Perovskite for Tandem Solar Cell Technology

Dinesh Kabra

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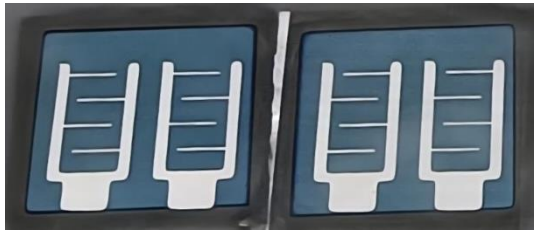

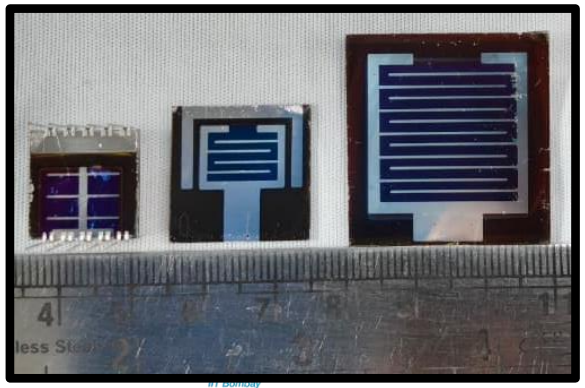

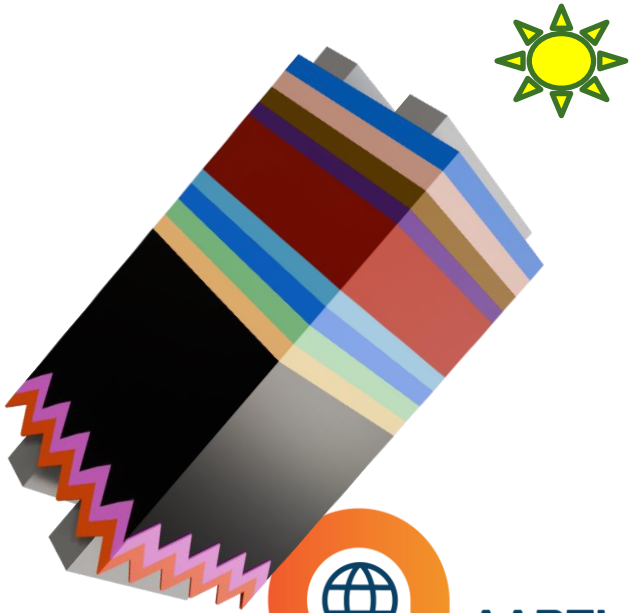

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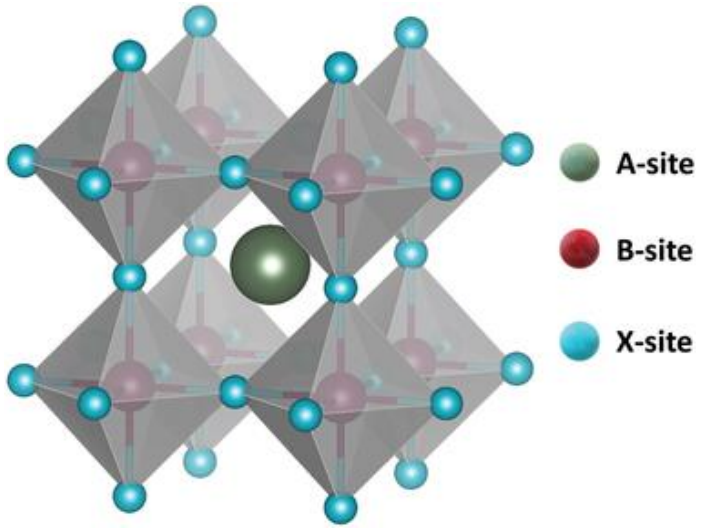
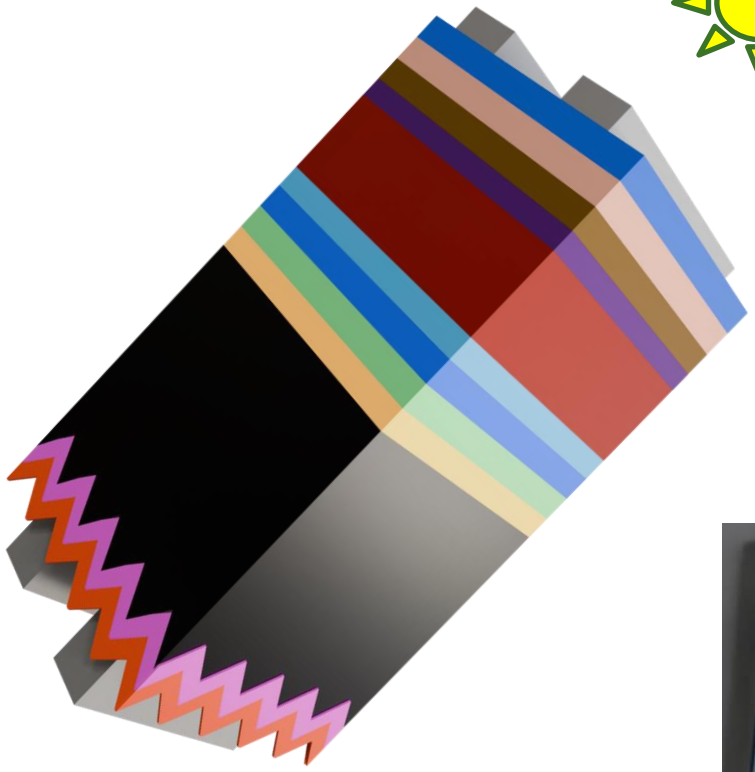
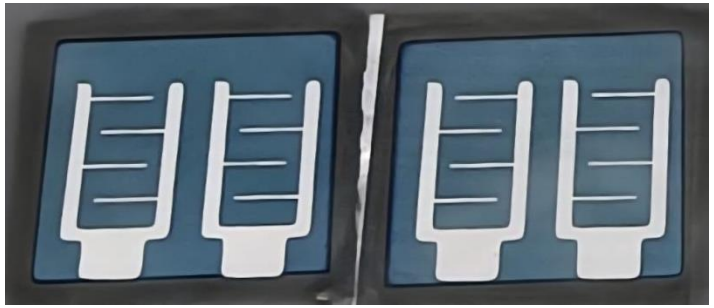
Breaking the Silicon Barrier

- Shockley-Queisser limit ~ 32%
- Silicon cells hit efficiency ceiling (theoretical 29 & practical 28; commercial ~26.5%)
- Single-junction physics limits further improvement
- Industry needed breakthrough materials for next leap
- Perovskites and tandem architectures



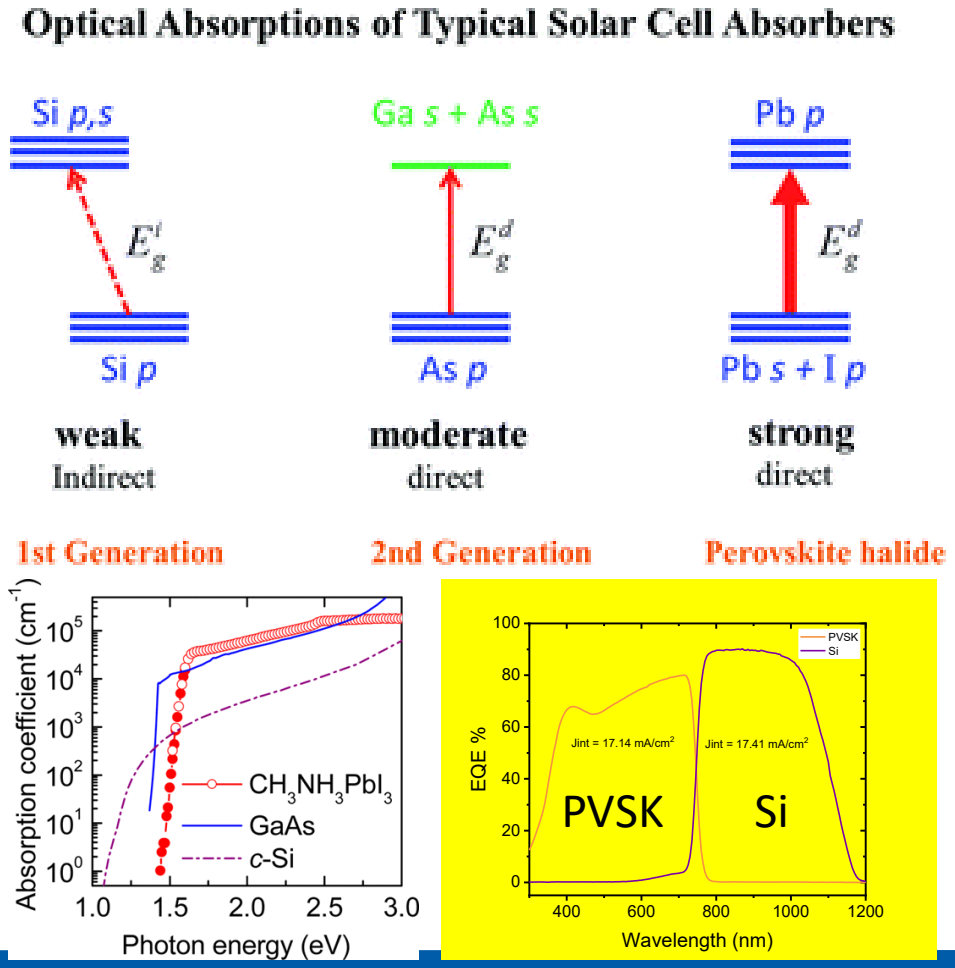


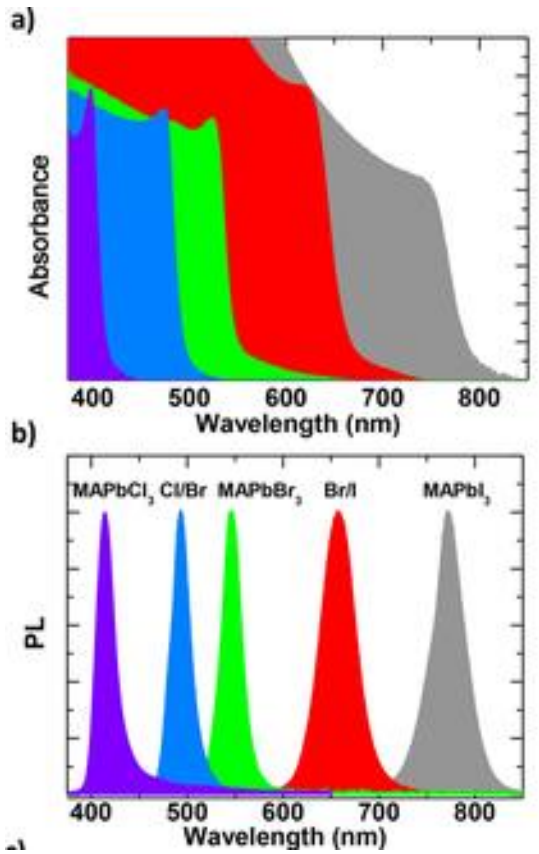
@ART-PV India



The Perovskite Revolution

- Crystalline compounds with tunable bandgaps
- Absorb different wavelengths than silicon
- 27% single-junction efficiency achieved (2025)
- Low-cost, low-temperature manufacturing

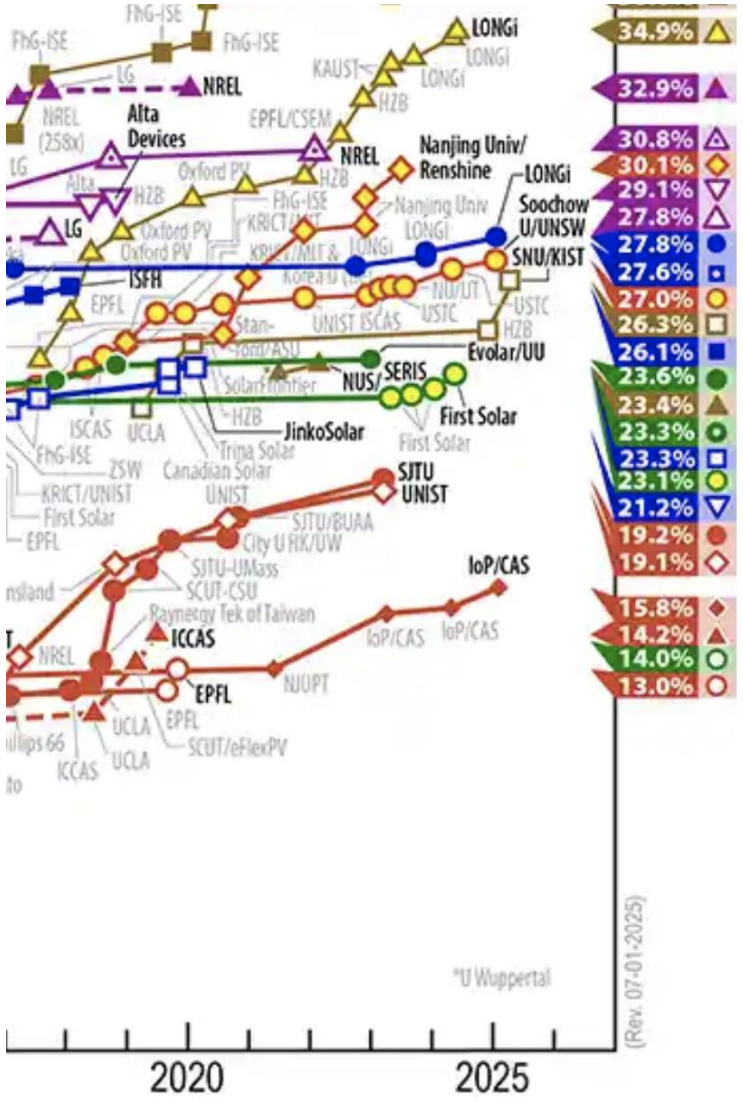




Tandem

PVSK-PVSK ~ 30.1%

Si-PVSK ~ 34.85%



China's Commercialization Edge

Microquanta Semiconductor installed what it calls the world's largest perovskite-based solar farm on a mountainside in Lishui, China.

A solar farm in Daqing, China, uses perovskite-based solar panels from UtmoLight.

Huaneng has commissioned a 5 MW perovskite PV plant in China's Qinghai province : 33% Module efficiency!
DH 2000h, TC400: degradation<5%.

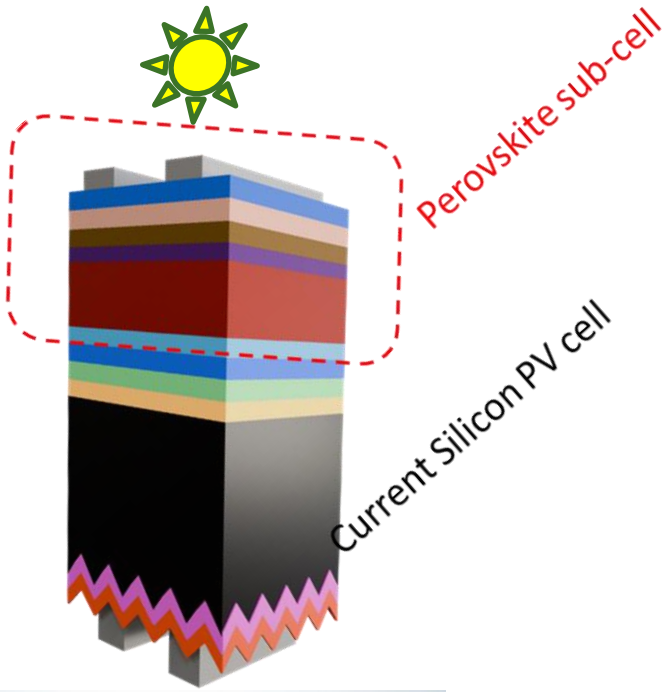
The four companies have officially passed International Electrotechnical Commission (IEC) 61215 standard panel stability assessments conducted in Germany.

UtmoLight's Zheng says a perovskite panel contains 0.5–1 g/m^2 of lead in its absorber layer, whereas full-size 2.8 m^2 silicon panels contain 4 g of lead in their solder.

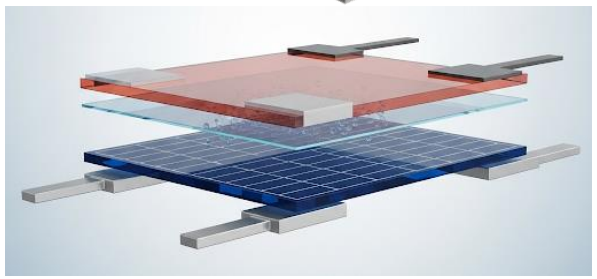
Microquanta has measured its emissions as 150 g of CO_2 per watt of generating capacity. The literature figure for silicon is over 400 g per watt.

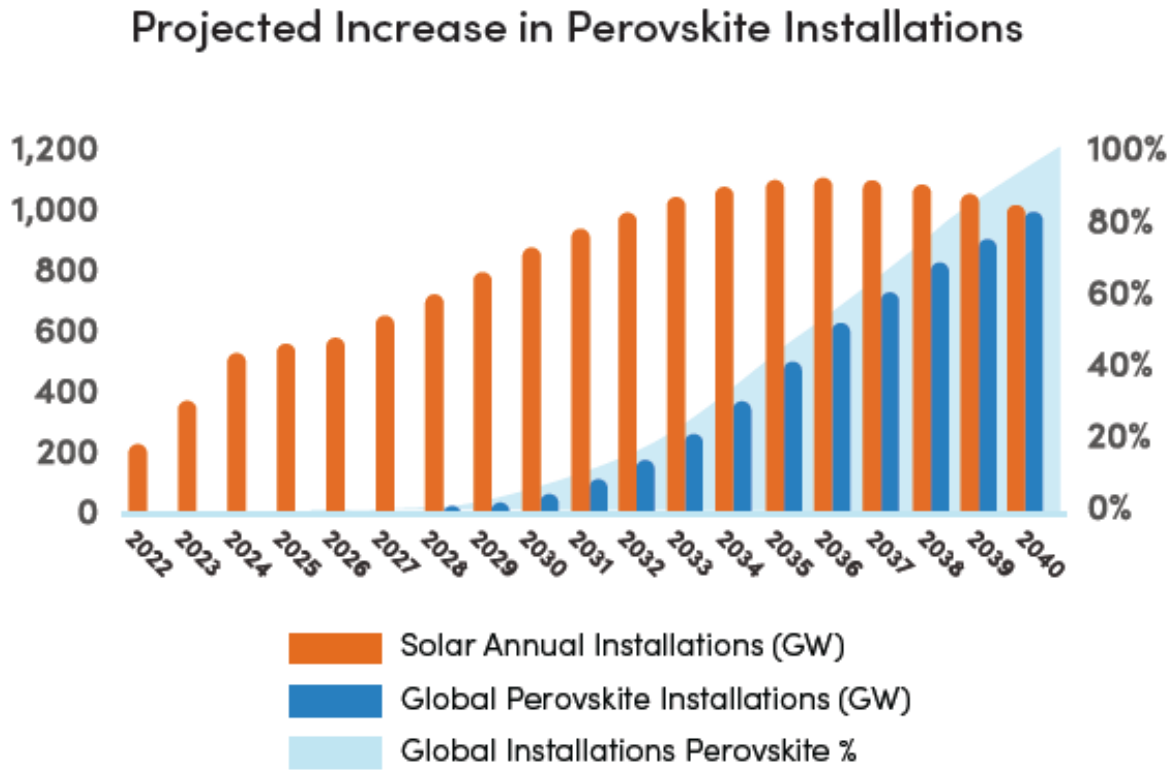
Market opportunity: Projection for Halide perovskite PV technology!

2T

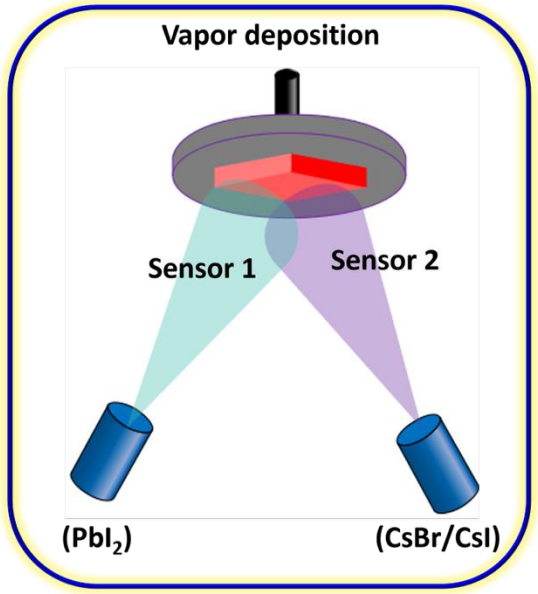


4T



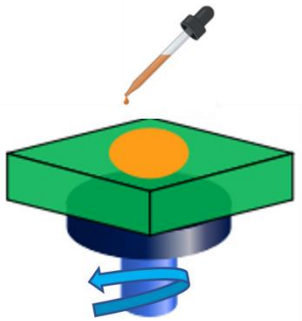


HYBRID ROUTE (Evaporation + spin-coating)



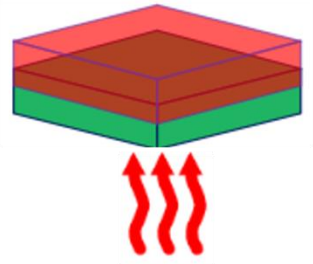
FAI/FABr/FACl (Ethanol)

+

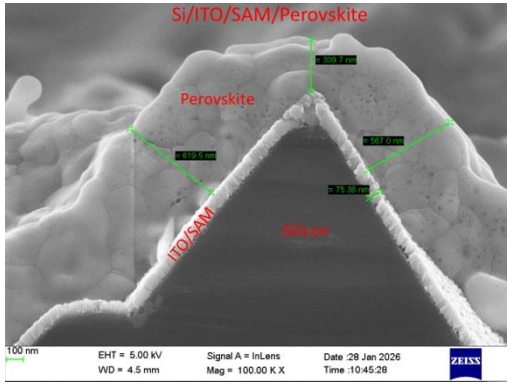


PbI_2/CsI

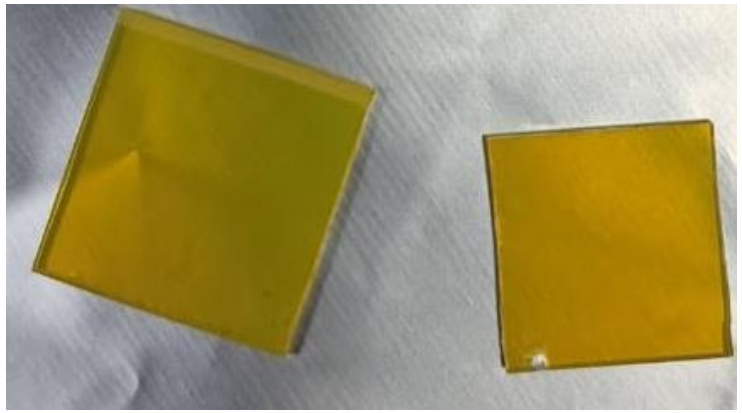
Perovskite film

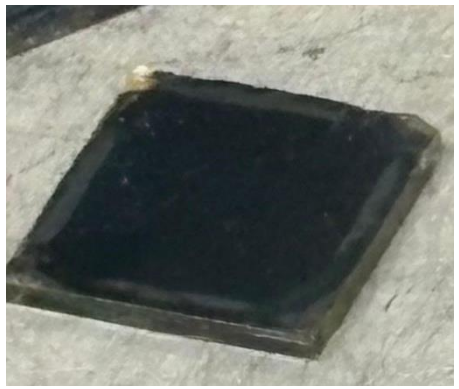


Annealing



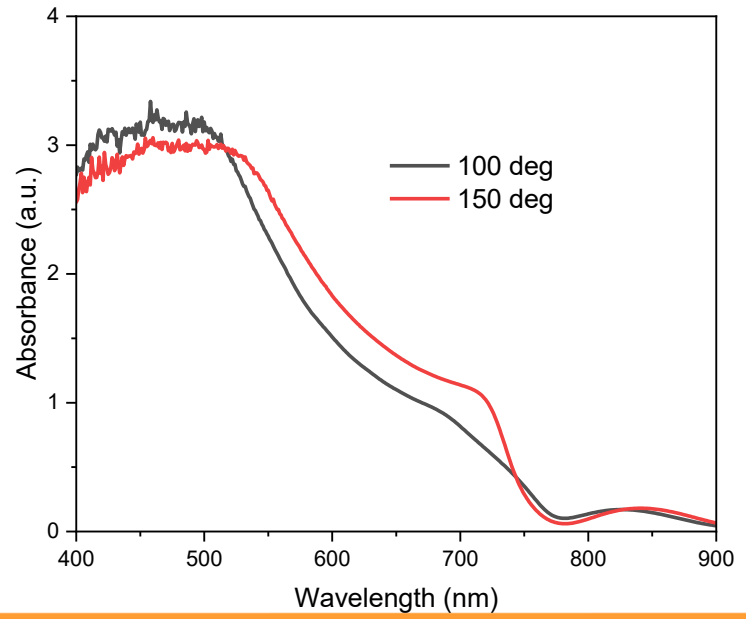
Double-cation Wide band gap perovskite on glass





Inorganic scaffold (PbI_2+CsI)

Perovskite films



Hybrid/full dry Processed Perovskite

- High
- Solv

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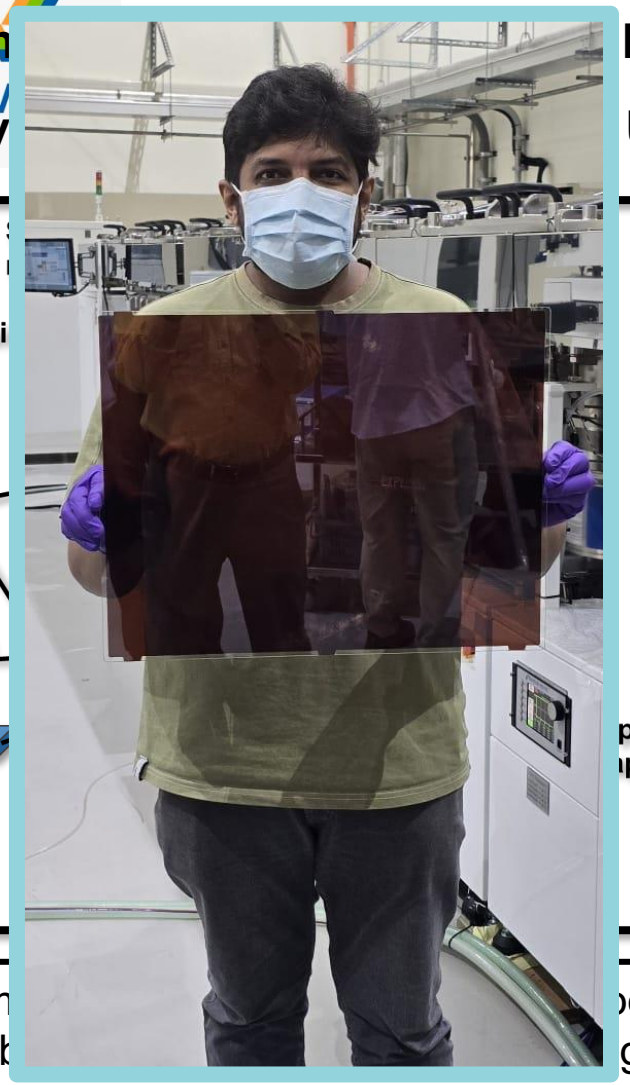
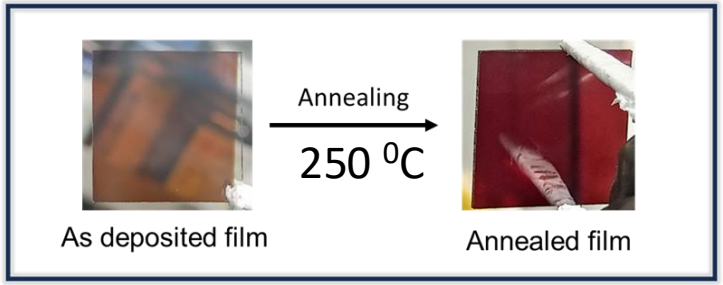
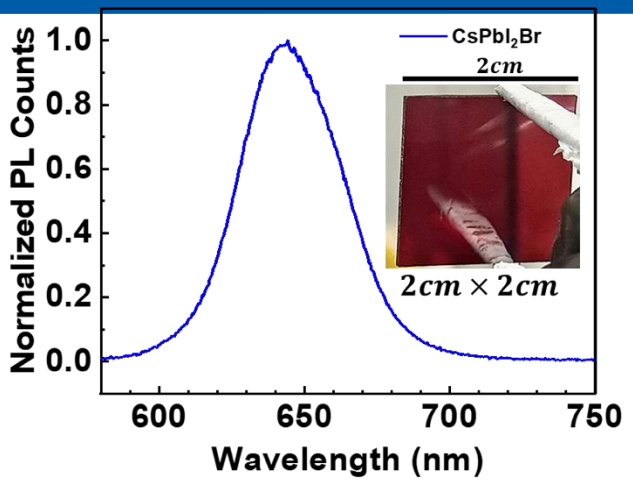
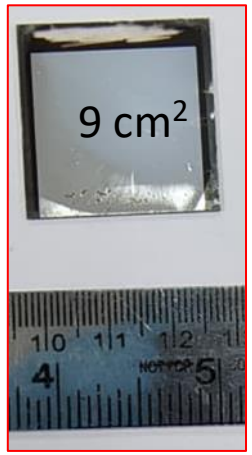
Uniform

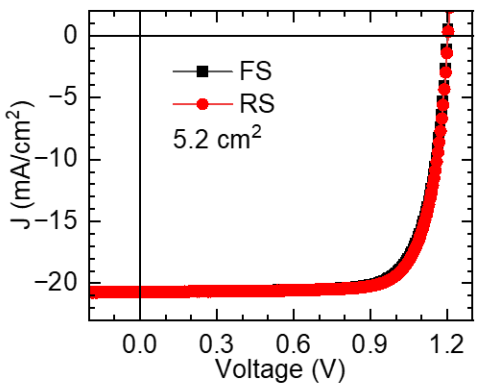


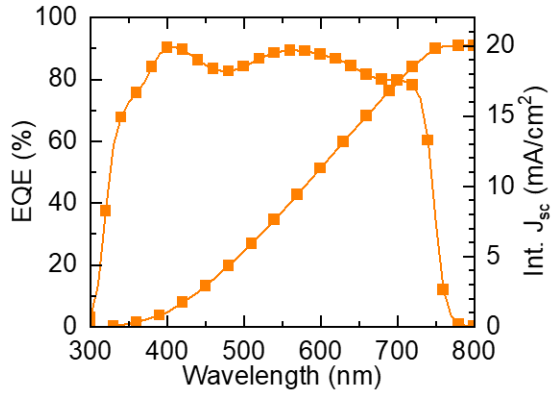




Larger cells, Eg 1.67 eV







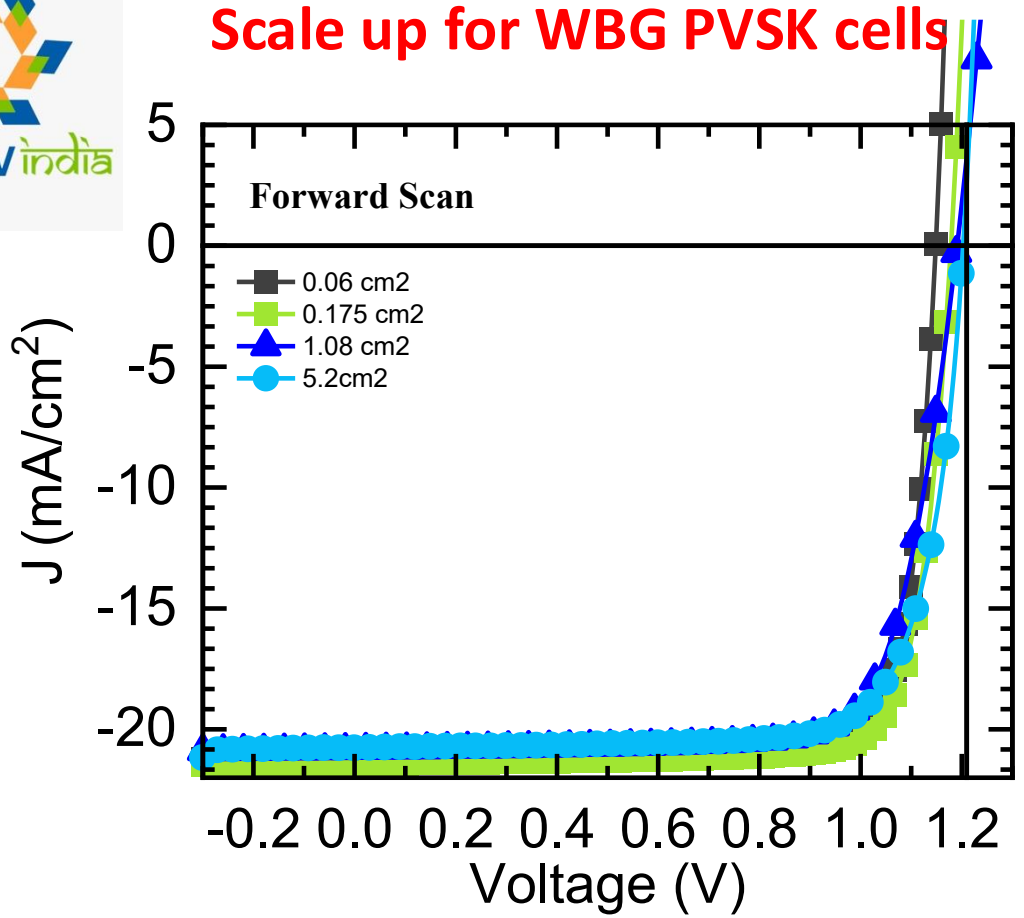
Device S30	Forward scan				Reverse scan			
	Jsc(mA/cm2)	VOC (V)	FF (%)	PCE (%)	Jsc(mA/cm2)	VOC (V)	FF (%)	PCE (%)
S30	21.79	1.195	74.3	19.3	21.77	1.195	76.1	19.8

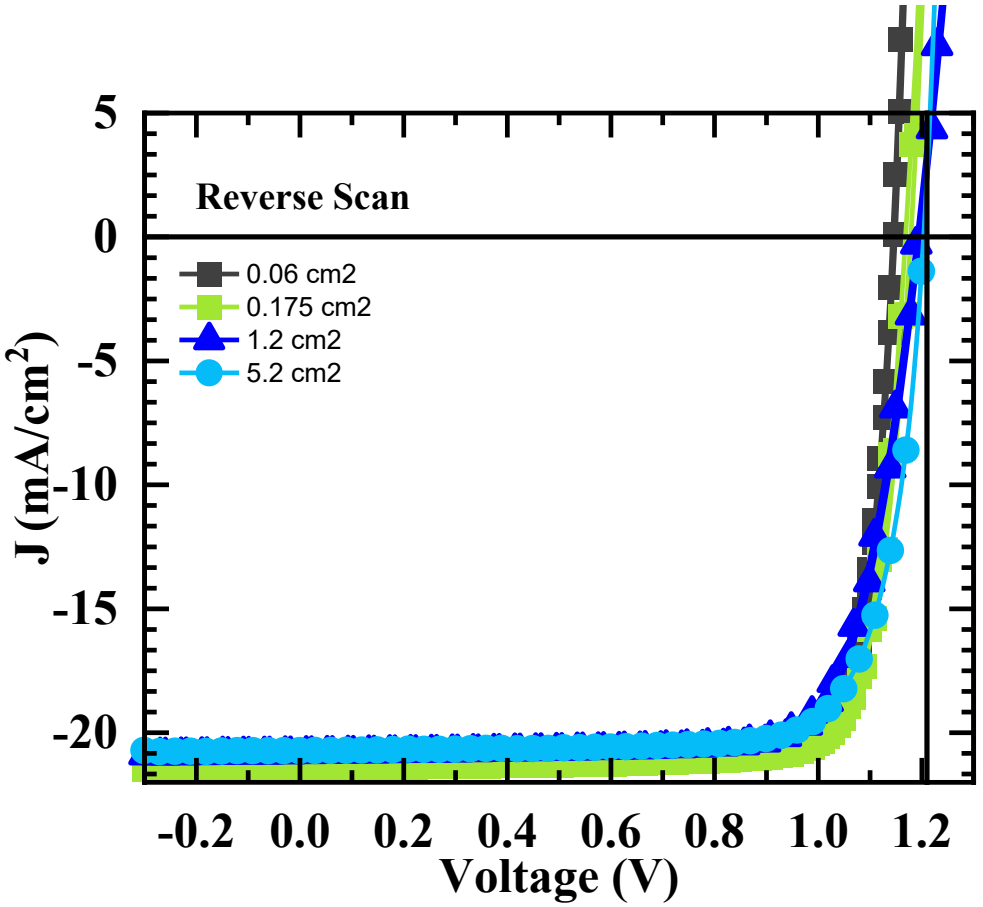
Gui

p through

Schen oration
chamb g three
sources simultaneously.

Scale up for WBG PVSK cells



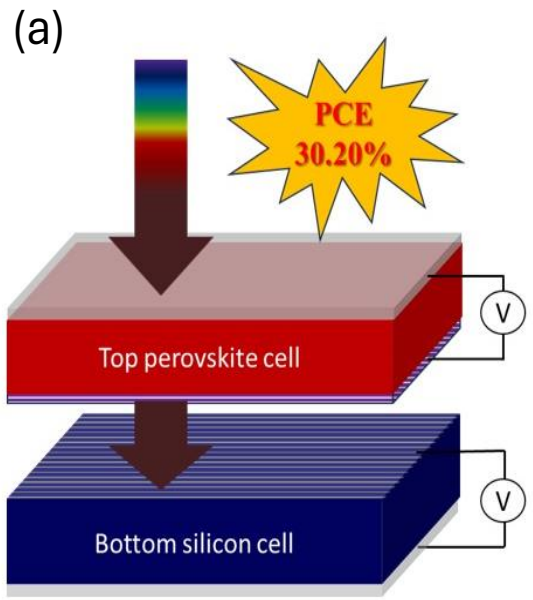


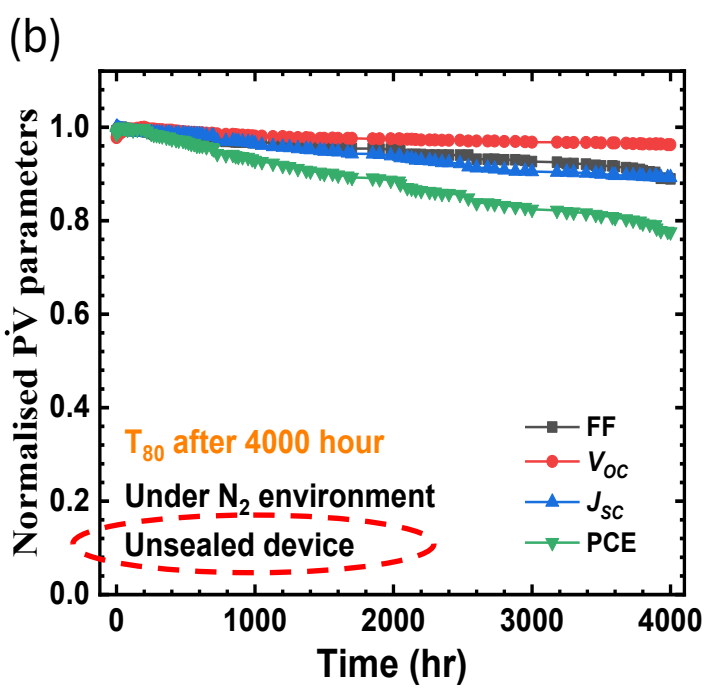
Sr.No.	Active Area (cm^2)	Forward scan				Reverse scan			
		Jsc (mA/cm^2)	V_{OC} (V)	FF (%)	PCE (%)	Jsc (mA/cm^2)	V_{OC} (V)	FF (%)	PCE (%)
1.	0.06	21.19	1.148	82.45	20.06	21.18	1.149	83.11	20.23
2.	0.175	21.17	1.179	81.31	20.553	21.12	1.169	81.89	20.52
3.	1.2	20.85	1.193	76.45	19.01	20.84	1.1994	77.15	19.29
4.	5.2	20.76	1.201	77.3	19.3	20.71	1.202	77.9	19.4

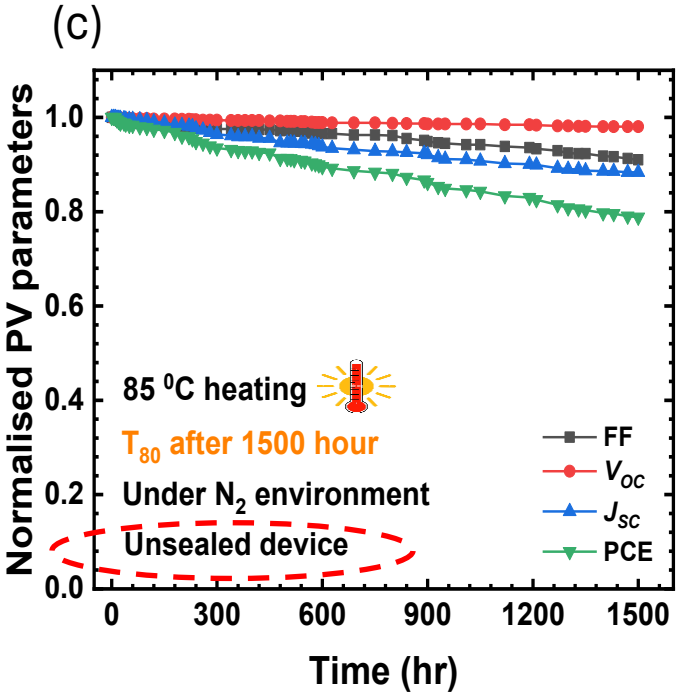
Sun's VOC : PCE > 22%

4T PCE > 32%

Stability







Novel Module Architecture for Improved Stability of Perovskites in 1000 Hour Damp Heat Test

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[2] Indian Institute of Technology Bombay (IITB), Powai, Mumbai 400076, India

***Abstract* — Photovoltaic (PV) energy is the fastest-growing form of energy production globally, and advancements in module design**

ESM architecture also benefits from a lack of need for vacuum lamination processes which require high temperatures

SC59419.2025.11132801

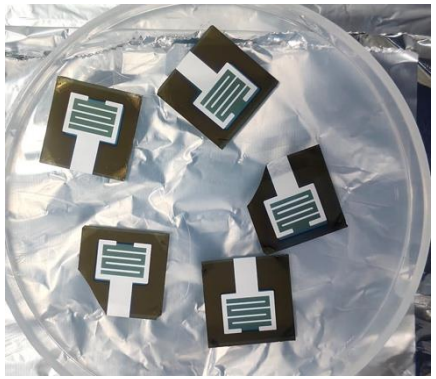
1000 DH test at CSU, USA

Sampath Walajabad at Colorado Fort Colins Campus

D. Gupta et al ACS AMI 2026 (Accepted)
Indian Patent Filed
PCT application under process

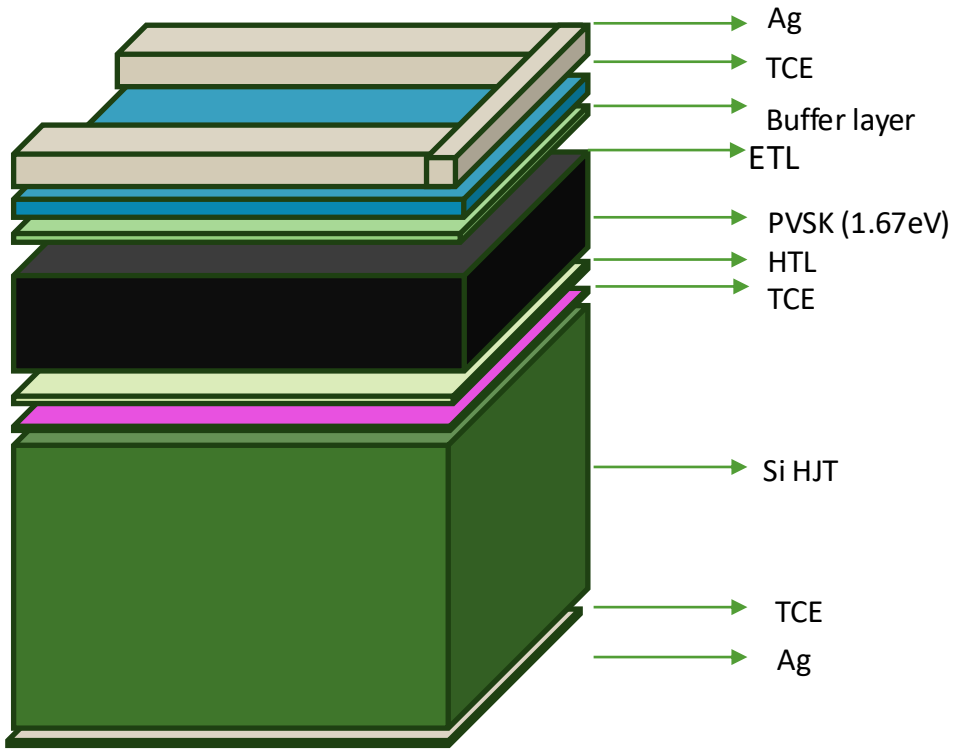
Si Perovskite 2T Tandem

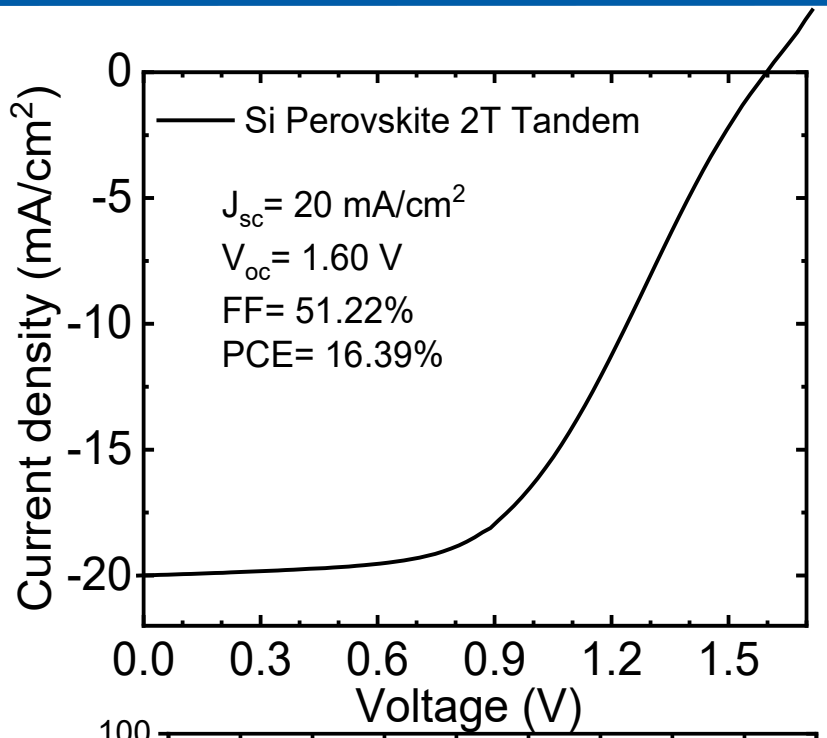
Top Side View

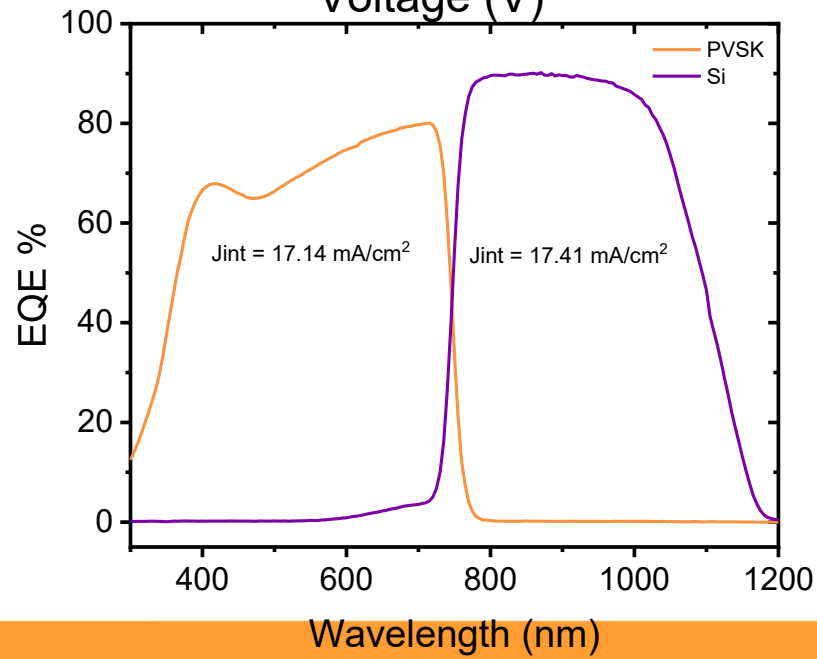


Rear Side View

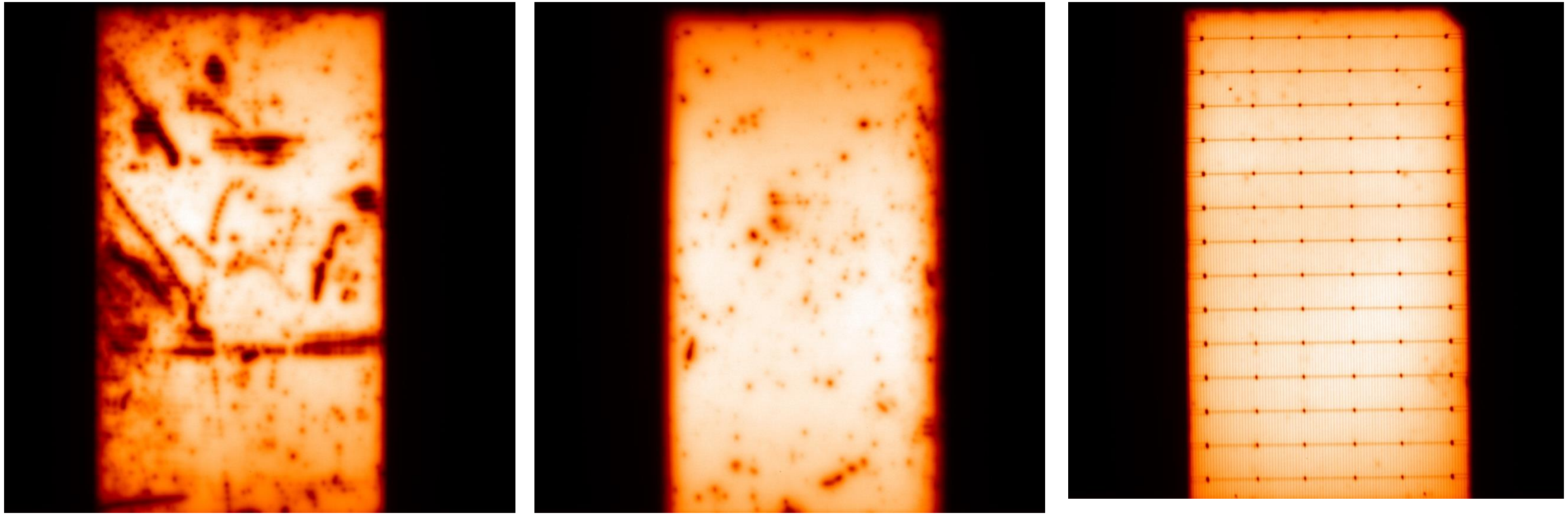
Schematic Diagram





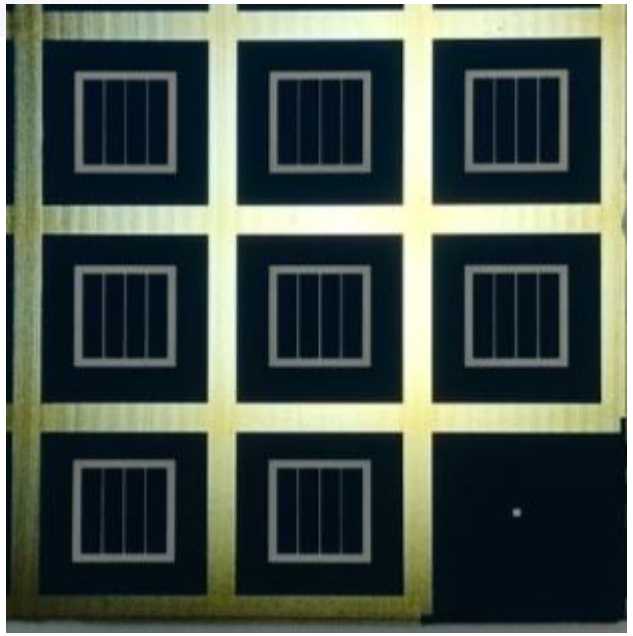


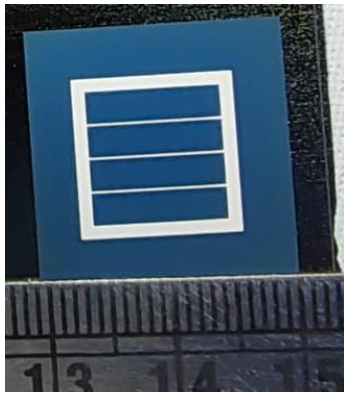
Semi-processed Si Cells



Shelf degradation of semi processed SHJ cells

TOPCon as sub-cell





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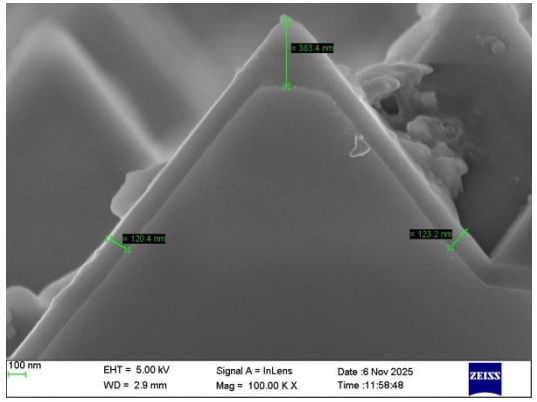
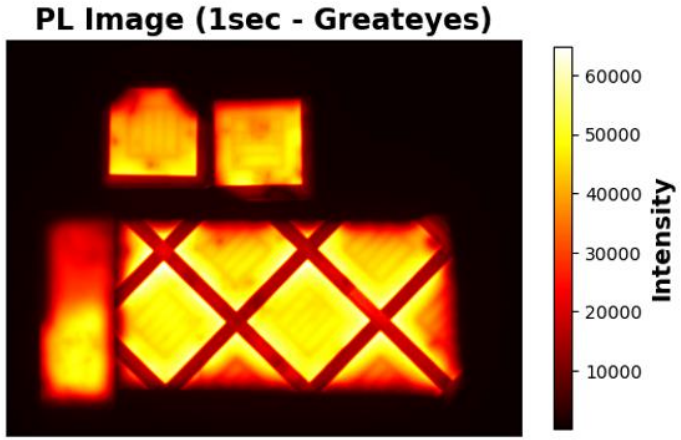
ISC Konstanz, Germany





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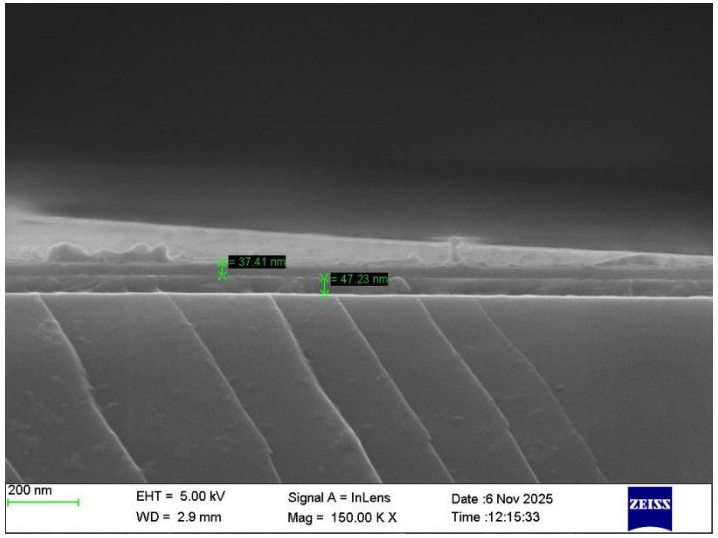
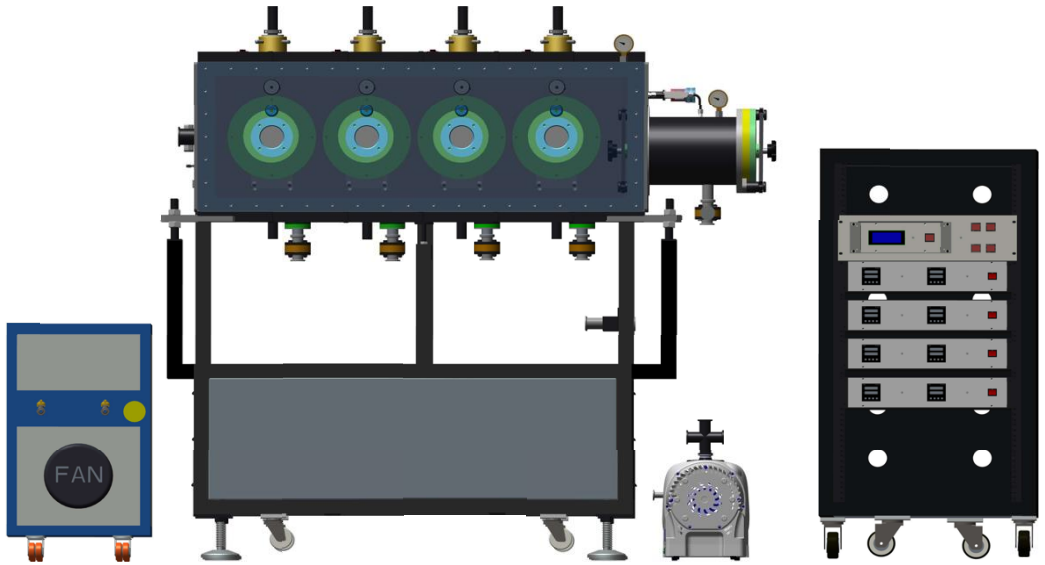
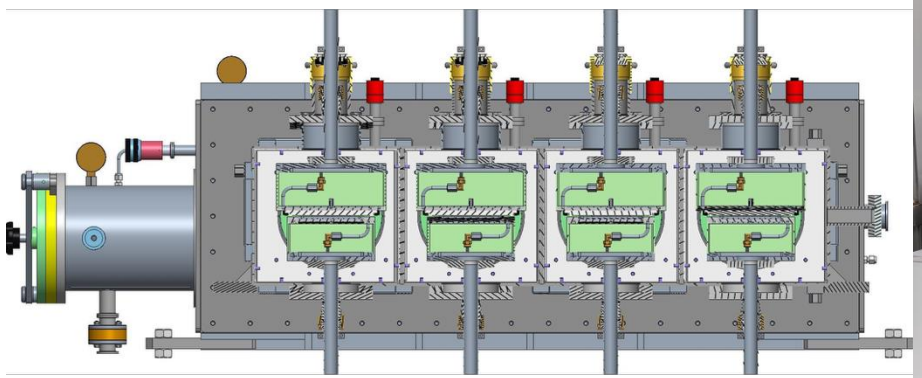
y_range = (120, 750)



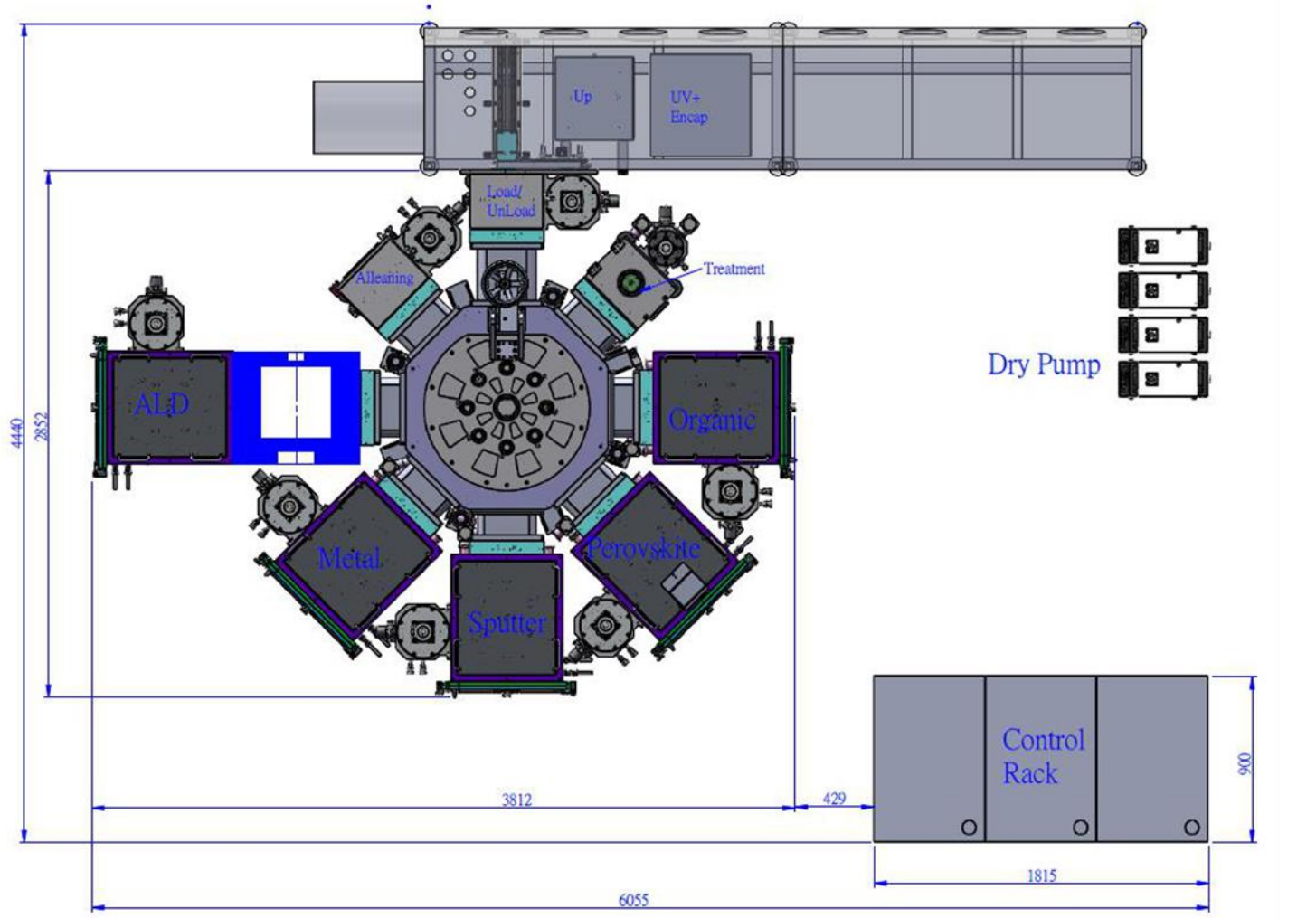
CSS (Close Space Sublimation) tool for high throughput

- High degree of material-transfer, low working pressure → low complexity
- Upgradable to robotic transfer : step towards pilot line





Fully automated cluster tool for G12 wafer size



Journey ahead…(Roadmap)

- Development of Space grade PV solution via Si-PVSK tandem cell technology (10 cm x 10 cm) with PCE> 30% : 12-18 months

- Development of M10/G12 half cut cell with PCE > 30%: 24-30 months

- Setting up 20 MW R&D pilot line solution: 36 months !!

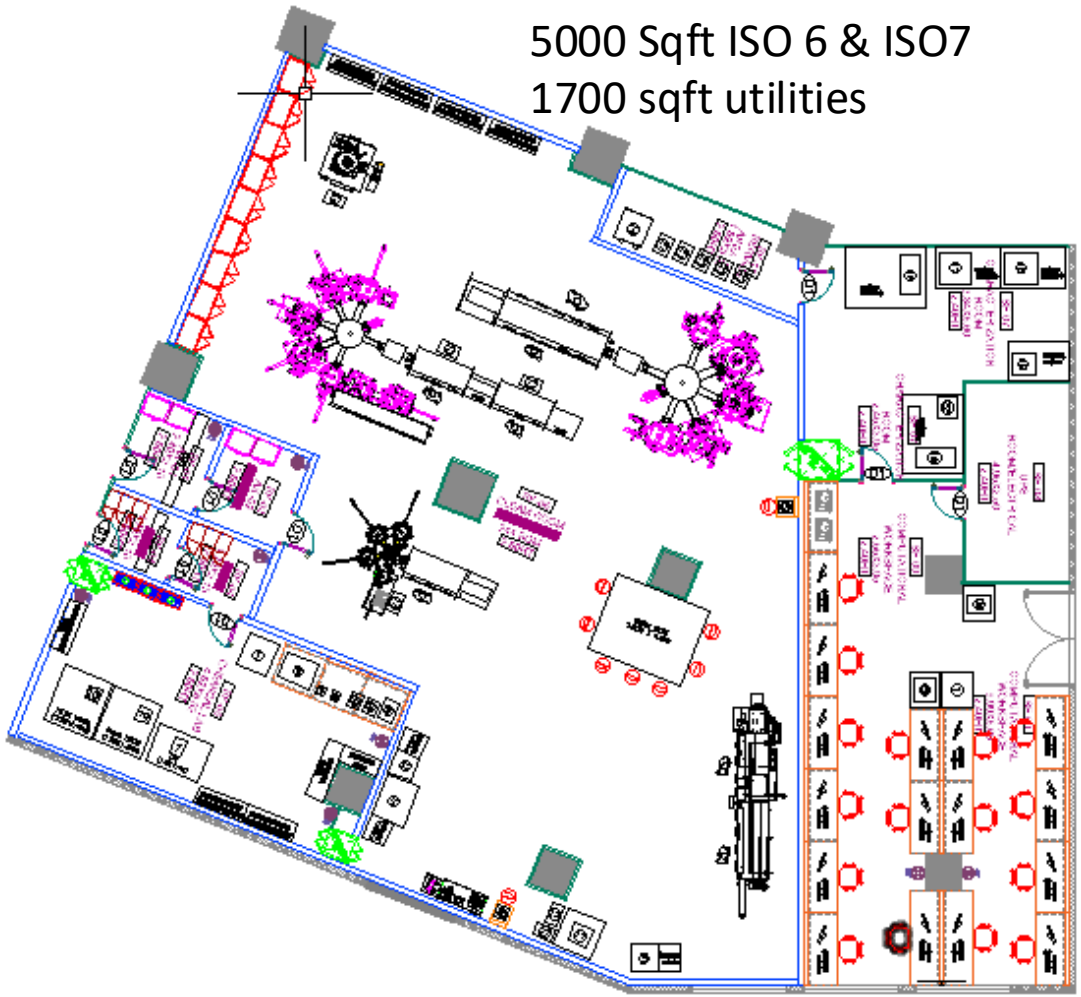
Acknowledgments:

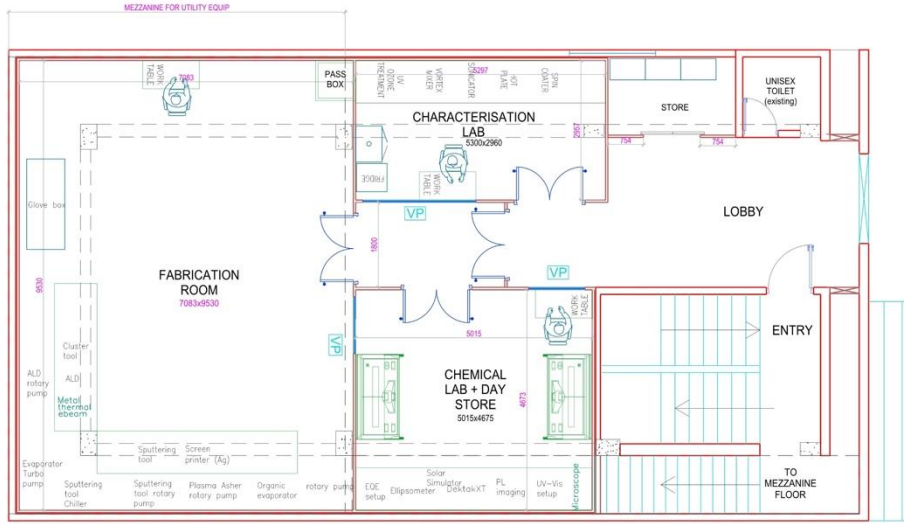
MNRE, First Solar

Indus Tower, Waaree Energies

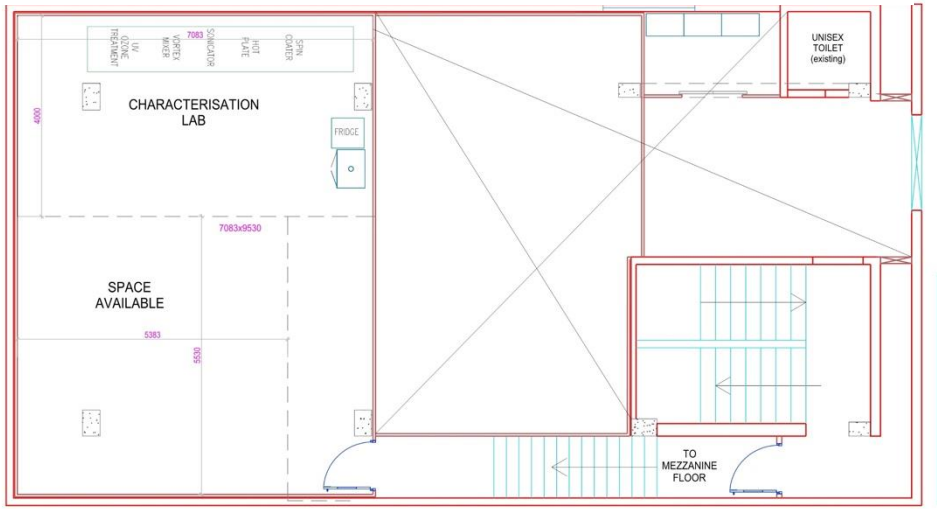
Upcoming facilities

ASPIRE IITB Research Park
5000 Sqft ISO 6 & ISO7
1700 sqft utilities





FIRST FLOOR PLAN
SCHEMATIC FOR DISCUSSION ONLY



MEZZANINE FLOOR PLAN
SCHEMATIC FOR DISCUSSION ONLY

Rabale – Navi Mumbai
5000 sqft