Contactless outdoor PL of silicon PV modules with large area excitation source

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Motivation:

- **quality control**
  - reliable energy supply
  - PV-plant as capital investment
  - insurance check
- **in-situ measurement**
  - no transport cost
  - no further module handling
- **throughput increase**
  - without physical contact
  - PL instead of EL

1 GW PV plant in Yanchi, Ningxia, China.

https://www.apricum-group.com

https://www.airportpark-berlin-neuhardenberg.de/.

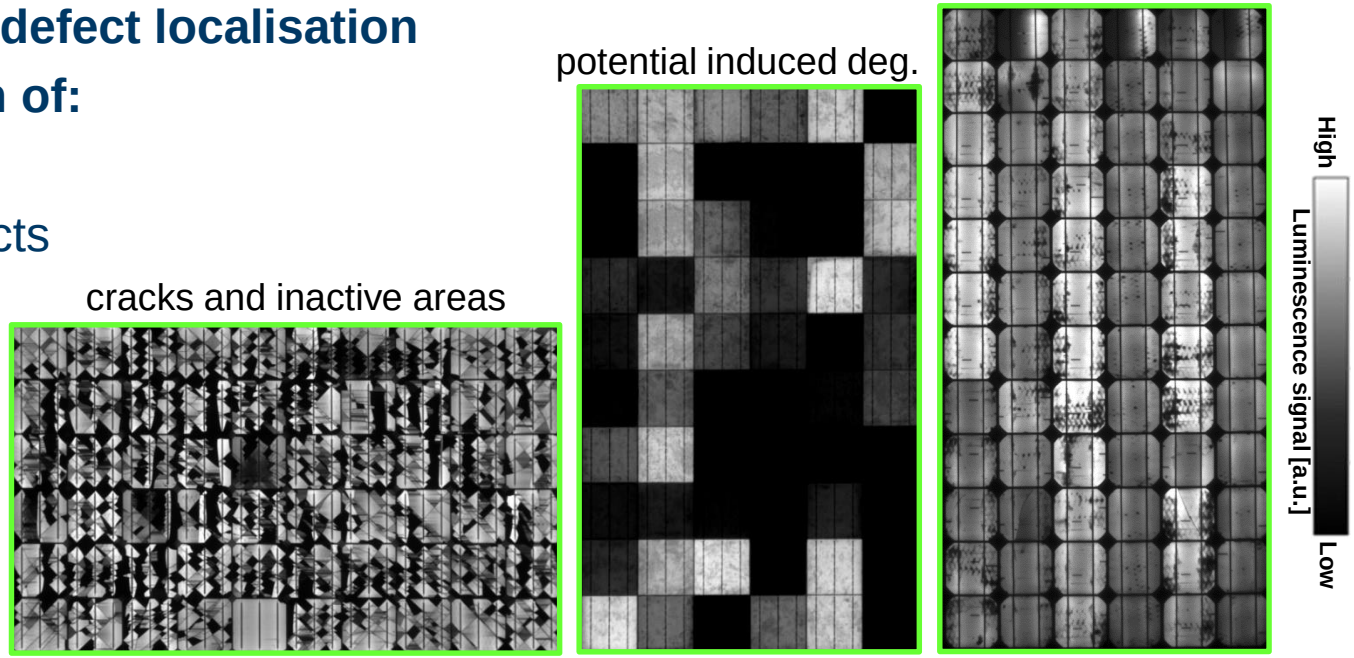
Advantages of luminescence imaging

- **brightness linked to efficiency**
- **high resolution defect localisation**
- **characterization of:**
  - hail-damage
  - busbar defects

cracks and inactive areas

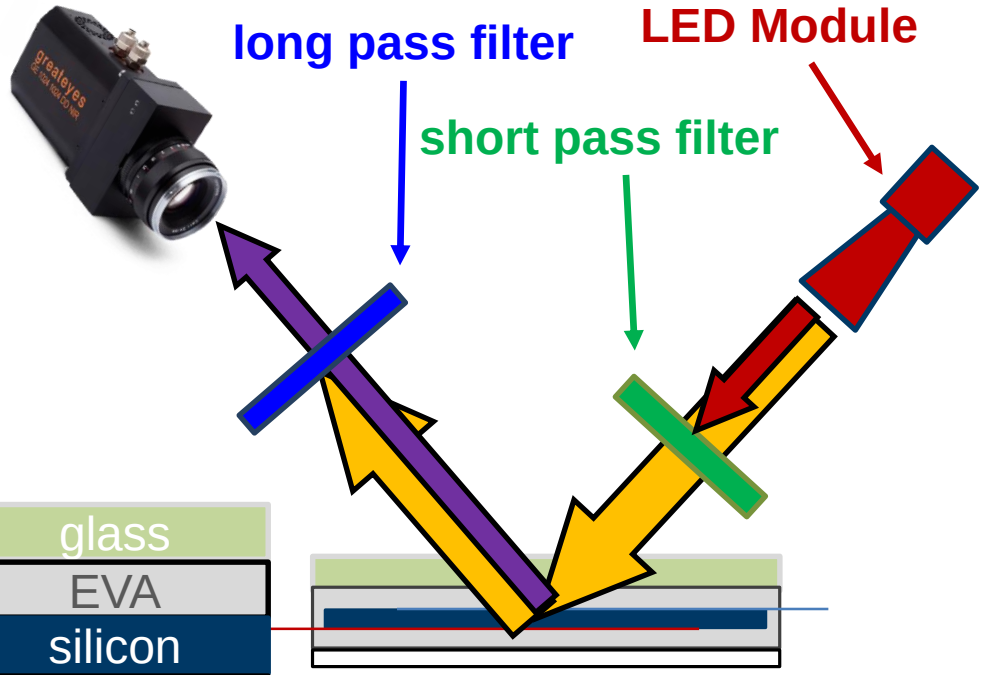
potential induced deg.

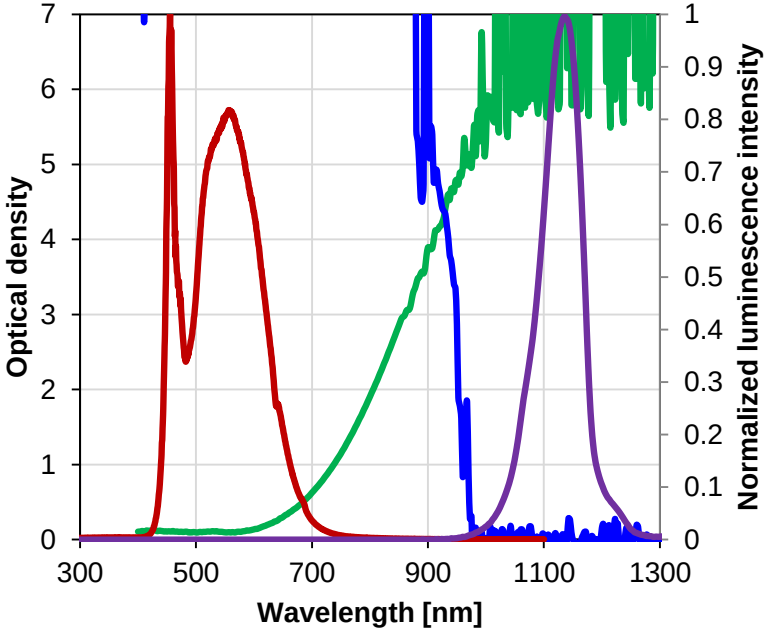
fabrication failures



EL images

Photoluminescence (PL) principle

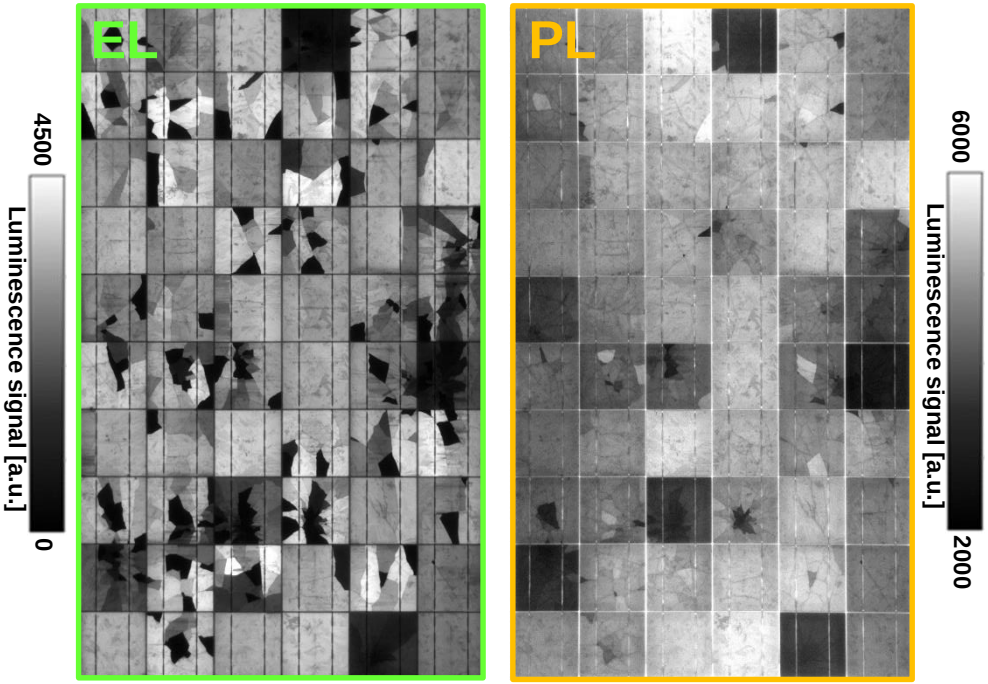


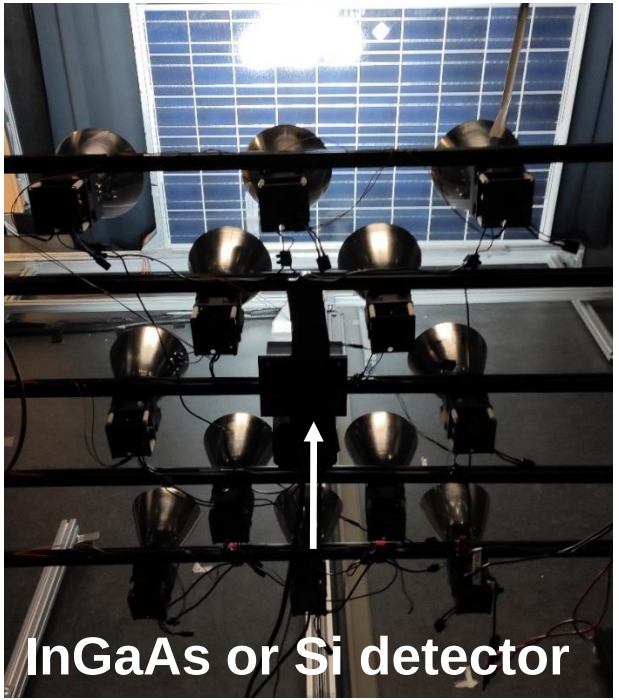


➡ **full contact free**

PL setup in the lab

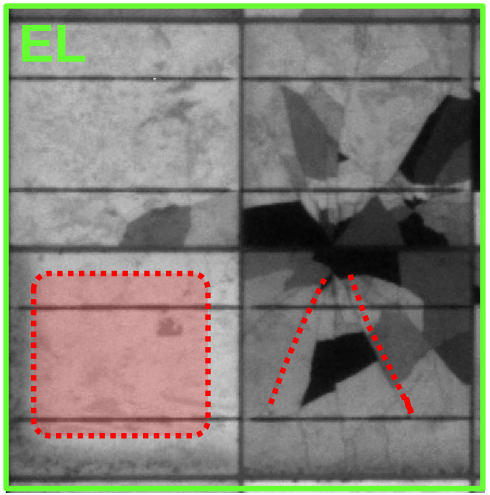
- EL and PL images with t_{int} = 15 s
- 12x 100 W broadband white LEDs



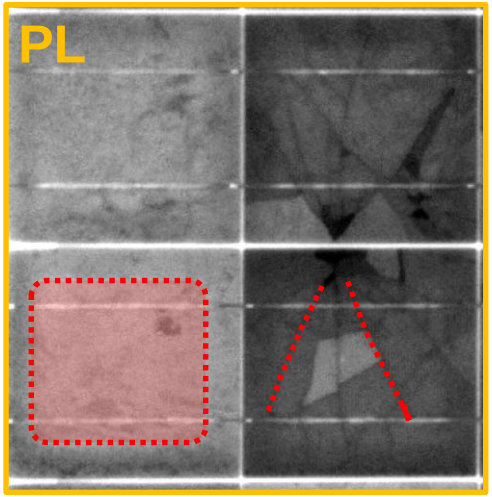


Challenge: no excitation selection

EL at 500 mA

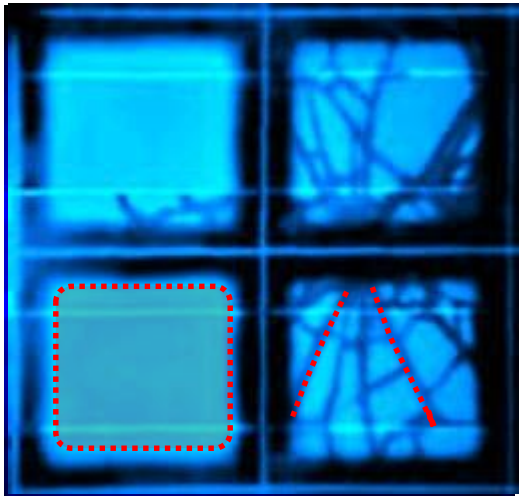


PL at about 57 W/m²

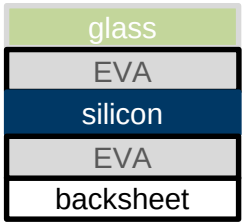


Low High
Luminescence signal [a.u.]

UV 330-360 nm

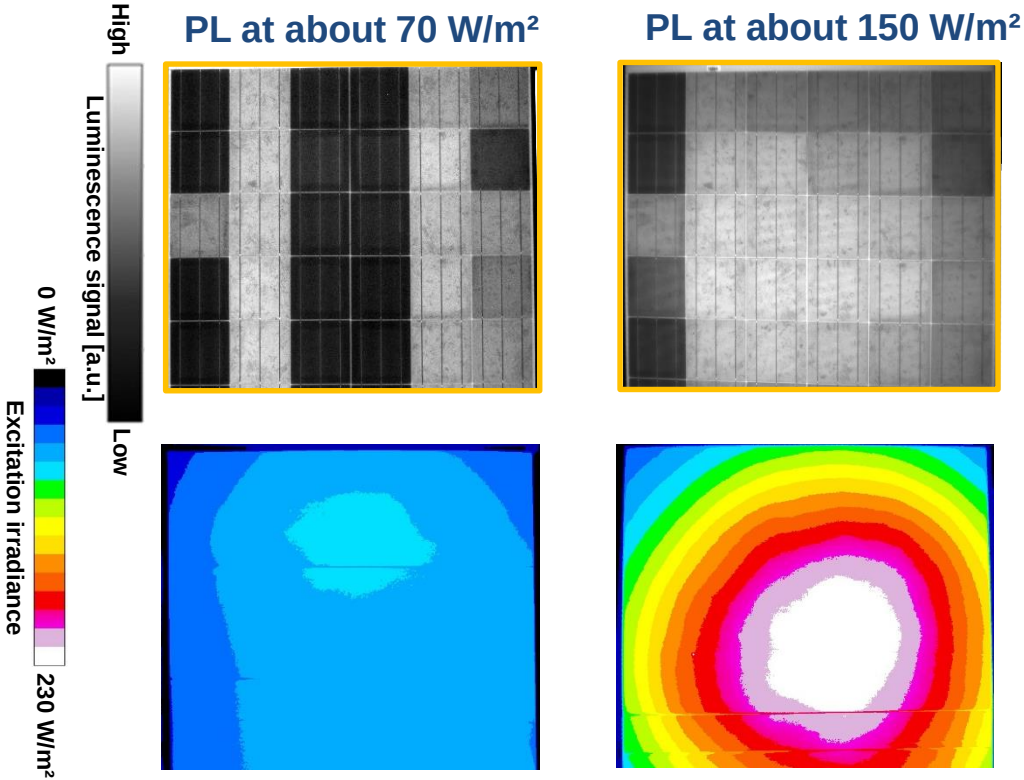


Low High
Fluorescence signal [a.u.]



additional information from encapsulation materials
no problem for Si characterisation

Challenge: homogeneity level



homogeneity level with variation of ± 10 W/m² is needed for reliable defect recognition

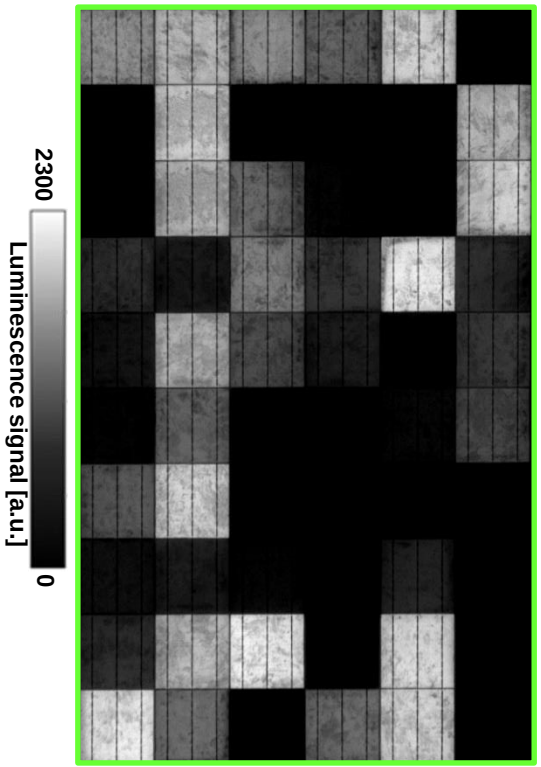
- ➢ flexible LED module mount
- ➢ each LED module intensity individual adjustable

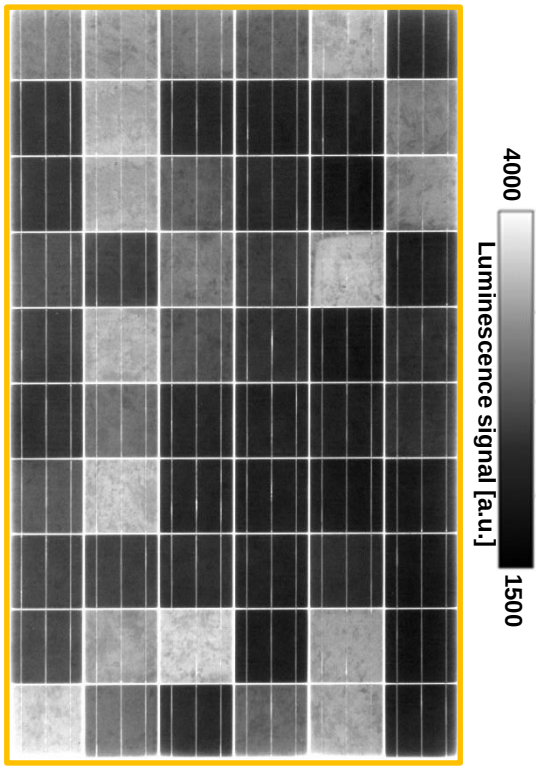
homogeneity level can be reached in challenging condition

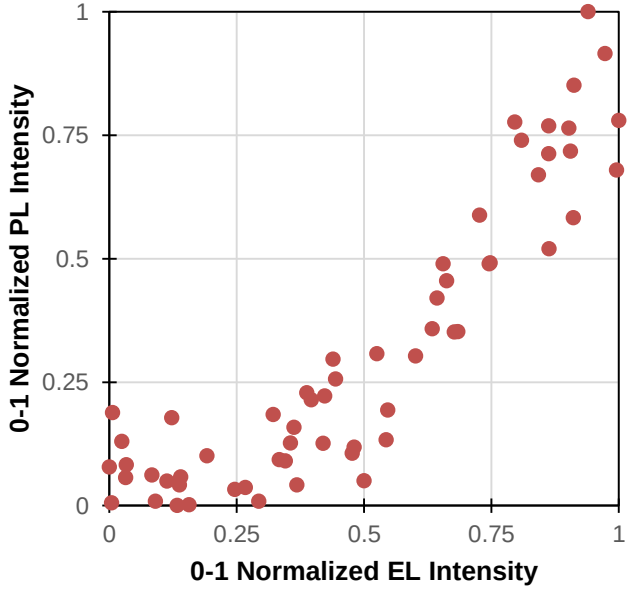
Potential induced degradation

EL at 500 mA

PL at about 57 W/m²





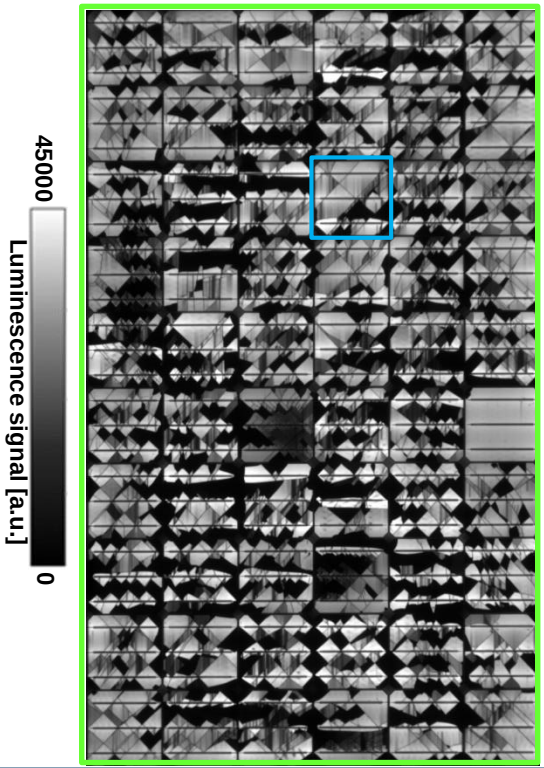


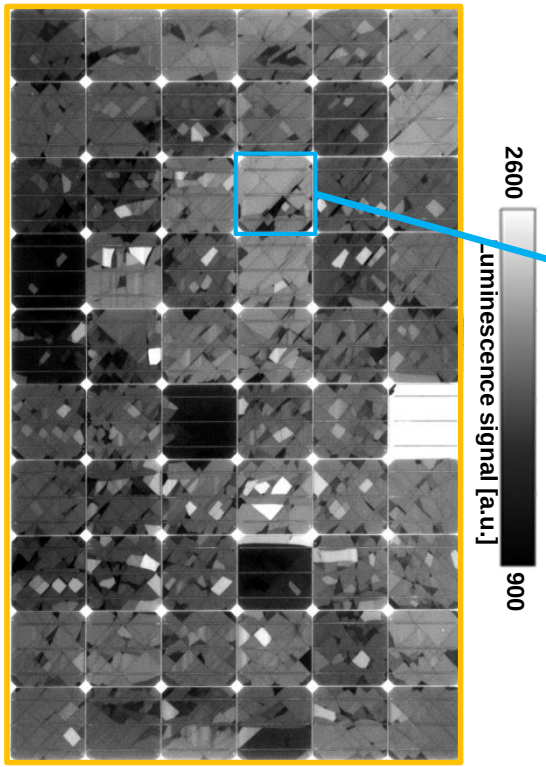
typical PID pattern is visible

Cracks and inactive areas

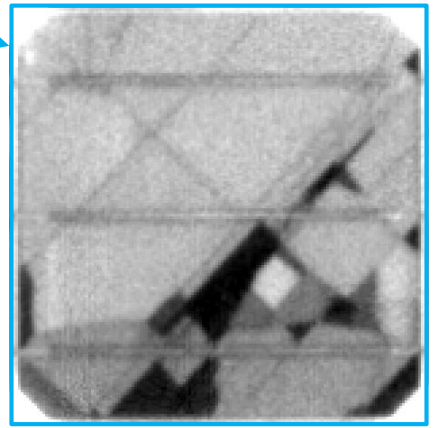
EL at 90% Jsc current

PL at about 57 W/m²





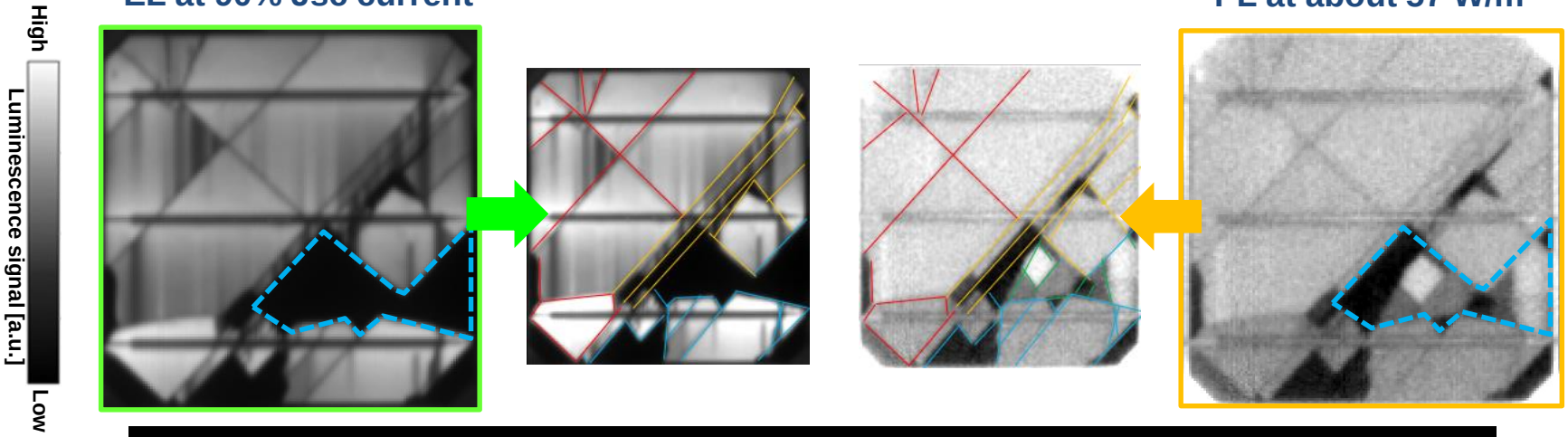
are ALL cracks and inactive areas visible?



Cracks

EL at 90% Jsc current

PL at about 57 W/m²



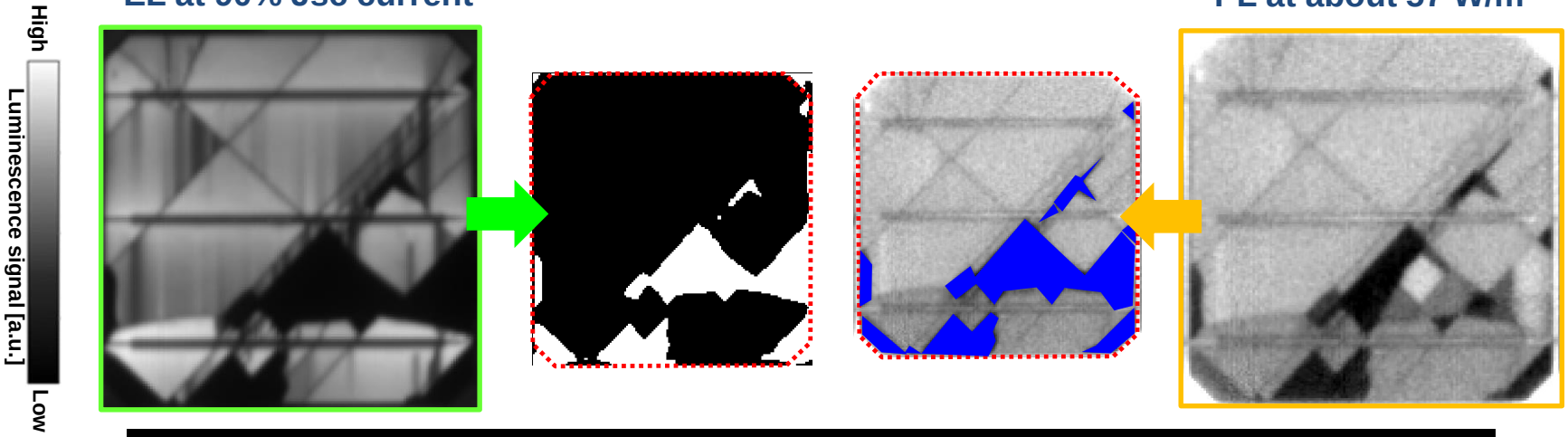
	EL (at 90% of Jsc)	PL (at about 57 W/m²)
#-cracks	39	47
Σ-crack length (pixel length)	1451.4	1612.9

all cracks recognizable here

Inactive area

EL at 90% Jsc current

PL at about 57 W/m²

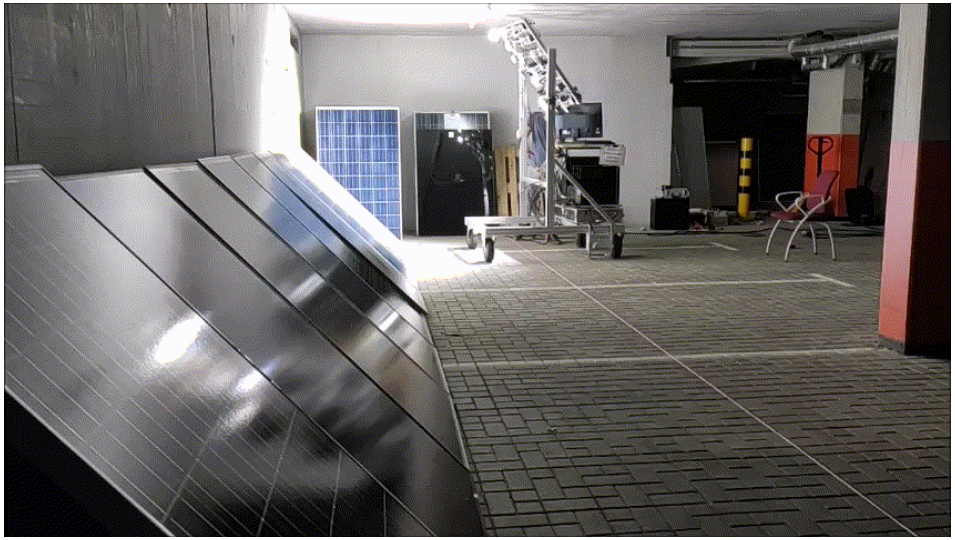


	EL (at 90% of Jsc)	PL (at about 57 W/m²)
Inactive area %	15.24	15.13

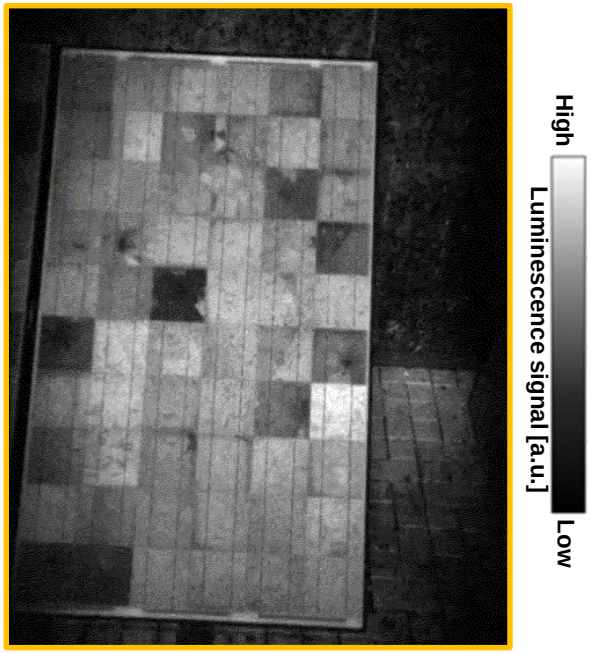
all inactive areas recognizable here

PL setup suitable for outdoor use

- Setup at work



- PL Movie



Summary:

- **full area PL functional**
  - all power-relevant defects are detectable
    - PID ✓
    - cracks ✓
    - inactive areas ✓
    - sc bypassdiode ✓
  - throughput: 1.6 s per PV module shown
- **preferred by operators**

Next Steps:

- **handheld setup**
- **outdoor testing**
- **increasing the throughput**

https://www.airportpark-berlin-neuhardenberg.de/.

Thank you for your attention.

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