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Design and Fabrication of Ultra-High Efficiency Hybrid Solar Modules based on CPV Micro-Tracking System

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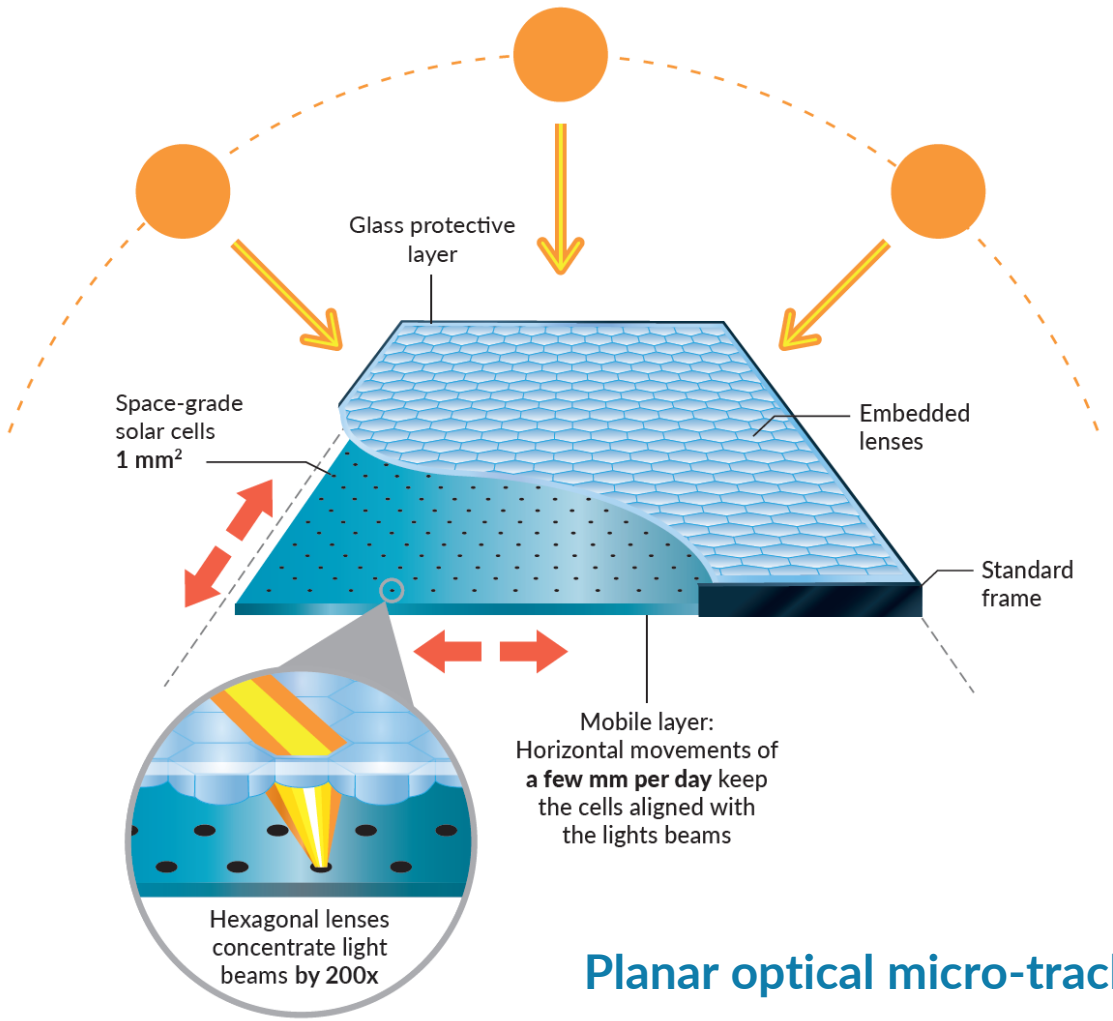
Insolight's Photovoltaic System

insolight



Planar optical micro-tracking

- Sunlight is **concentrated** on an array of highly efficient micro solar cells (multi-junctions)
- **Integrated** micro-tracking (module not moving)
- Standard **flat panel** form factor mountable on any racks or rooftops

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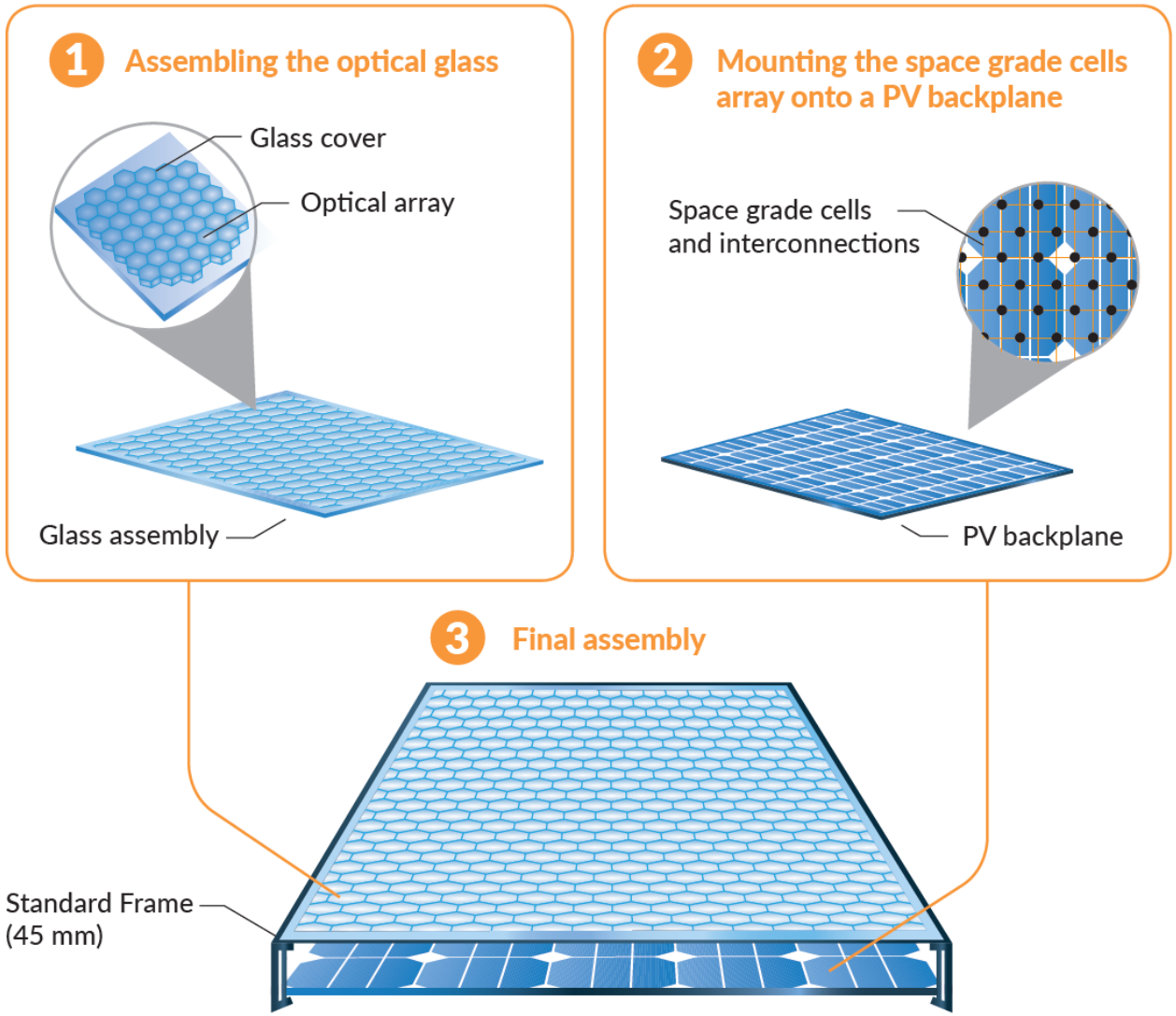
Hiperion Module Fabrication



- Multi-junction cells assembled on the transparent PCB, mounted on a conventional c-Si panel to form the **hybrid backplane**
- Assembly of the lens array with the front glass form the **optical layer**
- Framed to form **flat & static** solar PV module
- Innovative **architecture** to reach <30% efficiency under **direct** light while still harvesting **diffuse** sunlight

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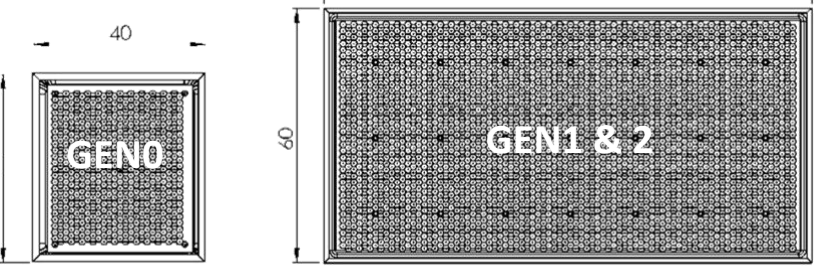
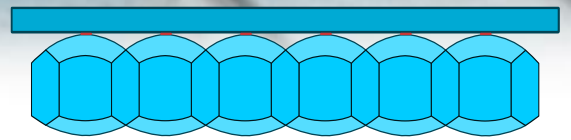
From GEN0 to GEN2

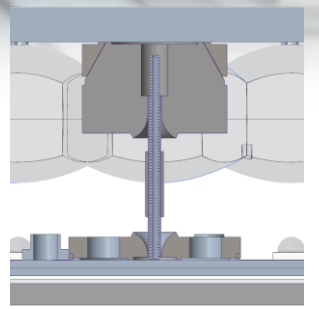


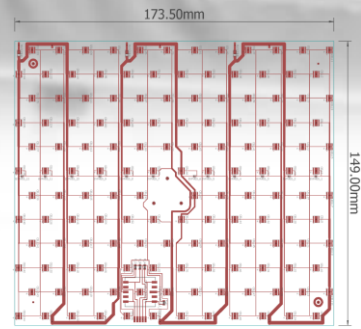
GEN1



Biconvex optics glued underneath glass

Guiding elements & actuators are **glued**

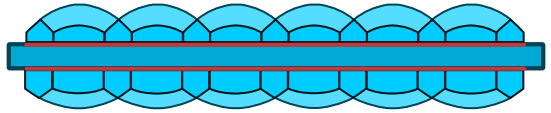




21 x

Assembled PCBs (silver)

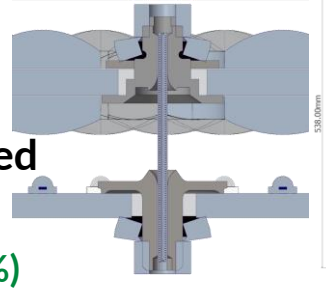
GEN2

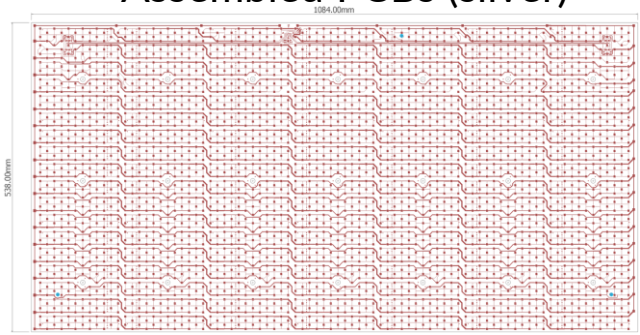


Plano-convex arrays around the glass

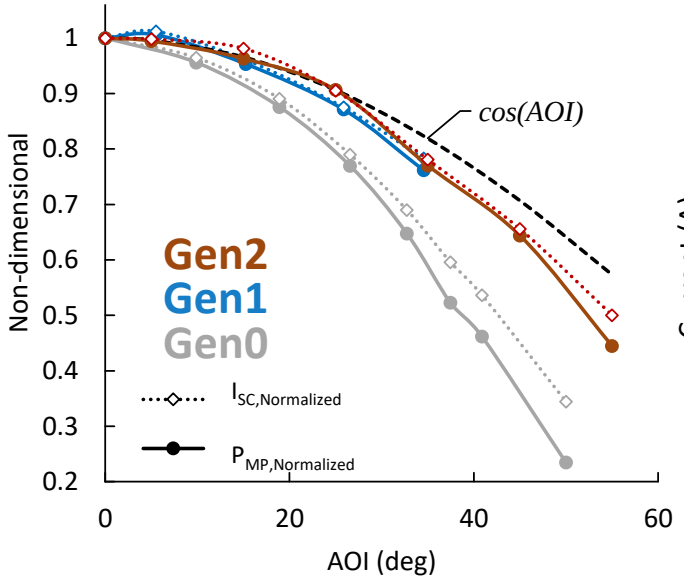
Guiding elements & actuators are **screwed**

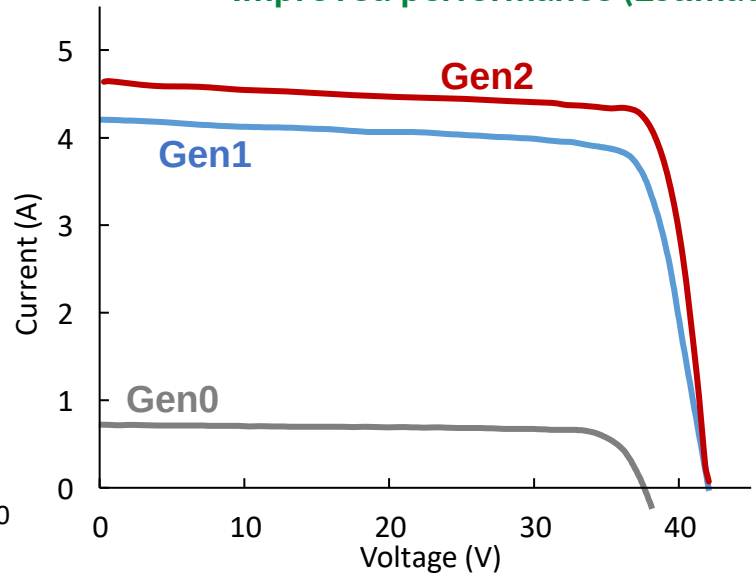
- ✓ **Improved reliability (adhesive area incr.)**
- ✓ **Improved performance (Estimated 8-15%)**





Monolithic PCB (copper)





	Gen0
V_{OC} [V]	38.2
I_{SC} [A]	0.96
P_{MP} [W]	29.9
V_{MP} [V]	33.5
I_{MP} [A]	0.89
FF [%]	82%
Eff. [%}	29.0%

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Assembly process in-depth review

Hiperion Partners:

Raw glass

Metallization

Transparent PCB

SMD package Cells

Pick and place

Monolithic PCB

Back glass

Si Cells

Monolithic + Si Cells lamination

FLASH TEST CHARACTERIZATION

Back plane Assembly

Guiding Elements

PMMA

Lenses Injection

PMMA Lenses

AR Glass

Optics Assembly

Mating

Frame

Frame Assembly

Junction Box + Cables

Actuators

Actuators Assembly

Final Module

FLASH TEST CHARACTERIZATION

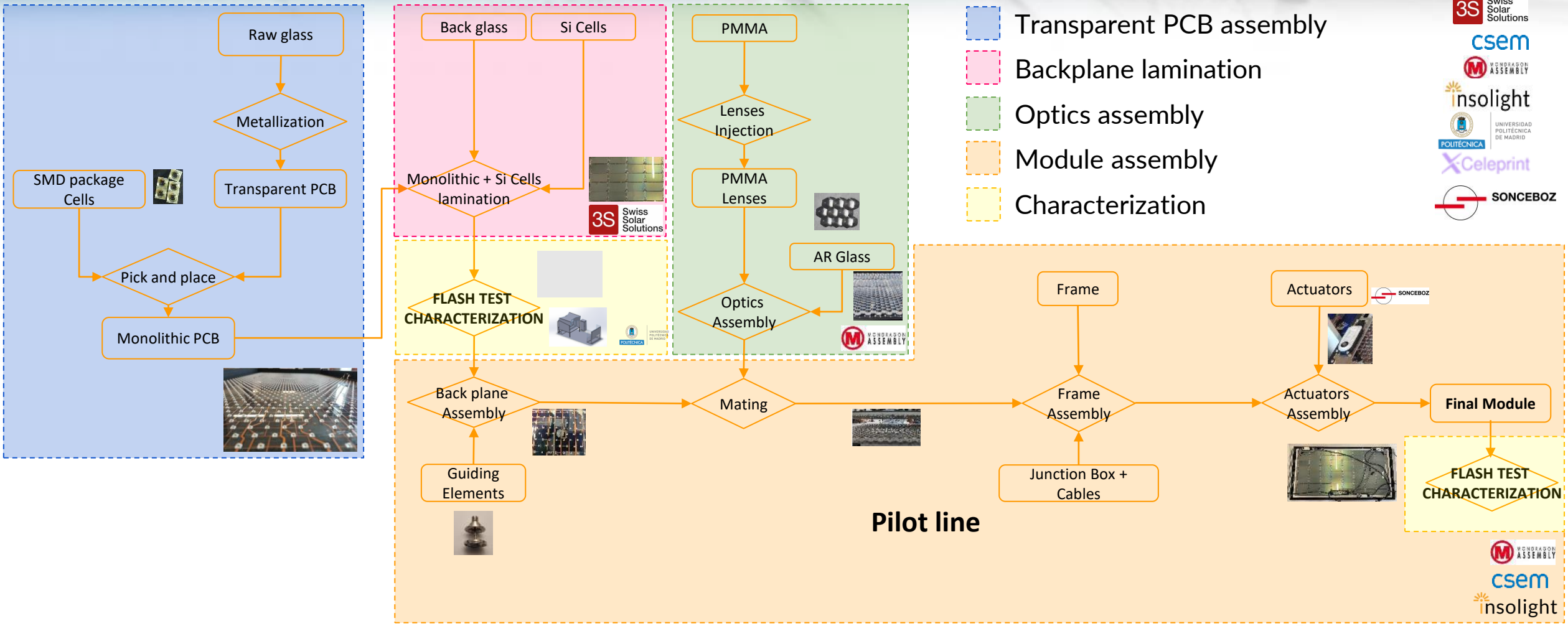
Pilot line

Assembly process in-depth review

Hiperion Partners:

Argotech, Swiss Solar Solutions, csem, Mondragon Assembly, insolight, Universidad Politécnica de Madrid, Celeprint, Sonceboz

Transparent PCB assembly
Backplane lamination
Optics assembly
Module assembly
Characterization



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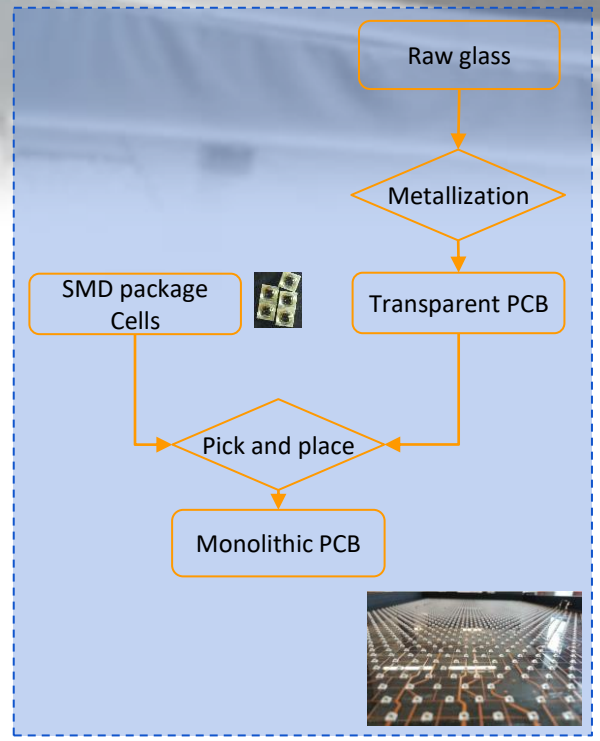
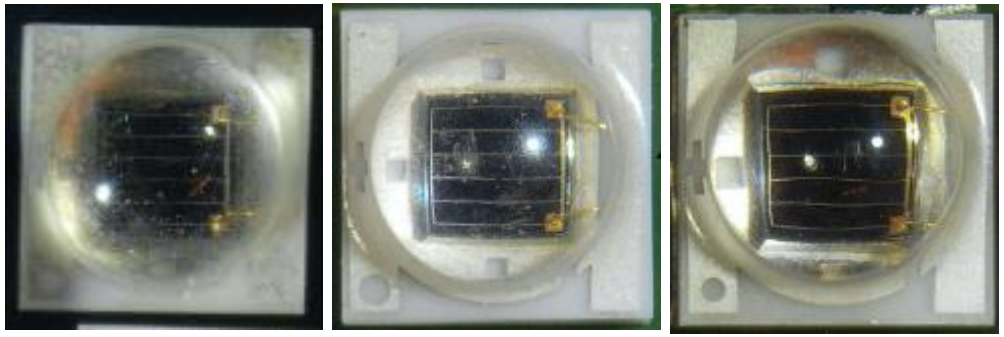
Transparent PCB to harvest direct sunlight

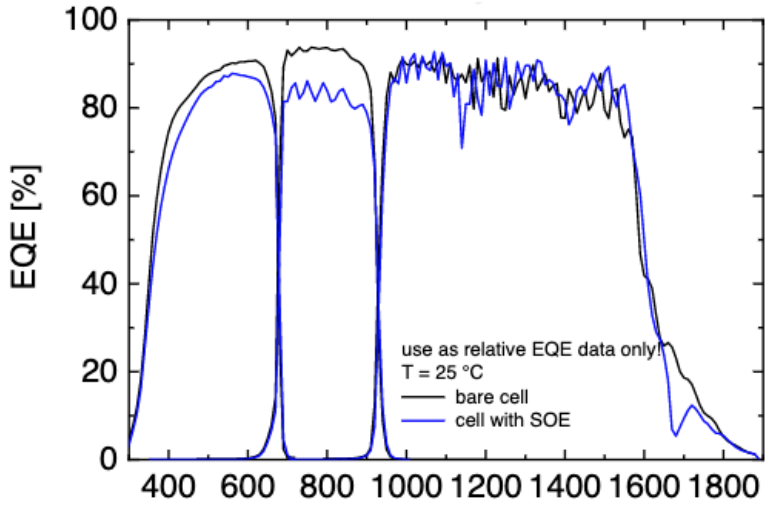


- Commercial space grade triple-junction cells in a standard LED SMD package (43% @180 suns, 25°C)

+ 5% performance in outdoor measurement (less defective SOE)

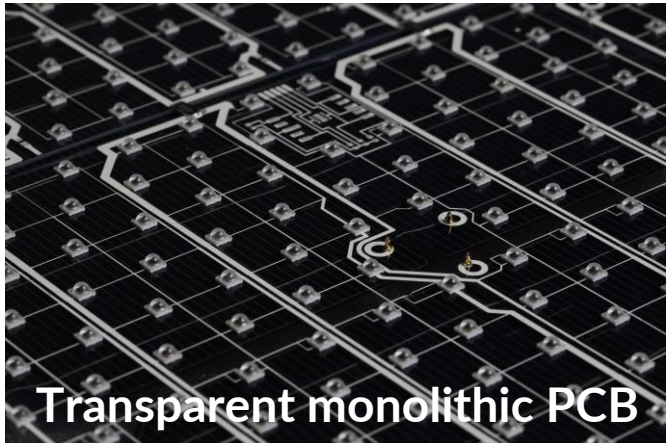


Dec. 2019 Apr. 2020 Aug. 2020



Iterations on process improvement with solar cell packager

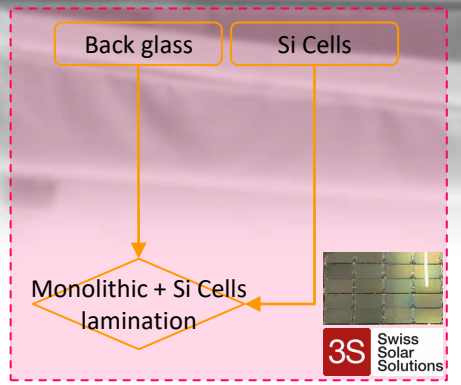
- Metallization on glass to obtain a **transparent PCB**
- **Pick and place** of receivers to transparent boards



XCeleprint

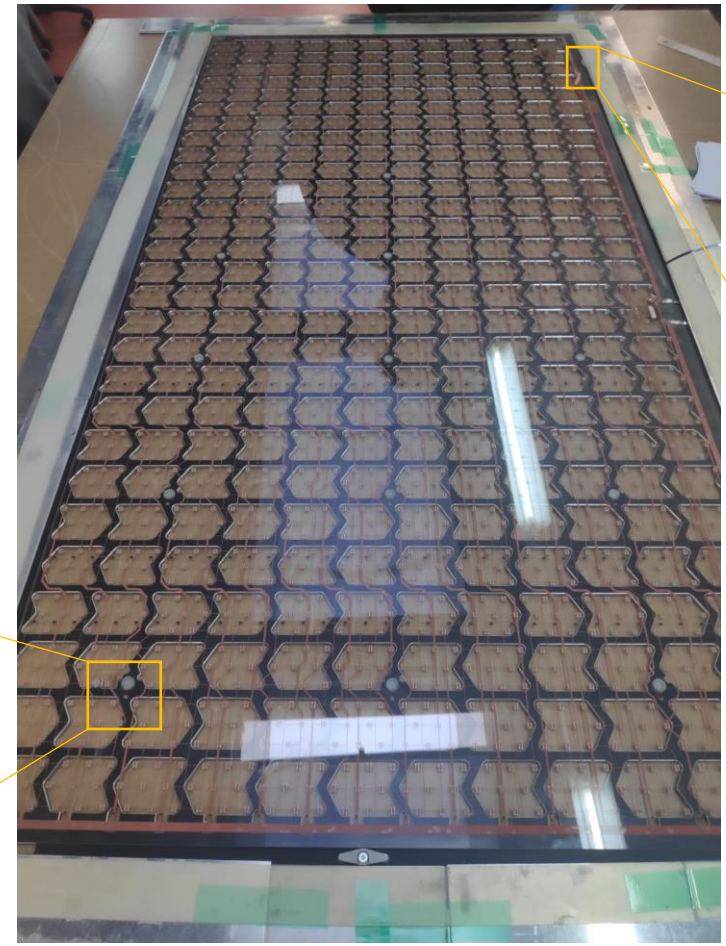
Argotech

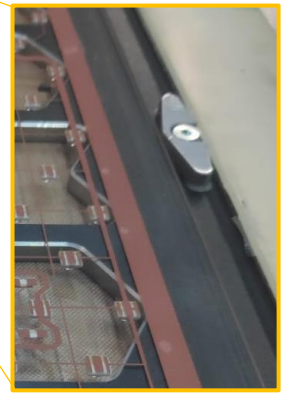
Photovoltaic module lamination



- **Backplane** : lamination product of the monolithic PCB and the secondary cells

- Lamination mold to **protect** the primary cells
- Mold provide a good **alignment** of the lamination stack





Alignment

Protection

csem

3S Swiss Solar Solutions

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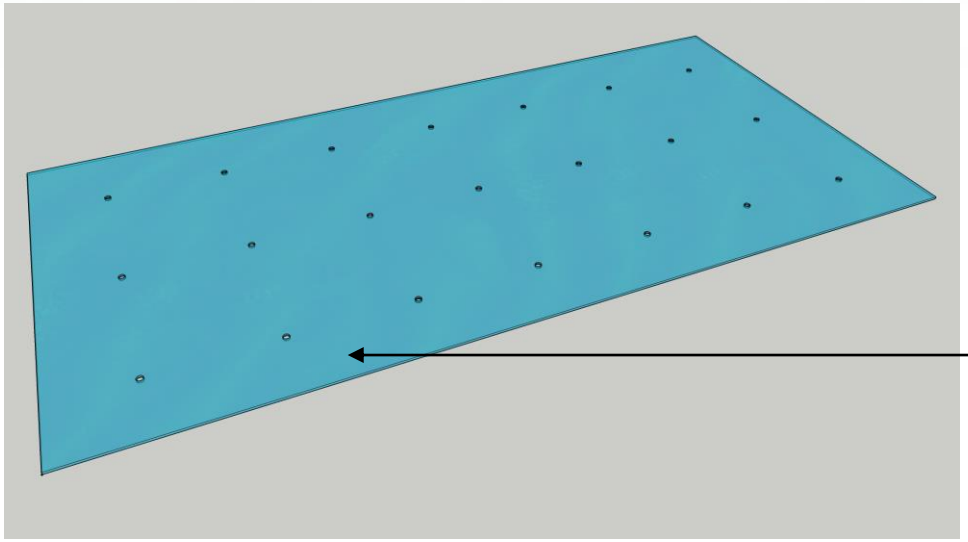
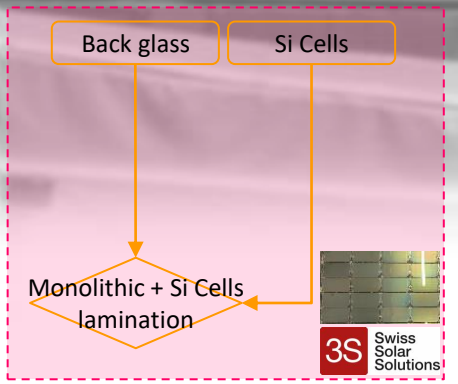
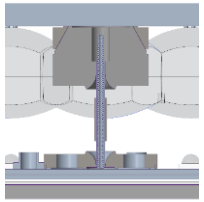
Photovoltaic module lamination

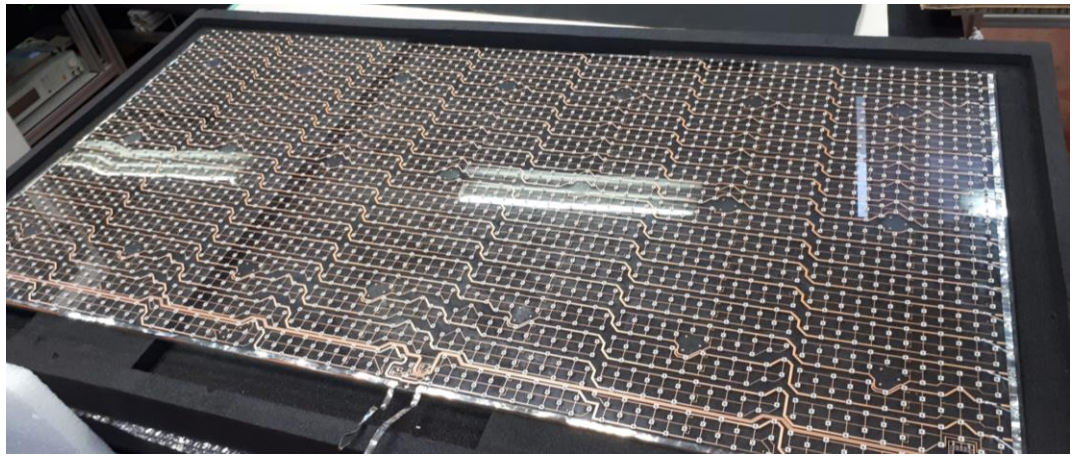




Monolithic PCB with III-V cells

- Transparent PCB for the **primary cells**
- Holes in the glass to hold the **guiding element**





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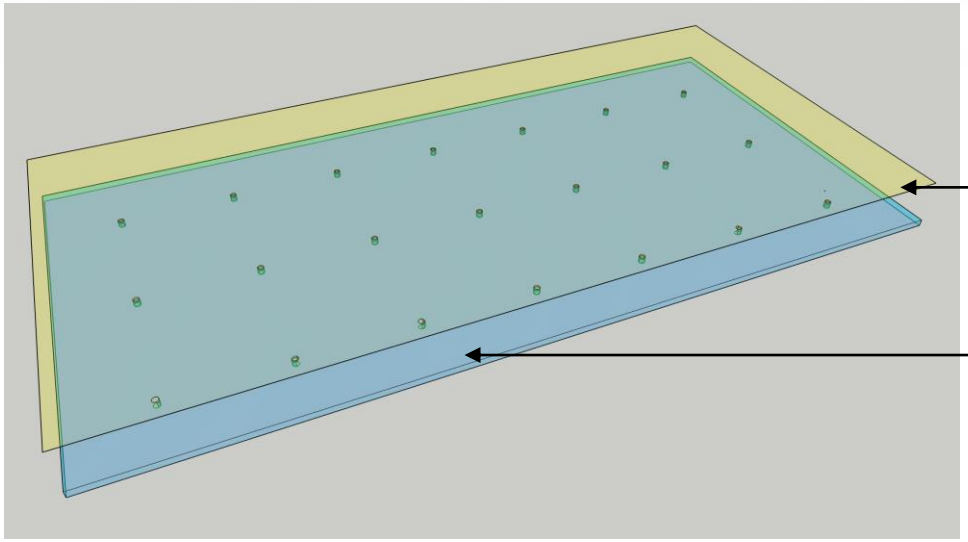
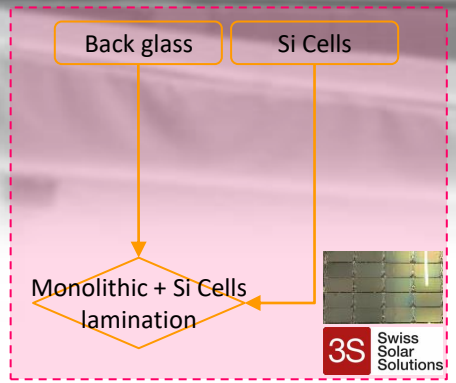
Photovoltaic module lamination

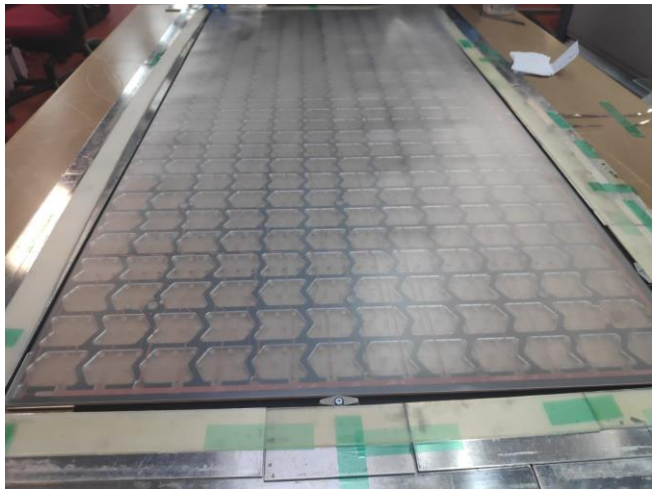


Encapsulant (layer 1)

Monolithic PCB with III-V cells



- Polyolefin encapsulant to achieve high reliability



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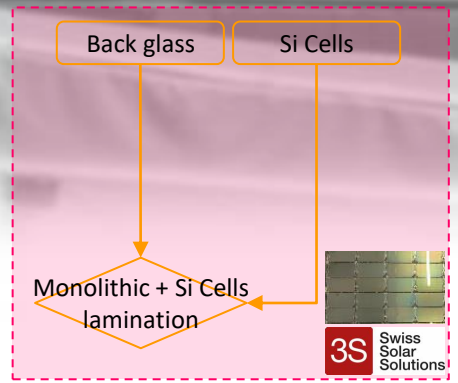
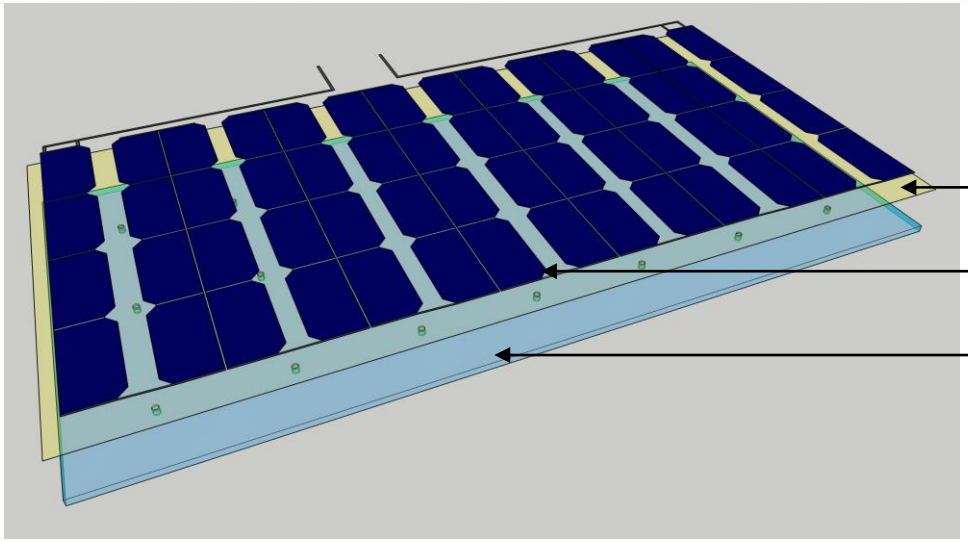
Photovoltaic module lamination



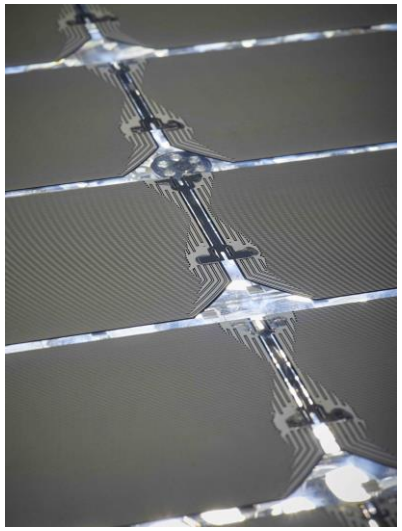


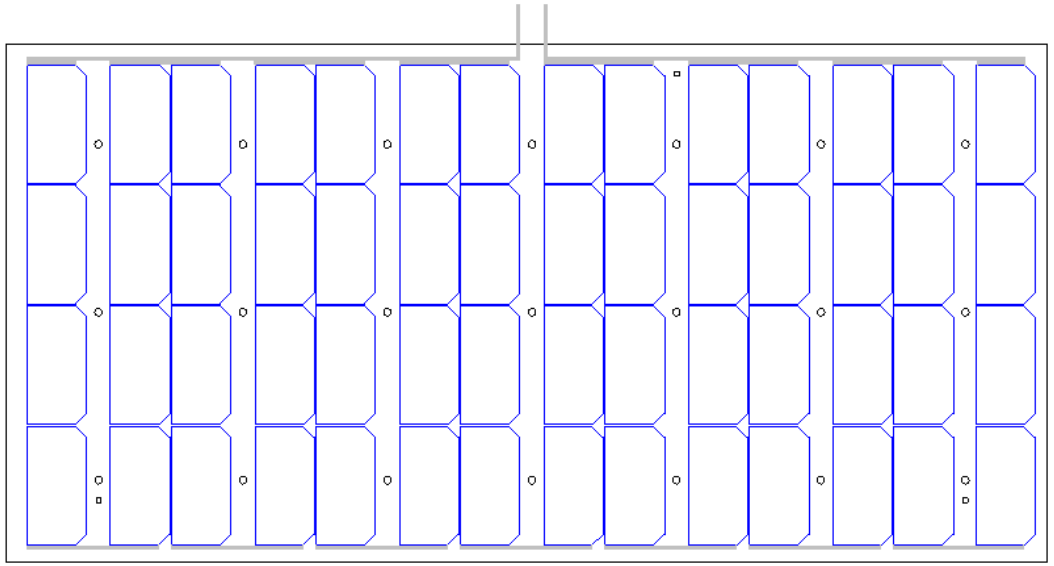
Encapsulant

Si-Cells & interconnections

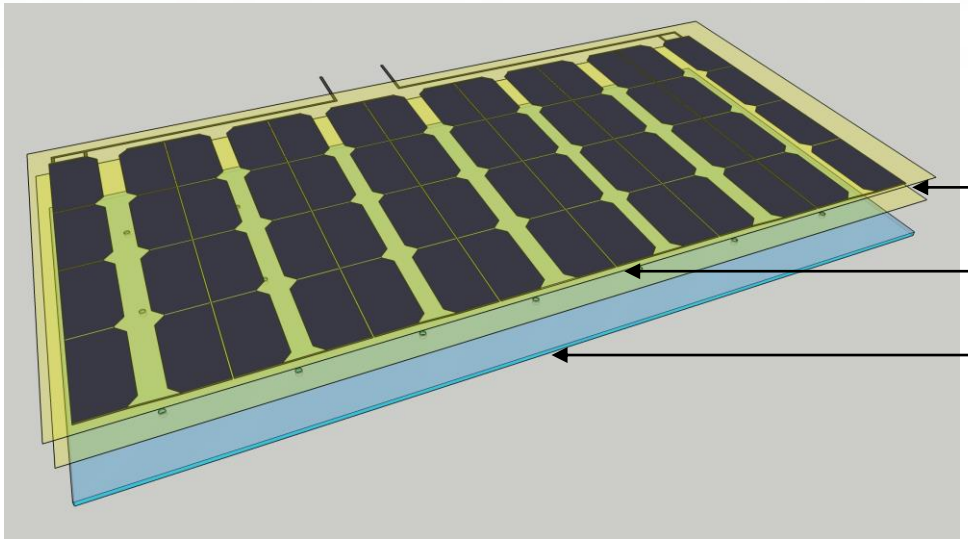
Monolithic PCB with III-V cells

- c-Si cells to **harvest** the diffuse sunlight (technology independent)
- Cell configuration designed by CSEM to **maximize** the output power





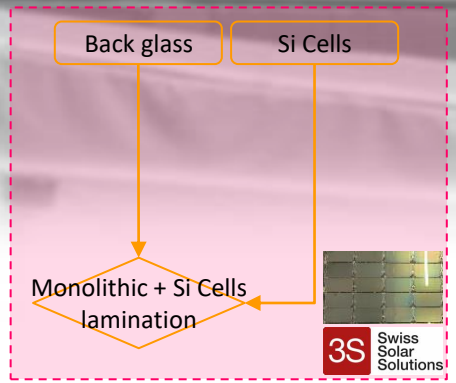
Photovoltaic module lamination



Encapsulant (layer 2)

Si-Cells & interconnections

Monolithic PCB with III-V cells



- c-Si cells to **harvest** the diffuse sunlight
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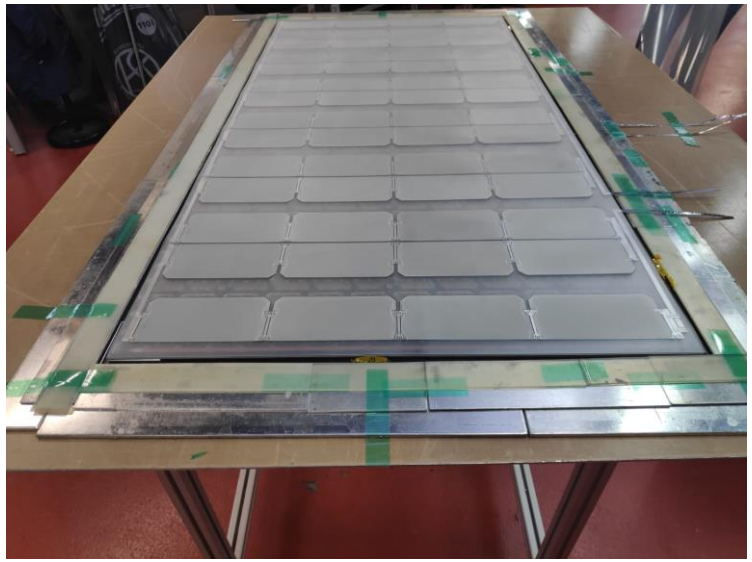

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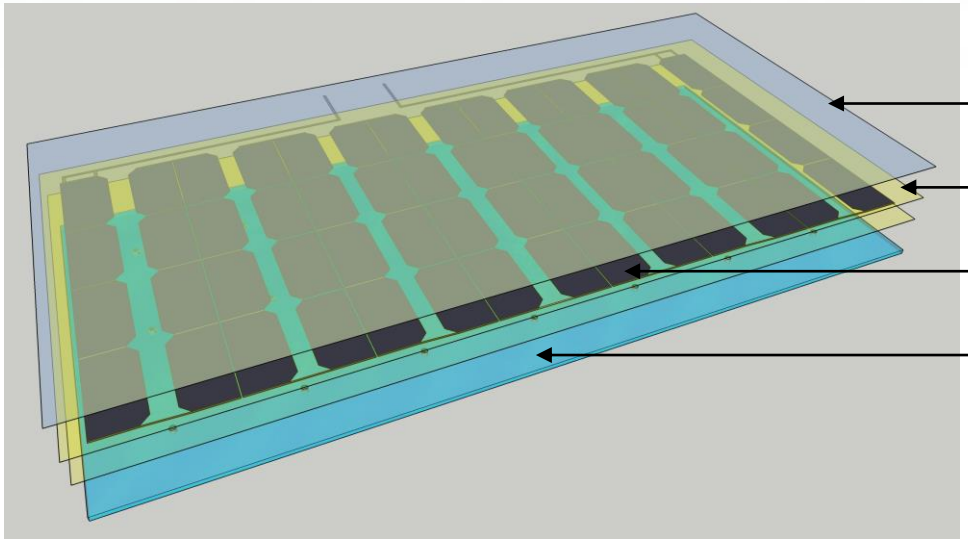
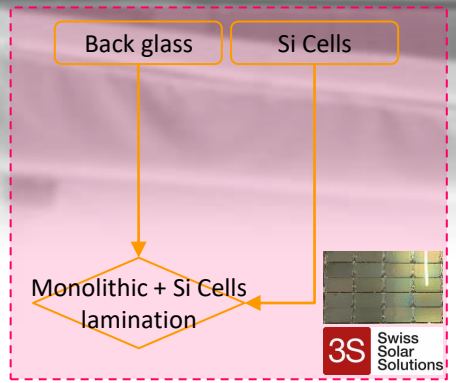
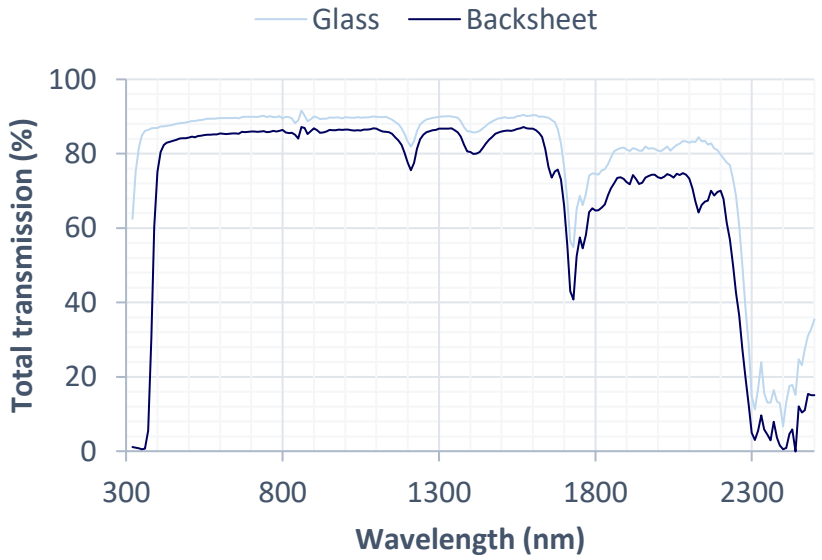
Photovoltaic module lamination



- Transparent backsheet
- Encapsulant (2 layers)
- Si-Cells & interconnections
- Monolithic PCB with III-V cells



- Transparent backsheet used to reduce the module **weight**
- Keep a good **transparency** at the back



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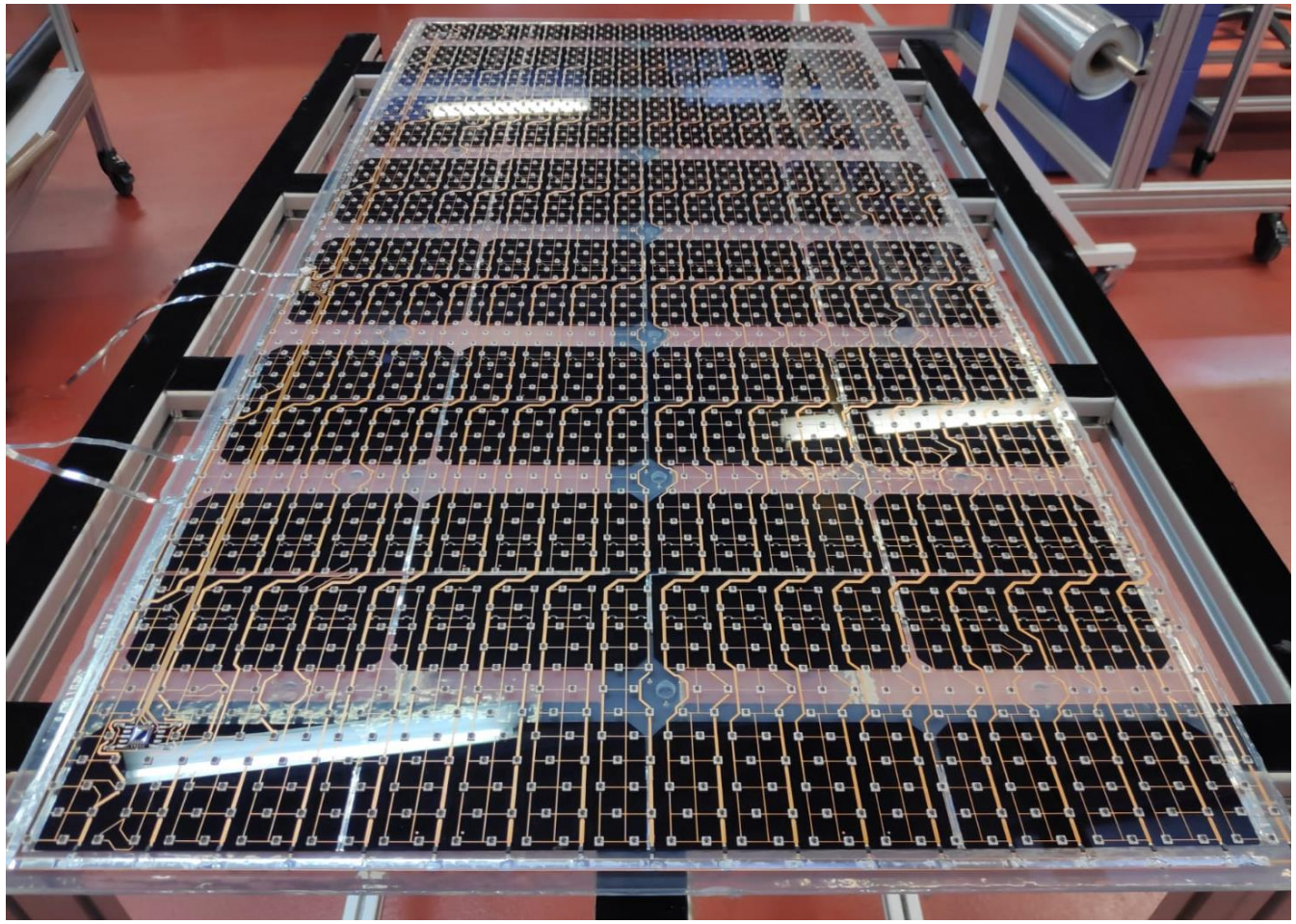
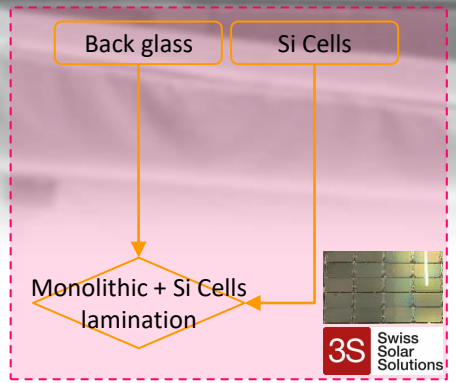
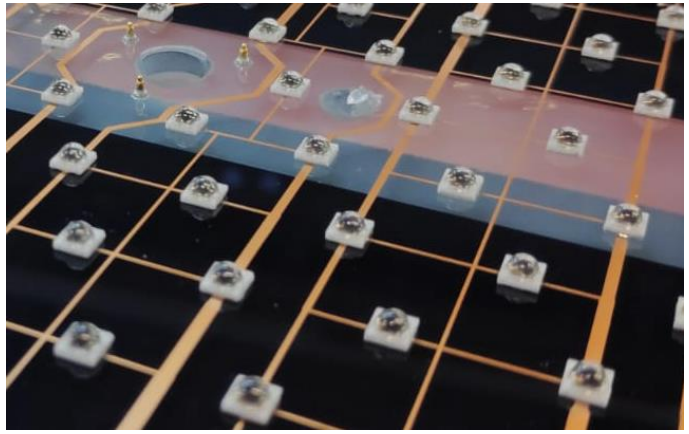
Photovoltaic module lamination





Hybrid backplane:
Superposition of 2 technologies



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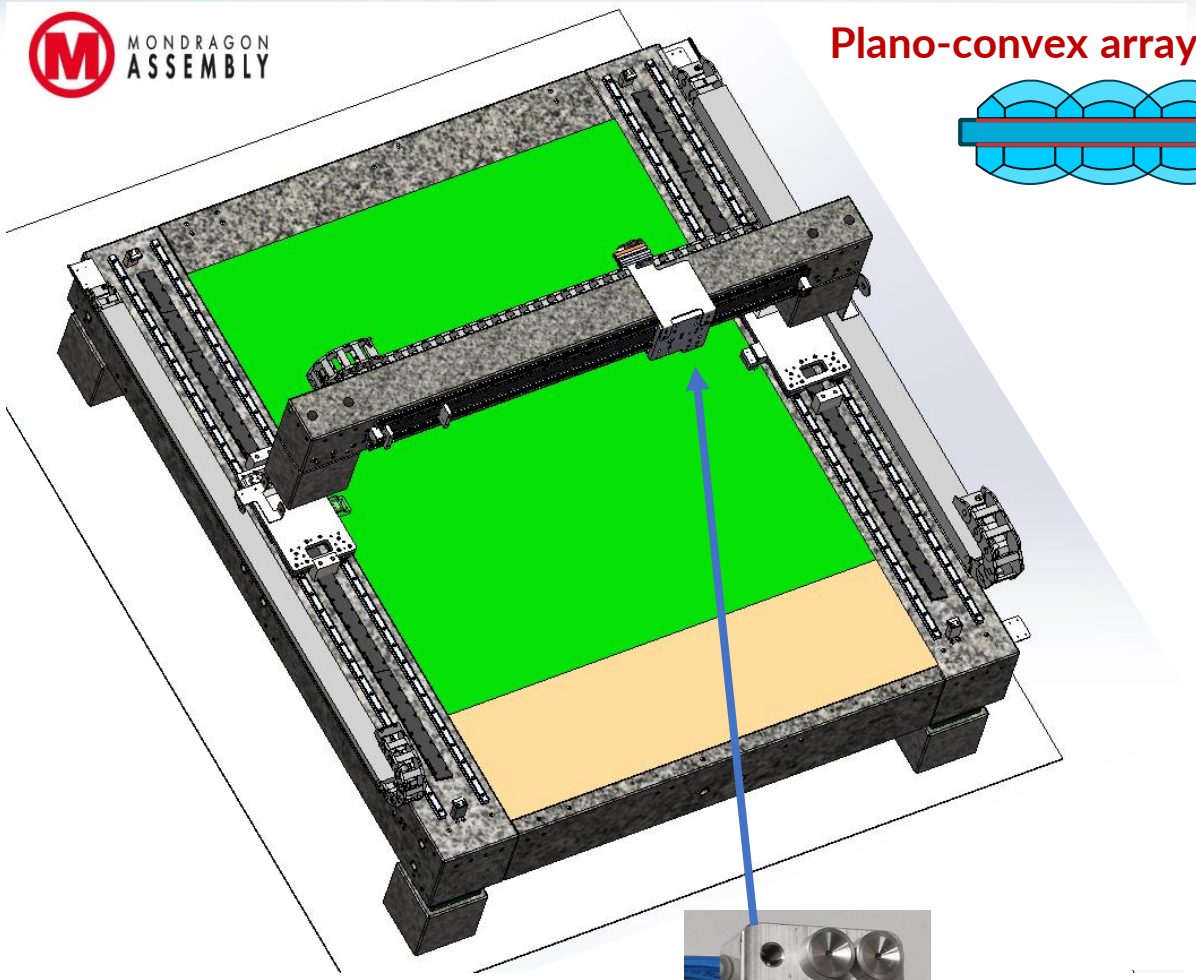
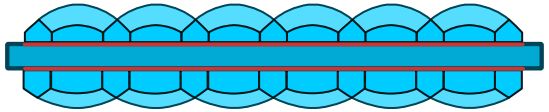
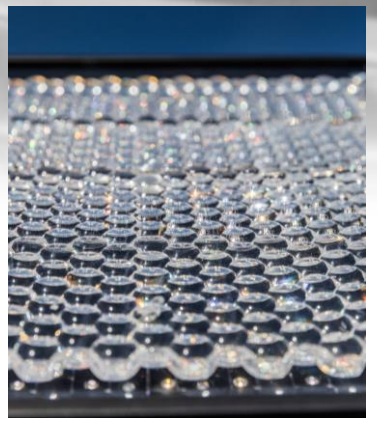
Automatic tool for optical arrays



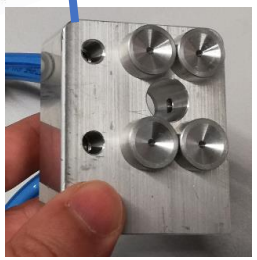
Plano-convex arrays around the glass

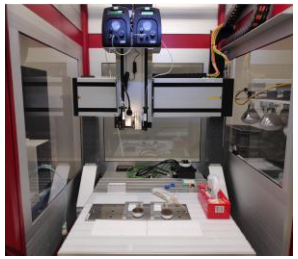




- **Lens assembly machine** developed by Mondragon Assembly to manufacture optical **arrays** from small lenses
- Pneumatic gripper picks up the lenses and place them on the glass before curing
- Glue is **cured** with UV light

Lens Assembly

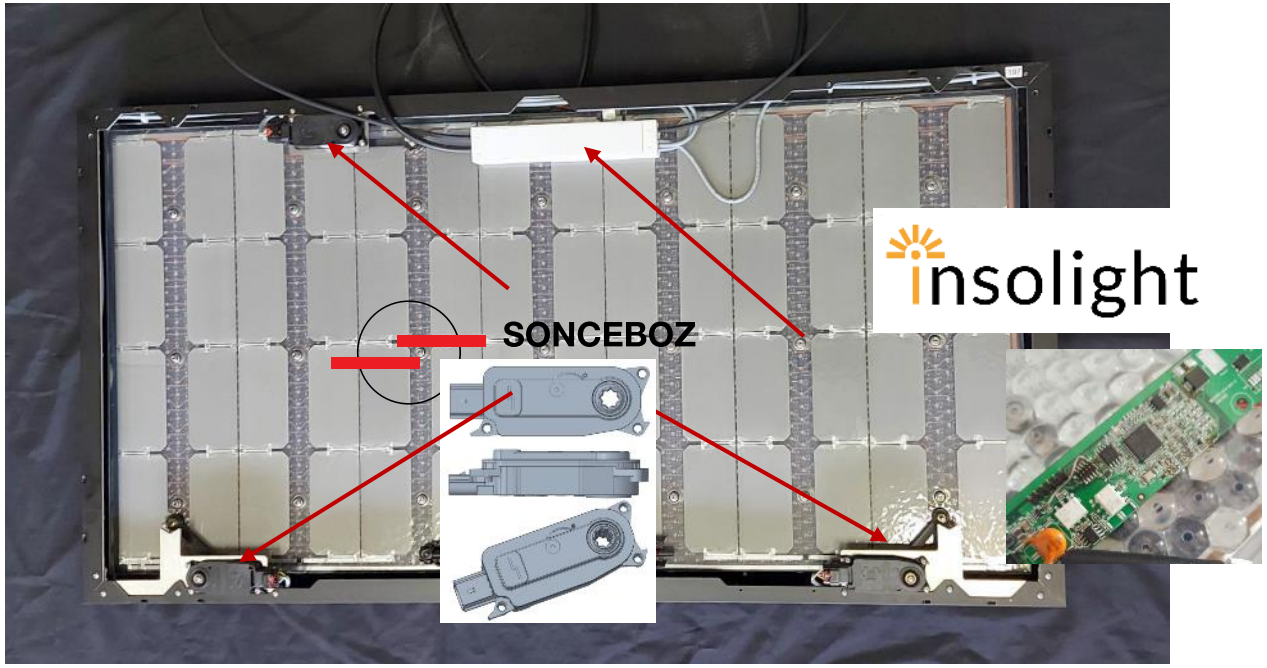




Mechanical Assembly – automated framing machine

- **Automated Framing** Machine designed by Mondragon Assembly for automated assembly of the frame

- **J-box and actuators** are then assembled by operators



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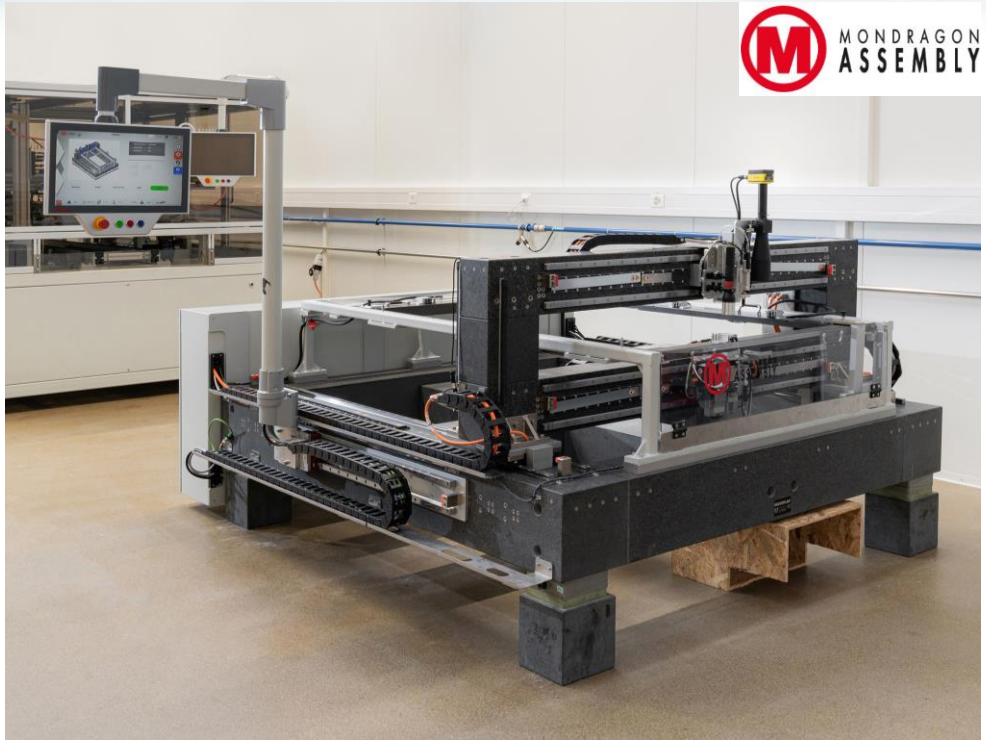
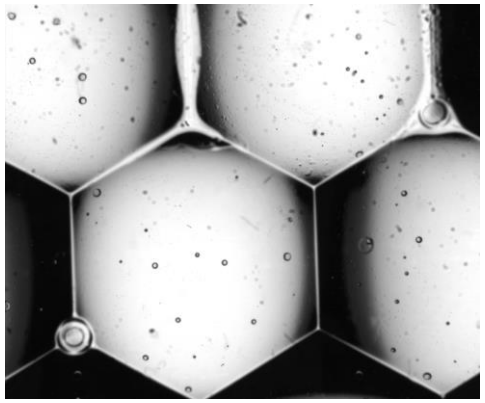
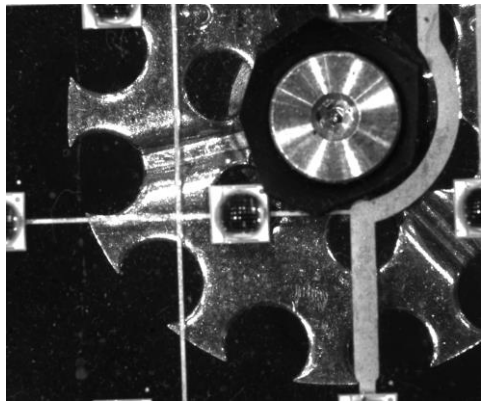
Characterization bench







- **Characterization bench** will measure
  - Backplane
  - Optical Plane
  - Full Module

- **Position** of the lenses on the glass can be measured.
  - collimated laser illuminate one lens
  - CCD camera capture the focus behind the lens

- Top glass **planarity** is measured to verify the bending of 2 glasses once the module is fully assembled

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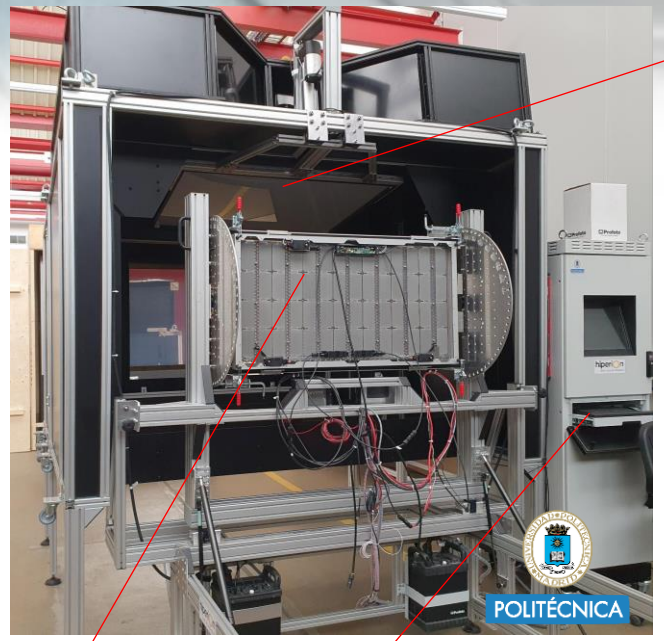
Hybrid sun simulator by UPM for power rating

- Flash test under **collimated direct light** to characterize the performance of the multi-junction solar cells (CPV)
- 2nd flash test to simulate the **diffuse light** to determine the performance of the secondary silicon cells (PV)

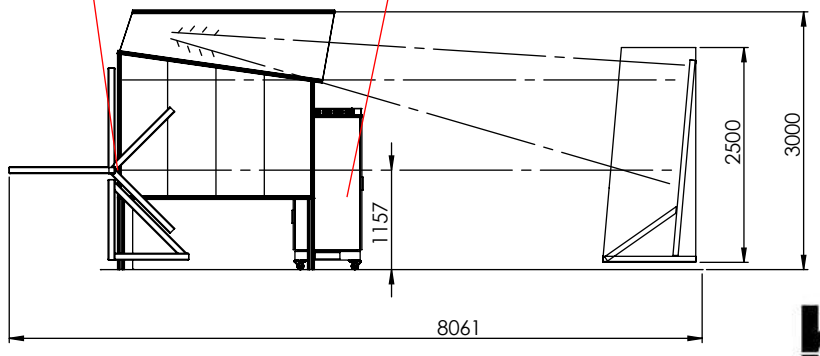


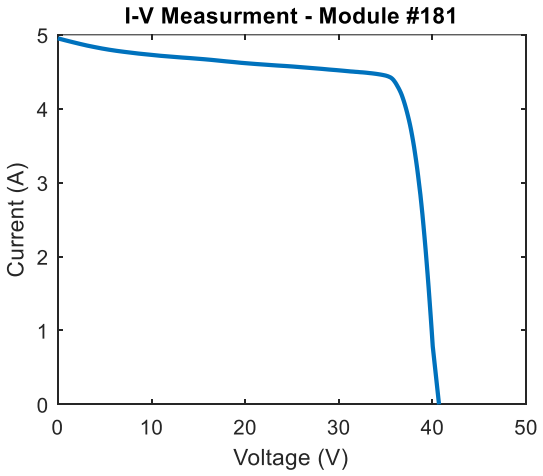
Retractable diffuser

Module support

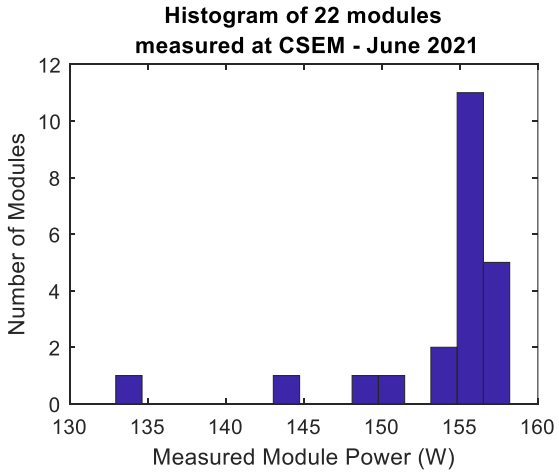
Operator station

Collimating mirror





I-V curve measured after installation



Summary of GEN2 modules measured

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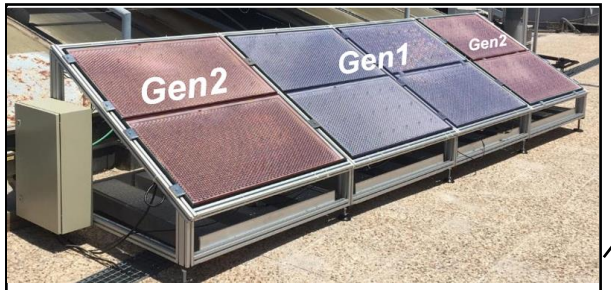
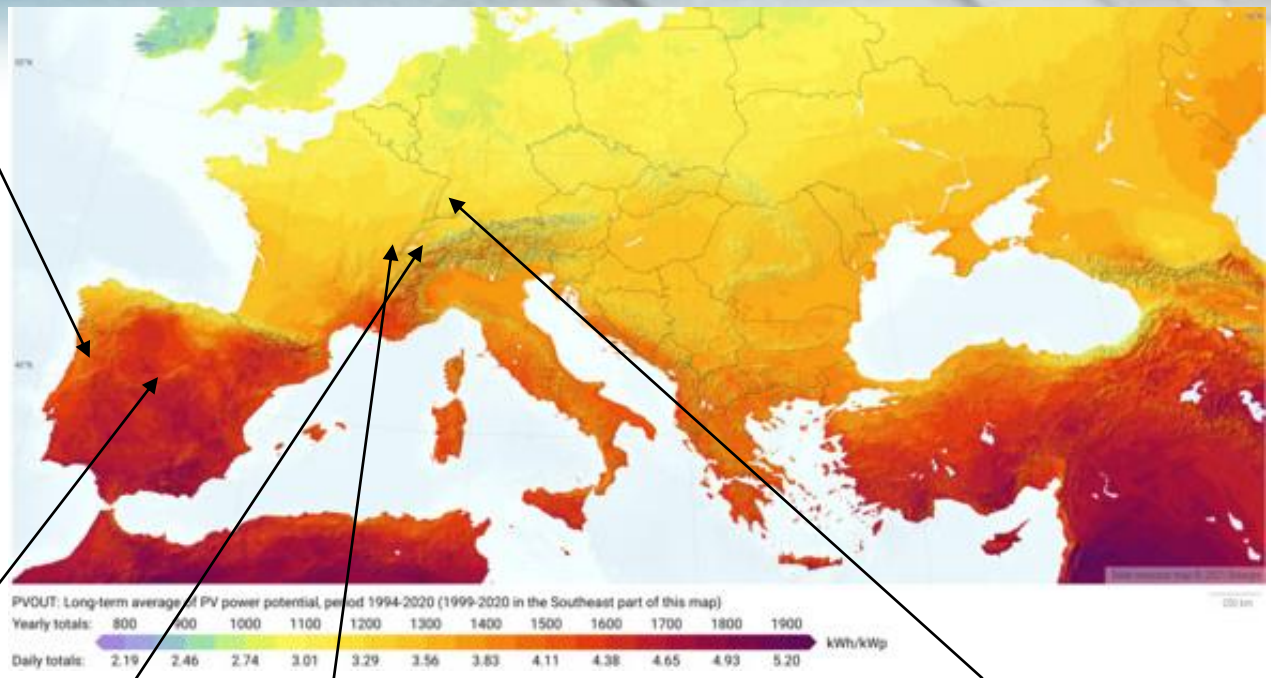
HIPERION monitoring pilot sites

Location: Region of Porto, PT
Climate: Warm oceanic
Irradiance: ~ 1500 kWh/kWp
Size: 15 modules
Period: 08.2022 – project end

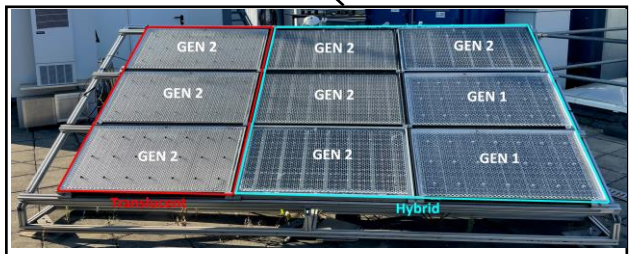


Location: Madrid, SP
Climate: Mediterranean
Irradiance: > 1700 kWh/kWp
Size: 11 modules
Period: 07.2022 – project end

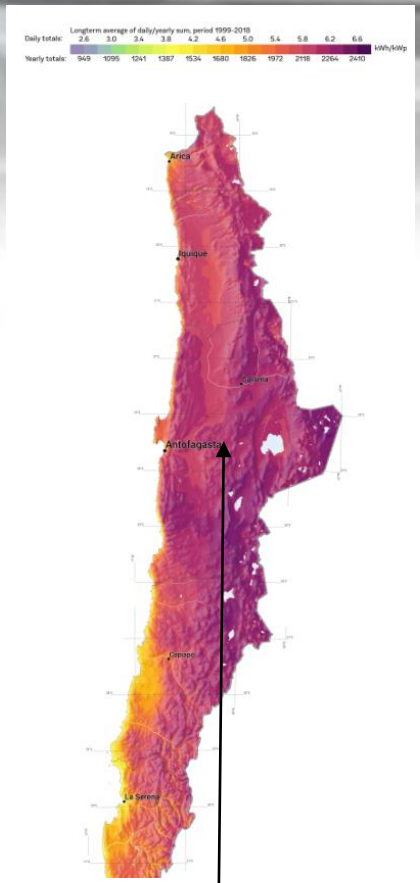
Location: Gstaad, CH
Climate: Continental
Irradiance: 1300 kWh/kWp
Size: 15 modules
Period: 10.2022 – project end



Location: Lausanne, CH
Climate: Continental
Irradiance: 1300 kWh/kWp
Size: 4 modules
Period: 08.2022 –project end



Location: Freiburg in Breisgau, DE
Climate: Semi-continental
Irradiance: 1200 kWh/kWp
Size: 6 modules
Period: 07.2022 – project end



Location: Atacama, Chile
Climate: Coastal desert
Irradiance: >2300 kWh/kWp
Size: 30 modules
Period: ?.2022 – project end

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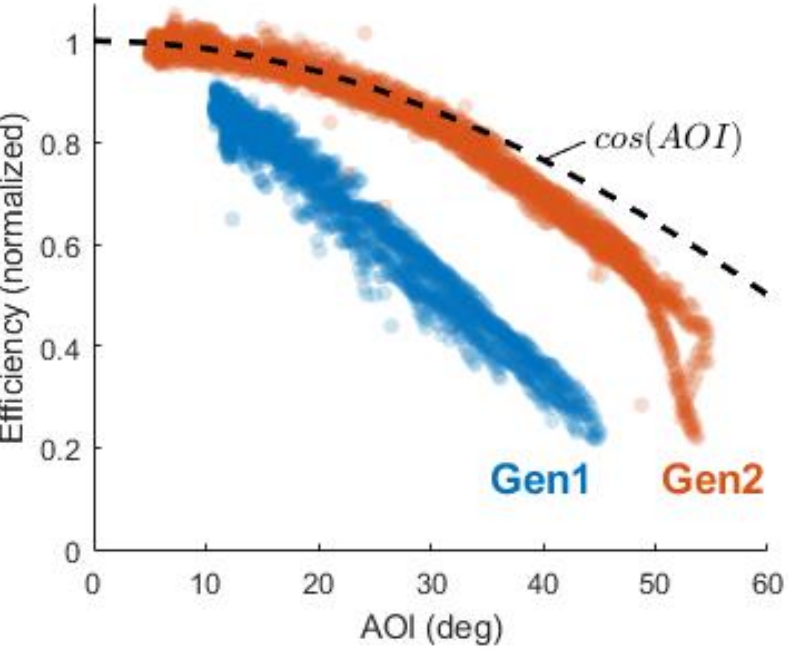
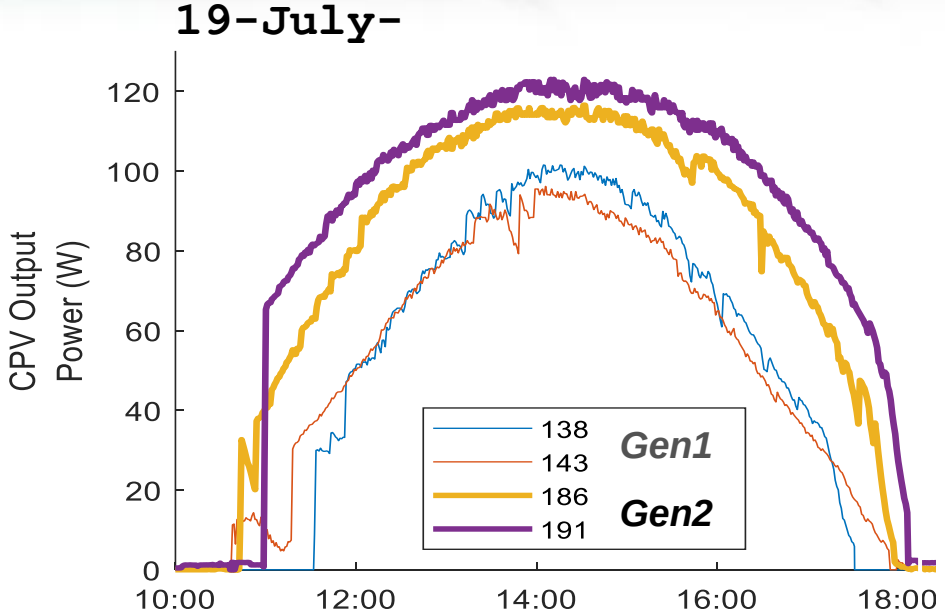
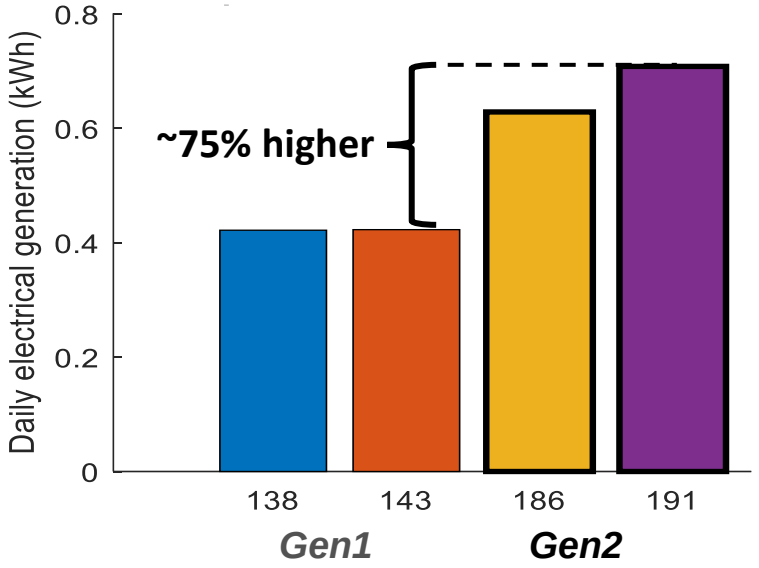
Outdoor performances







- Improvement in Gen2 performance is clearly seen during electrical generation in self-tracking.
  - **Efficiency (max power)**
  - **Tracking range and performance (efficiency at high AOI)**
- Up to 75% more daily energy generation

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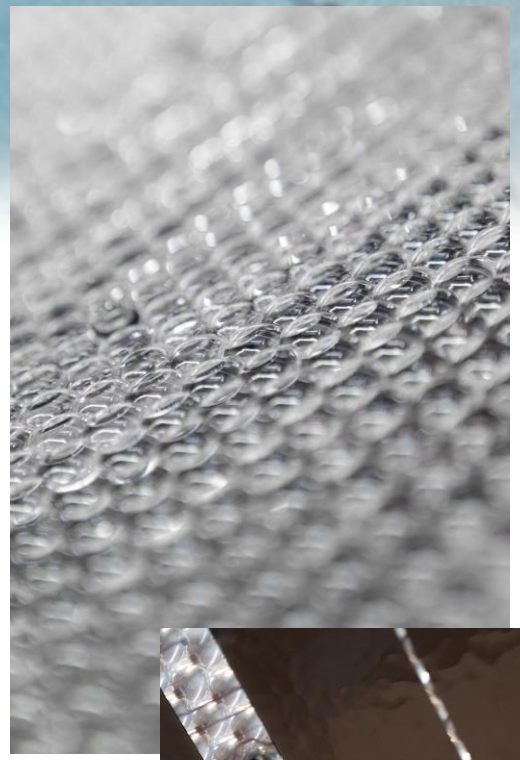
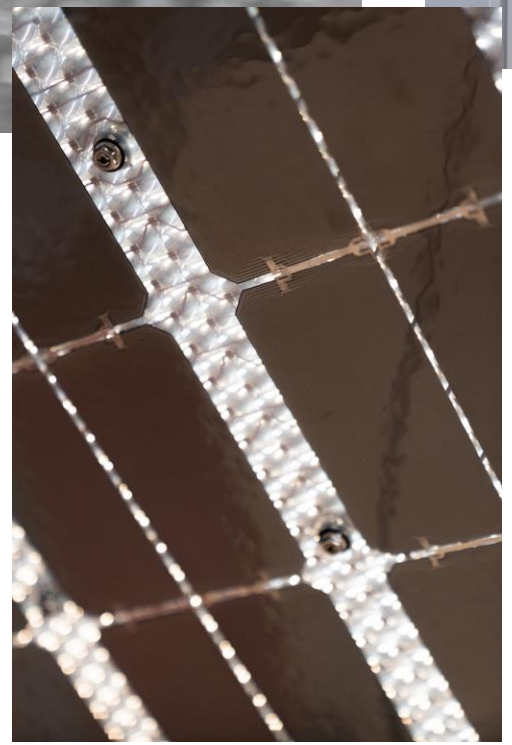
Conclusions

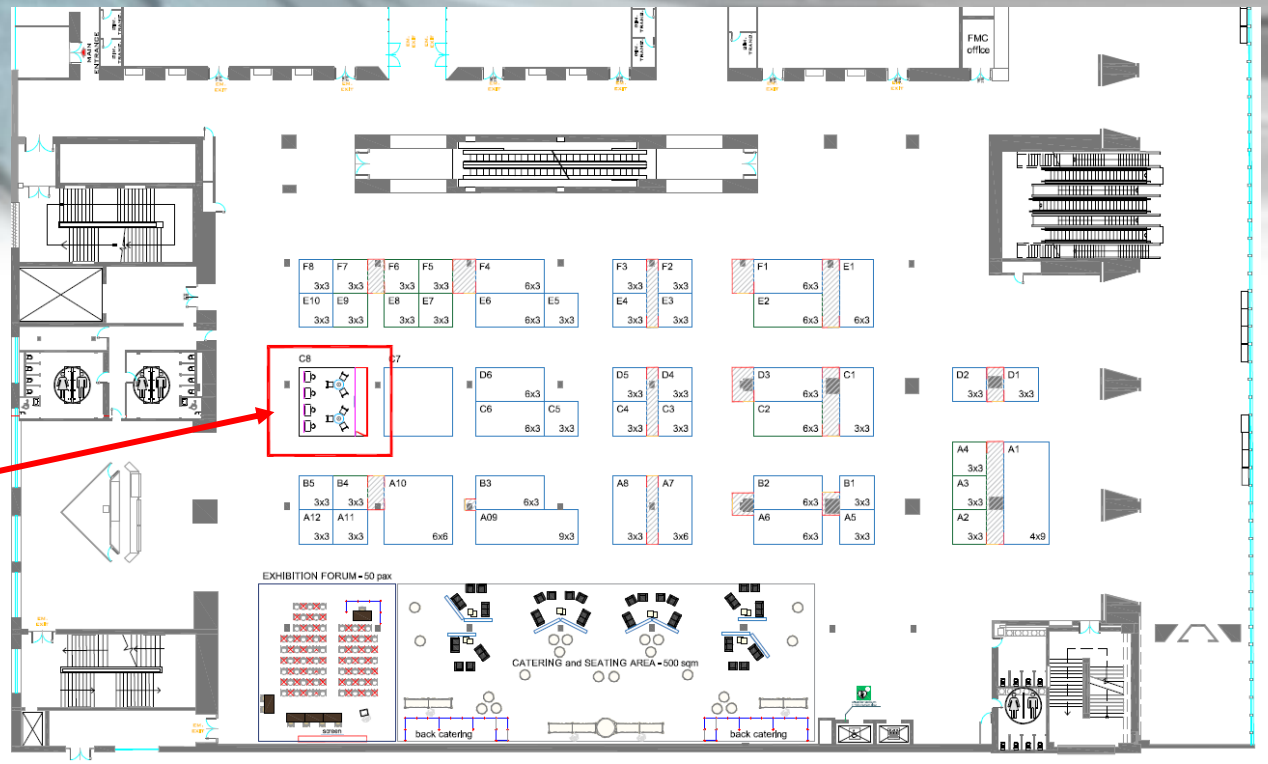
- 2 generations of hybrid module designs **demonstrated and fabricated**
- **Pilot line** set up in Neuchâtel (CH) and 100 m^2 of Hybrid modules being built to demonstrate compatibility with industrial automated mass production
- Validate the performances with commercial **pilot sites in Europe and Atacama desert**





You want to know more?

- Visit our H2020 booth at WCPEC-8



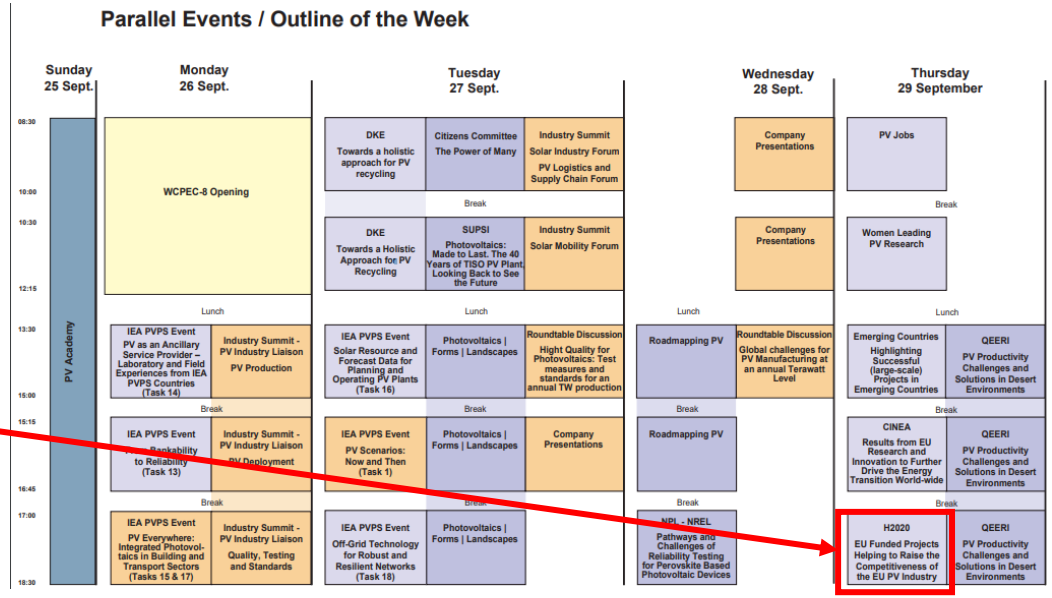
- Come to our parallel event:

Thursday 28.09 at 17:00, Auditorium Yellow 2

H2020

EU Funded Projects Helping to Raise the Competitiveness of the EU PV Industry

Jointly organised with HighLite, Hiperion, Super PV and Go-PV projects



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Follow us:

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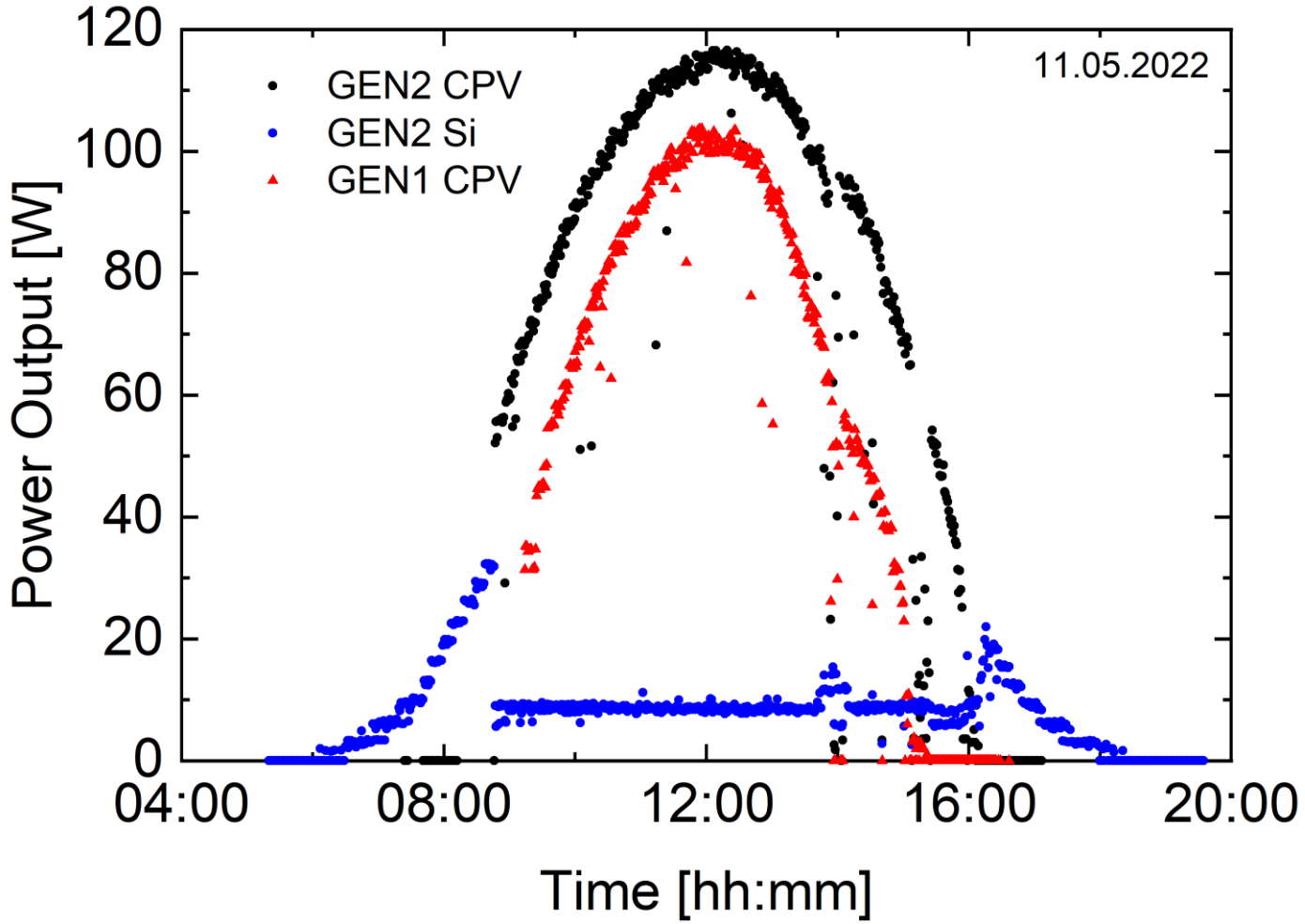
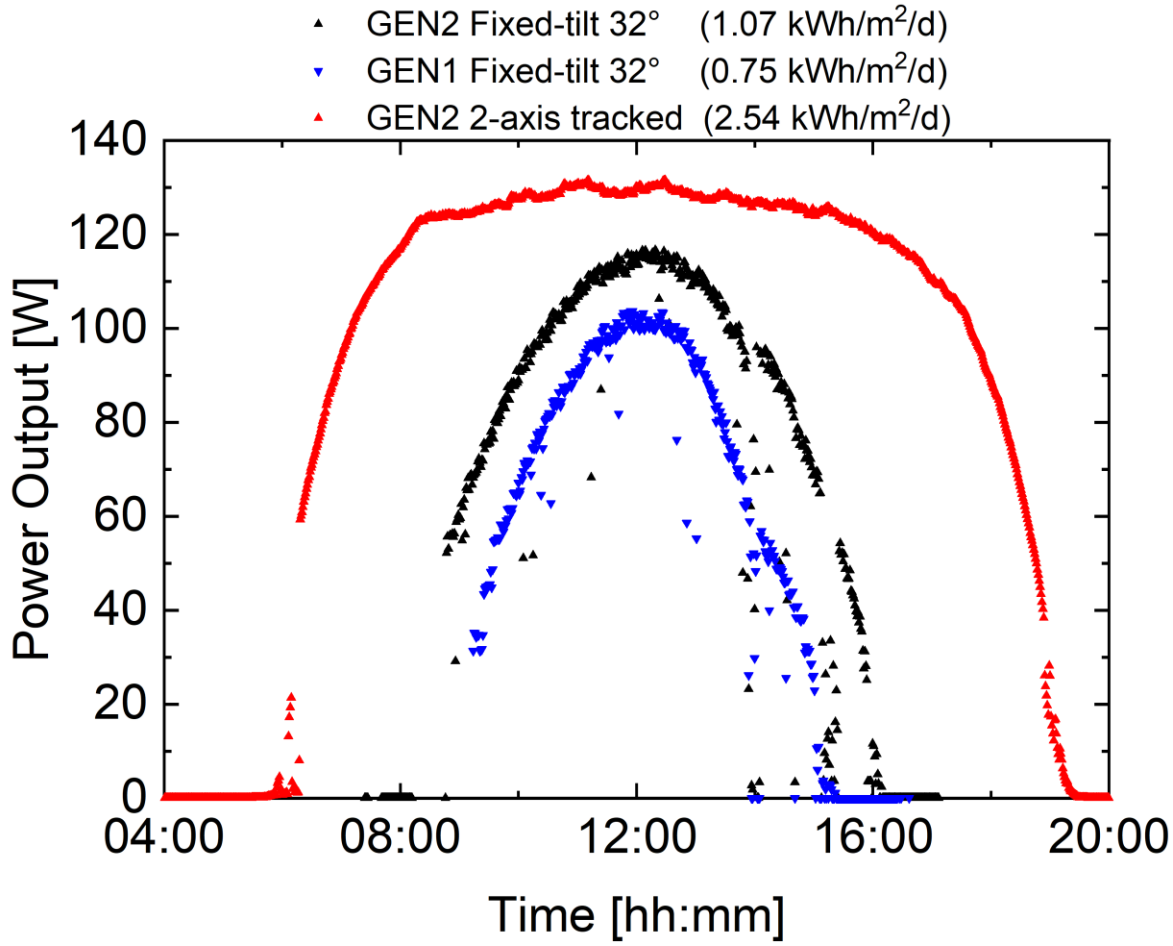
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 857775

Results from Freiburg pilot





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Achievements & Perspectives (KPIs & KERs)

Key performance indicators (KPIs)

Key performance indicators (KPIs)	Target	Actual
*Efficiency under **direct** sunlight*	> 30%	> 29 %
*Efficiency for the harvest of **diffuse** sunlight*	17%	12.5%
Additional energy generation vs. standard module	+50%	+35% (fixed-tilt) +50% (single-axis)
Bill-Of-Materials for > 100 MWp/year	<150€/m2	<200€/m2
CAPEX for 100 MWp production line	4M€	~6M€

Key exploitable results (KERs)

- **Micro-CPV architecture with very small solar cells and lenses** typically 1 order of magnitude smaller than in regular CPV modules.
- Integrated **micro-tracking system with standard module form-factor**, removing the need for complex dual-axis trackers and opening **new markets** for CPV (especially rooftops).
- **Hybrid backplane**, with a tandem of GaAs and c-Si solar cells, enabling the capture of both **direct** and **diffuse** sunlight.
- New **metrology equipment and standards**

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