

Stabilisation Process of Thin-Film Photovoltaic Modules Monitored Under Outdoor Conditions

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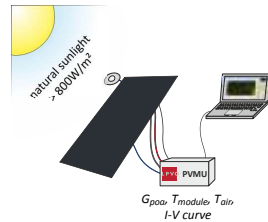


Outline

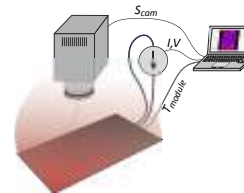
Thin-Film PV modules



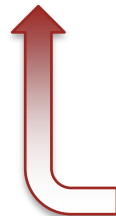
Performance measurements



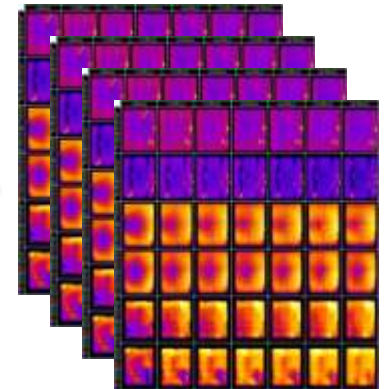
Electroluminescence



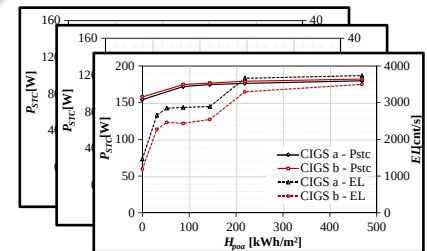
Outdoor exposure



EL images



Quantitative results



PV Modules



- Amorphous silicon
 - › a-Si (A and B)
 - › $P_{MPP} = 105 \text{ W}$
 - › $\eta = 6.6 \%$



- Micromorph silicon
 - › a-Si/ μ c-Si (A and B)
 - › $P_{MPP} = 135 \text{ W}$
 - › $\eta = 9.6 \%$



- Chalcopyrite
 - › CIGS (A and B)
 - › $P_{MPP} = 170 \text{ W}$
 - › $\eta = 13.8 \%$

Outdoor exposure

- At LPVO test facility
 - › Continuous monitoring
 - I-V characteristics
 - Ambient parameters
 - › Operating in **MPP**, SC or OC

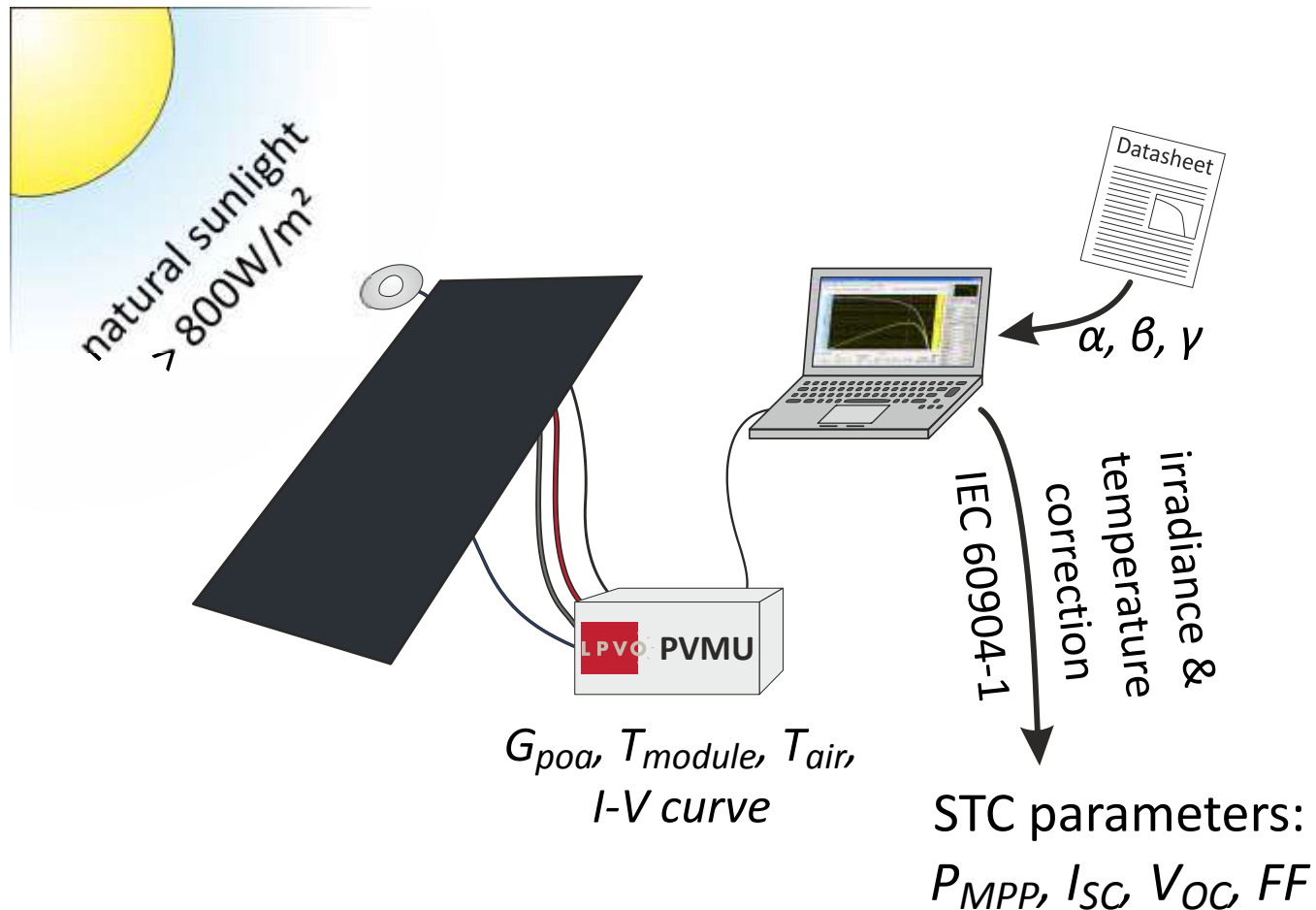


- IEC 61646: Stabilisation: 60 kWh/m^2
- Measurements
 - › April 10 2014 to July 16 2014
 - › 0, 31, 52, 87, 144, 219, 469 kWh/m^2



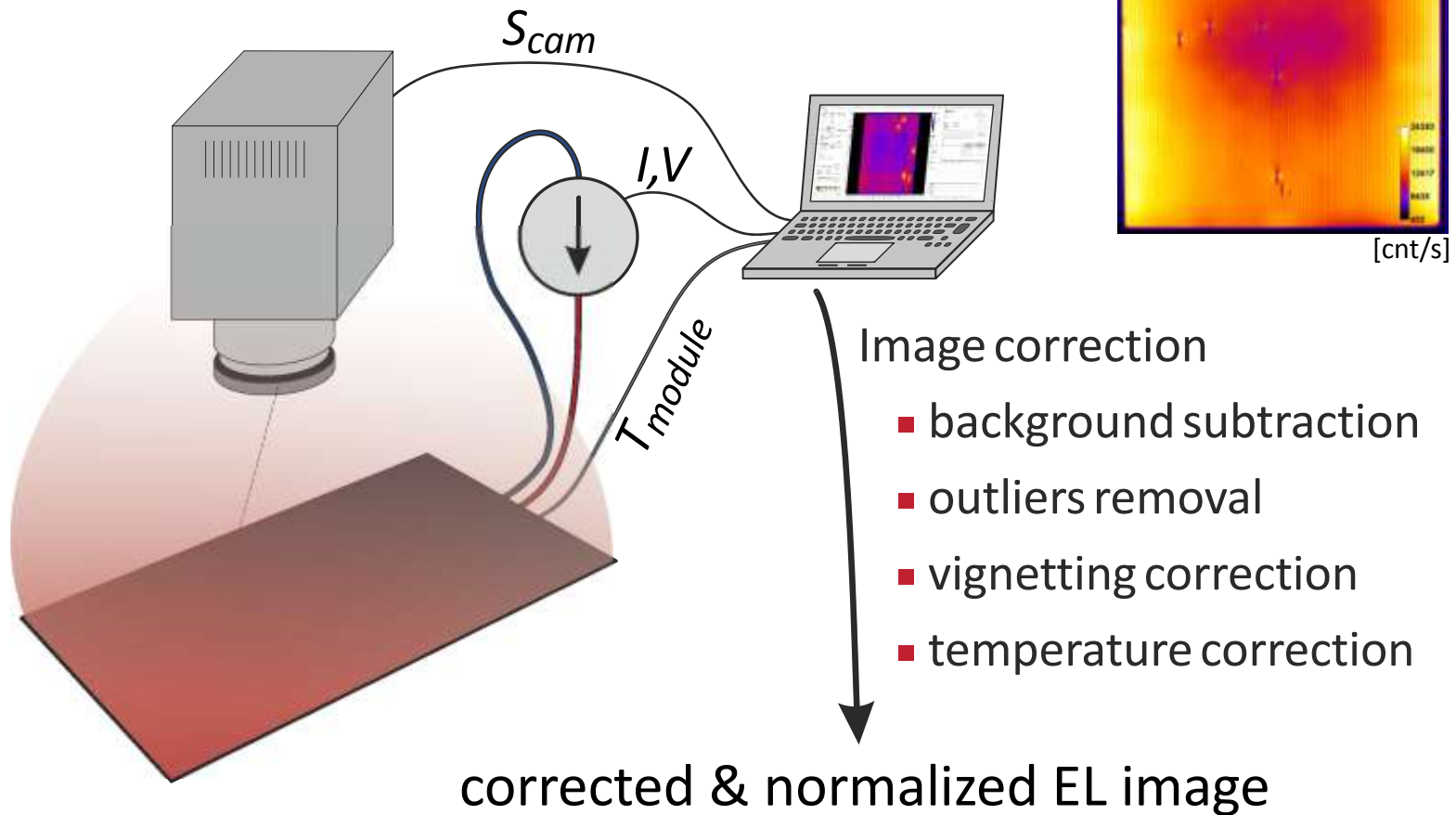
Measurement

Performance



Measurement

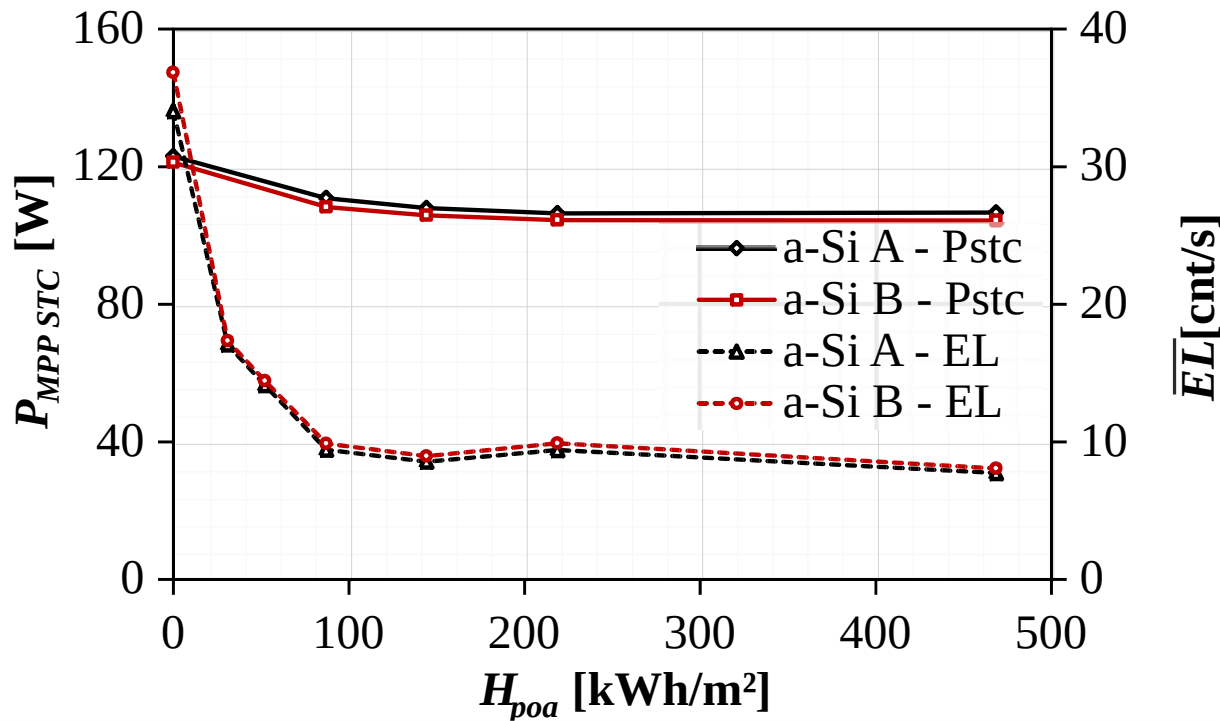
Electroluminescence (EL)



[] M. Bokalič et al., JAP 114, 123102, 2013

Quantitative results

Amorphous silicon PV modules



$P_{MPP\ STC}$	EL	behaviour	module to module
↓	↓	correlated	not matched

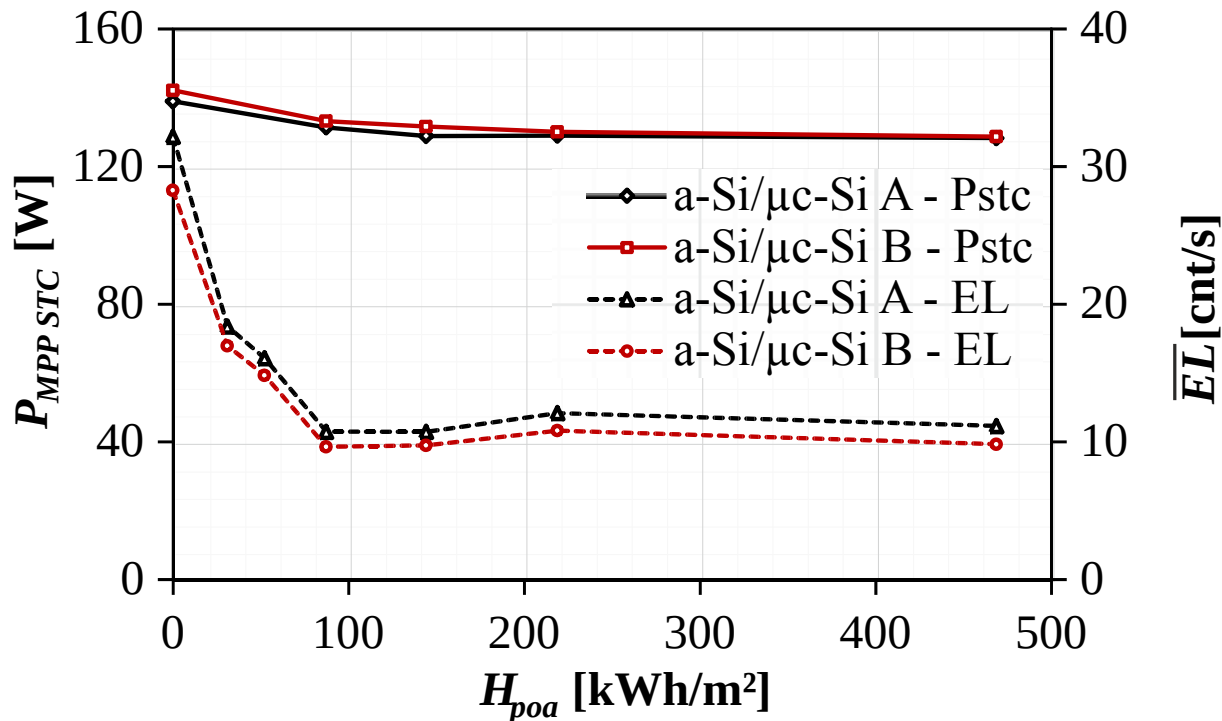
$P_{MPP\ STC}$	A	B
initial [W]	123.0	121.2
final [W]	106.7	104.4
d [%]	-13.3	-13.9

EL	A	B
initial [cnt/s]	34.0	36.8
final [cnt/s]	7.7	8.1
d [%]	-77.3	-78.1

@13.4 mA/cm²

Quantitative results

Micromorph silicon PV modules



$P_{MPP\ STC}$	EL	behaviour	module to module
↓	↓	correlated	not matched

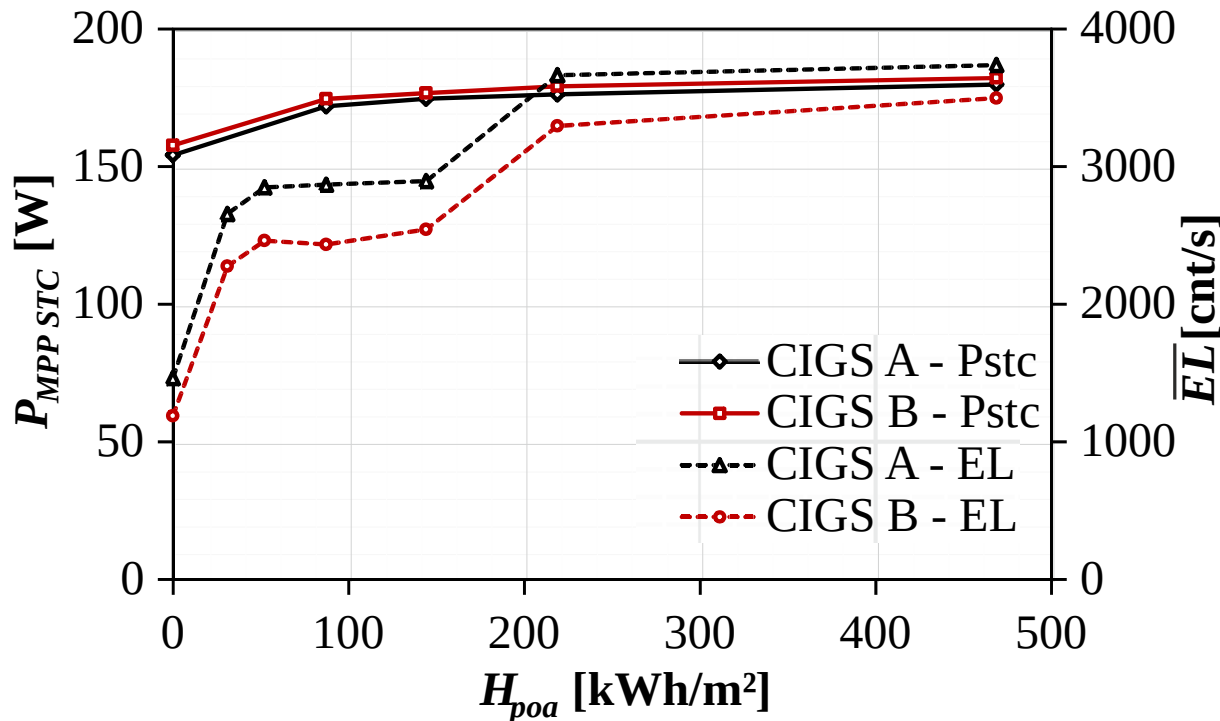
$P_{MPP\ STC}$	A	B
initial [W]	139.0	142.2
final [W]	128.3	128.7
d [%]	-7.7	-9.5

EL	A	B
initial [cnt/s]	32.2	28.3
final [cnt/s]	11.2	9.8
d [%]	-65.3	-65.2

@11.9 mA/cm²

Quantitative results

CIGS PV modules



$P_{MPP\ STC}$	EL	behaviour	module to module
↑	↑	correlated	not matched

$P_{MPP\ STC}$	A	B
initial [W]	154.2	157.8
final [W]	179.8	182.2
d [%]	+16.6	+15.5

EL	A	B
initial [cnt/s]	1465	1190
final [cnt/s]	3738	3497
d [%]	+155	+194

@33.1 mA/cm²

Quantitative results

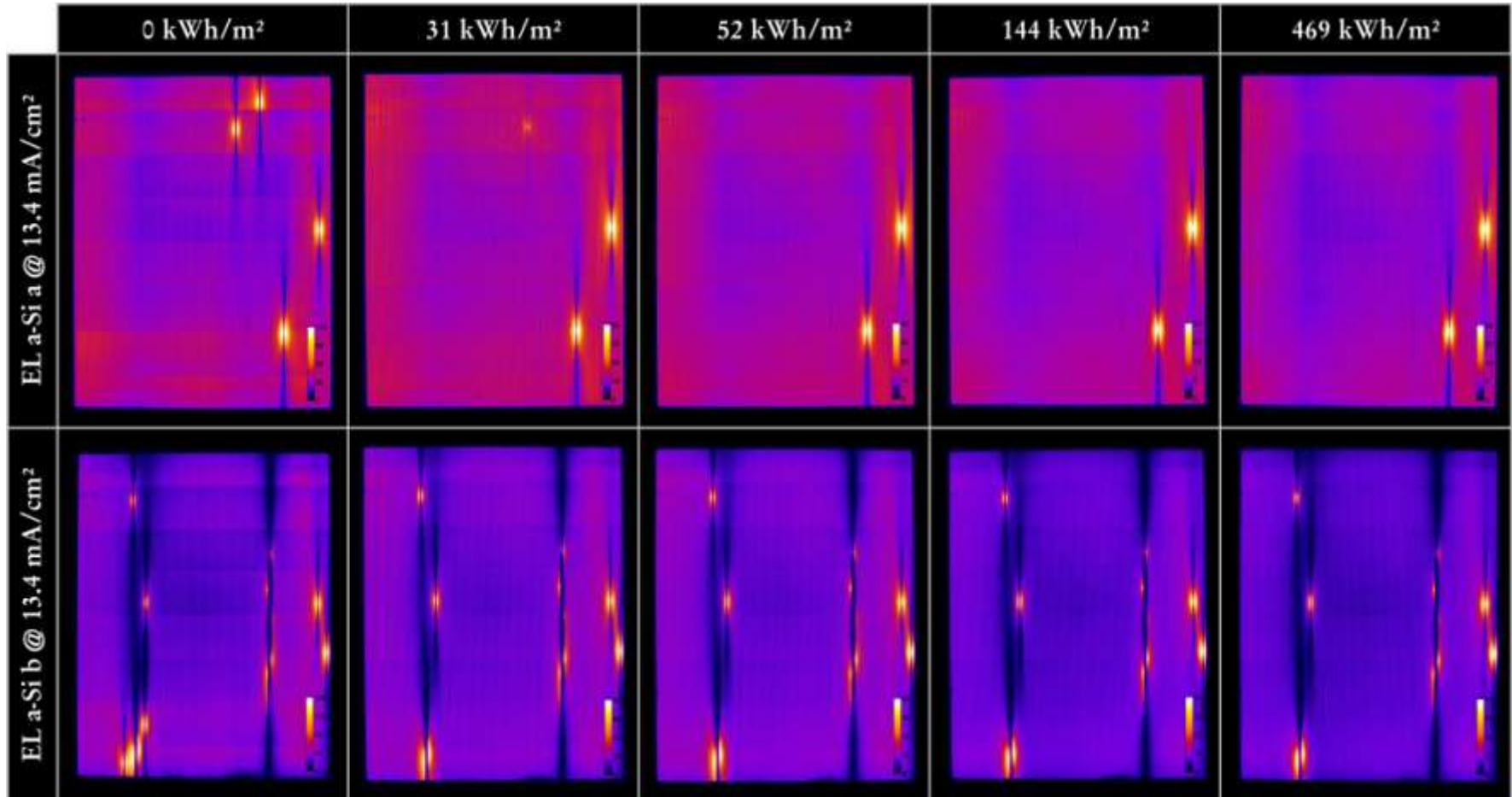
Summary

	$P_{MPP\ STC}$	EL	behaviour	module to module
a-Si	↓	↓	correlated	not matched
a-Si/ μ c-Si	↓	↓	correlated	not matched
CIGS	↑	↑	correlated	not matched

- Stabilisation direction varies with PV technology
- $P_{MPP\ STC}$ and EL behaviour are correlated on per module basis
- Discrepancies are observed between different modules

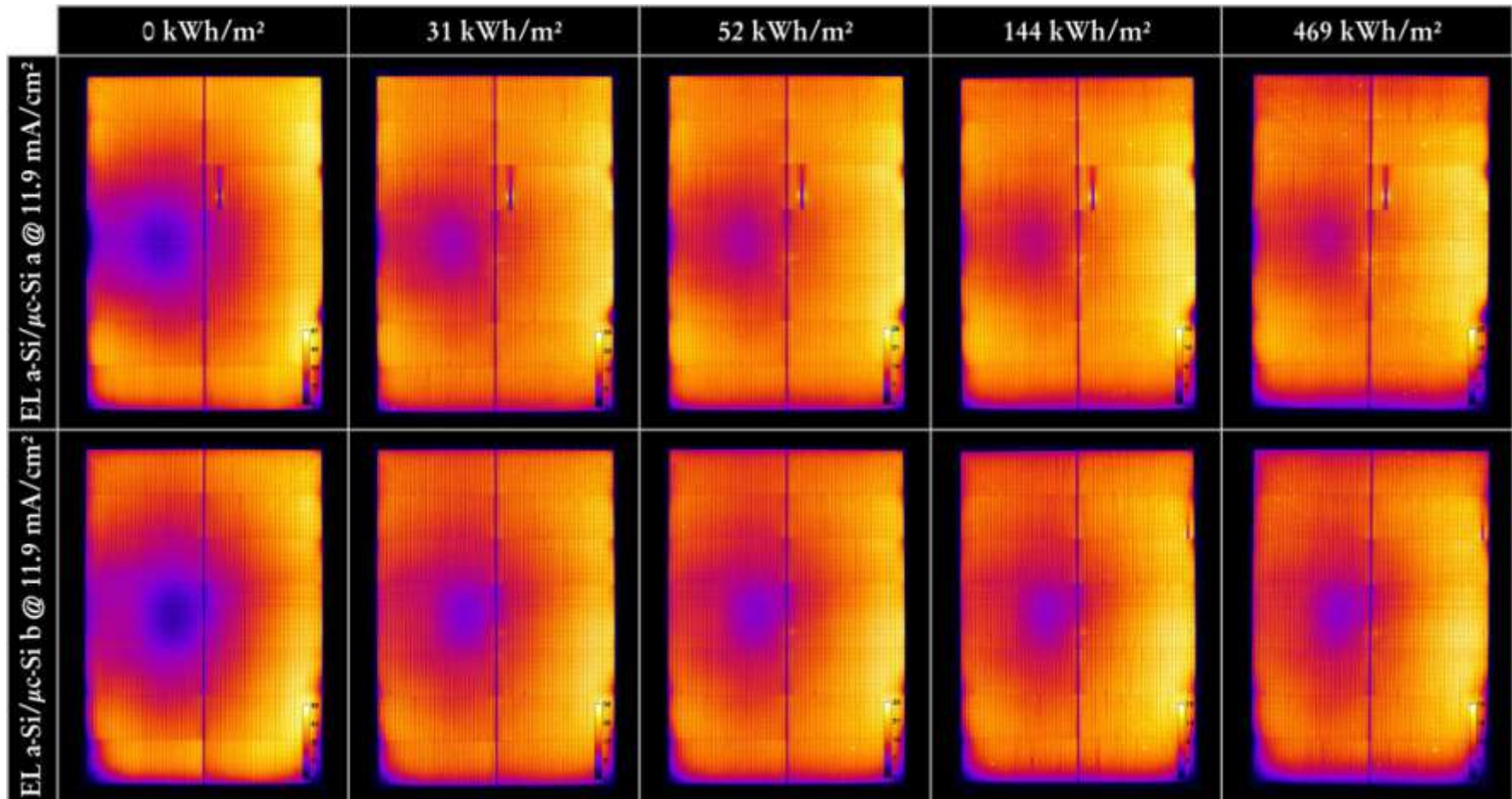
Qualitative results

Amorphous silicon PV modules



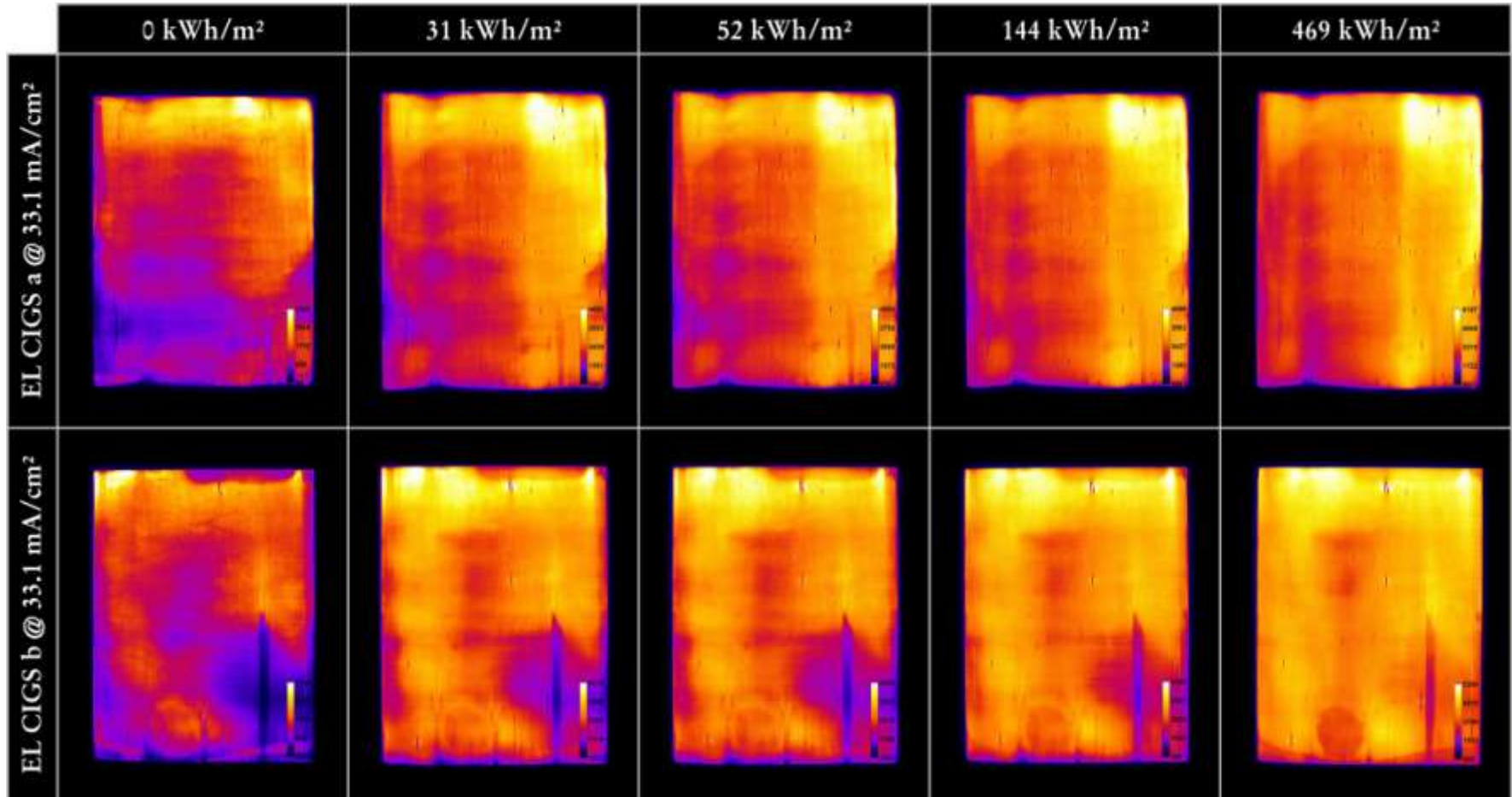
Qualitative results

Micromorph silicon PV modules



Qualitative results

CIGS PV modules



Conclusion

- Stabilisation of TF PV modules
 - › is technology dependent
 - › 60 kWh/m² of irradiation is barely adequate
- EL monitoring provides beneficial complementary information
 - › EL intensity is much more sensitive to changes than $P_{MPP\ STC}$
 - › EL behaviour is correlated with $P_{MPP\ STC}$ behaviour
 - Possible to use EL for $P_{MPP\ STC}$ estimation
 - › Discrepancies between EL and $P_{MPP\ STC}$ for different modules of the same technology must be understood
- EL images reveal spatial changes
 - › help understand performance changes
 - › enable prediction of further development of inhomogeneities

Acknowledgement

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Thank you for your attention

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