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EU Funded projects to raise the competitiveness of the EU PV industry: HIPERION

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WCPEC-8 WORLD CONFERENCE ON PHOTOVOLTAIC ENERGY CONVERSION

Milano, 26-30.09. 2022

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

HIPERION

HYBRID PHOTOVOLTAICS FOR EFFICIENCY RECORD USING INTEGRATED OPTICAL TECHNOLOGY

Solar installers

ENGIE Laborelec

MUON electric

Technological start-up

insolight

Management / Dissemination / communication

UP Lille

compáz

Industrial companies

MONDRAGON ASSEMBLY

3S Swiss Solar Solutions

SONCEBOZ

IQE

XCeleprint

Argotech

PV research centers

Universidad Politécnica de Madrid

POLITÉCNICA

Politechnika Łódzka

Fraunhofer ISE

csem

Outline

- **Concept**
- A bit of history
- Module Fabrication
- Pilot site and main results
- Broad range of PV application
- Achievements & Perspectives

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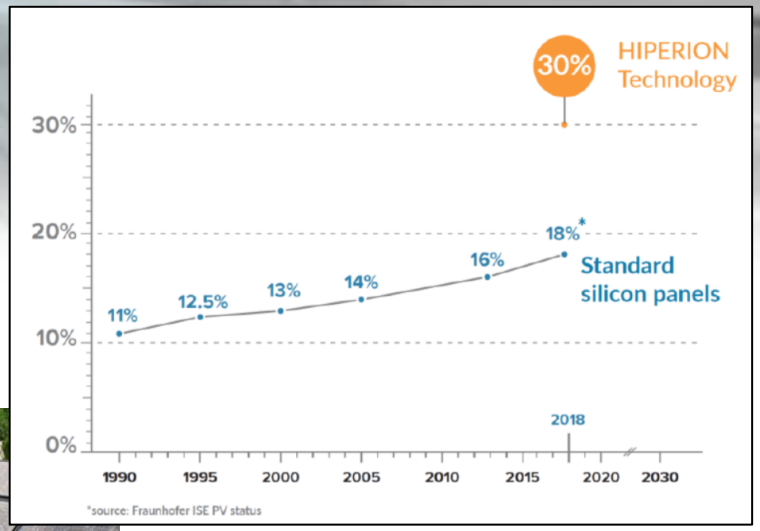
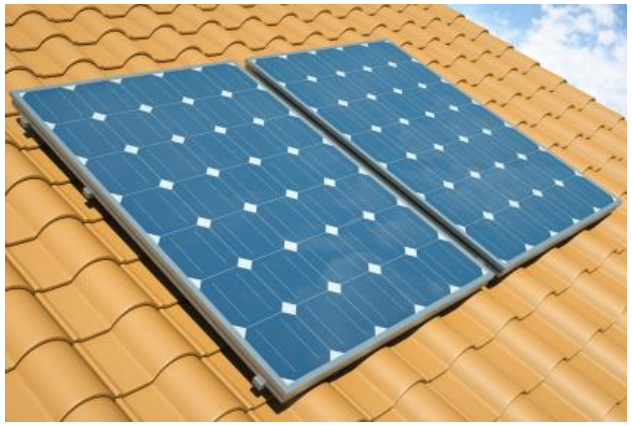
Concept



CONVENTIONAL PV



- Simple & reliable
- Rooftop & utility scale
- Diffuse light harvesting
- Limited efficiency (≈20%)

CONCENTRATED PV

- Complex
- Utility scale only
- No diffuse light harvesting
- High efficiency (>30%)

HIPERION

- Flat panel
- Rooftop & utility scale
- Diffuse light harvesting
- High efficiency (>30%)

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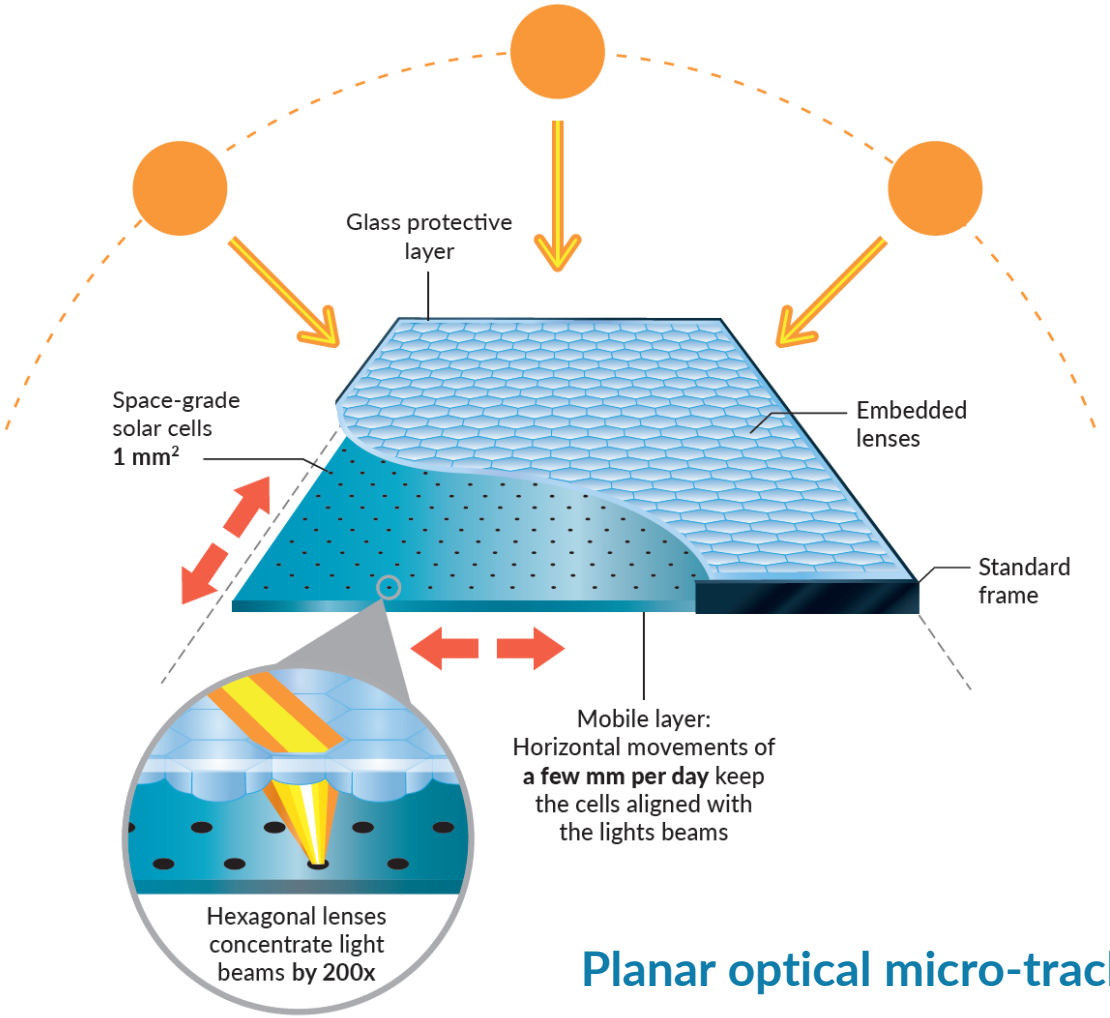
Insolight's Photovoltaic System

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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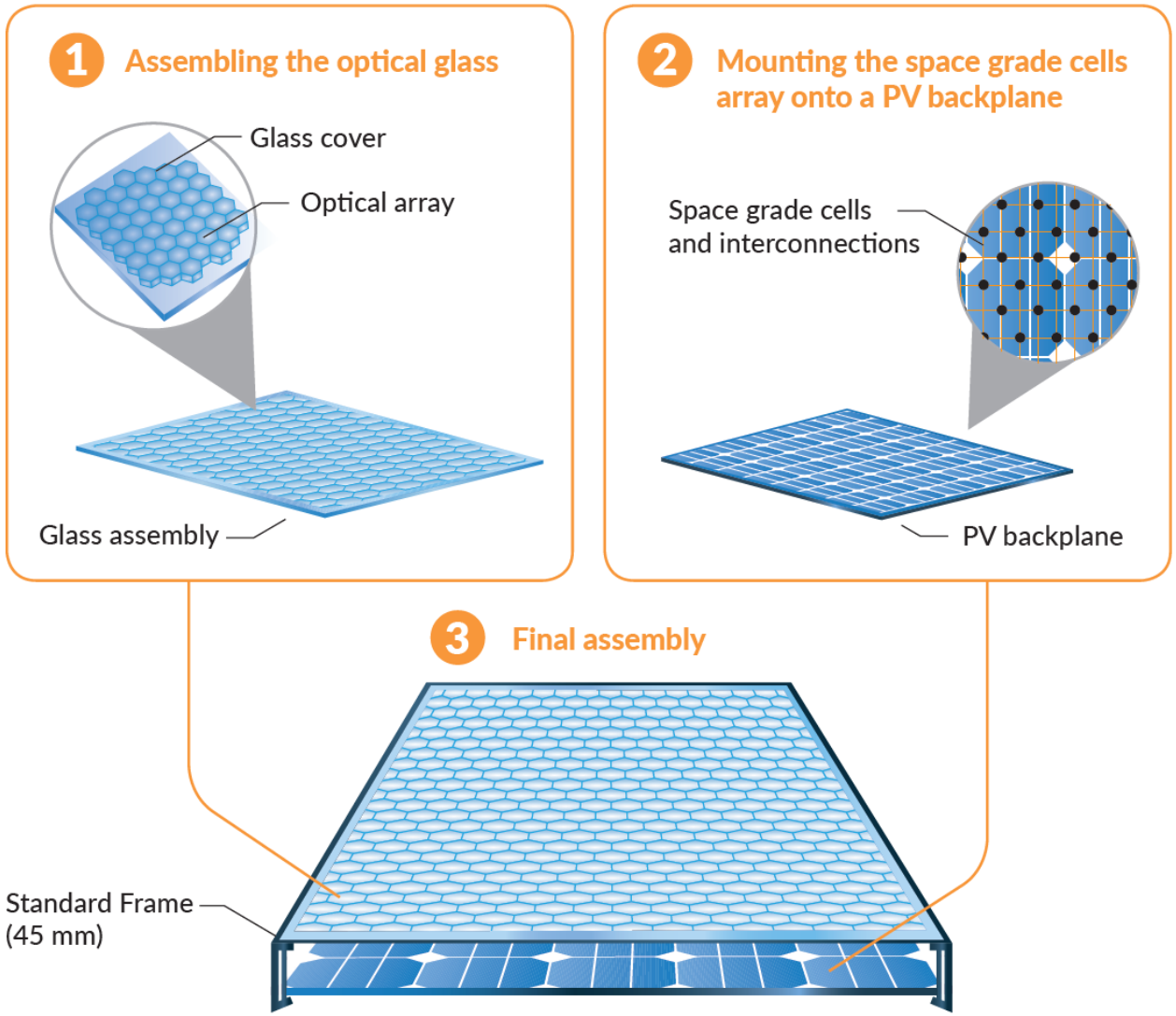
Hiperion Module Fabrication



- 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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A bit of history

First production phase of GEN2 module

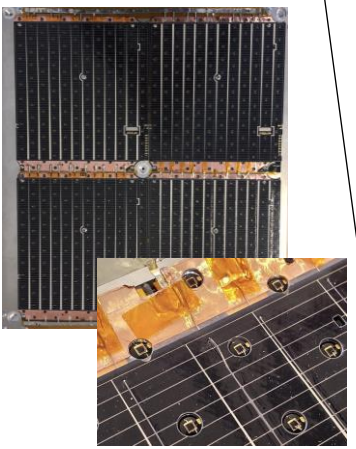
First hybrid concept
10.2018

HIPERION start
09.2019 → 09.2023

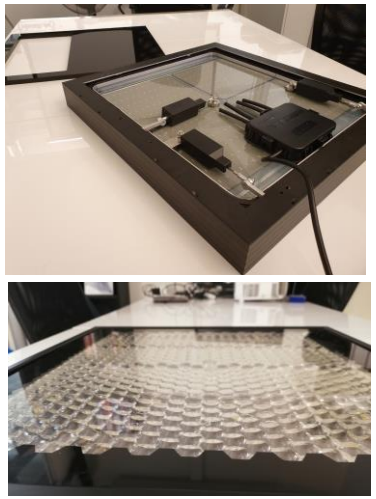
TODAY
09.2022

2019 | 2020 | 2021 | 2022 | 2023

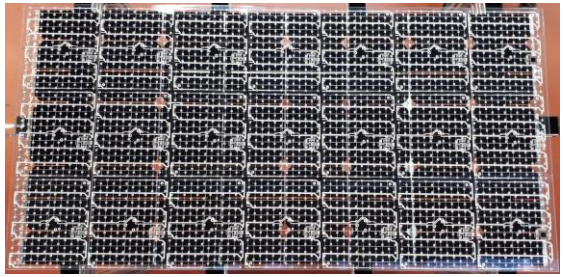
Holes in wafer



First GEN0 module

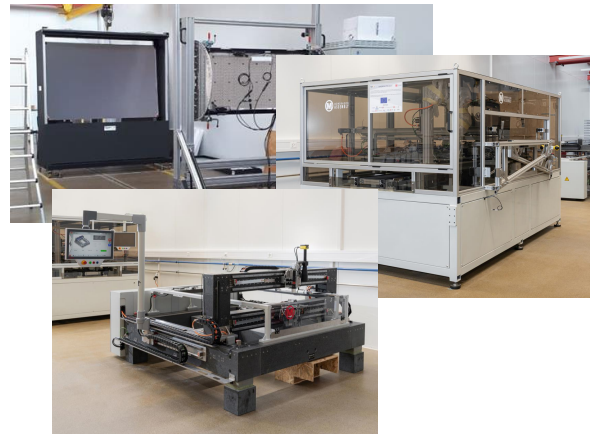


First GEN1 module

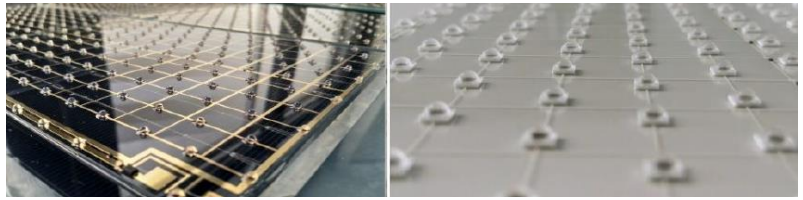


First monolithic backplane

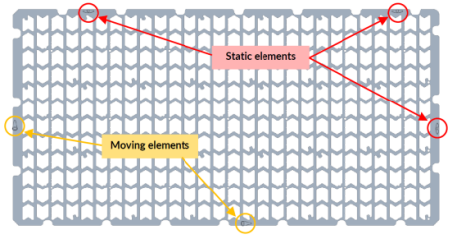
Hiperion pilote line



PCB on glass → translucent modules idea

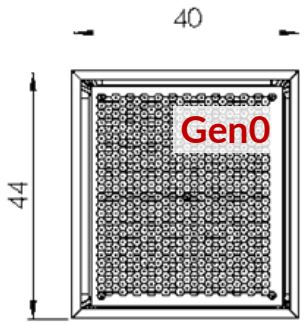


Large area glass PCB lamination



First commercial demo pilot

HIPERION Module Scale Up Over Generations



	Description	Size* (m)	Area* (m2)	Cells*
Gen0	"Pre-Hiperion"	0.3 × 0.3	0.1	600

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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:

Transparent PCB assembly

Raw glass

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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

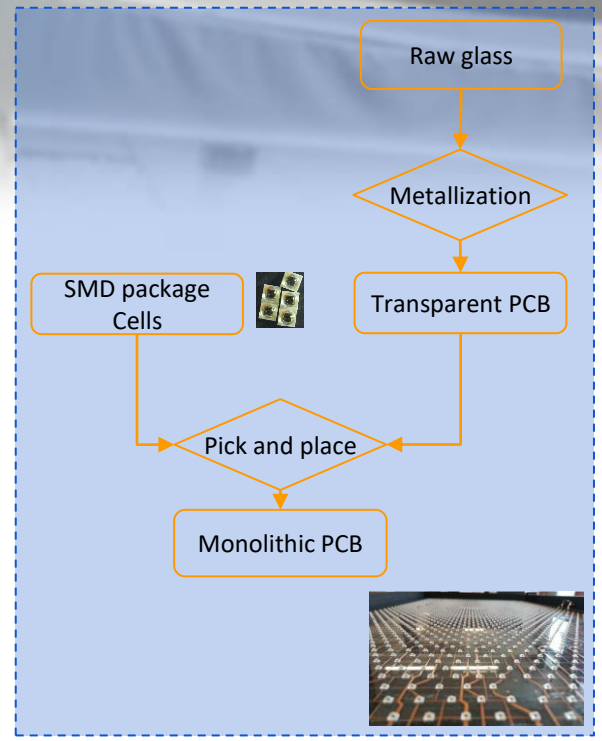
Actuators Assembly

Final Module

FLASH TEST CHARACTERIZATION

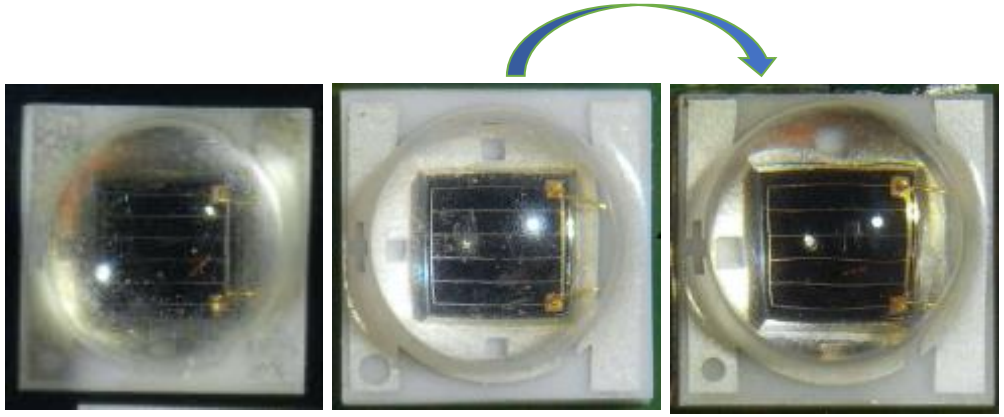
Pilot line

Transparent PCB to harvest direct sunlight

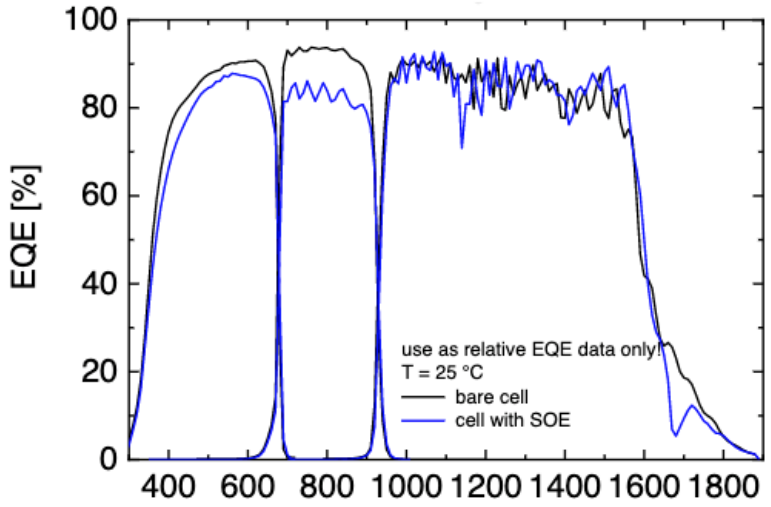


- Commercial space grade triple-junction cells in a standard LED SMD package (43% @180 suns, 25°C)

+ 5% performance in outdoor measurement

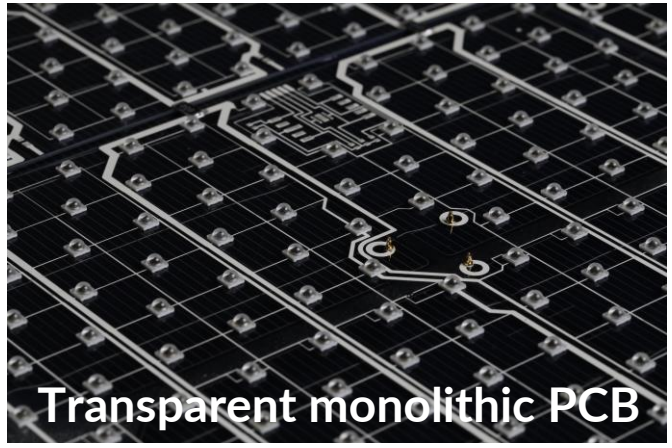


Dec. 2019 Apr. 2020 Aug. 2020



Iterations on process improvement with solar cell packager

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



Argotech

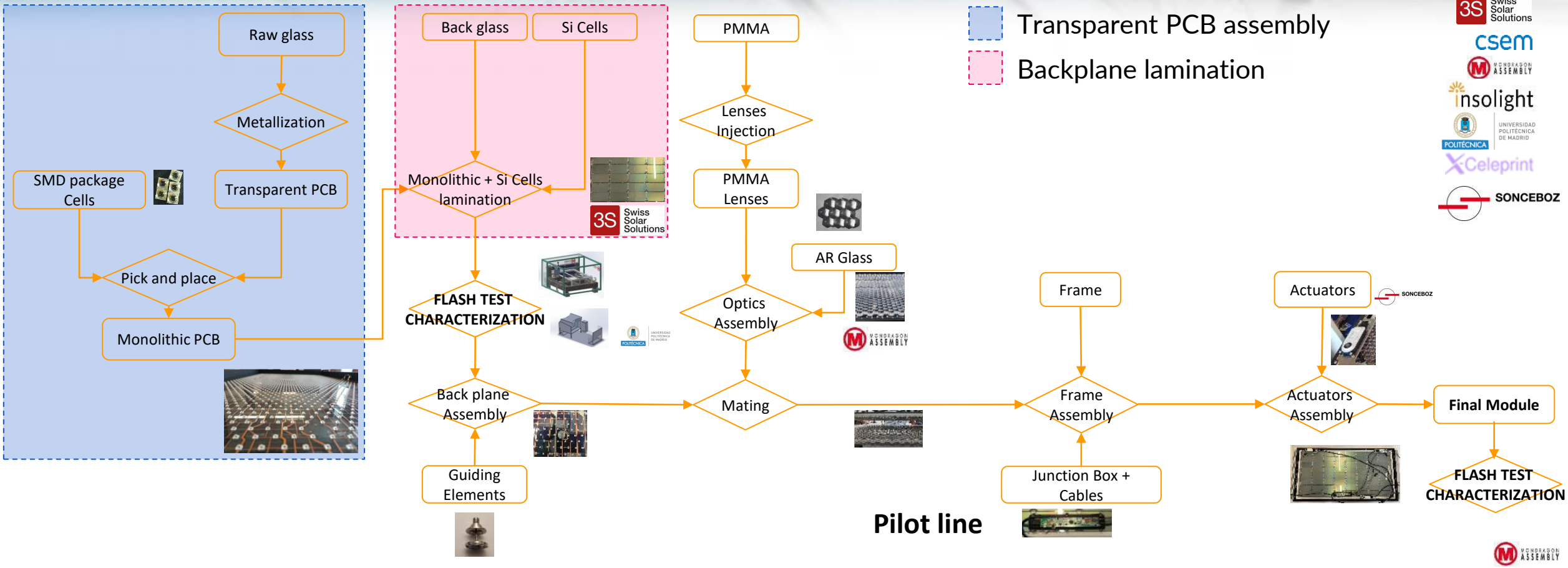
Celeprint

Assembly process in-depth review

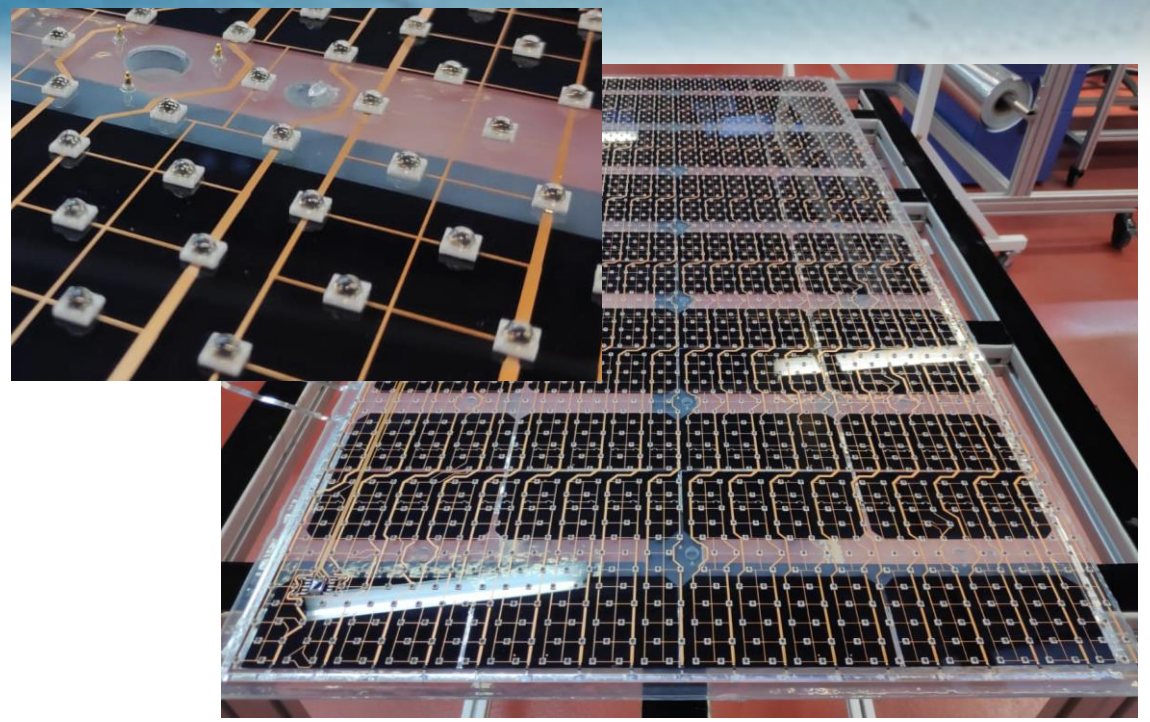
Hiperion Partners:

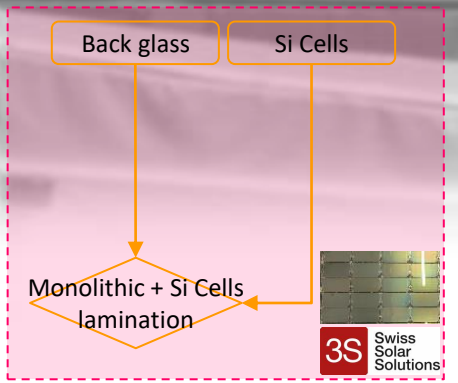
Transparent PCB assembly

Backplane lamination

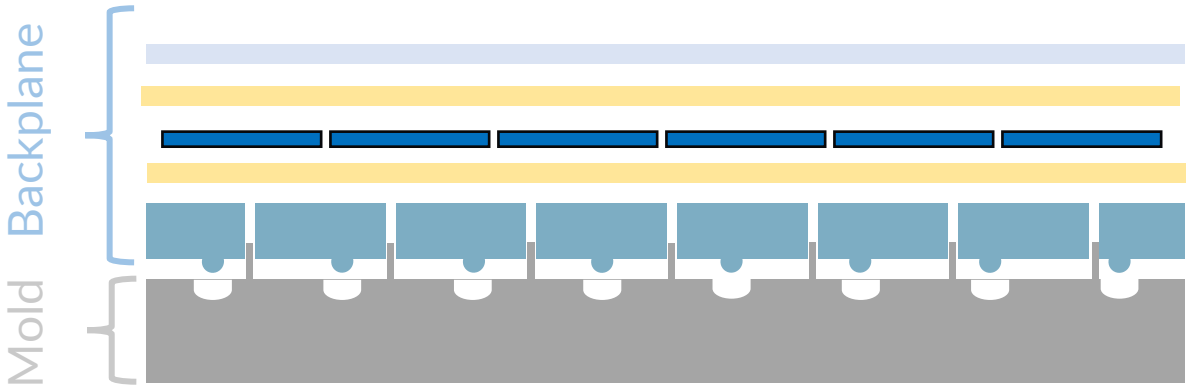


Photovoltaic module lamination





- Hybrid superposition of 2 technologies (MJ and c-Si)
- Glass-backsheet architecture to have a light and bifacial module



Transparent backsheet

2ndary Cells + interconnections & encapsulant

Monolithic glass + primary cells

Future GEN2 lamination mold

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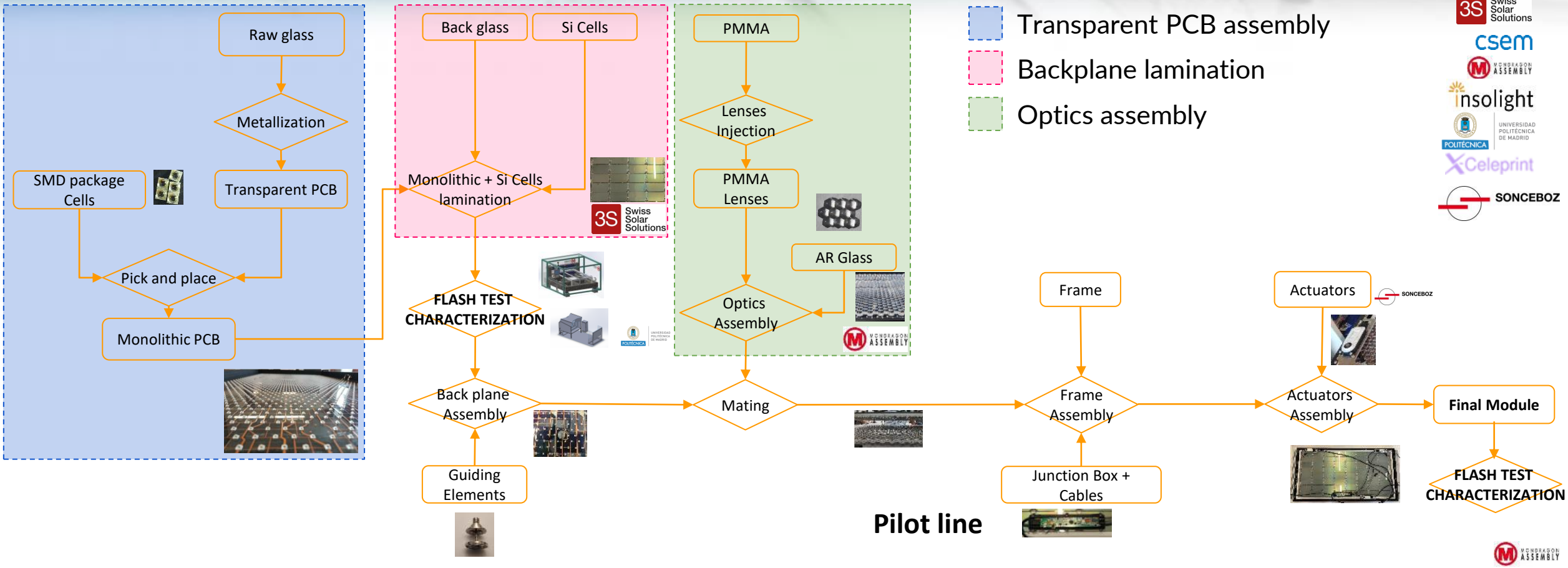
csem 3S Swiss Solar Solutions

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



Mondragon Assembly
csem
insolight

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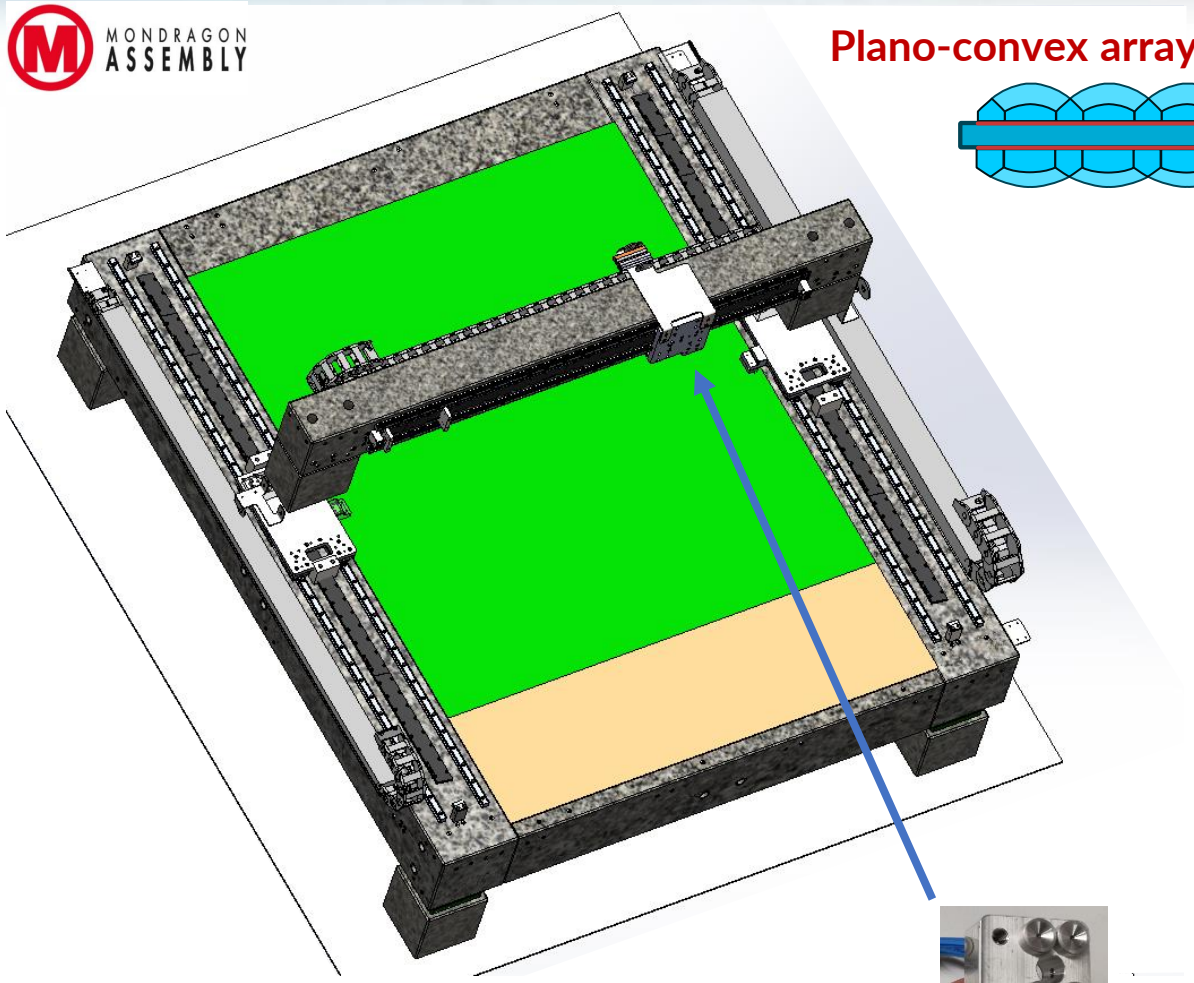
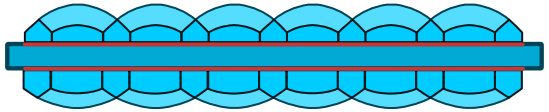
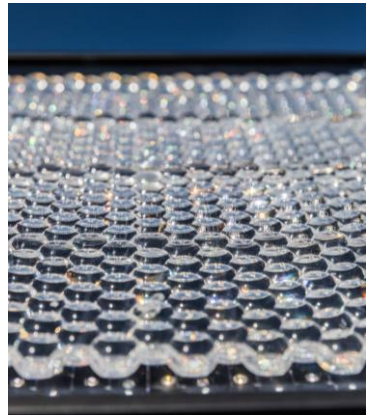
Automatic tool for optical arrays



Lens Assembly

Plano-convex arrays around the glass





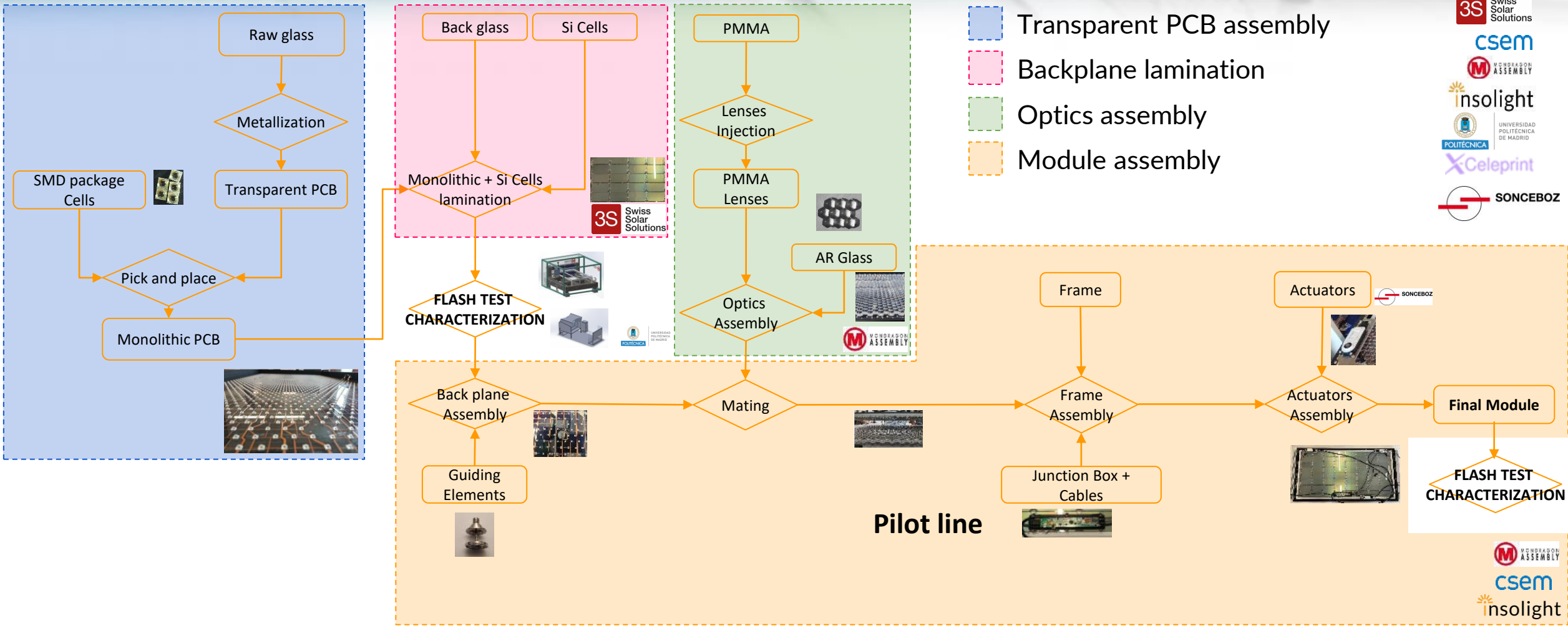
- **Lens assembly machine** developed by Mondragon Assembly
- Manufacture optical **arrays** from small lenses
- Pneumatic gripper picks up the lenses and place them on the glass before curing

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



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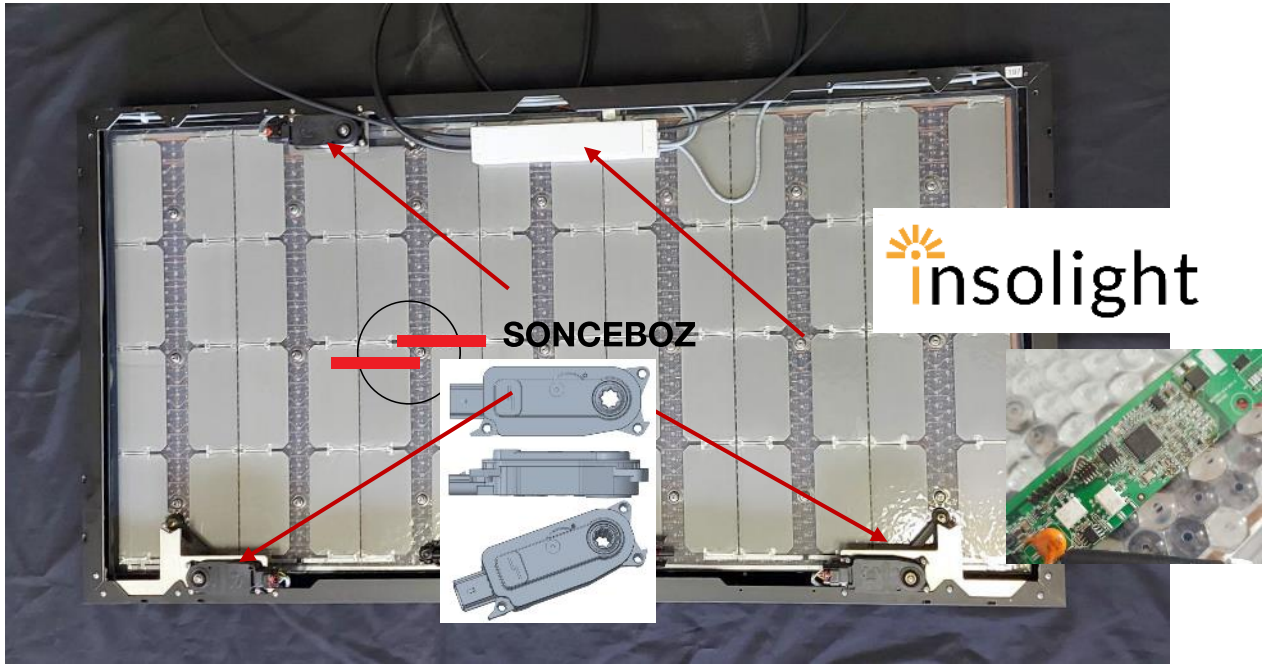
Mechanical Assembly – automated framing machine

- **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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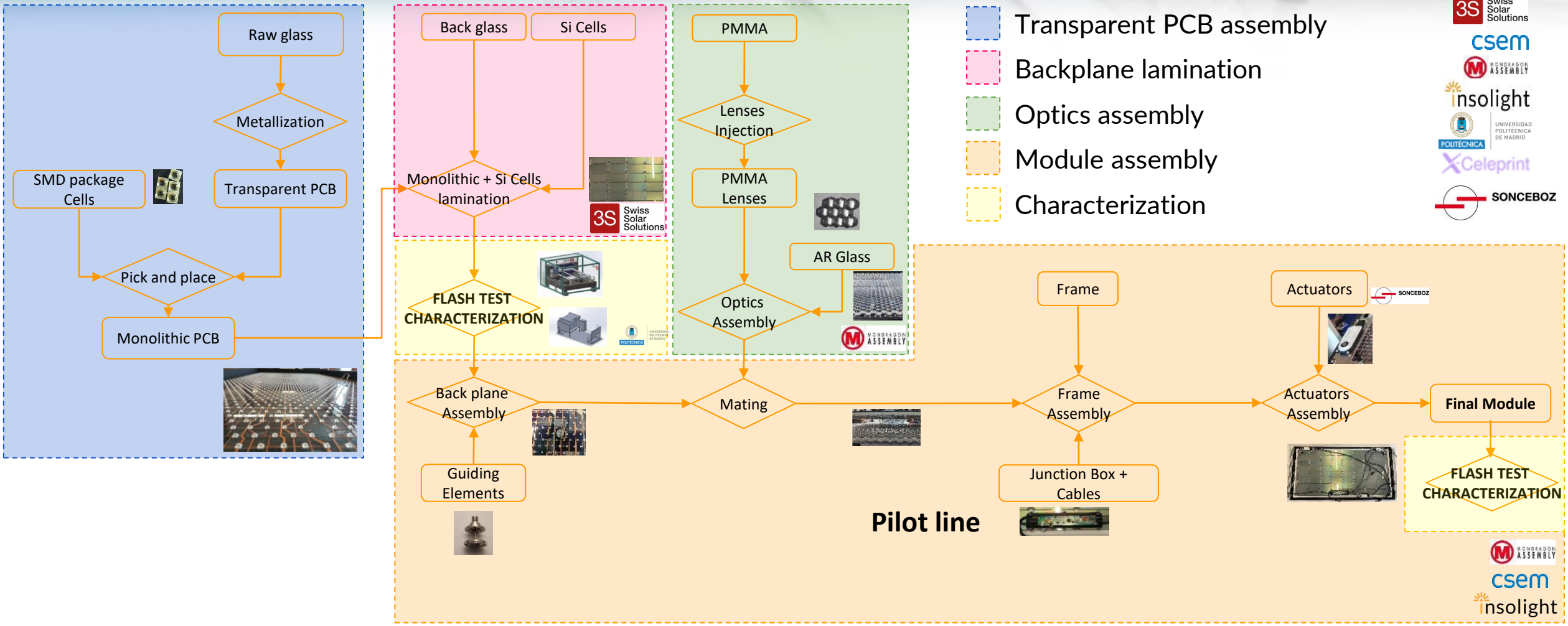
Transparent PCB assembly
Backplane lamination
Optics assembly
Module assembly
Characterization



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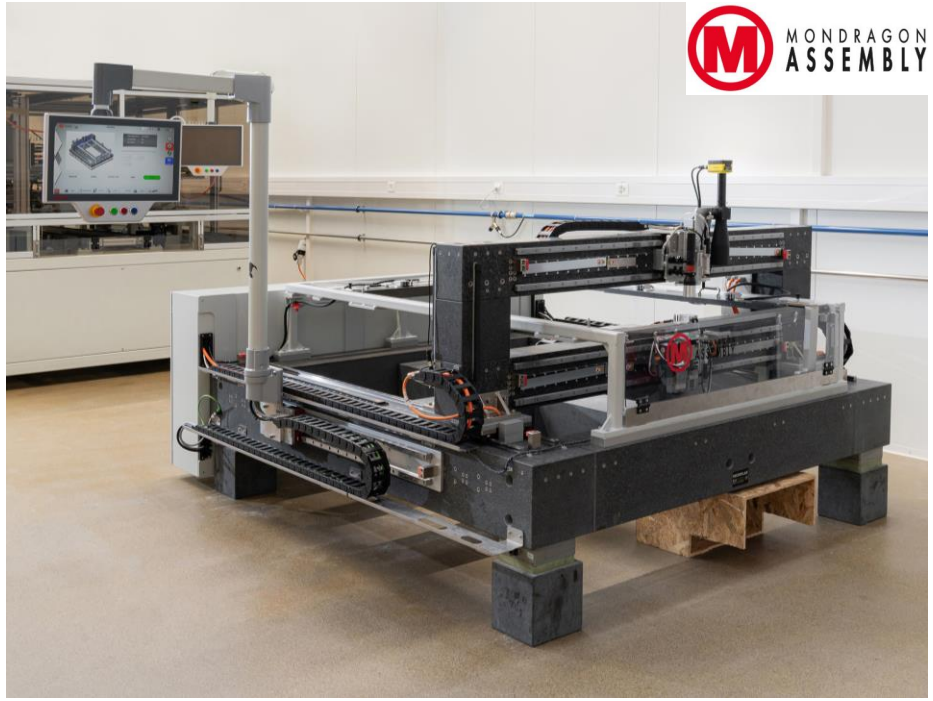
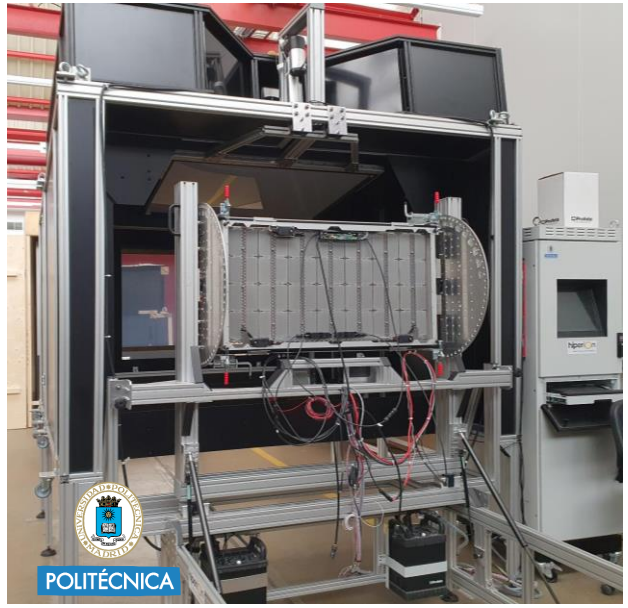
In-line and end-of-line test equipment

Characterization bench



- Top glass **planarity** to check the bending
- **Position** of the lenses with respect with high tolerances (laser + CDD camera)

Sun Simulator

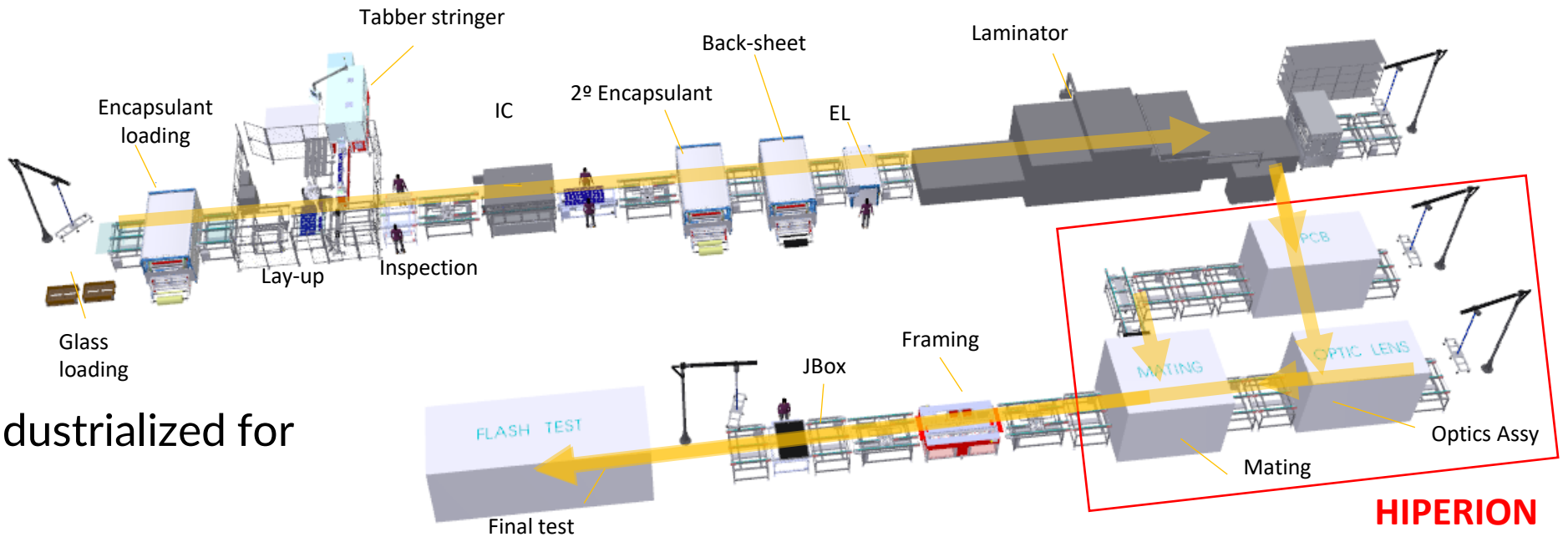


- **Sun simulator** to validate the performances
- **Collimated direct light** to characterize multi-junction solar cells (CPV)
- **Diffuse light** secondary silicon cells (PV)

Toward GW production line

- **Bring to industry** a hybrid solar module which combines PV and CPV

- Set-up the **pilot line** to demonstrate the assembly of these modules



- The technology can be industrialized for **mass production**

- Possible integration by manufacturers into their **existing** line

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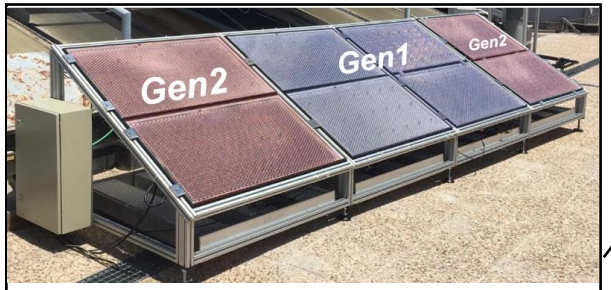
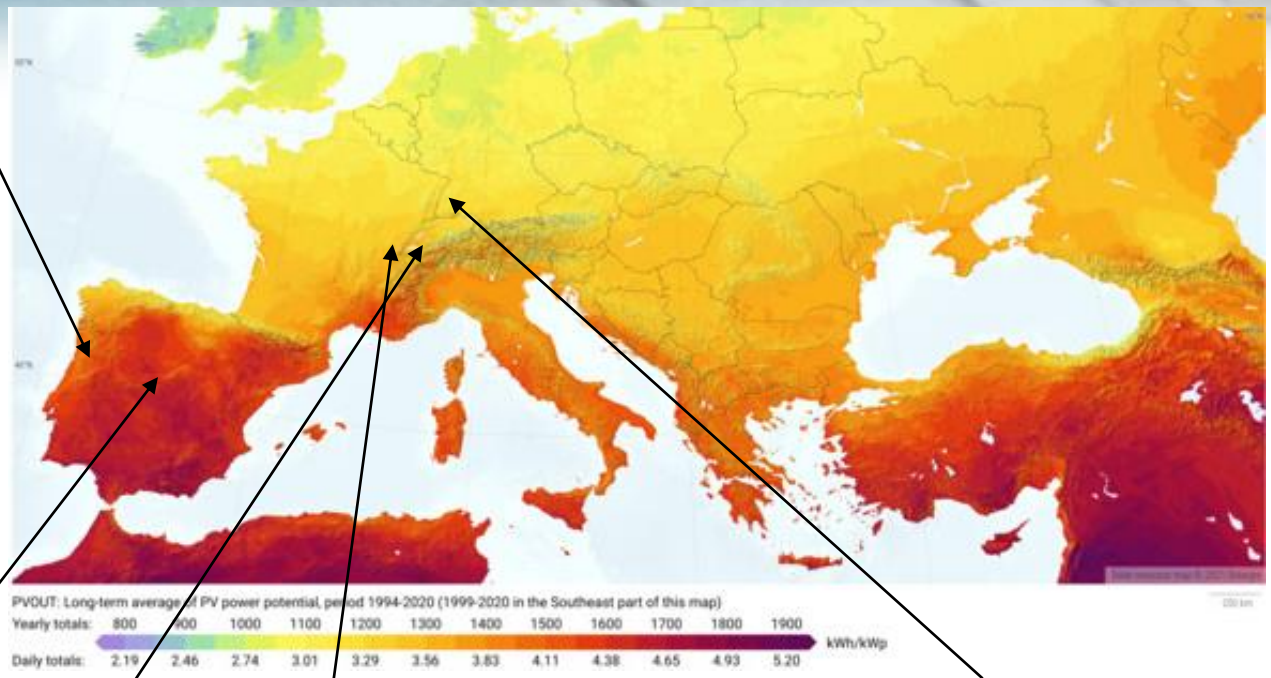
HIPERION monitoring pilot sites

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

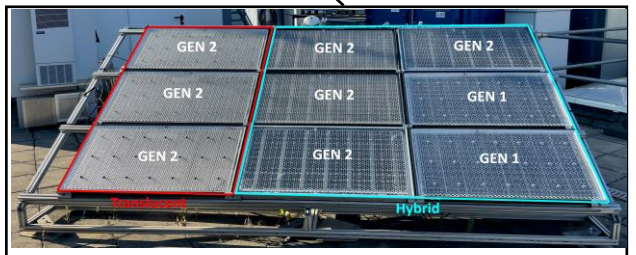


Location: Madrid, SP
Climate: Mediterranean
Irradiance: > 1700 kWh/kWp
Size: 11 modules
Period: 07.2022 – project end

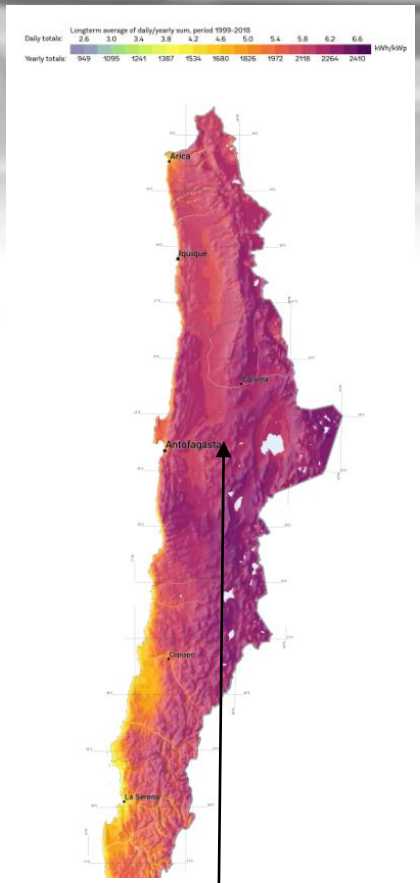
Location: Gstaad, CH
Climate: Continental
Irradiance: 1300 kWh/kWp
Size: 15 modules
Period: 10.2022 – project end



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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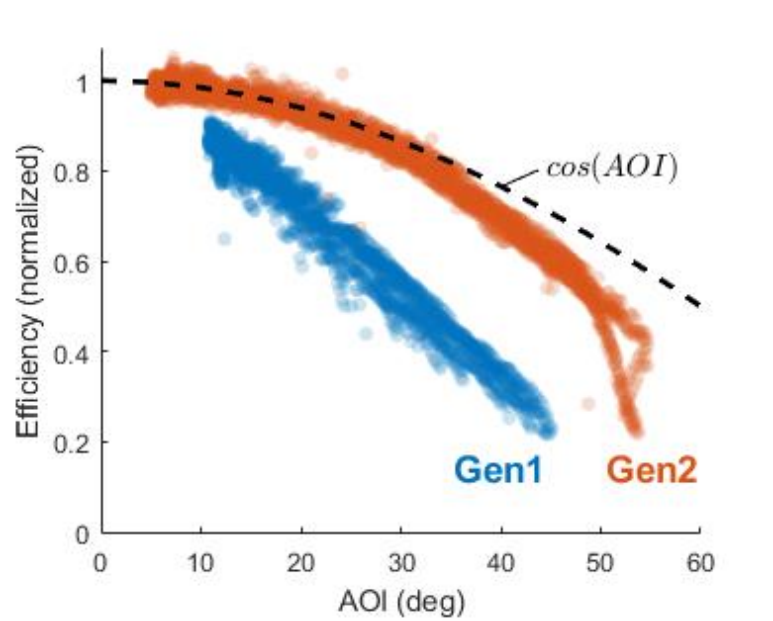
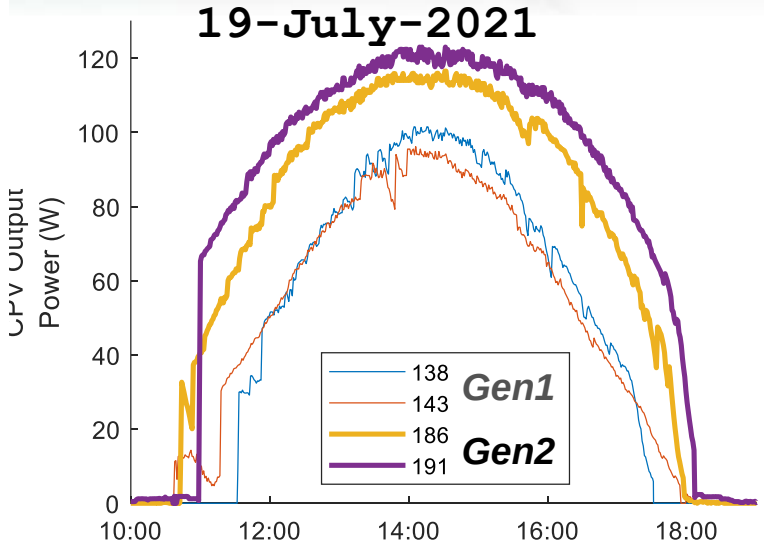
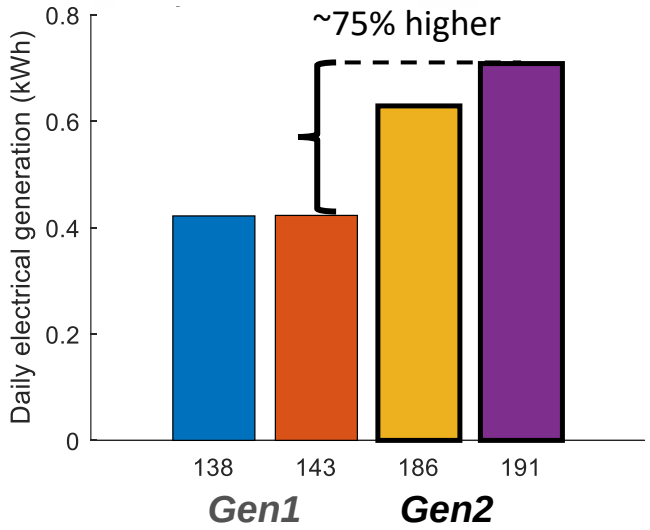
Outdoor performances







- 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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High power density

- W/m^2 over $\$/W$
- **Space constrained** applications

Urban Rooftop & zero energy buildings

EV Charging Station

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Transparent module for AgriPV

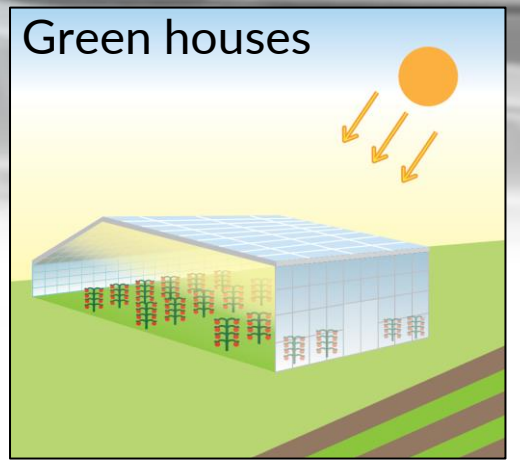
- Removing the silicon backplane and using the **transmitted light** for crops!

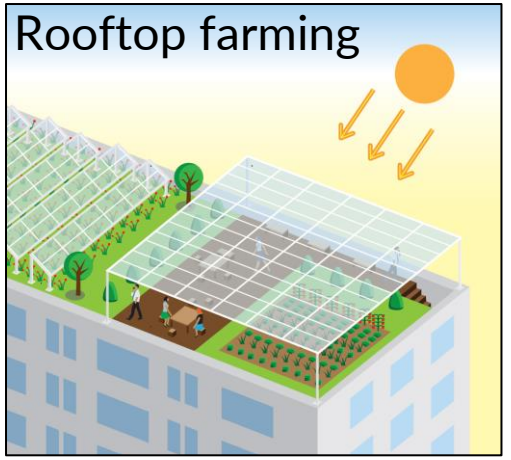
E-mode: Max electricity production

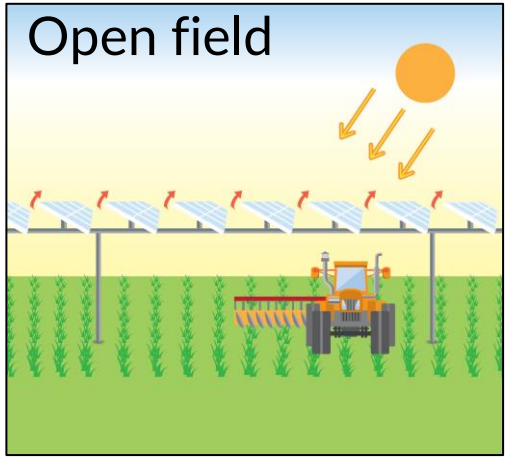
Direct light captured, diffuse light transmitted

MLT-mode: Max Light Transmission

Direct and diffuse light transmitted

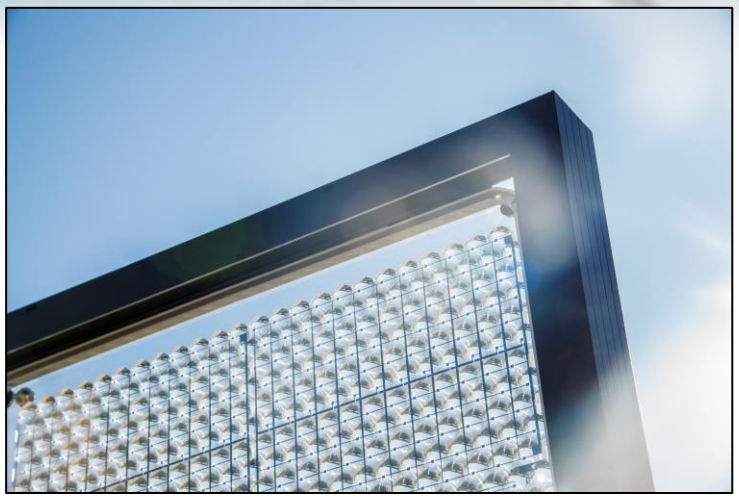


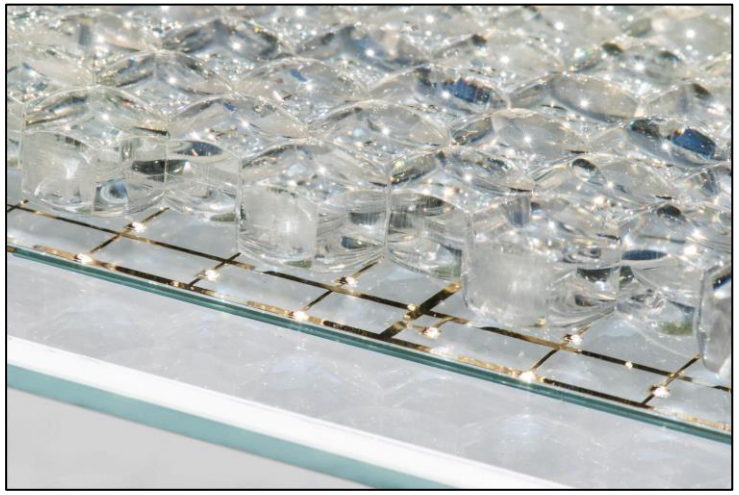


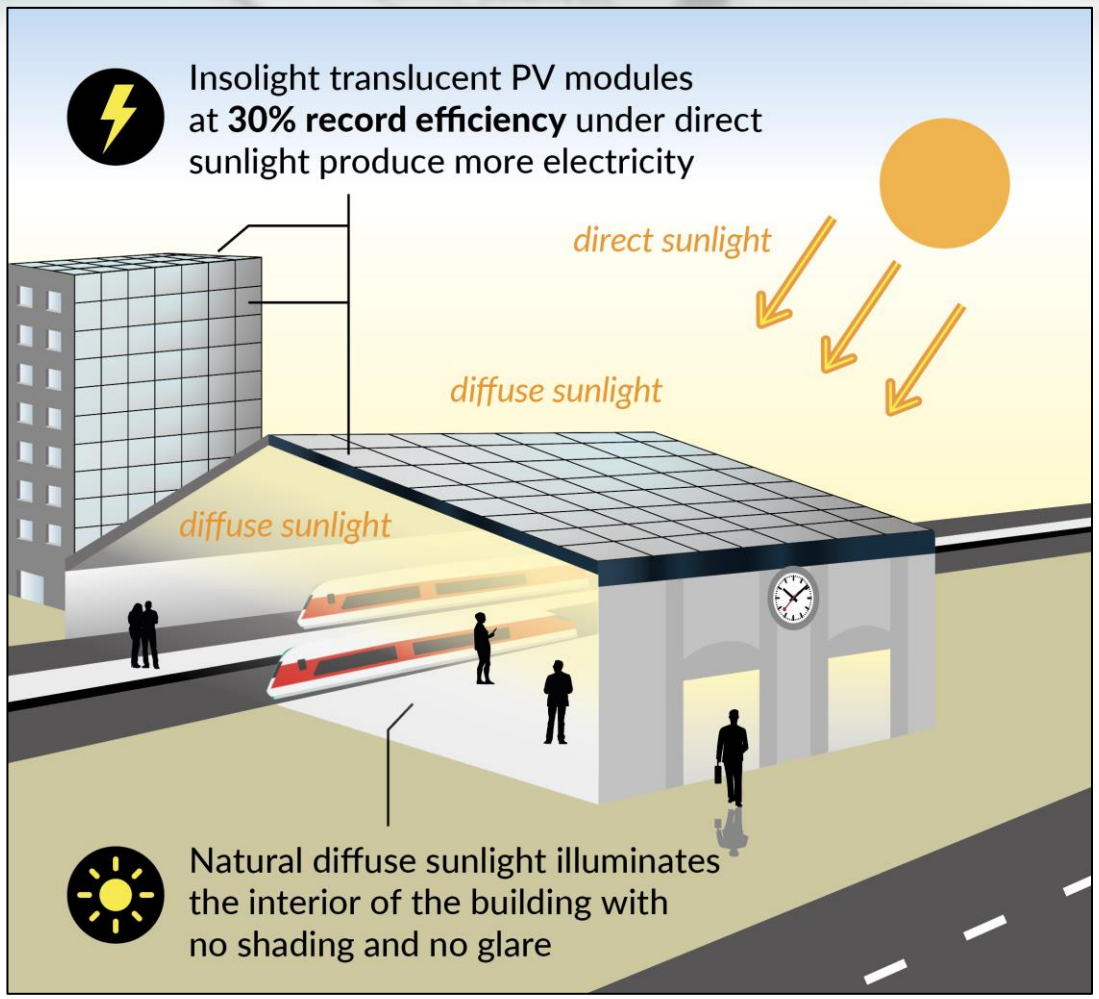


Transparent module for BIPV

- Removing the silicon backplane and using the transmitted light **indoor illumination**







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Outline

- Concept
- A bit of history
- Module Fabrication
- Pilot site and main results
- Broad range of PV applications
- **Achievements & perspectives**

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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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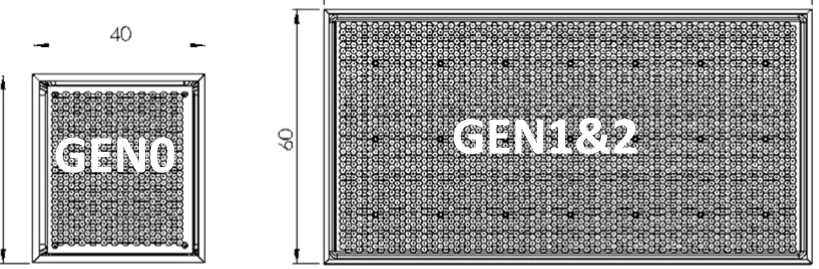
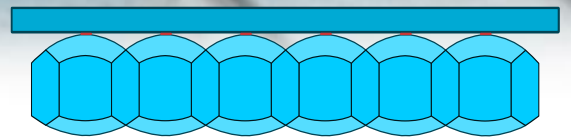
From GEN0 to GEN2

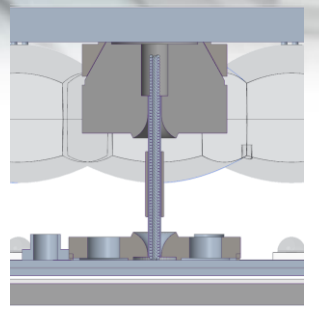


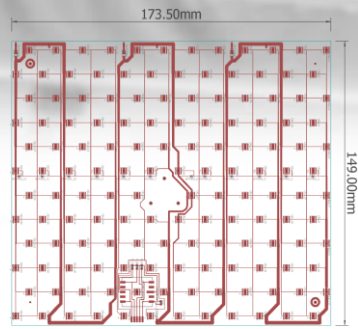
GEN1



Biconvex optics glued underneath glass

Guiding elements & actuators are **glued**

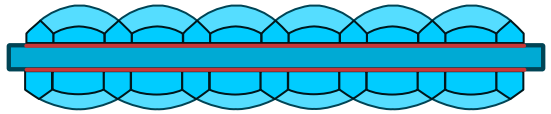




21 x

Assembled PCBs (silver)

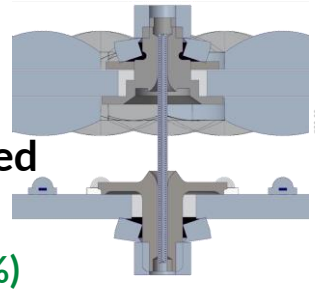
GEN2

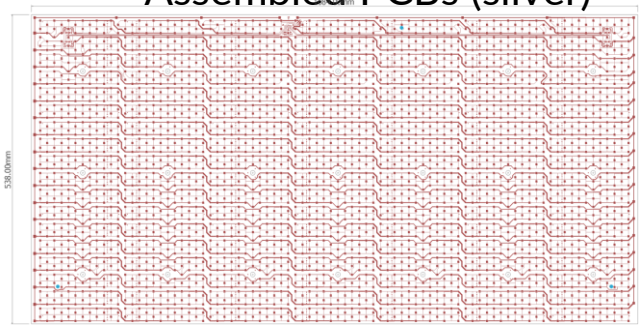


Plano-convex arrays around the glass

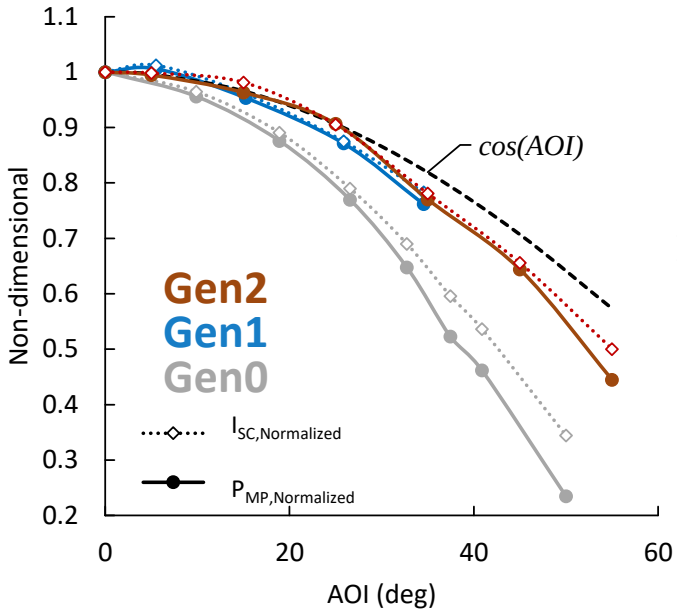
Guiding elements & actuators are **screwed**

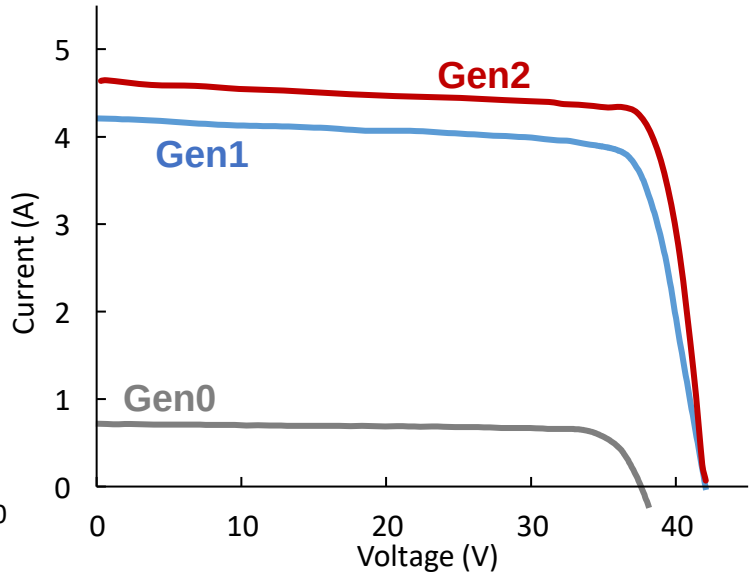
- ✓ **Improved reliability (adhesive area incr.)**
- ✓ **Improved performance (Estimated 8-15%)**





Monolithic PCB (copper)





	Gen0	Gen1	Gen2
V_{OC} [V]	38.2	42.1	**42**
I_{SC} [A]	0.96	4.27	**4.57**
P_{MP} [W]	29.9	141	**156**
V_{MP} [V]	33.5	36.5	**37.1**
I_{MP} [A]	0.89	3.87	**4.20**
FF [%]	82%	78%	**81%**
Eff. [%}	**29.0%**	↓ 26.0%	↑ 29.0%

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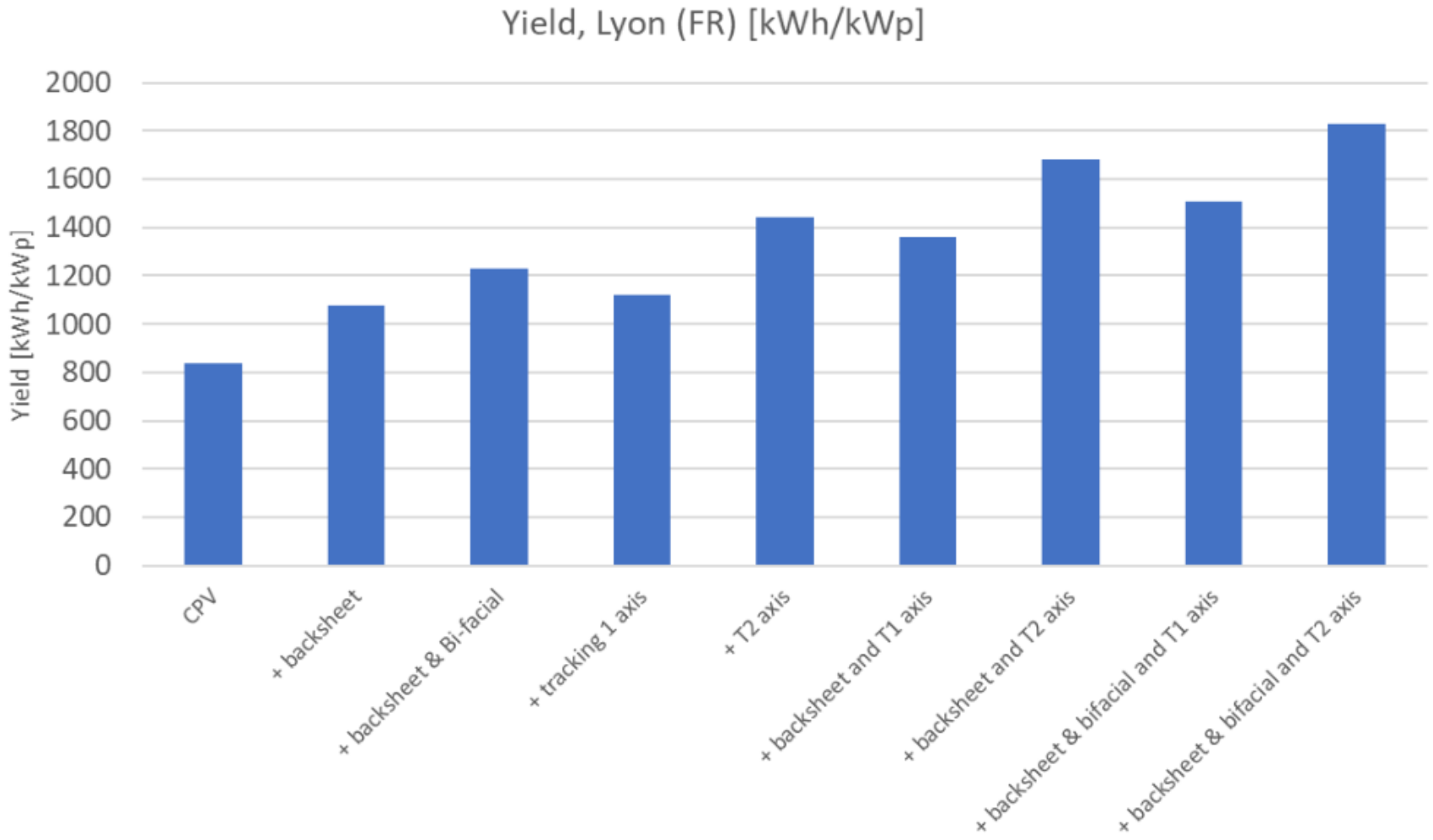
Energy yield: scenarios



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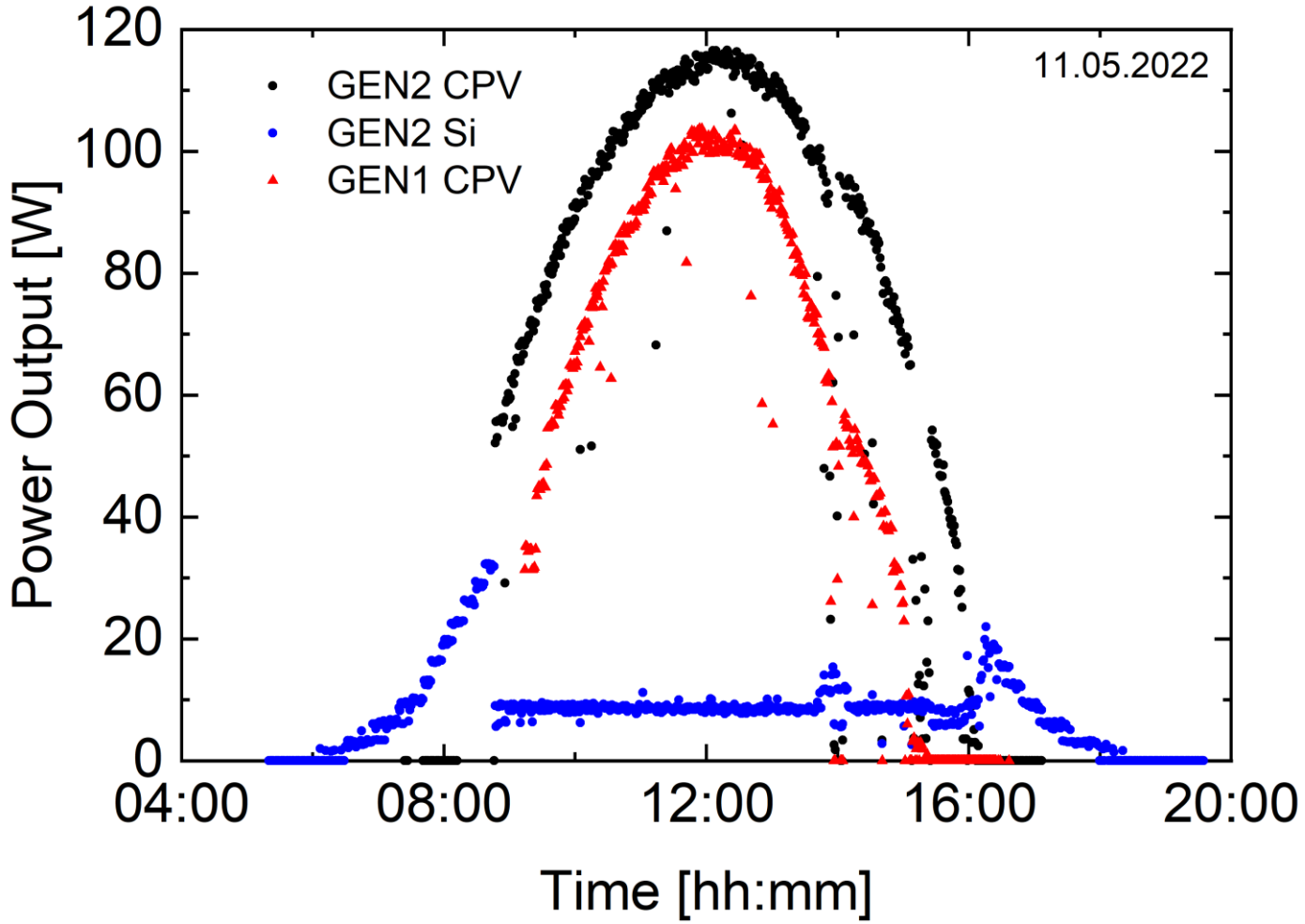
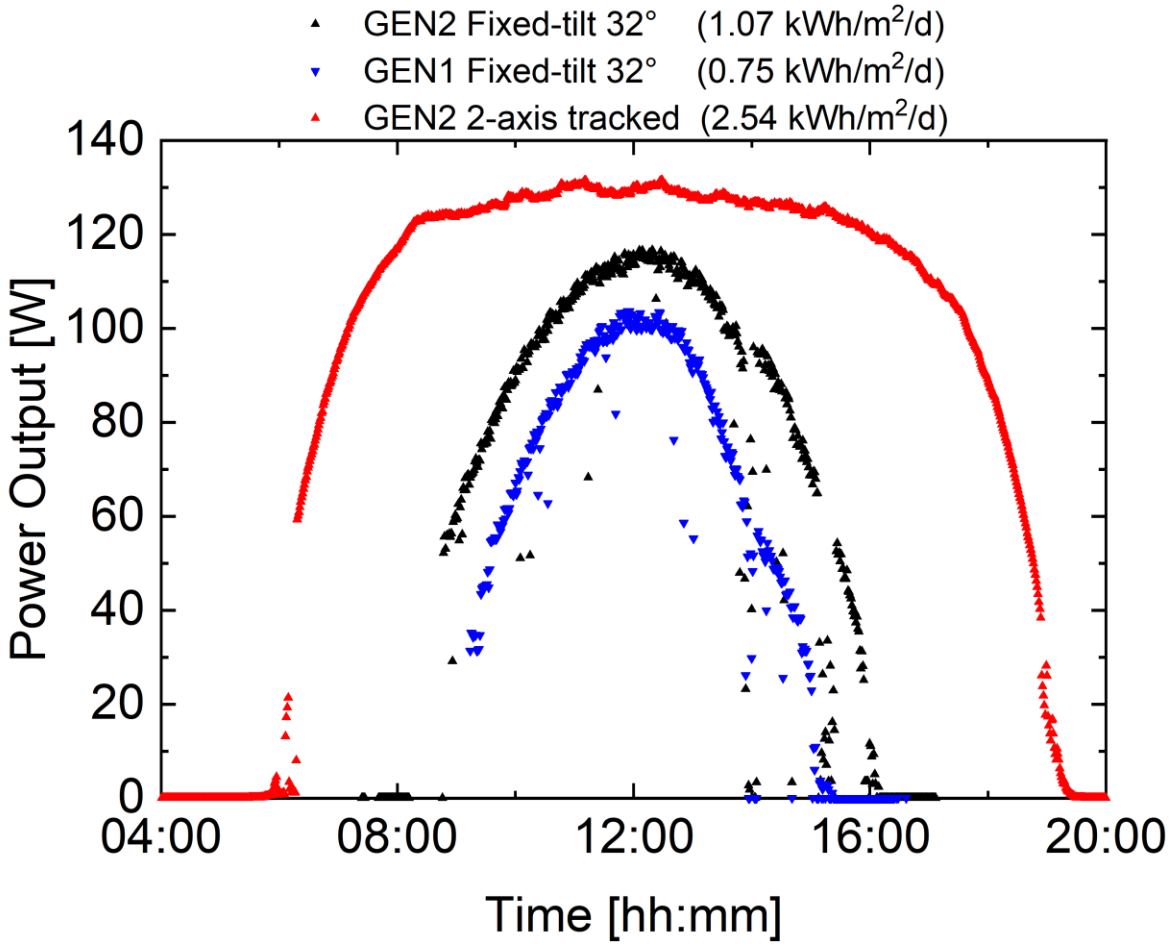
Results from Freiburg pilot





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