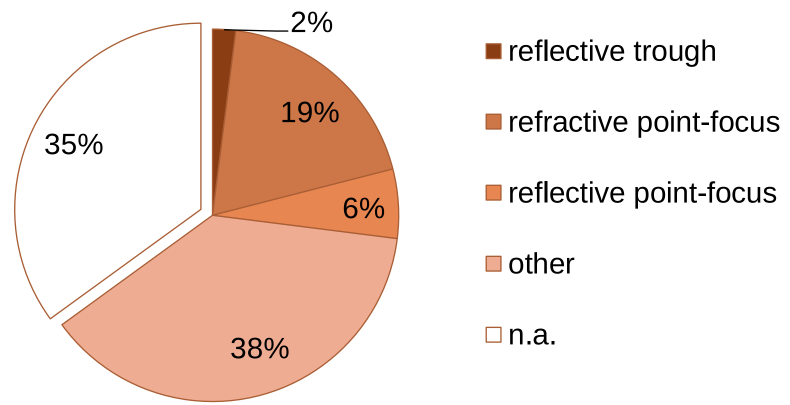
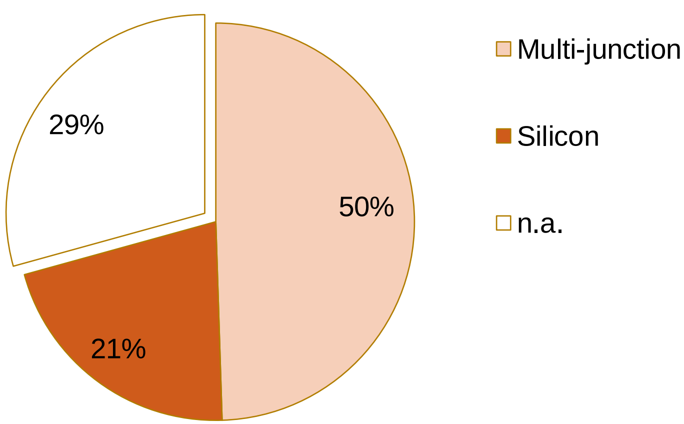
Concentration factor



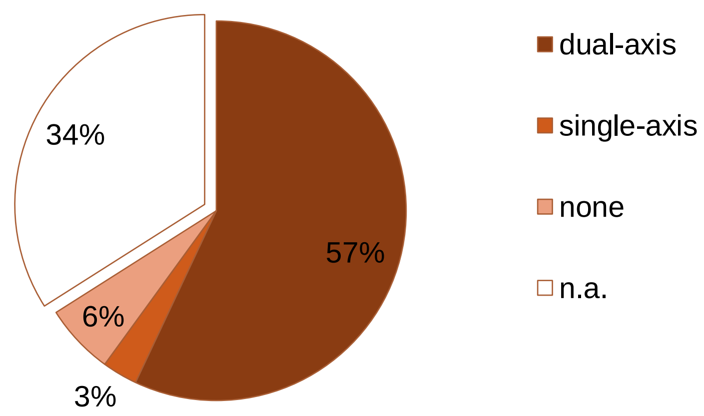
Optics

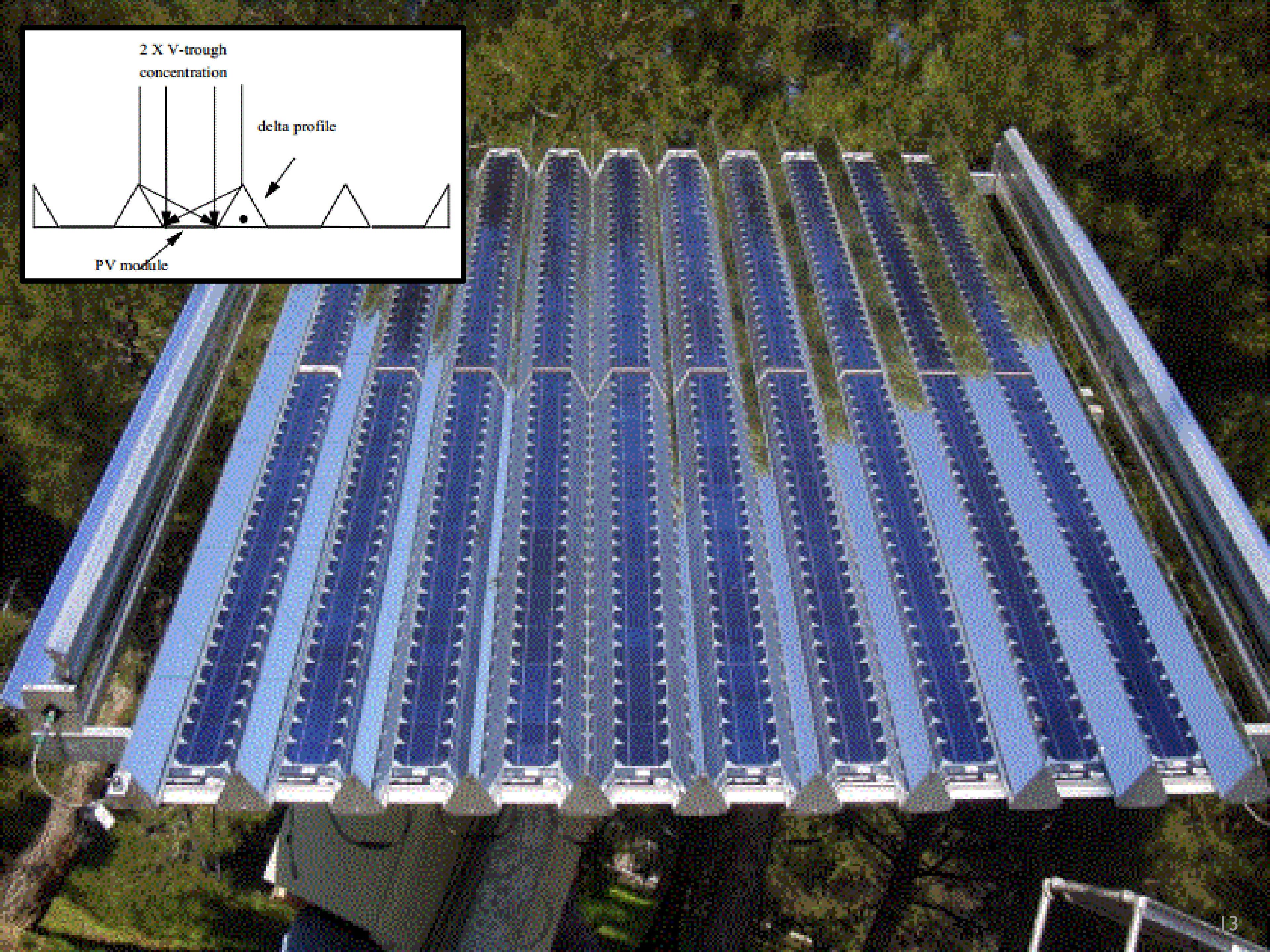


Solar cell technology



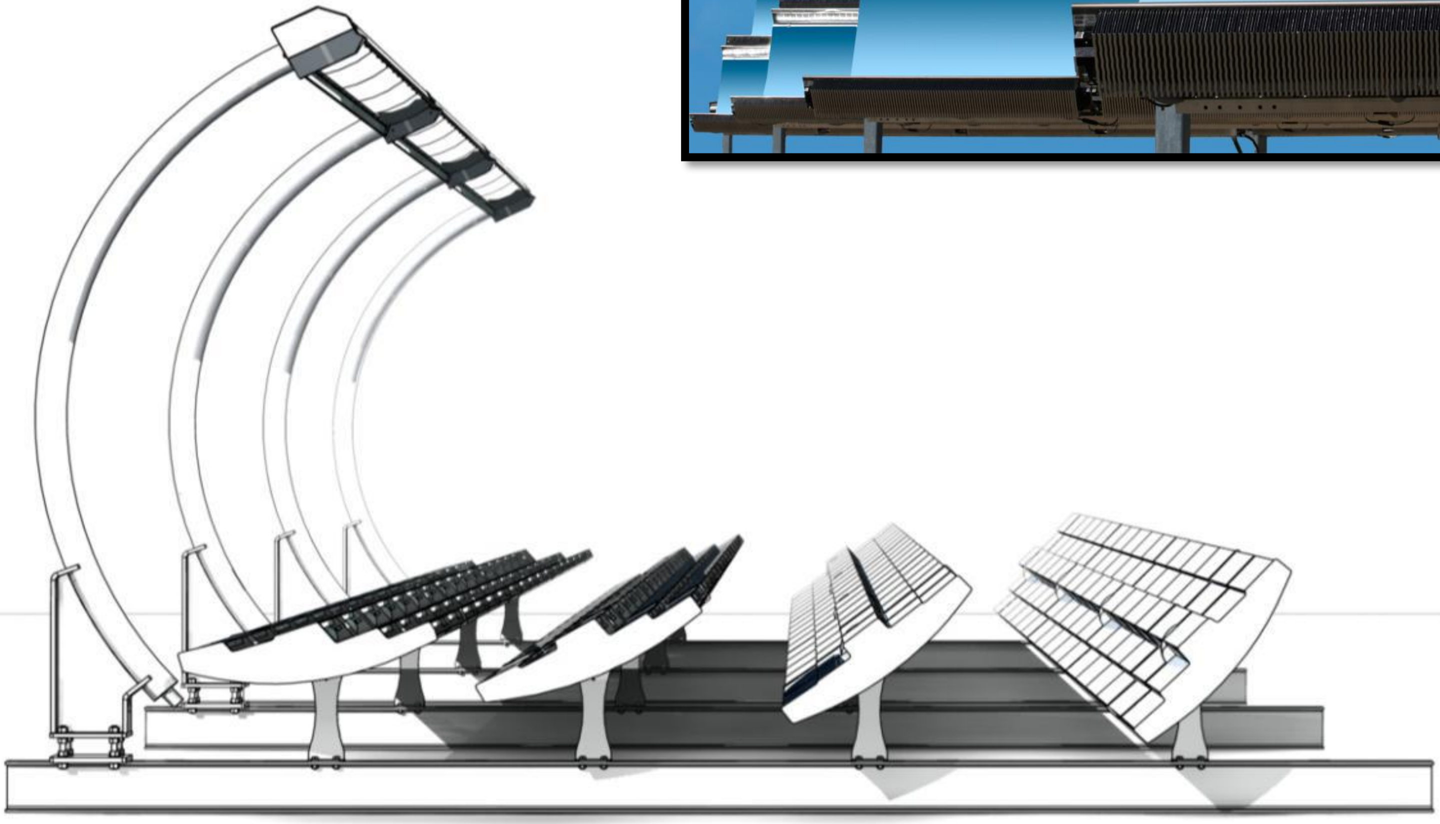
Tracking

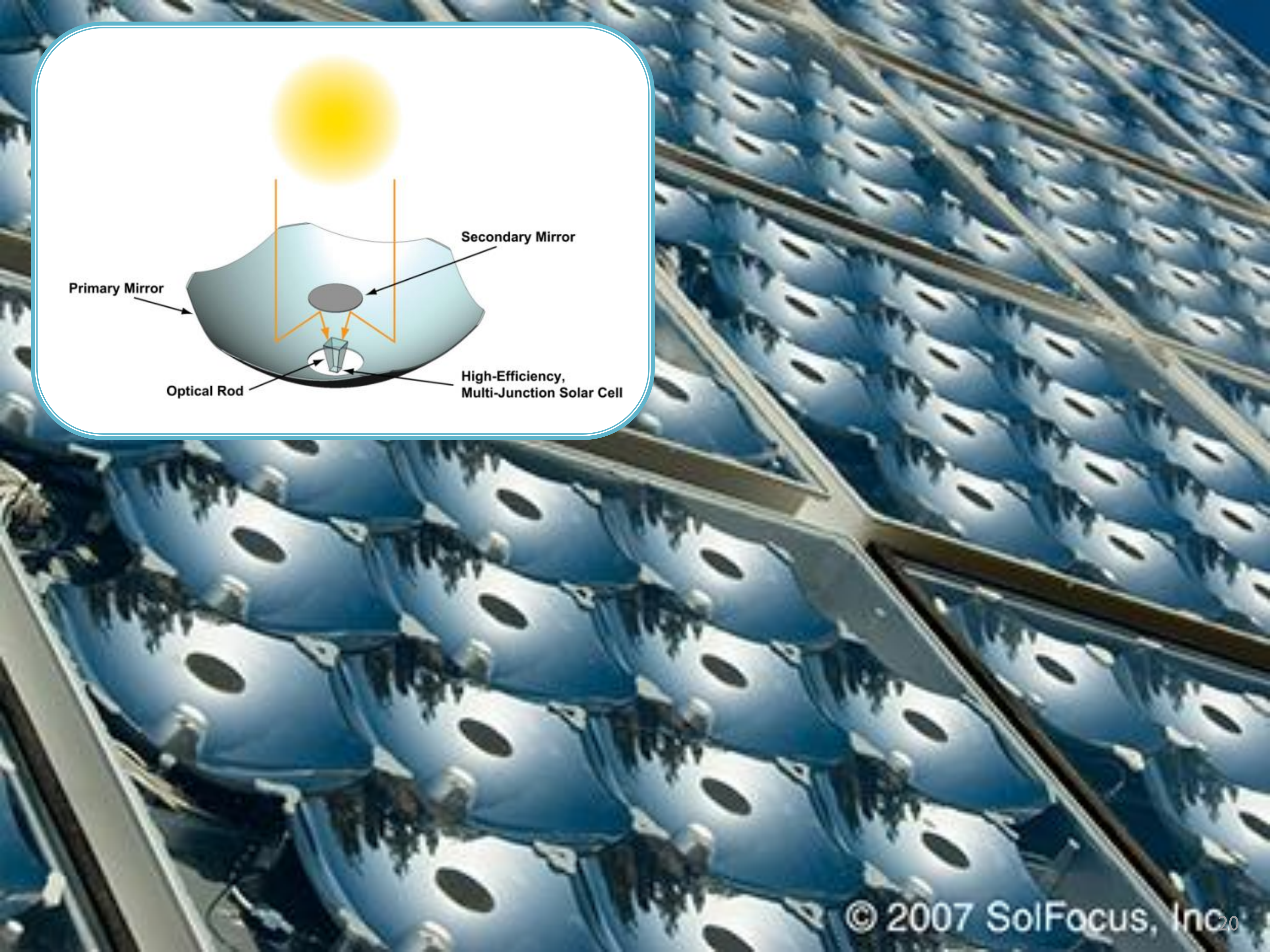


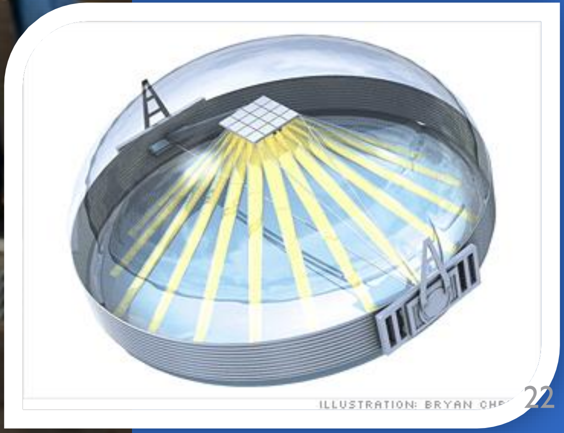

2 X V-trough
concentration
delta profile
PV module

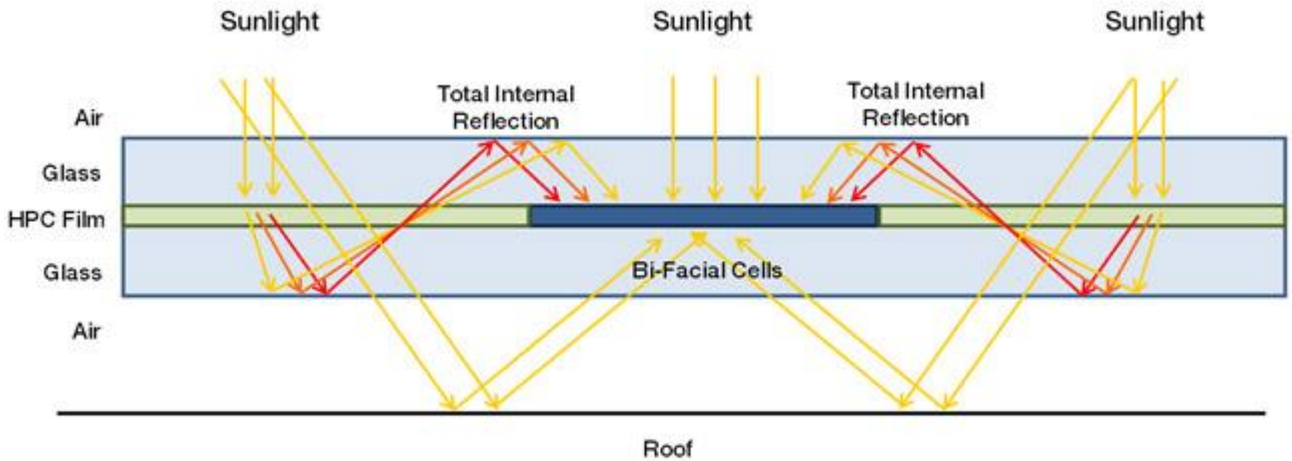


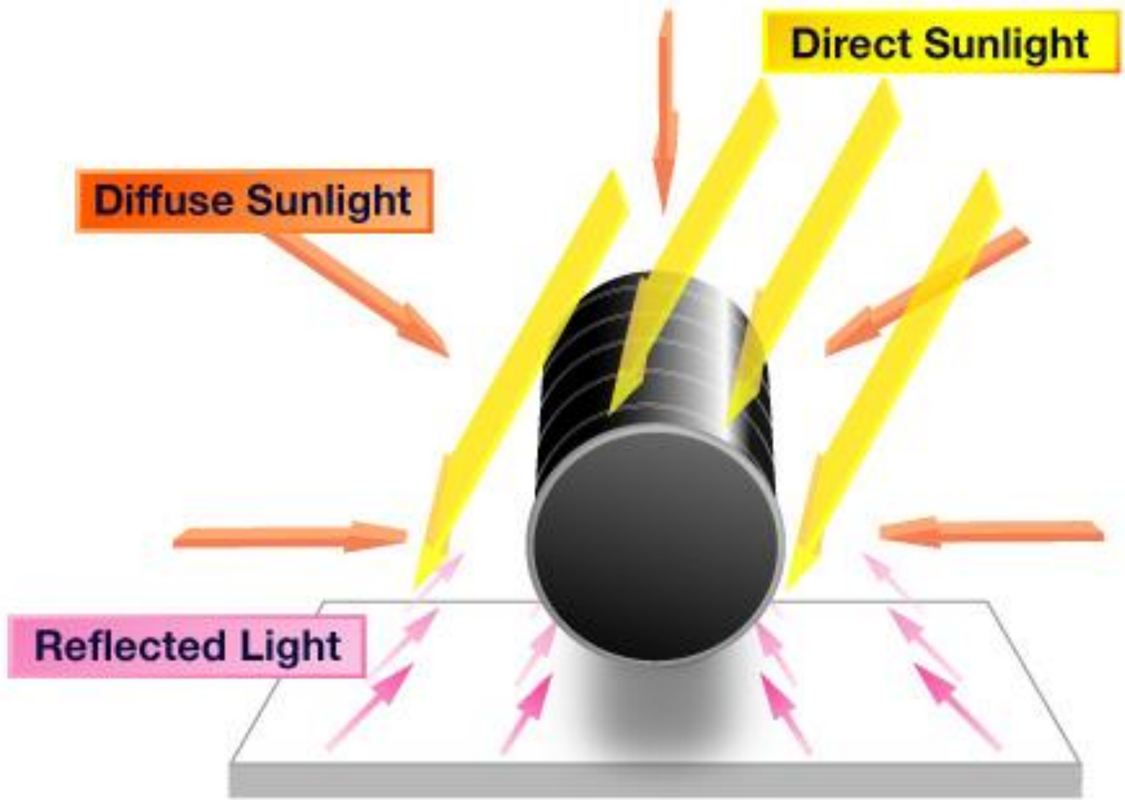
TRAXLE
SOLAR TRACKERS & RIDGE CONCENTRATORS
by POULEK SOLAR Co.Ltd.




© 2007 SolFocus, Inc.
Secondary Mirror
Primary Mirror
Optical Rod
High-Efficiency,
Multi-Junction Solar Cell



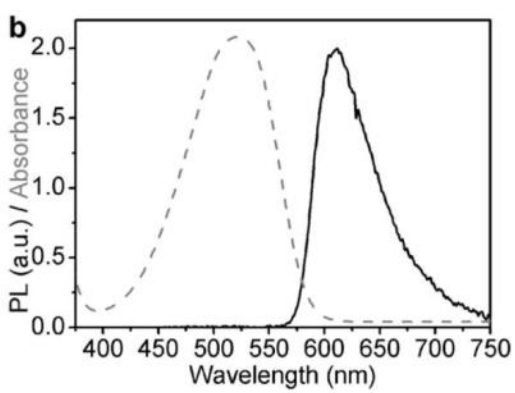

Sunlight
Sunlight
Sunlight
Total Internal Reflection
Total Internal Reflection
Air
Glass
HPC Film
Glass
Air
Bi-Facial Cells
Roof

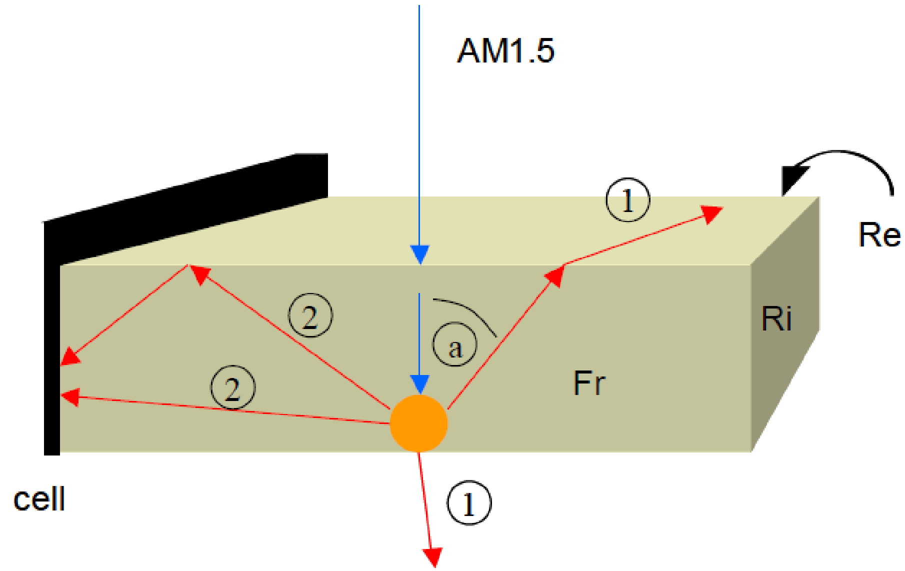

Direct Sunlight
Diffuse Sunlight
Reflected Light

CPV – CONCENTRATION PV

Luminescent concentrator

- Old idea A.Goetzbergeret *al*, Appl. Phys. 14, 123 (1977)
- Recently back to fashion M.Currie, Science 321, 226 (2008)
- (Potentially) low cost
- No tracking required
- Low efficiencies (<7%)
- Short lifetime (days)

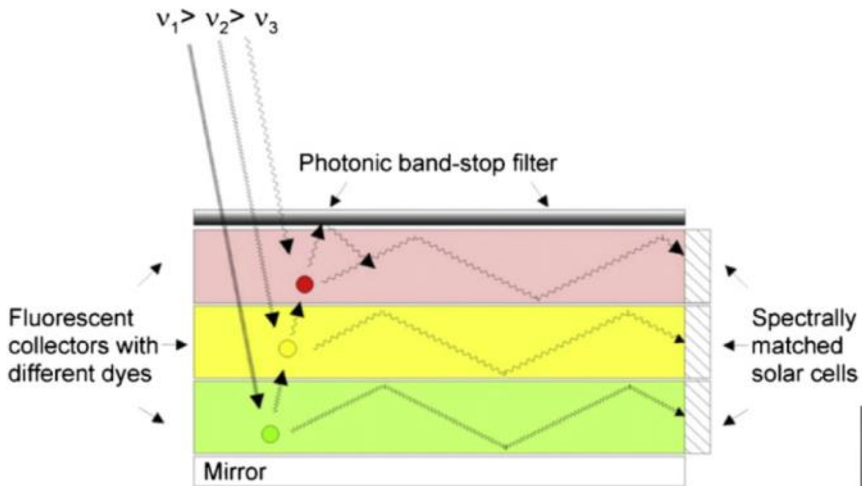




L.H. Sloof *et al, Luminescent concentrator: a bright idea for spectrum conversion?*, 20th Euopean PV Conference, Barcelona, 2005

CPV – CONCENTRATION PV

Luminescent concentrator



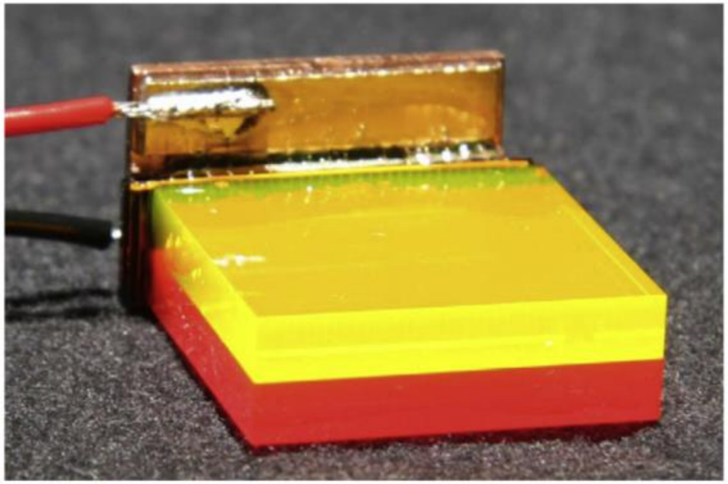


Fig. 4. A photograph of the described stack system before the remaining three solar cells were attached.

J.C. Goldschmidt *et al*, Increasingthe efficiency of fluorescent concentrator systems, Solar Energy Materials & Solar Cells 93 (2009) 176–182

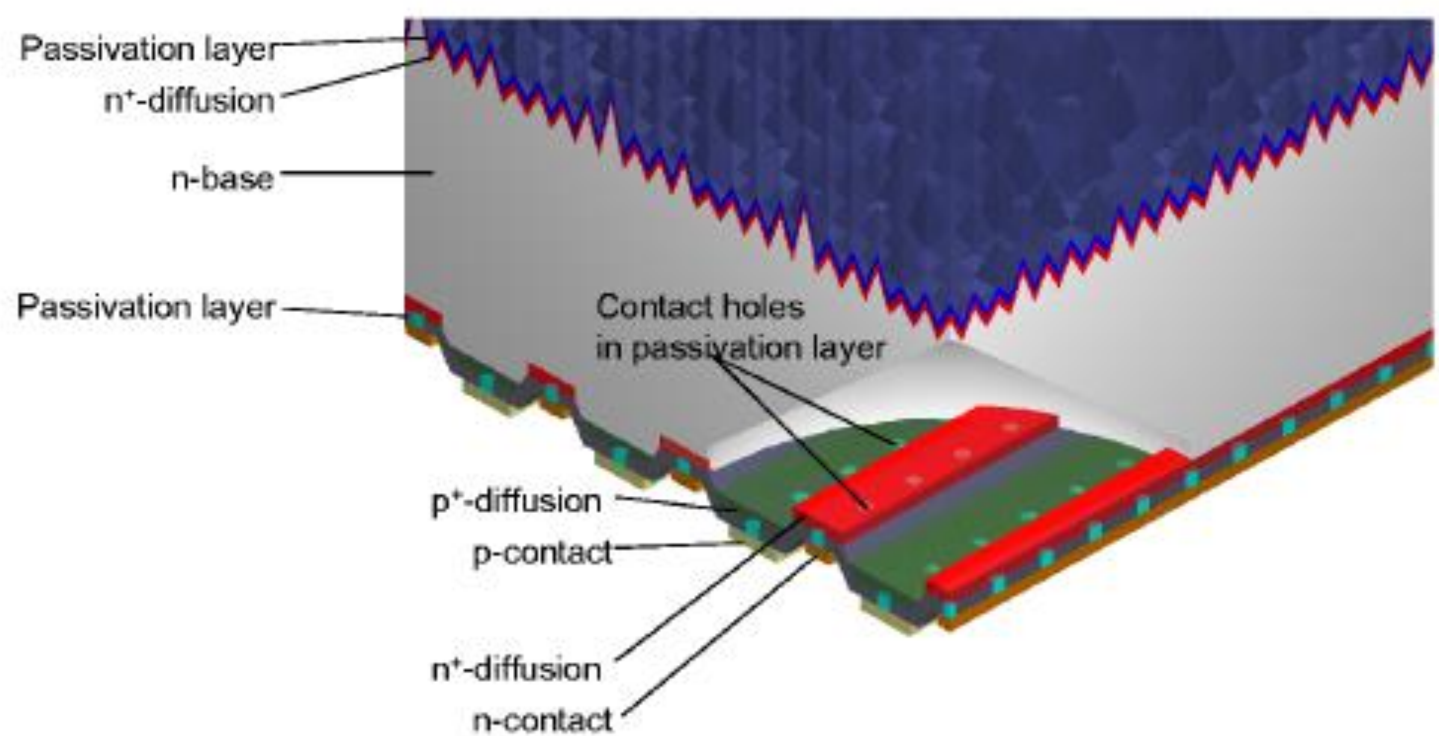
CPV – CONCENTRATION PV

High efficiency silicon solar cells

- High quality silicon: lifetime >> thickness
- Strong doping below contacts
  - To reduce contact resistance
  - To reduce recombination
- High quality surface passivation, textured surface & antireflective film
- Back contact or emitter wrap through
  - Increased thickness to reduce series resistance
  - Reduced thickness to increase area

CPV – CONCENTRATION PV

High efficiency silicon solar cells



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High efficiency multijunction solar cells

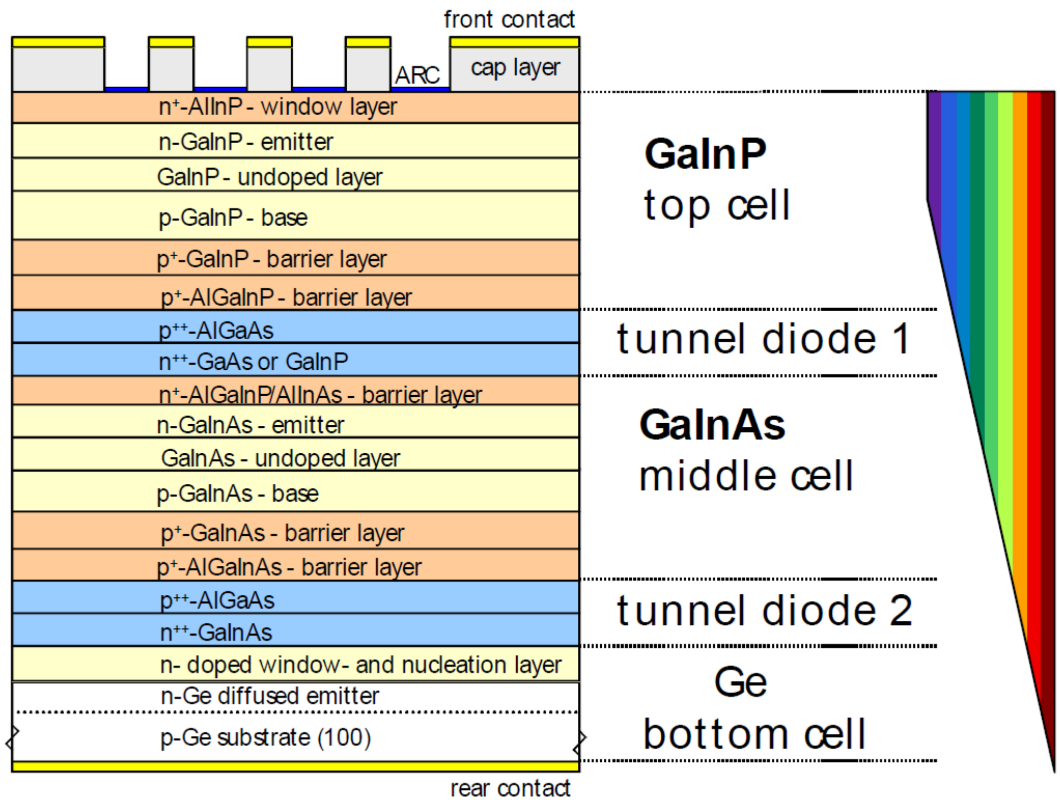
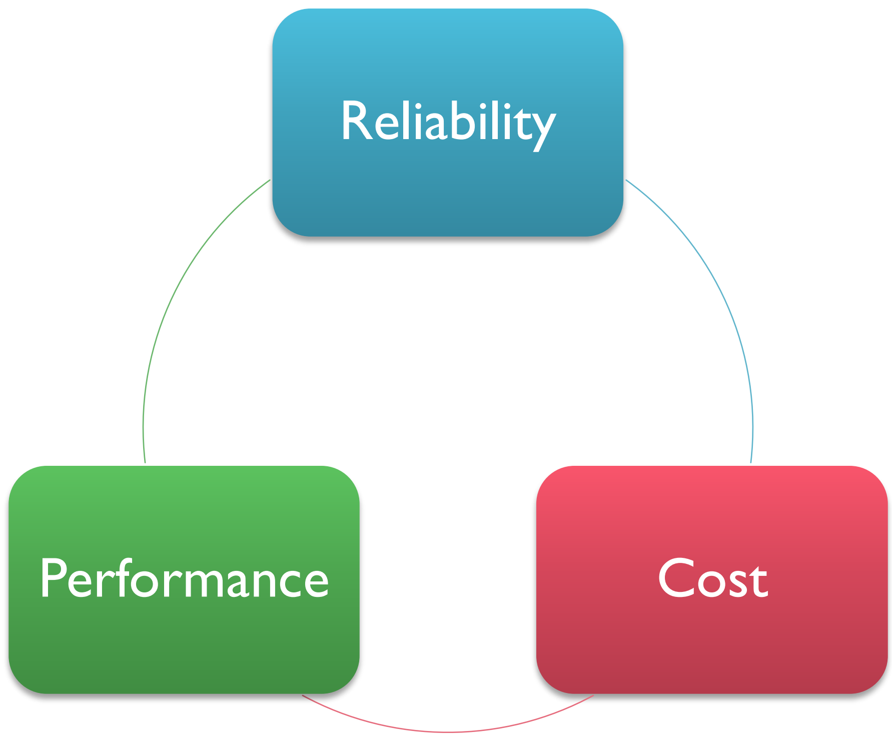


Figure 4-2: Schematic layer system of a GaInP/GaInAs/Ge triple solar cell on Ge substrate.

A. Bett *et al*, Concentration PV, in The Strategic Research Agenda (SRA), EU Photovoltaic Technology Platform, 2006

CPV – CONCENTRATION PV

So many options, what's the best CPV?



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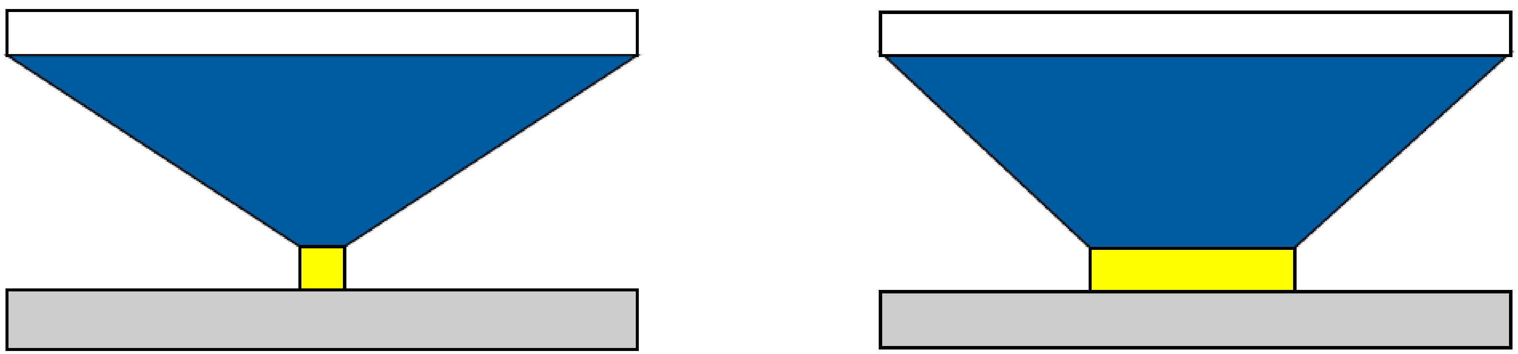
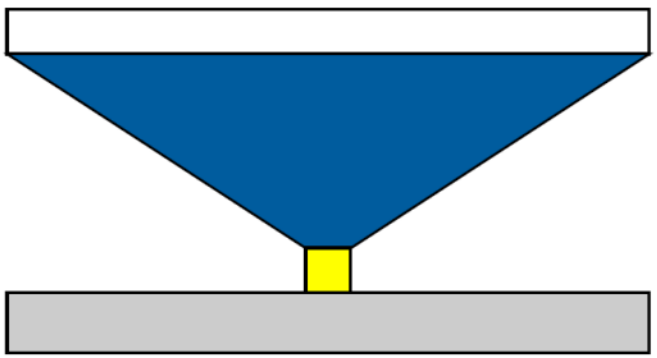


Choosing the 'right' concentration factor X

- Cost of rigid structure
- Cost of solar cell
- Efficiency of solar cell
- Alignment issues (wind, thermal expansion, assemply tolerance)

CPV – CONCENTRATION PV

So many options, what's the best CPV?



Large cells and optics

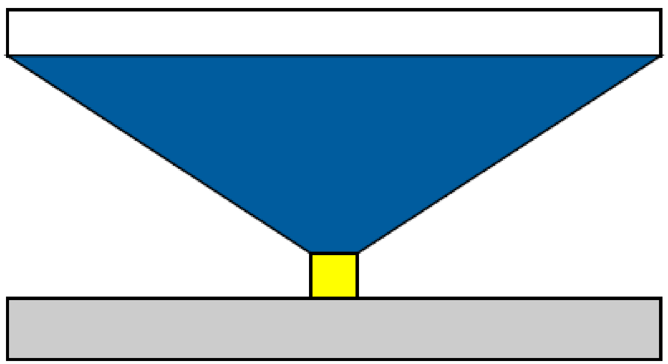
- ✓ Reduced part count
- ✓ Rigid structure
- ✓ Can use active cooling
- ✓ Modulairy can be advantage

Small cells and optics

- ✓ Reduced material cost
- ✓ Aesthetic appeal
- ✓ Heat is distributed
- ✓ Smaller current

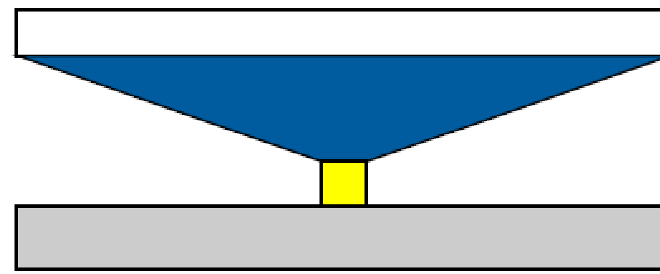
CPV – CONCENTRATION PV

So many options, what's the best CPV?



Higher f number

✓ Easier assembly (higher tolerance to misalignments)



Lower f number

✓ Reduced thickness
✓ Innovative and more appealing design

CPV – CONCENTRATION PV

So many options, what's the best CPV?

The jury is still out…

Time will tell which one is best, if any.