Micro-optics, principles and architectures

Guido Vallerotto

Instituto de Energía Solar, Universidad Politécnica de Madrid, Madrid (SPAIN)

POLITÉCNICA

INSTITUTO
DE ENERGÍA
SOLAR

Content

- Introduction to micro-concentrator photovoltaic (μCPV)
- Optical systems in μCPV: advantages and challenges
- Integrated tracking
- Insolight case: double convex concentrating lens
- Ray-tracing demonstration of integrated tracking
- Conclusions

Micro-concentrator photovoltaic (μCPV)

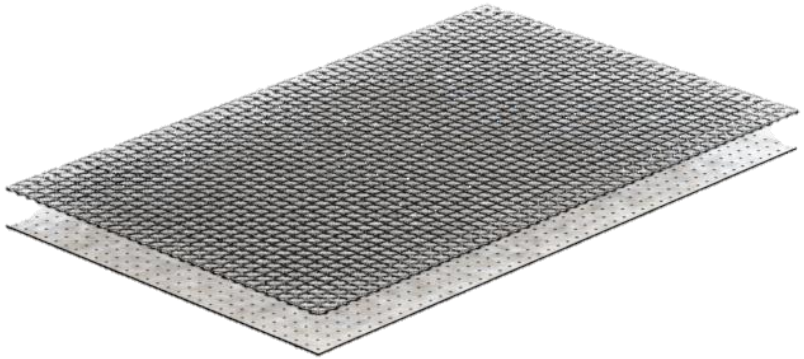
μCPV ⟶ Solar cell size < 1 mm^2

The size of all the other components reduce accordingly

Same shape factor than conventional flat PV modules

- Bulkiness reduction – weight and volume
- Temperature control improved
- Lower current → series resistance losses reduced

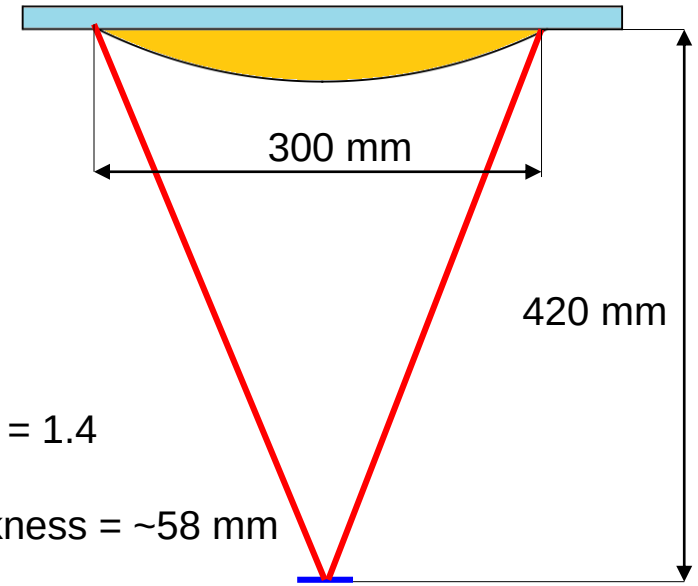
- Manipulation and interconnection of thousands of elements per m^2
- The optical alignment of different stages with micrometric precision



Optical systems in µCPV

- Reduced dimension allows for aspheric profile

Conventional CPV

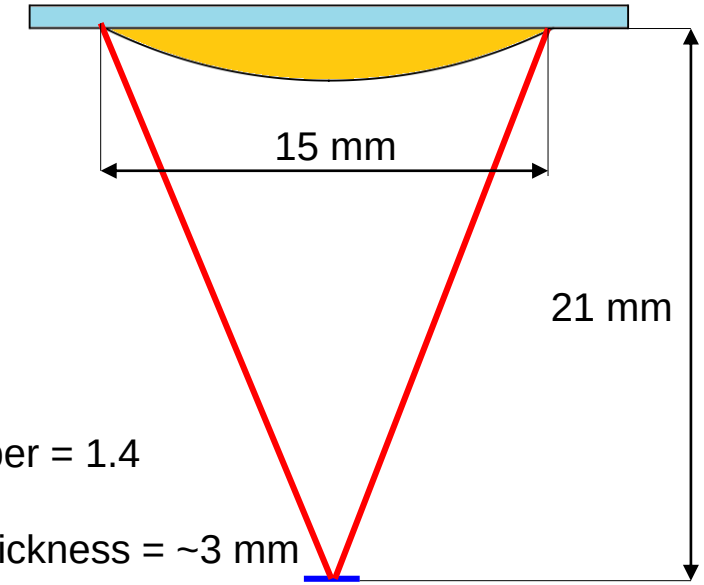


F-number = 1.4

Lens thickness = ~58 mm

Require Frenselization → Additional losses for draft angles and tips rounding

Micro-CPV



F-number = 1.4

Lens thickness = ~3 mm

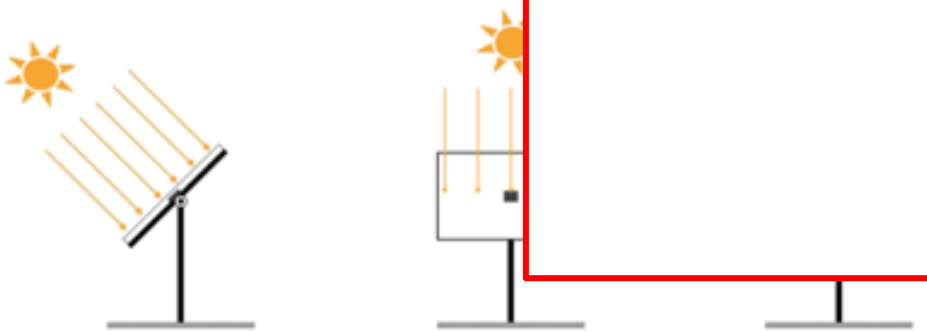
Does not require Frenselization → low absorption and no additional losses for draft angles and tips rounding

Integrated tracking

Conventional CPV

Design method: maximize the concentration capability when the collimated light reaches the lens perpendicularly to the lens aperture

Requires tracking to m
along the day

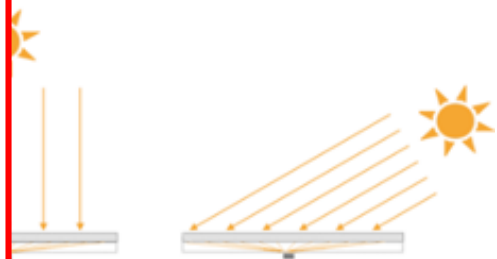


AOI = 0° AOI = 0° AOI = 0°

The external tracker place the CPV module always perpendicular to the sunrays

Micro-CPV with integrated tracking

Design method: maximize the angular tolerance of the lens defined as the capability of concentrating the light in a point focus when
eaches the lens with a
incidence (AOI)



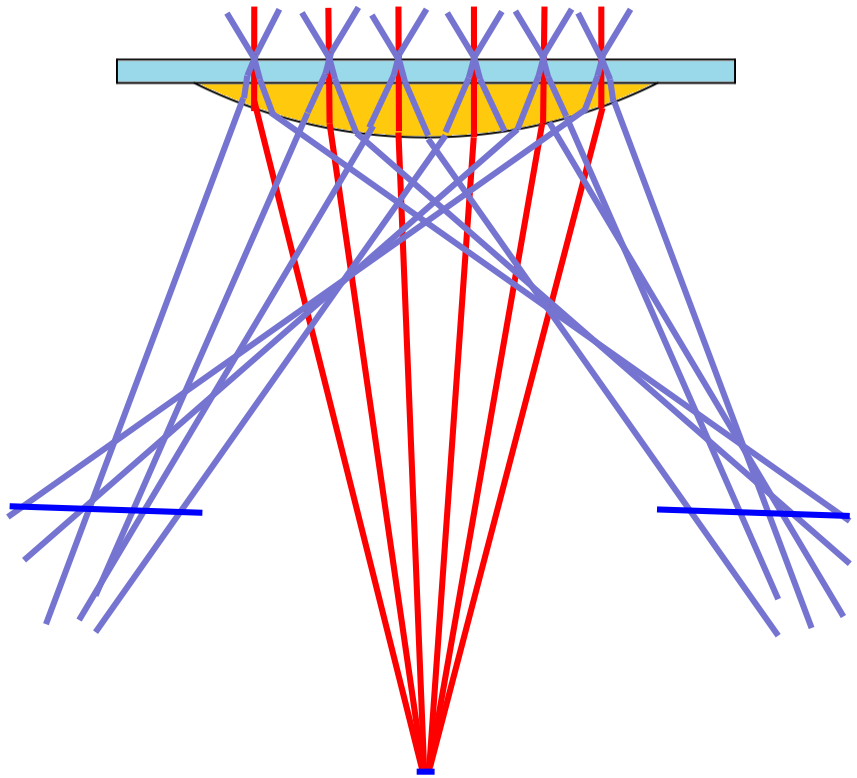
0° AOI >> 0°

The internal tracker place the solar cells in the position where the optics is projecting the light spot

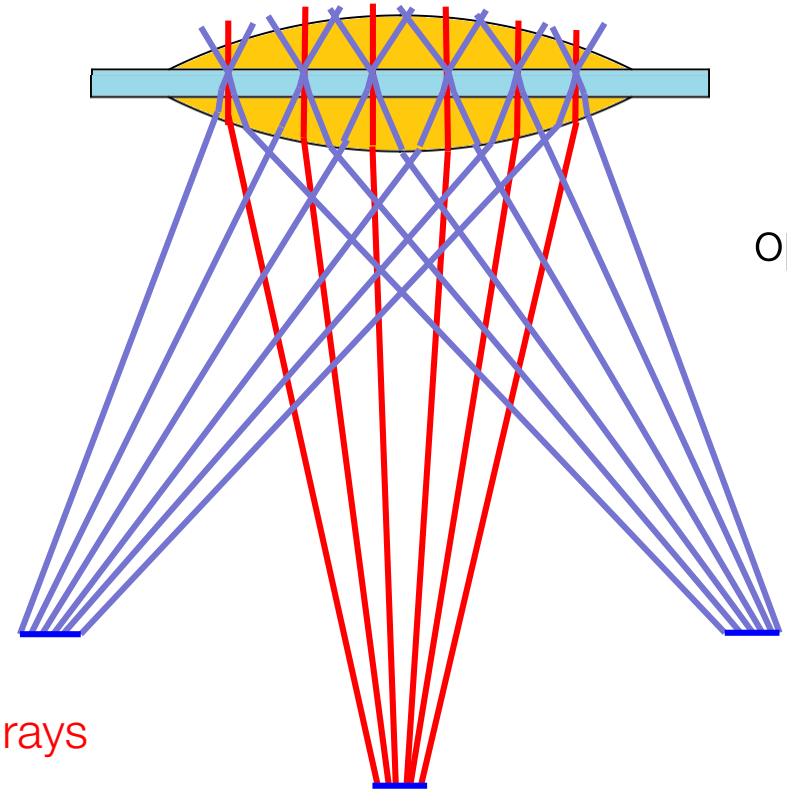
Possible to work in fixed tilt position!

Integrated tracking

Conventional CPV lens



CPV lens designed for integrated tracking



Minimum 2 optical surfaces

On-axis rays

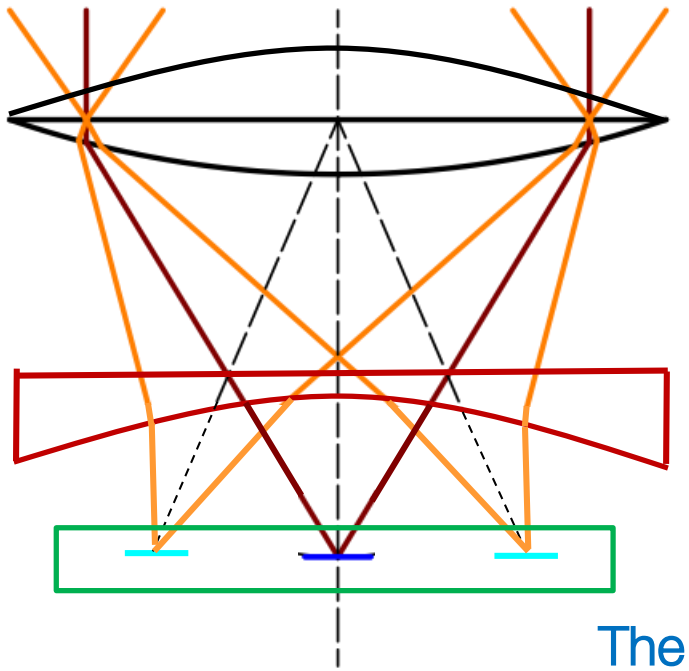
Off-axis rays

High concentration on-axis (AOI = 0°)
Completely uncontrolled off-axis (AOI ≠ 0°)

Lower concentration on-axis (AOI = 0°)
Same concentration off-axis (AOI ≠ 0°)

Integrated tracking

Adding a third optical surface may provide **PLANAR** tracking

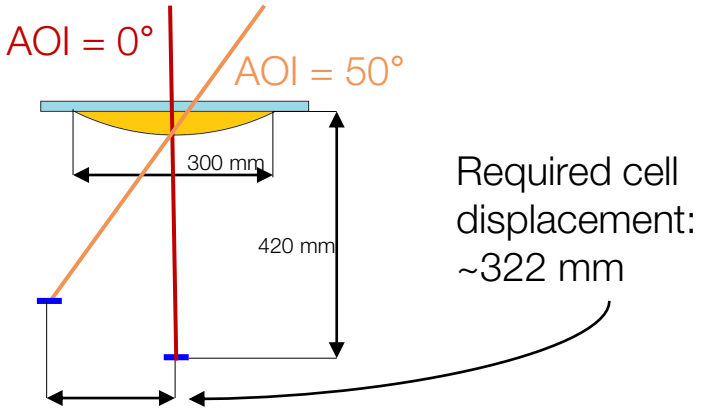


On-axis rays
Off-axis rays

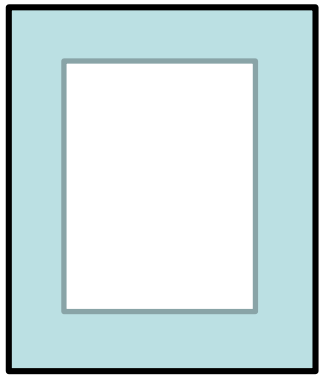
Cell position on-axis
Cell position off-axis

The spot follows a quasi-circular trajectory

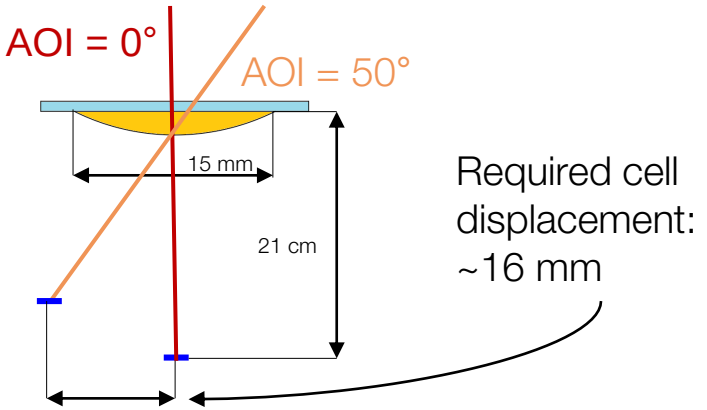
Conventional CPV



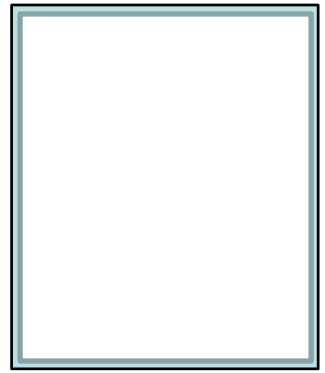
Required cell displacement: ~322 mm



Micro-CPV

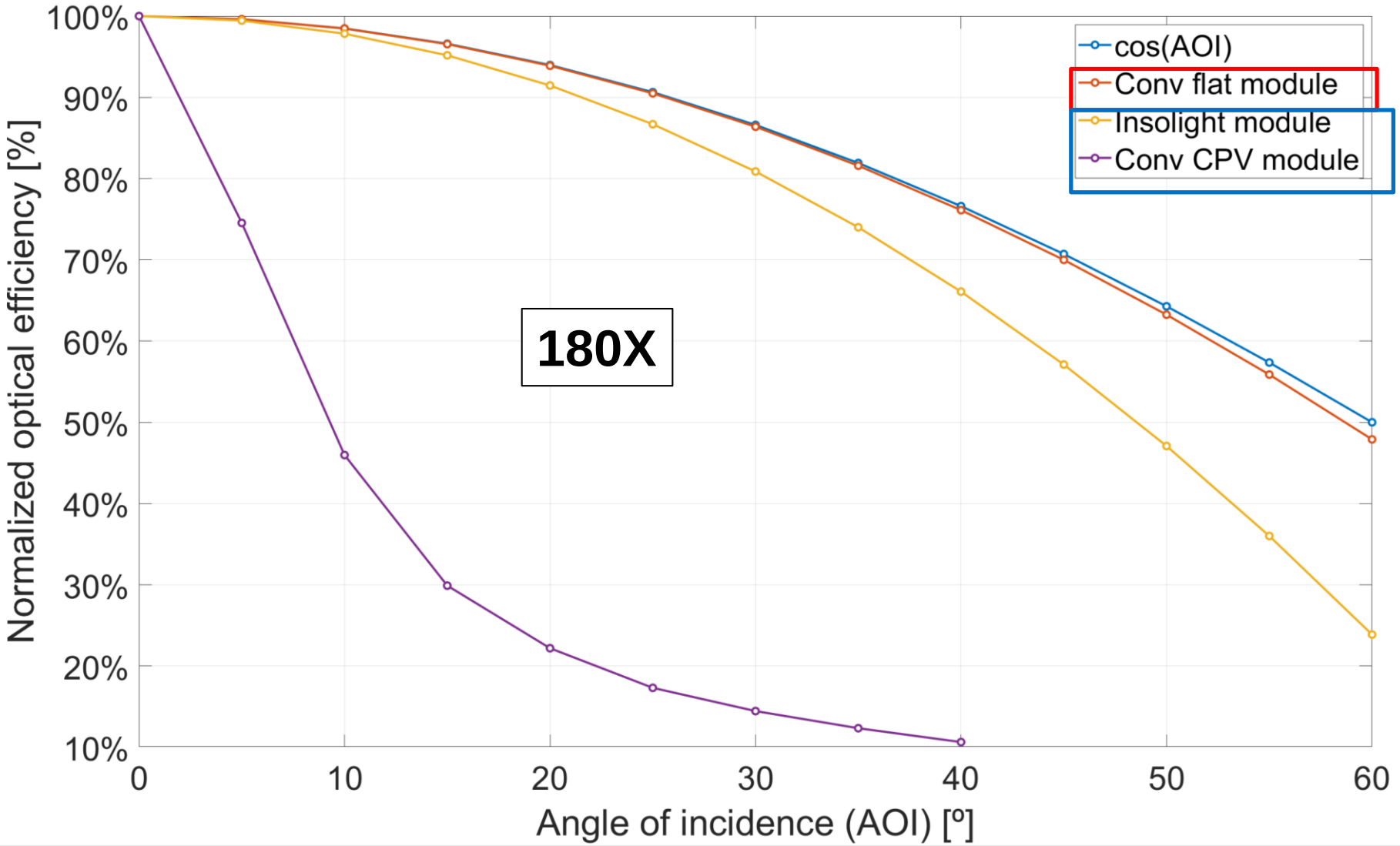


Required cell displacement: ~16 mm



Lost area

Integrated tracking



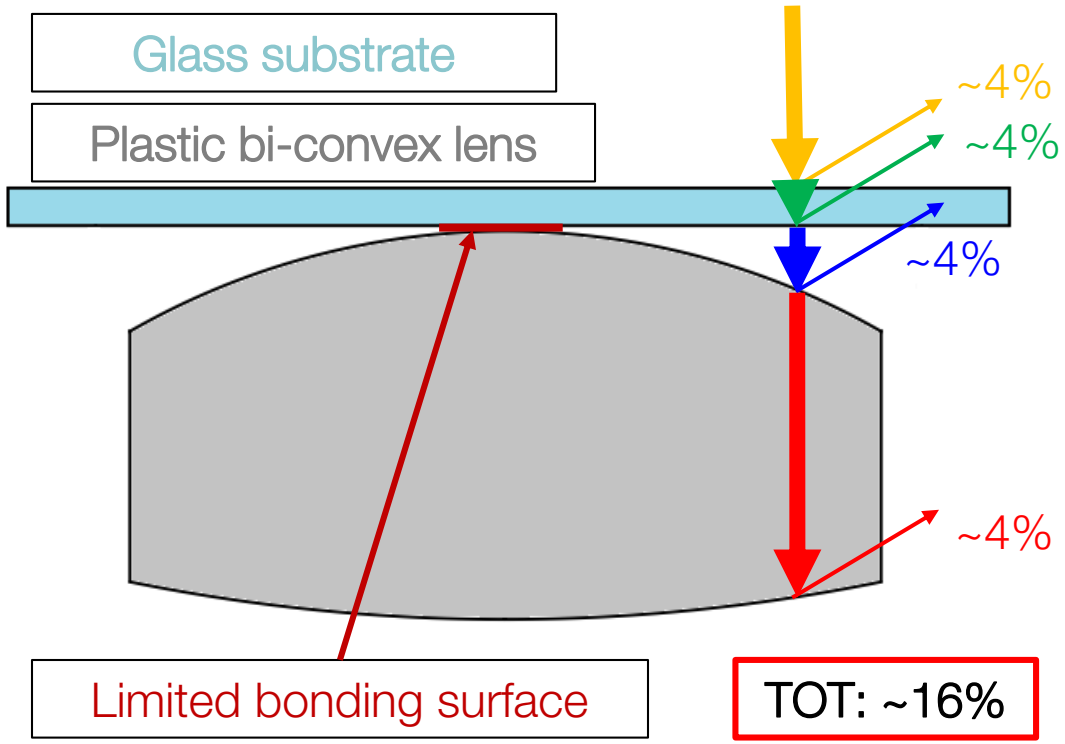
$$IAM = \frac{1 - \exp\left(\frac{-\cos(AOI)}{a_r}\right)}{1 - \exp\left(\frac{-1}{a_r}\right)}$$

Martin and Ruiz incident angle model

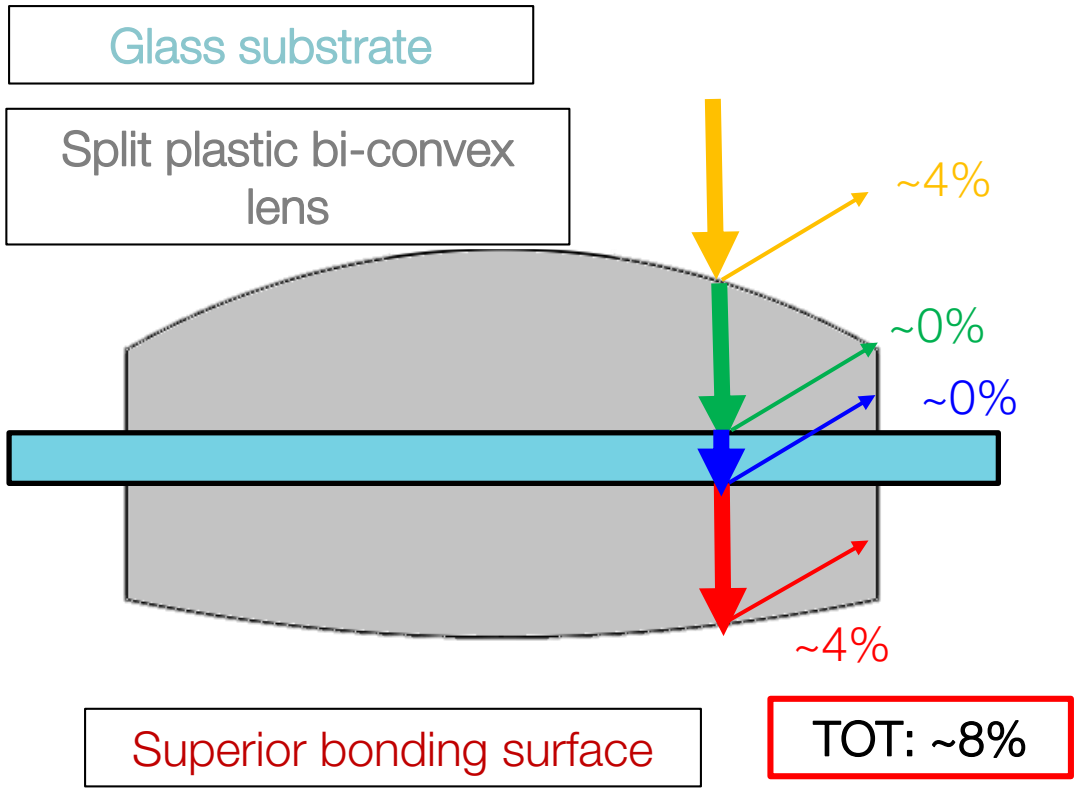
Ray-tracing simulation results

Insolight case

Hiperion design GEN0-1



Hiperion design GEN2



Conclusions

- μCPV has the potential to increase the efficiency and to reduce the costs of the system
- The reduced system (and components) size allows the implementation of integrated tracking system:
  - μCPV modules with integrated tracking may work at fixed tilt condition maintaining the high efficiency proper of modern MJ solar cell
  - Reduced dimensions allows to manufacture modules with the same shape factor of conventional flat PV modules
- HIPERION optics angular performance is close to the ideal cosine-like response of a flat module in the range of $0° \leq AOI \leq 50°$
- More complex optical systems have the potential to further extend the tracking range of the optics.

Workshop on HIPERION hybrid CPV/PV modules pilot installations at UPM and Fraunhofer ISE

Maximizing energy yield in space-constrained PV applications

POLITÉCNICA

INSTITUTO DE ENERGÍA SOLAR

Fraunhofer ISE

insolight

csem