

# High-efficiency planar-tracking concentrator photovoltaic modules with hybrid direct/diffuse light collection for rooftop installations



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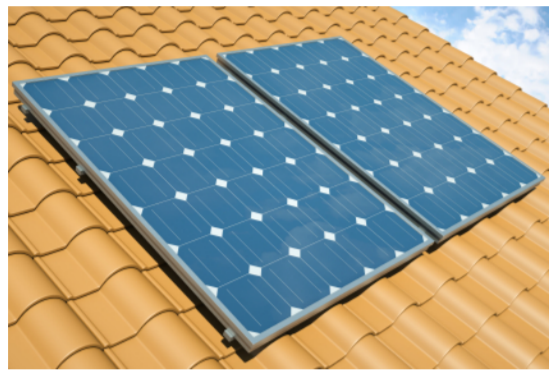
POLITÉCNICA



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## Challenges of the PV industry

- Weak market penetration: only 1% of world electricity
- No more leverage on decreasing costs (dominated by installation costs)
- Limited efficiency of current technologies: reaching their max at 22%



- SIMPLE & RELIABLE
- DIRECT + DIFFUSE LIGHT
- ROOFTOP & UTILITY
- LOW EFFICIENCY ( $\approx 20\%$ )

## Concentrated PV : hasn't lived up to its promises

- Reaching 41.4 % efficiency at the module level [1]
- Expensive dual axis tracking, large footprint
- Limited to localizations with high content of direct light (DNI)



- HIGH EFFICIENCY ( $>30\%$ )
- ONLY DIRECT LIGHT
- COMPLEXITY & COST
- UTILITY-SCALE ONLY

## This project: Hybrid Si/III-V with planar micro-tracking

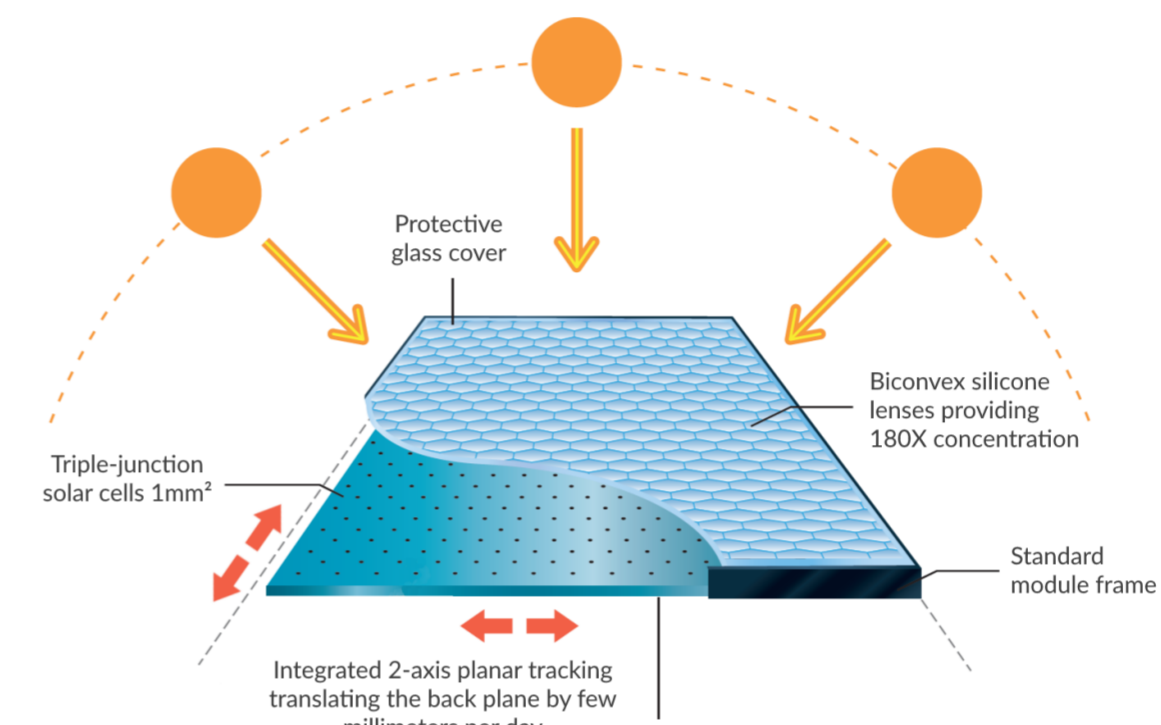
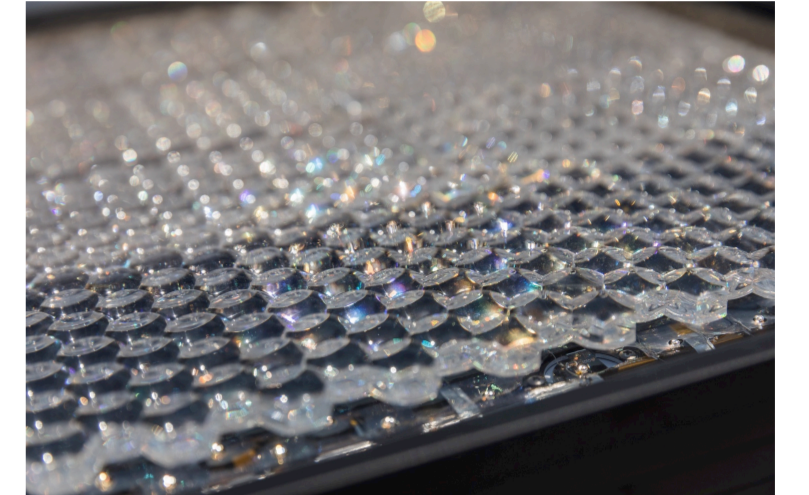
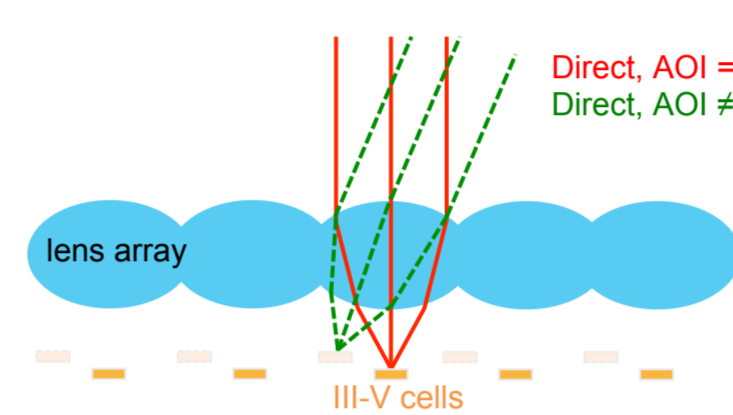
- Micro-tracking integrated in the module (fixed-tilt)
- Compatible with rooftop installations (high market value)
- Si/III-V architecture combines the capture of direct and diffuse sunlight



- HIGH EFFICIENCY ( $\sim 30\%$ )
- DIRECT + DIFFUSE LIGHT
- PLANAR TRACKING
- ROOFTOP & UTILITY

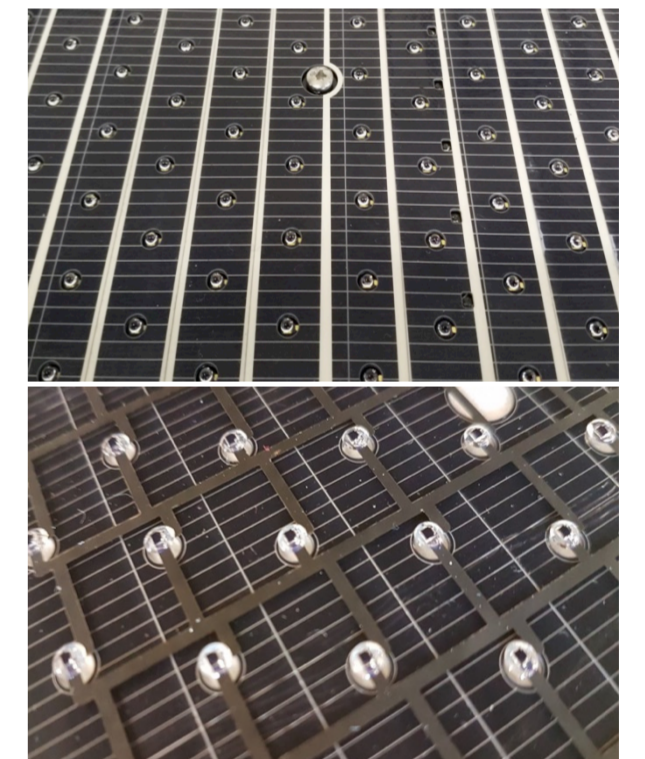
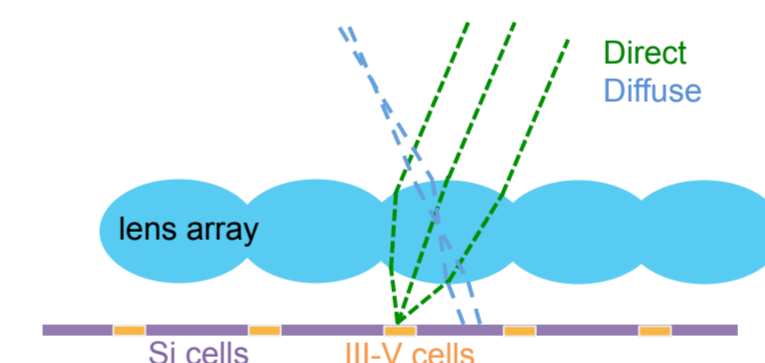
## Planar micro-tracking : principles

- Focusing sunlight on high-efficiency cells (concentration factor  $\sim 180$ )
- Fixed-tilt module with integrated 2-axis tracking mechanism



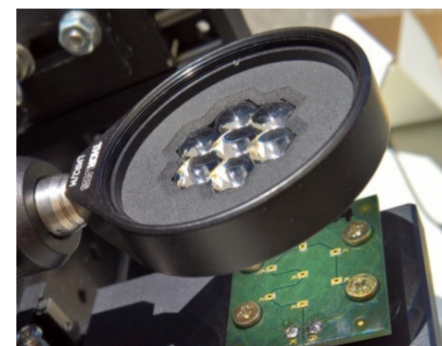
## Hybrid Si/III-V architecture

- High efficiency III-V cells capture direct sunlight (concentrated)
- Low-cost Si cells capture diffuse sunlight (transmitted)
- Two architectures evaluated:
  - Si cells with holes
  - III-V cells on a glass substrate



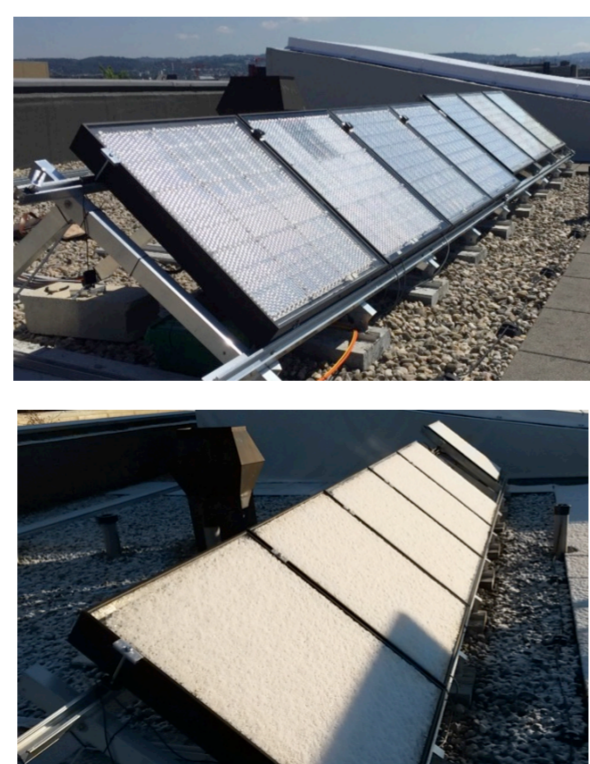
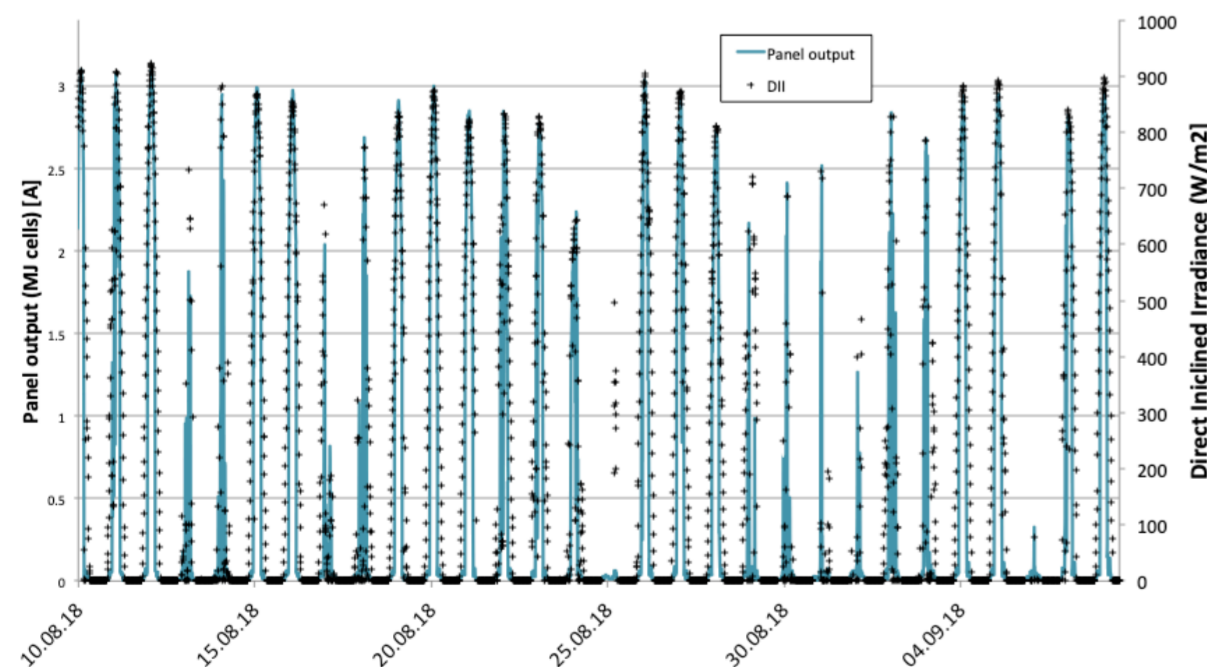
## Laboratory prototype performance (2016)

- 7-lens array prototype focusing on  $0.6 \times 0.6 \text{ mm}^2$  InGaP/GaAs/InGaAsNSb multi-junction cells [2][3]
- **36.4 % peak efficiency** vs direct sunlight in outdoor measurements (Freiburg / Germany)
- Validated over AOIs of  $\pm 40^\circ$



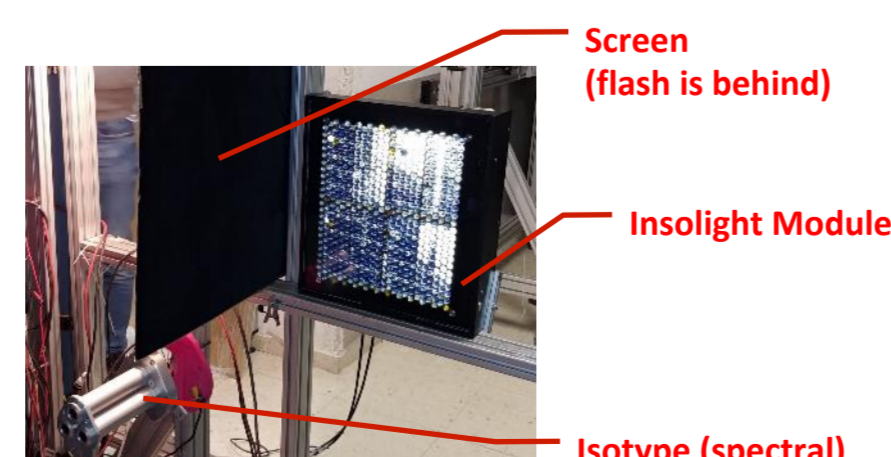
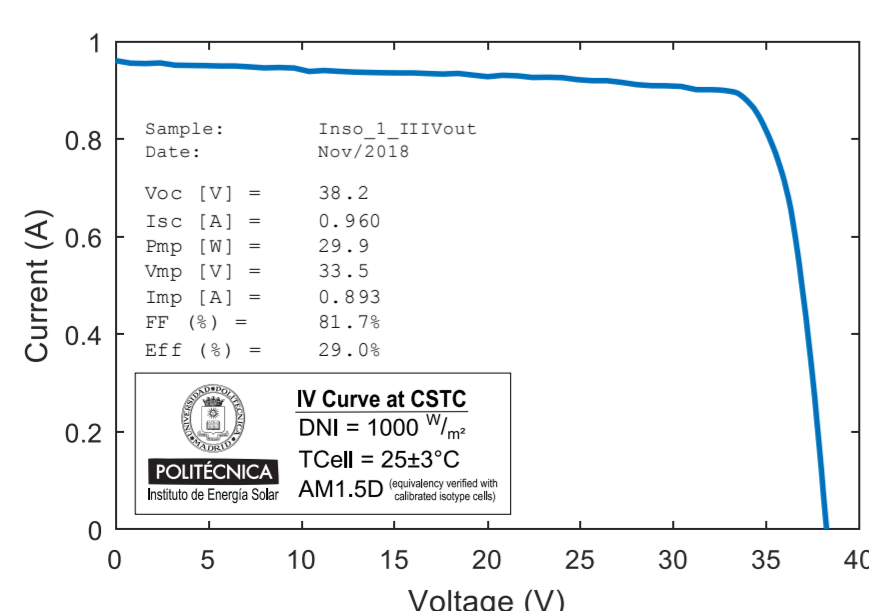
## Pilot site

- Functional  $0.4 \text{ m}^2$  modules, connected to the grid
- Continuous operation and data logging since Dec. 2017
- Validation of tracking mechanism
- Robust conversion of direct irradiance

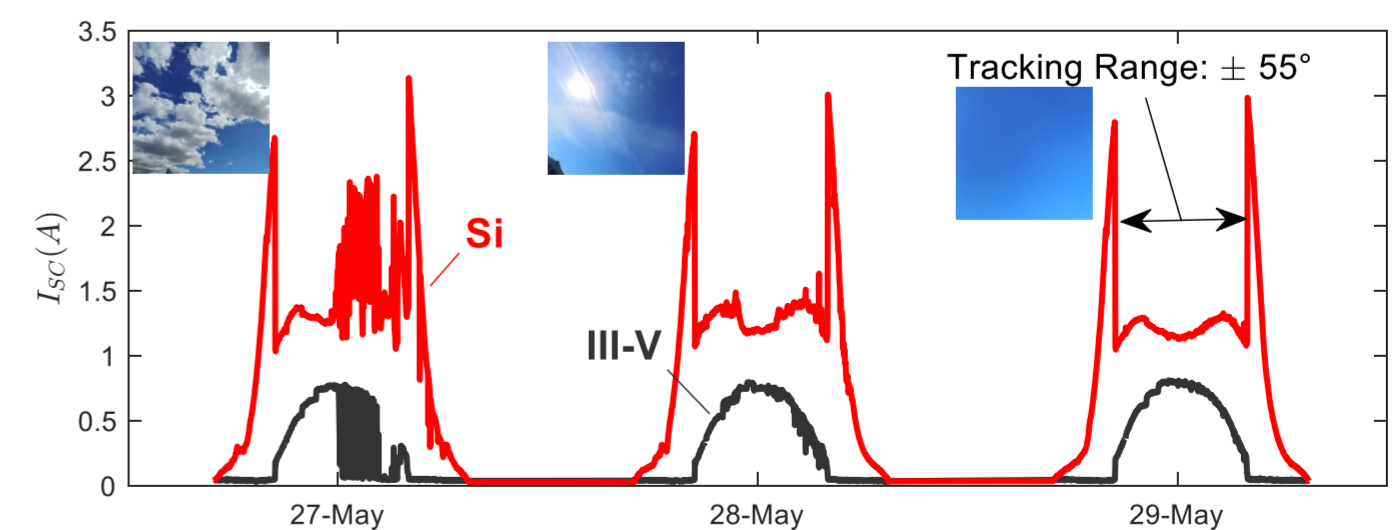
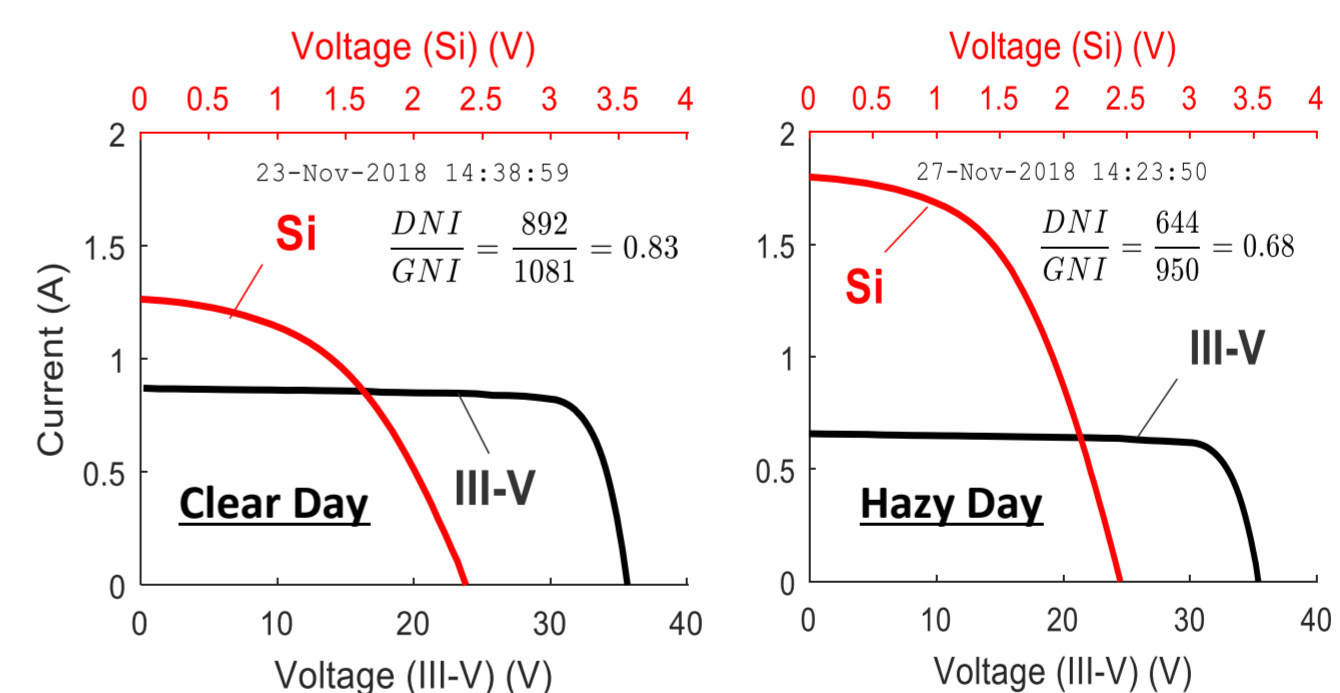


## Module performance (2018)

- Measured on a  $0.1 \text{ m}^2$  module ( $574 \text{ GaInP/GaInAs/Ge } 1 \text{ mm}^2$  cells)
- **29.0 % efficiency** vs direct sunlight (indoor measurement @ C-STC) [3][4]



## Outdoor measurement campaign on-going in Madrid [4]



## Perspectives

- The Swiss start-up Insolight is working on the commercialization of the planar micro-tracking hybrid systems
- A pilot production line is funded (H2020 – HIPERION project)

- [1] Fraunhofer ISE, "Concentrator Photovoltaics Shows Peak Performance – Module Efficiency Reaches 41.4 %." (2018).
- [2] E. Chinello, *et al.*, Global Challenges 1, 1700095 (2017).
- [3] G. Nardin *et al.*, AIP Conference Proceedings 2149, 040001 (2019).
- [4] S. Askins *et al.*, IEEE-PVSC 46 (2019).

