

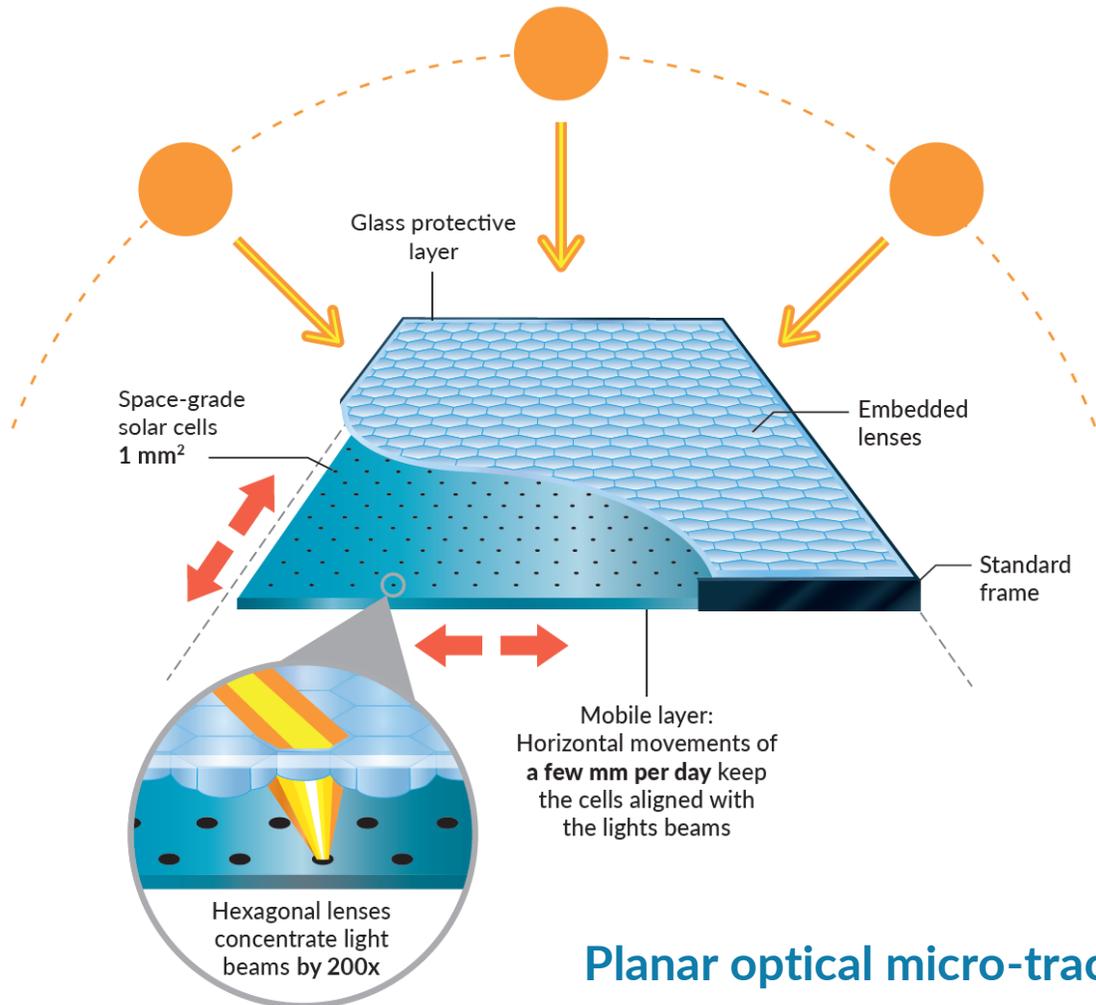
Automated assembly of hybrid PV modules

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CSEM / HIPERION



Insolight's Photovoltaic System

 insolight

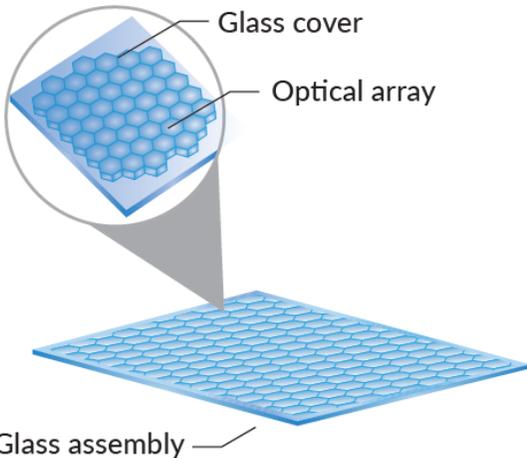


Planar optical micro-tracking

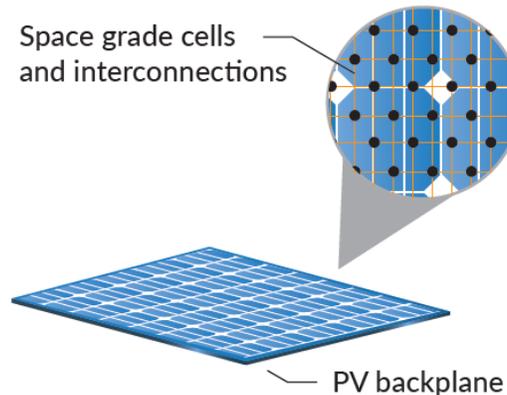
- Sunlight is **concentrated** on an array of highly efficient micro solar cells (multi-junctions)
- **Integrated** micro-tracking (module not moving)
- Standard **flat panel** form factor mountable on any racks or rooftops
- Insolight's system is an **overlay on top** of mainstream PV modules

Hiperion Module Fabrication

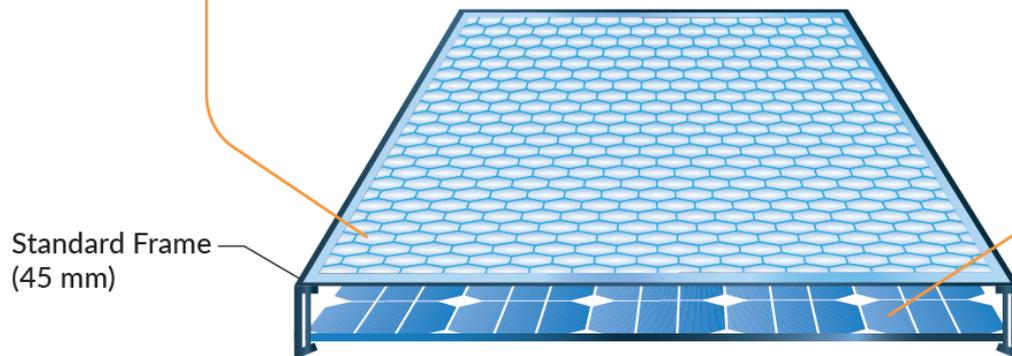
1 Assembling the optical glass



2 Mounting the space grade cells array onto a PV backplane



3 Final assembly



- 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

Toward GW production line

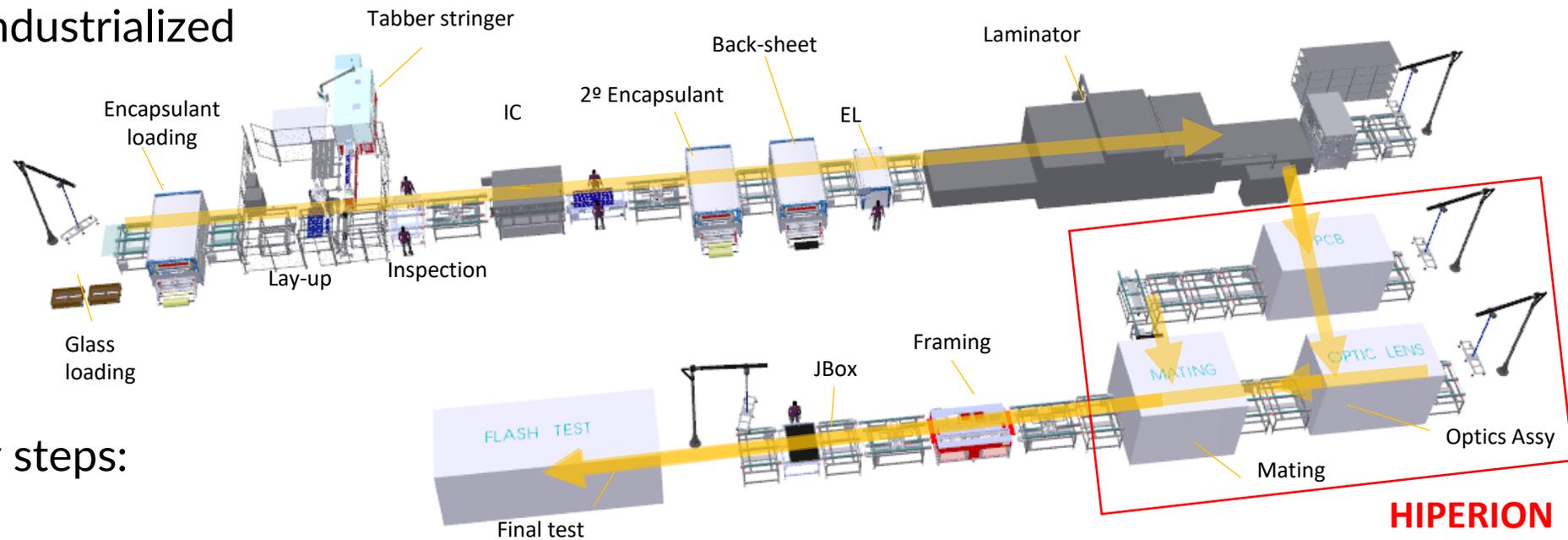
- **Bring to industry** a hybrid solar module which combine PV and CPV
- Set-up the **pilot line** at CSEM to demonstrate the assembly of these modules

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

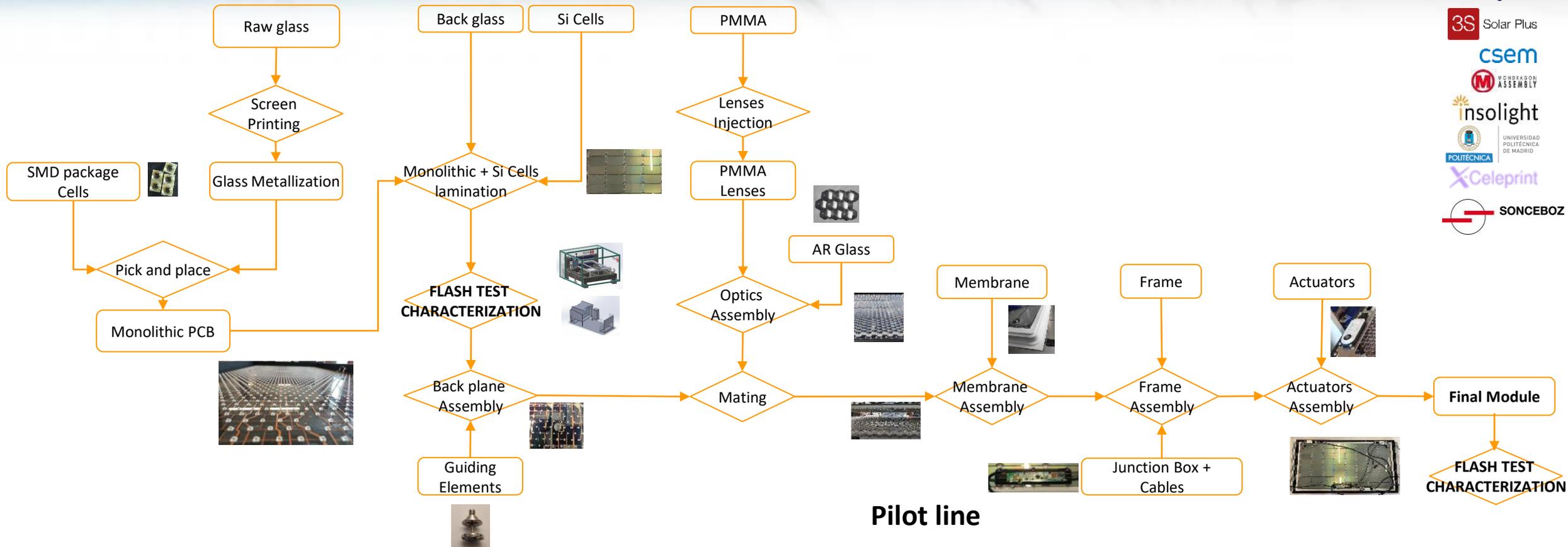
- Integration by manufacturers into their **existing** line

- **Few additional** assembly steps:

- PCB assembly
- Optic Assembly
- Mating



Assembly process in-depth review

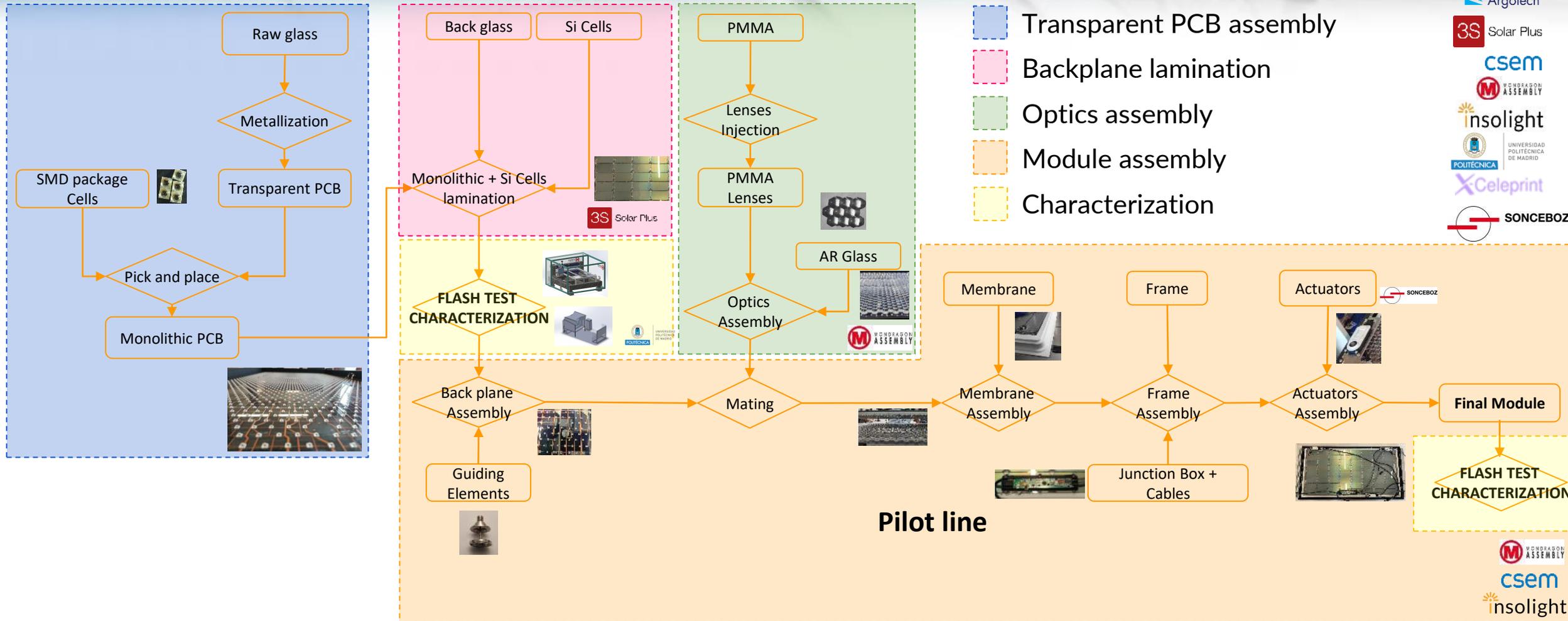
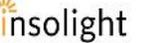


Hiperion Partners:



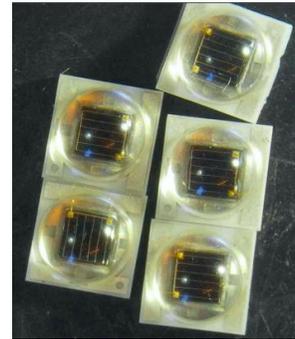
Assembly process in-depth review

Hiperion Partners:



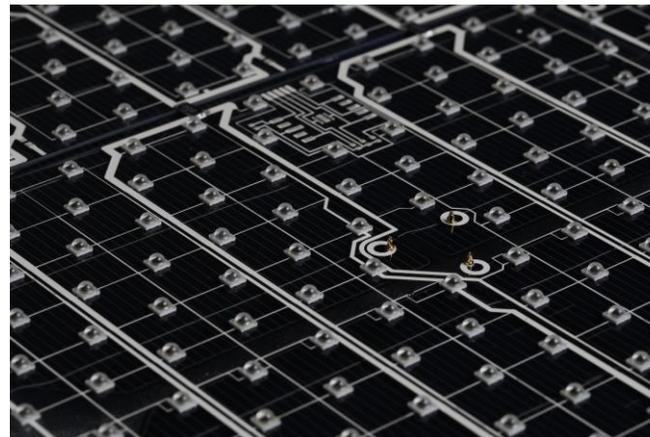
Transparent PCB to harvest direct sunlight

Singulated COIs with optical elements

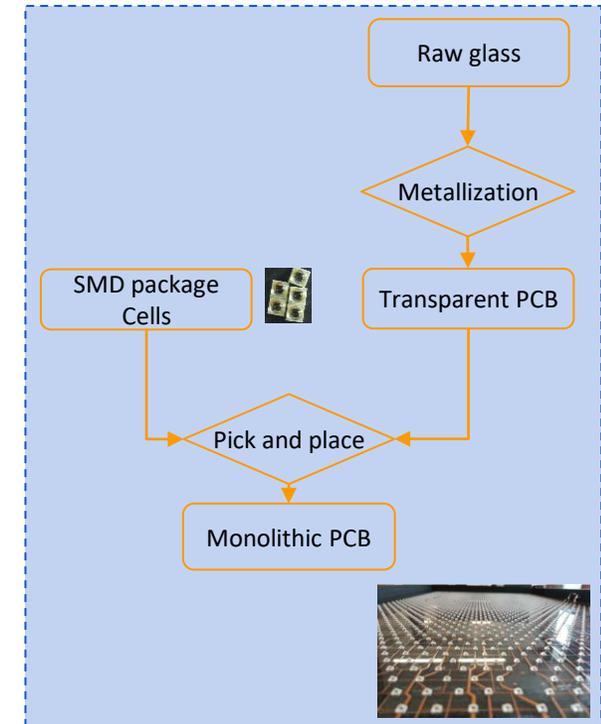


- Commercial cells from space grade multi-junction cells **packaged** in a standard LED SMD package
- Metallization on glass to obtain a **transparent PCB**
- **Pick and place** of receivers to transparent boards

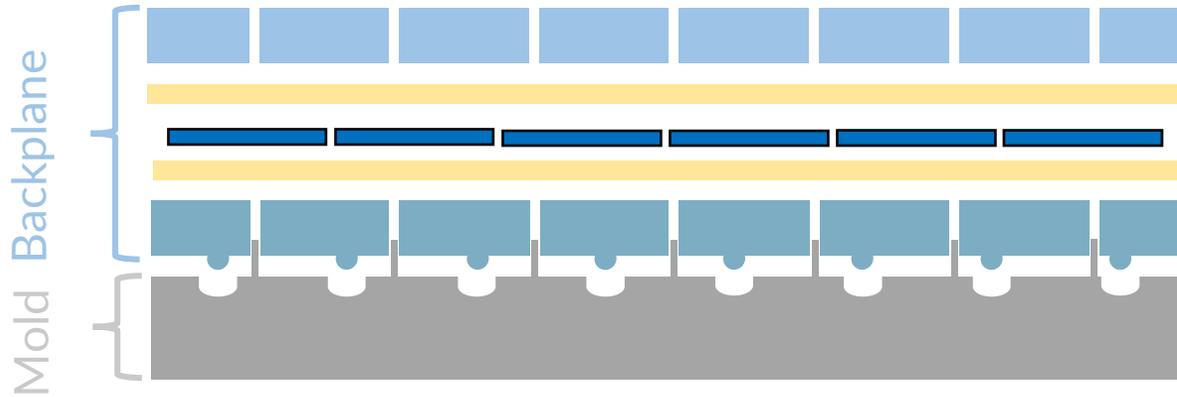
Transparent monolithic PCB



COIs assembled to backplane



Photovoltaic module lamination

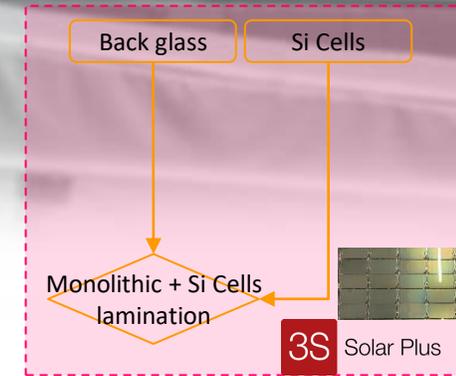


Back glass

2ndary Cells + interconnections & encapsulant

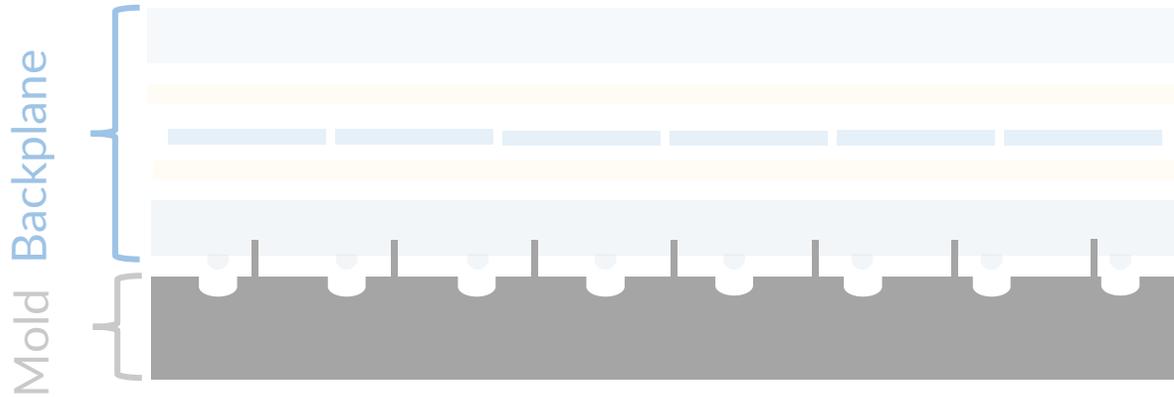
Monolithic glass + primary cells

Future GEN2 lamination mold



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

Photovoltaic module lamination

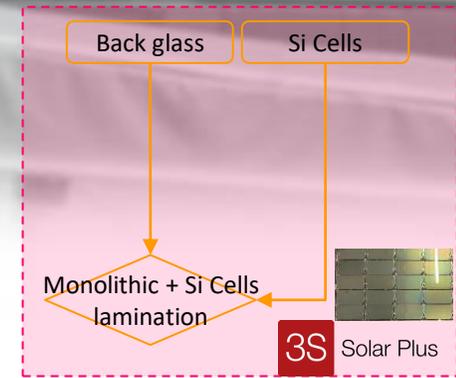


Back glass

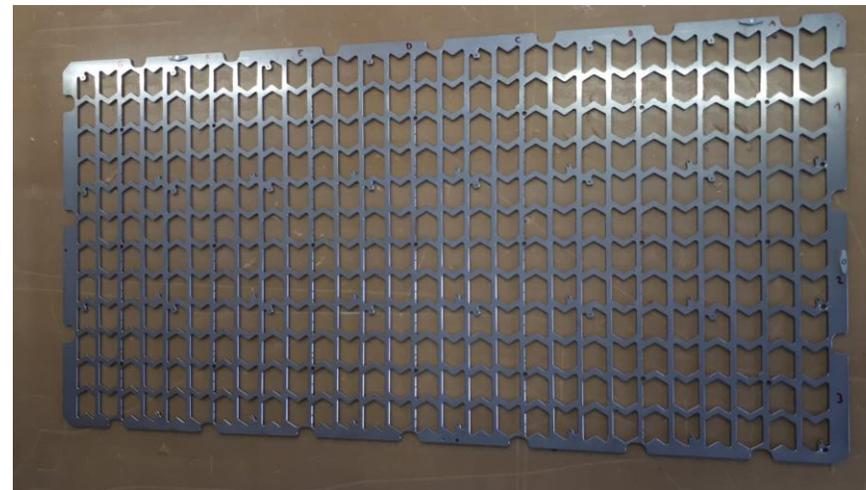
2ndary Cells + interconnections & encapsulant

Monolithic glass + primary cells

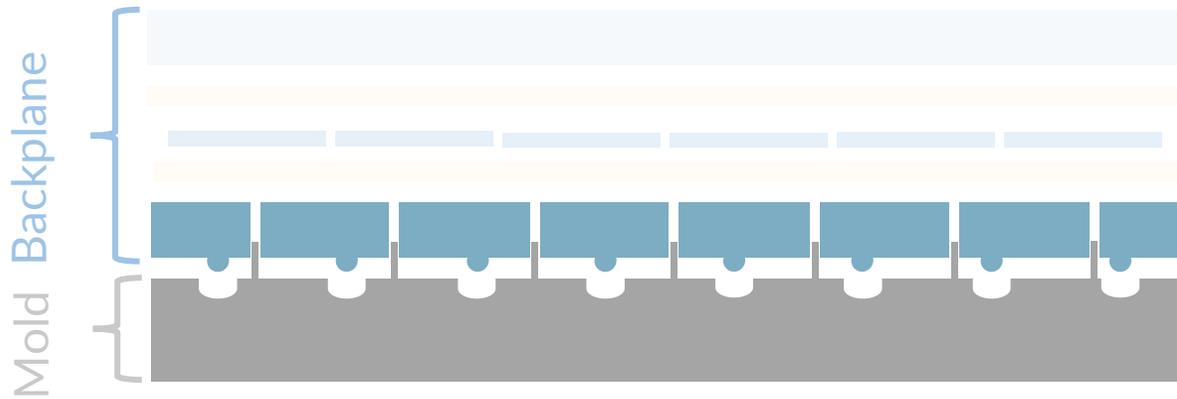
Future GEN2 lamination mold



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



Photovoltaic module lamination

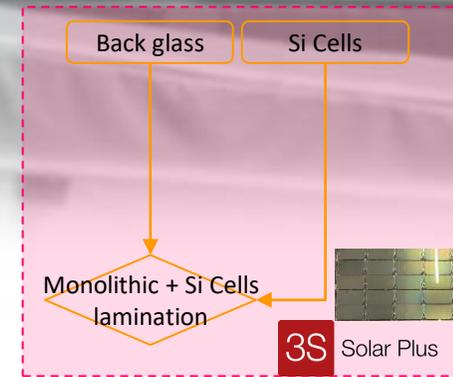


Back glass

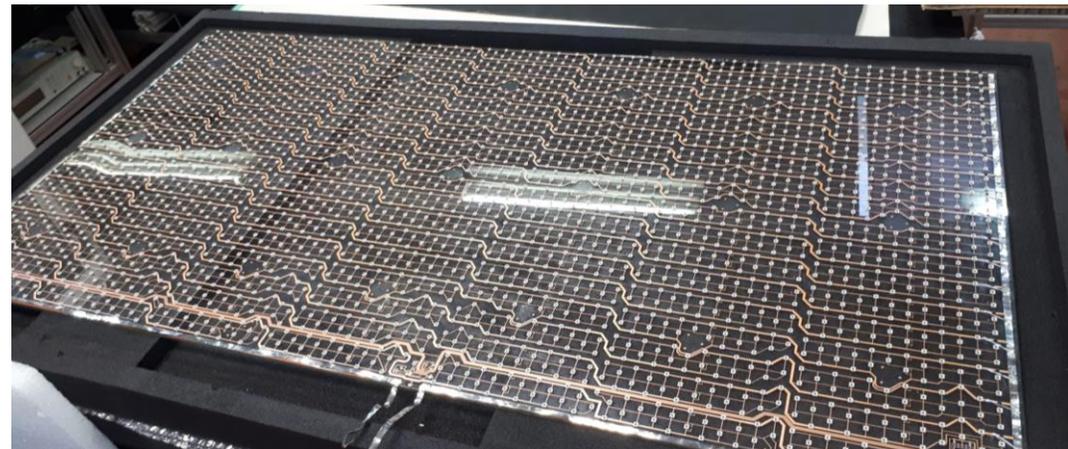
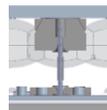
2ndary Cells + interconnections & encapsulant

Monolithic glass + primary cells

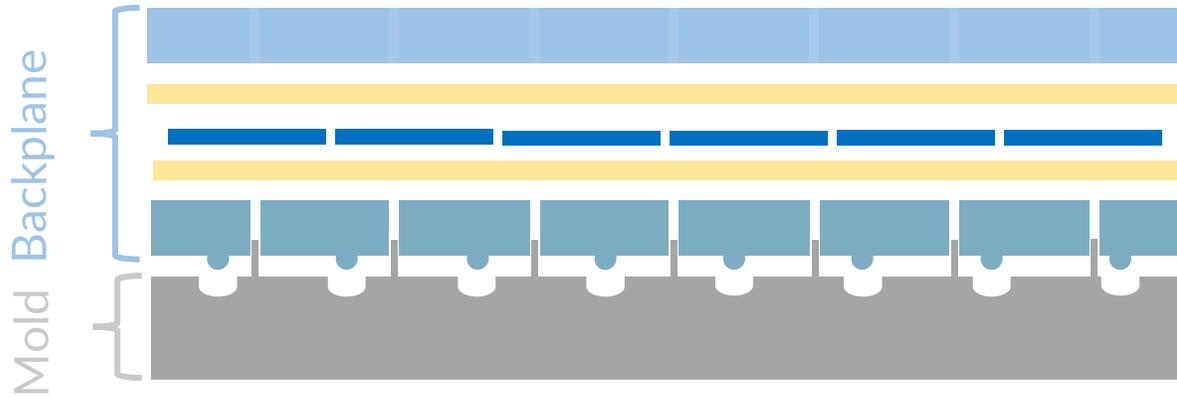
Future GEN2 lamination mold



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



Photovoltaic module lamination

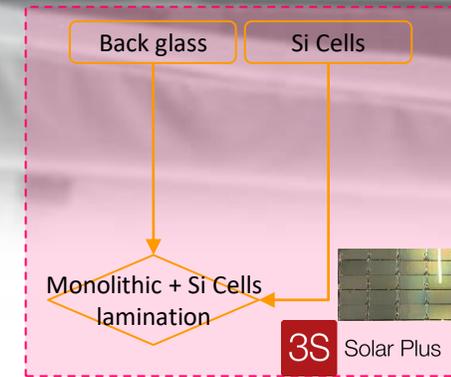


Back glass

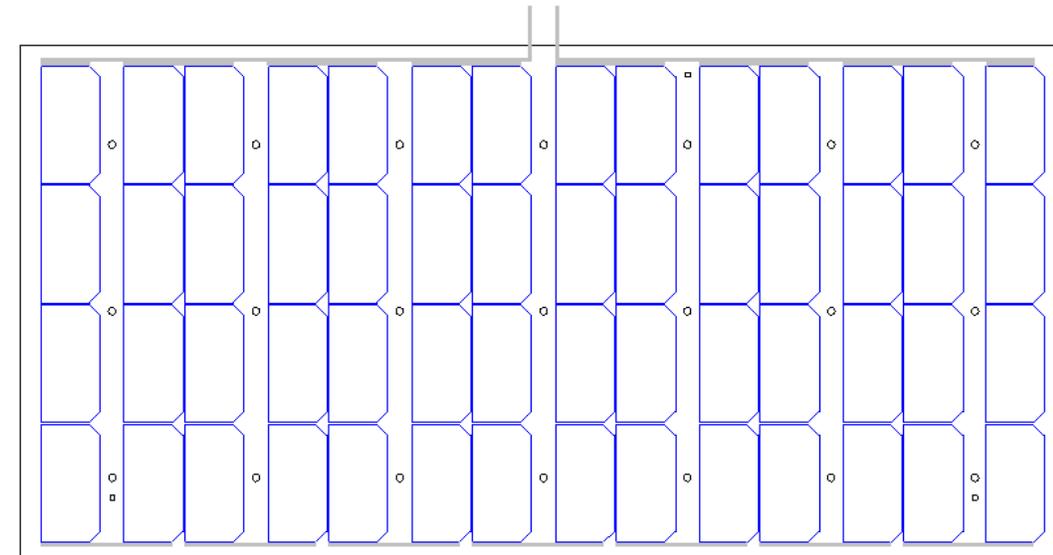
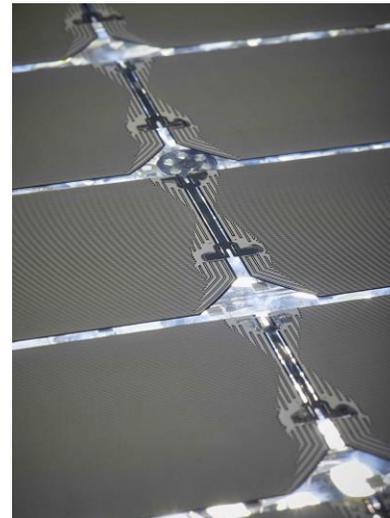
2ndary Cells + interconnections & encapsulant

Monolithic glass + primary cells

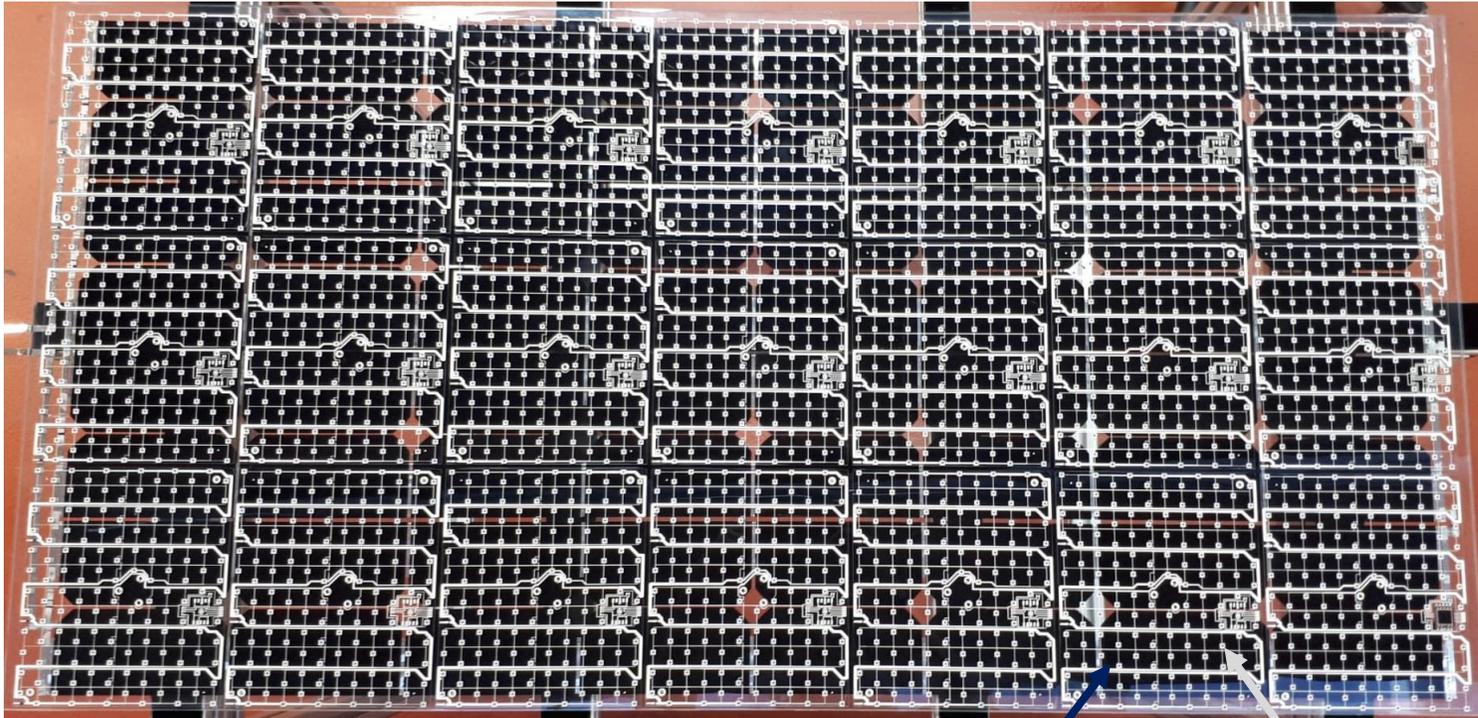
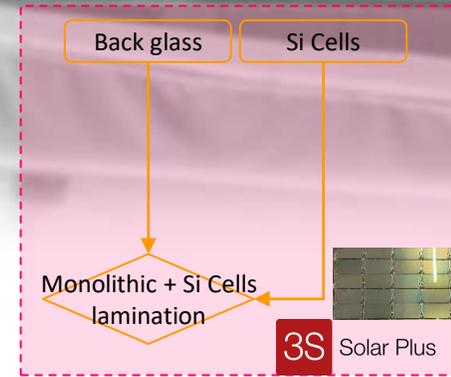
Future GEN2 lamination mold



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



Photovoltaic module lamination



Secondary cell
(conventional PV)

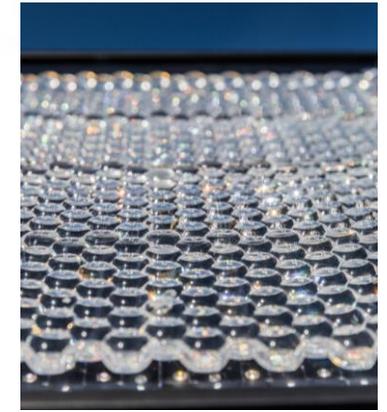
Primary cell
(under concentration)

- Superposition of 2 technologies provide a very efficient module in **any weather** conditions
- Hybrid system combines **advantages** of both technologies

Automatic tool for optical arrays



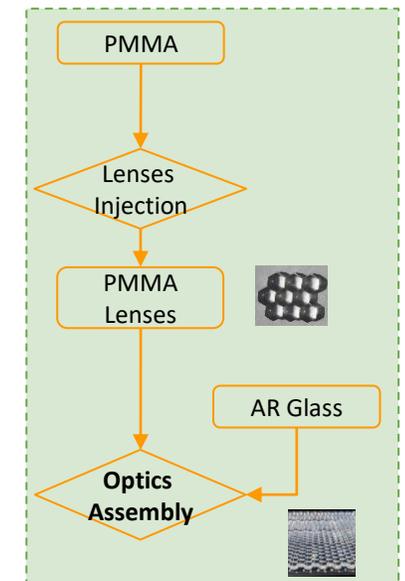
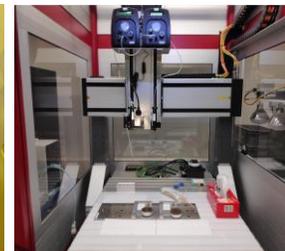
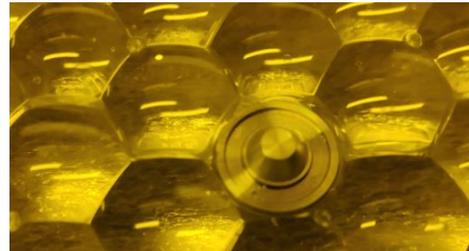
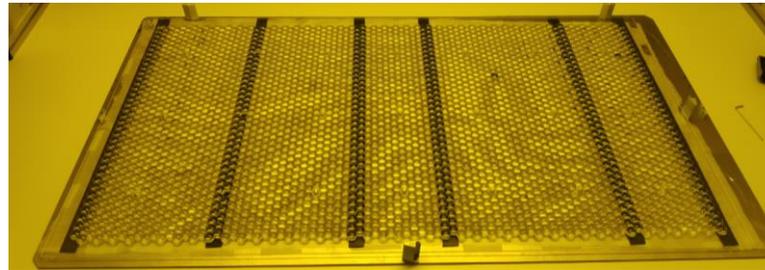
Lens Assembly



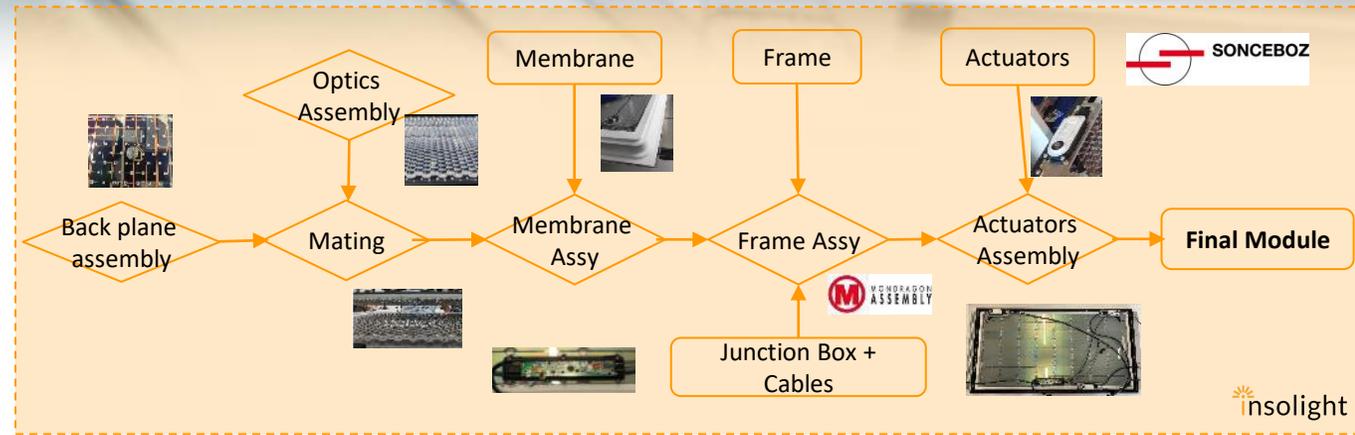
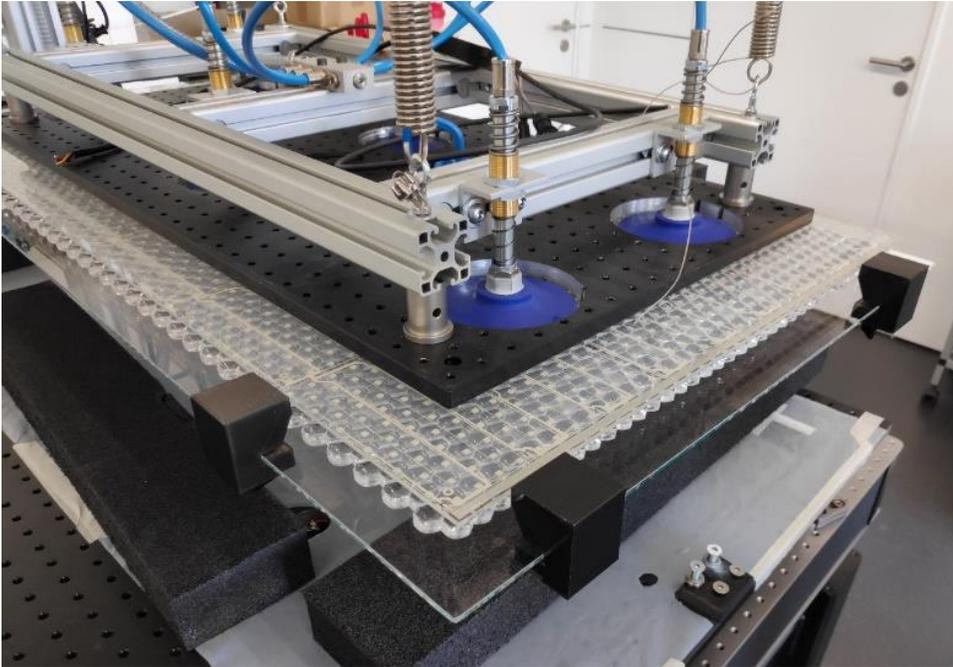
- **Lens assembly machine** developed by Montdragon Assembly
- Manufacture optical **arrays** from small lenses

Automatic tool for optical arrays

- Mechanical jig to **position** the lens and the guiding element with high positioning tolerances (0.3 mm)
- Lens surface filled with adhesive to **bond** lens and glass
- Glue is **cured** with UV light



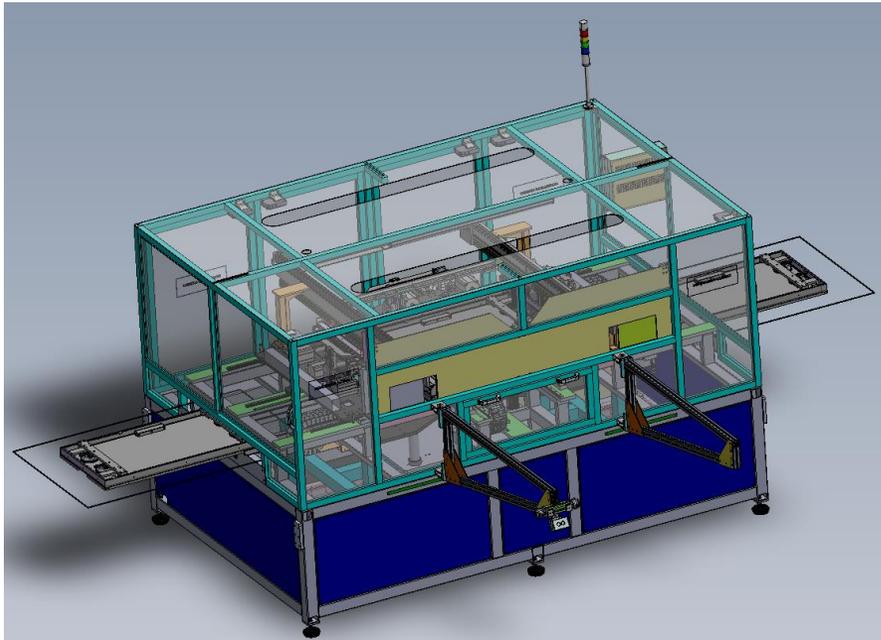
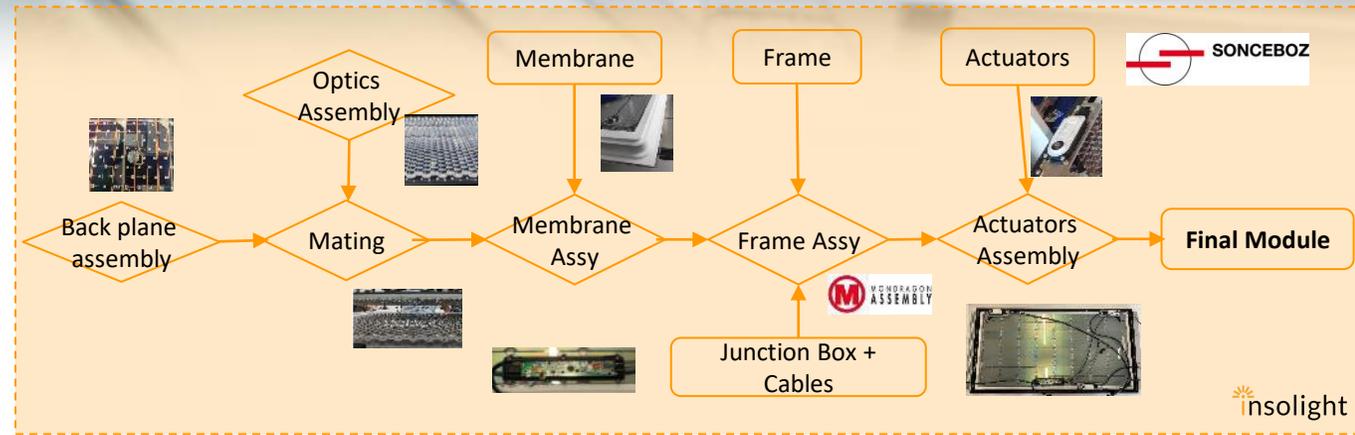
Mechanical Assembly – Mating



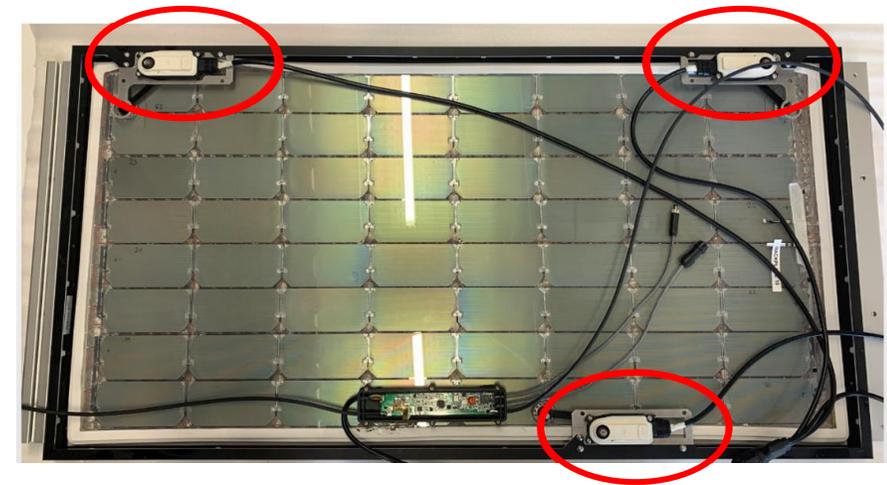
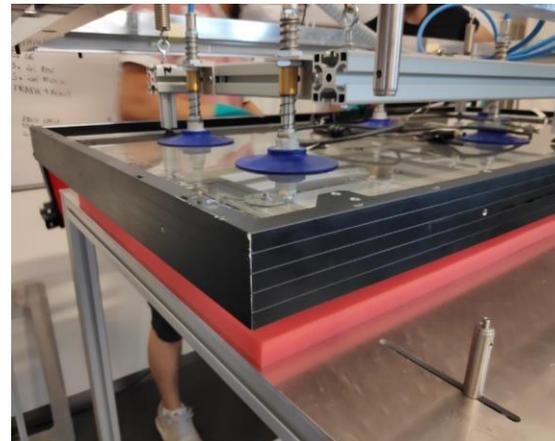
- **Mating** : Manual assembly of the backplane and the optical layer held by the guiding elements

Mechanical Assembly – Framing

- **Framing** : Automated assembly of the frame, junction box and actuators
- **Automated Framing** Machine designed by Montdragon Assembly

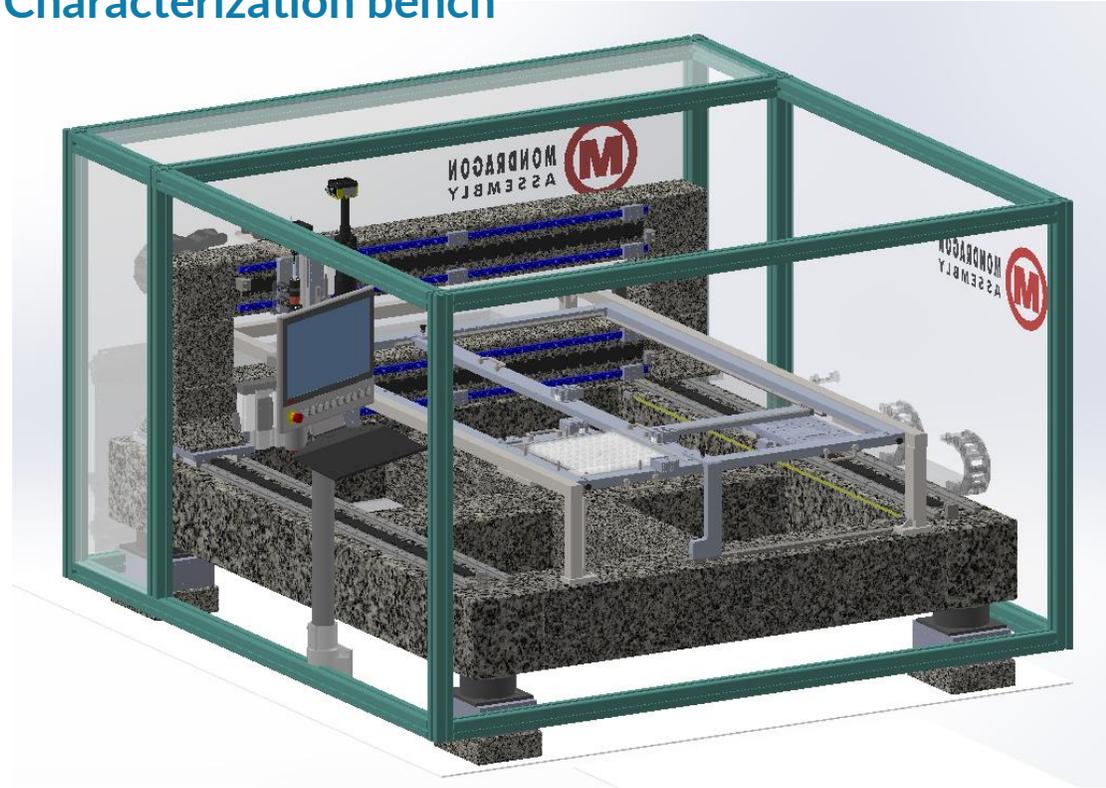


Automated Framing Machine



In-line and end-of-line test equipment

Characterization bench



- **Characterization bench** will measure
 - Backplane
 - Optical Plane
 - Full Module
- Top glass **planarity** is measured to verify the bending of 2 glasses once the module is fully assembled
- **Position** of the lenses and primary cells on the glass can be measured.
 - collimated laser illuminate one element
 - CCD camera capture the focus behind the lens

In-line and end-of-line test equipment

- **Sun simulator** developed by UPM to validate the performances of the backplane and the module
- 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)



Sun Simulator

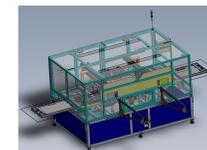
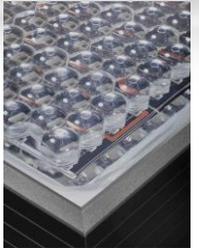
Deployment on pilot installations & Monitoring



- Modules deployed on **3 pilot installations** (Lausanne, Madrid, Freiburg)
- **100 m²** modules will be produced with the pilot line
- Integrated **sun-tracking** algorithm operational

Conclusion & Achievement

- **Bring to industry** highly efficient hybrid solar module which combines PV and CPV technologies
- Demonstrate at pilot line level the **assembly** of these high efficiency modules
- Validate the performances and reliability test with commercial **pilot site in Europe**
- Hybrid module **design** demonstrated and 15 m² currently monitored
- **Pilot line** is being set up in Neuchâtel (CH) in order to built 100 m² of Hybrid module
- Design compatible with **automation** of full production line



Perspectives

- Key manufacturing processes will be demonstrated at **industrially meaningful level**
- **Scale-up to GW** production is being established based on current module by IQE
- **Word record efficiency** and above any flat module currently on the market (final modules aims to demonstrate efficiency above 30% under direct sunlight and 17% under diffuse sunlight)





Thank you!