DaySy
Daylight Luminescence for PV Systems

How to Check 400kW$_{peak}$ Per Day With Electroluminescence

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solarzentrum stuttgart

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Solarzentrum Stuttgart

- Research and development in photovoltaics and industrialization thereof
- In close cooperation with Institute for Photovoltaics, University of Stuttgart
- Products/developments
  - Novel surface texture for crystalline silicon
  - PV module optimization
    - White colored cell interconnector +1%$_{rel}$ efficiency
  - Lifetime calibrated photoluminescence imaging system
    - Full QSSPC integration
    - Very high irradiation homogeneity on 20x20cm²
  - Daylight luminescence analysis

Institute for Photovoltaics, Uni Stuttgart

Solar cell research

- Laser doped selective emitter
- Innovative solar cell concepts
- Fully laser processed IBC solar cells
  - → $\eta \approx 22$ %!

PV system research

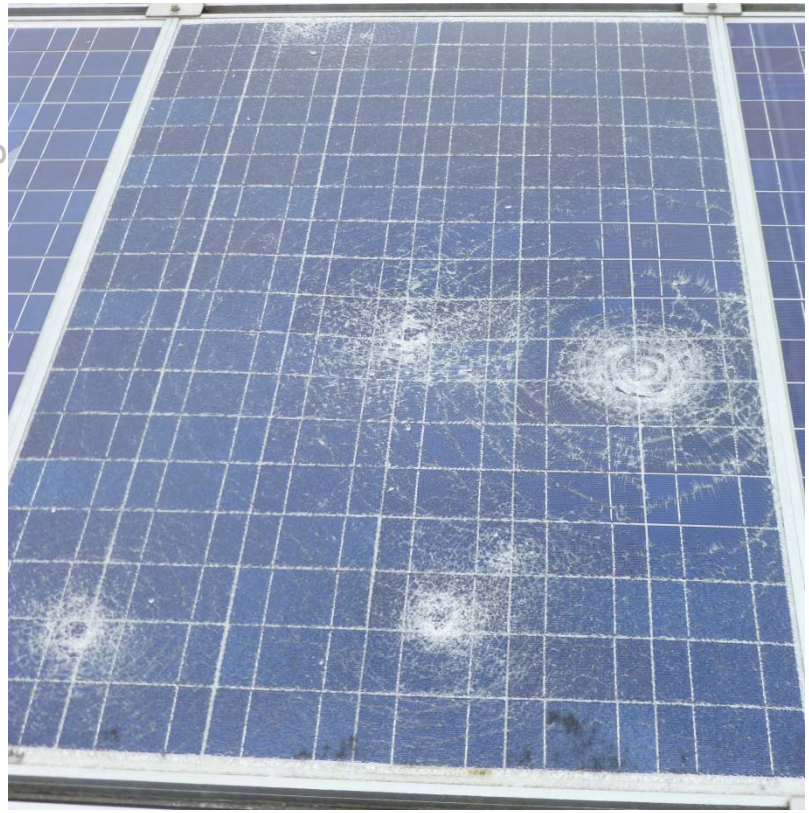
- PV system analysis and monitoring since 2004
  - Stuttgart, Cyprus, Egypt

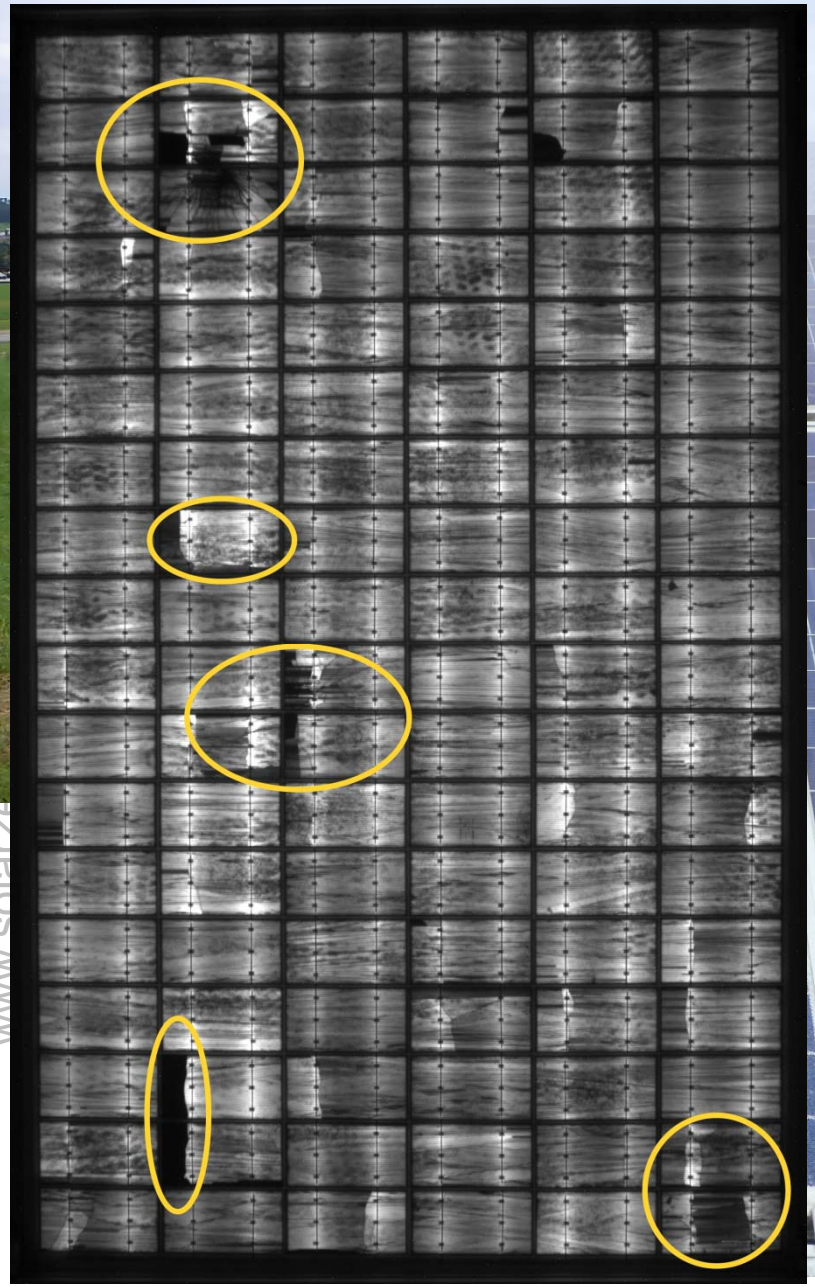
Characterization

- Lifetime calibrated photoluminescence systems
- Daylight luminescence system: DaySy

Why Electroluminescence?

- Defects are not always obvious!





Extreme hail in Germany 2013

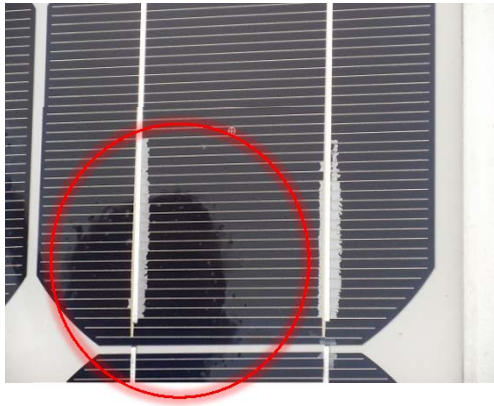
- About 1/3 of modules in this PV plant with obvious glass failure
- All others seemed undamaged

BUT

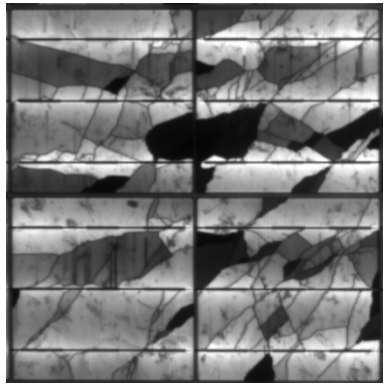
- Dark room EL analysis proves 95 out of 96 modules with hail damage!

Module Failure Modes

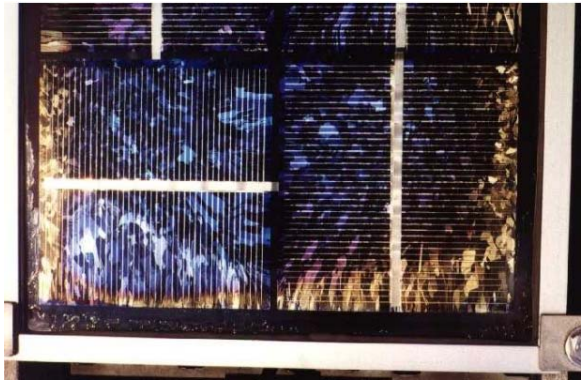
Delamination



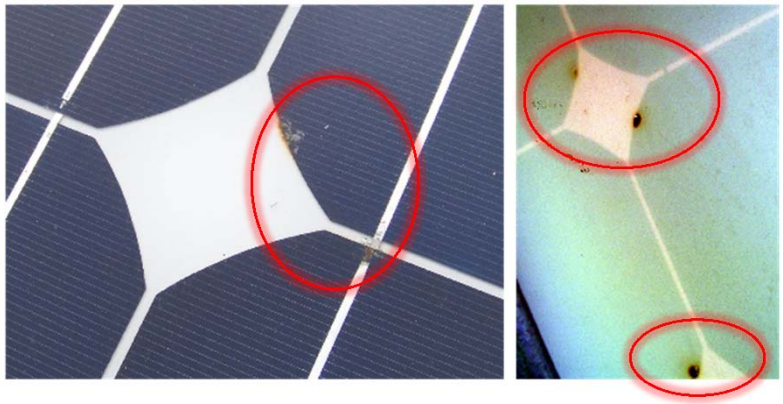
Microcracks, broken cells, finger interruptions



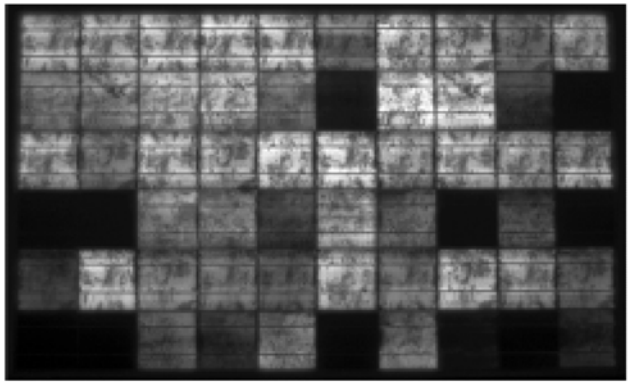
Browning



Hot spots

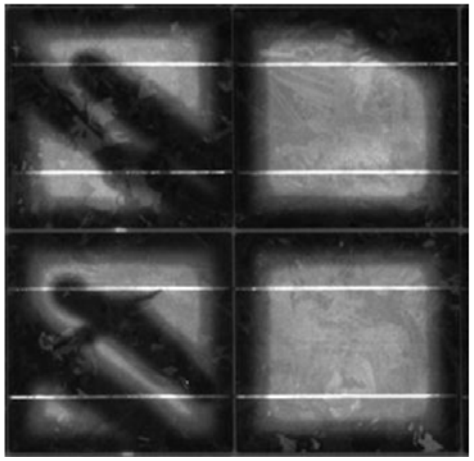


Potential induced degradation (PID)



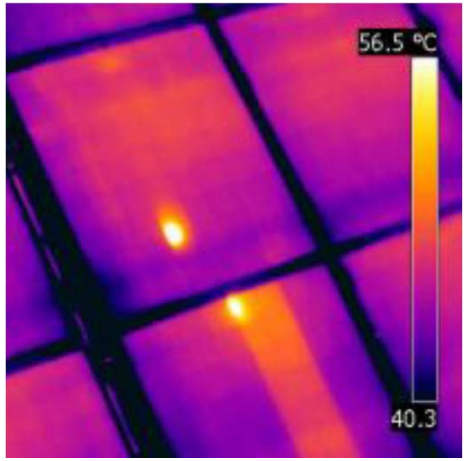
Optical Characterization Methods

UV - Fluorescence

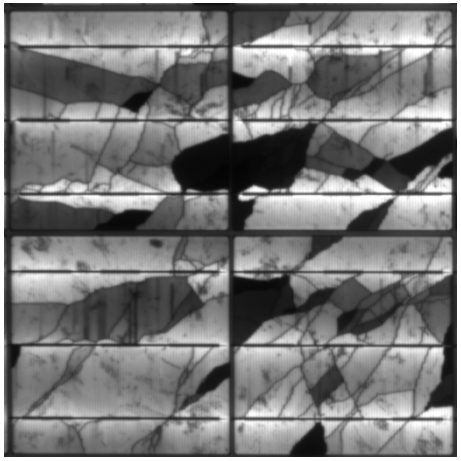


Köntges et. al., 27th EUPVSEC 2012

Thermography



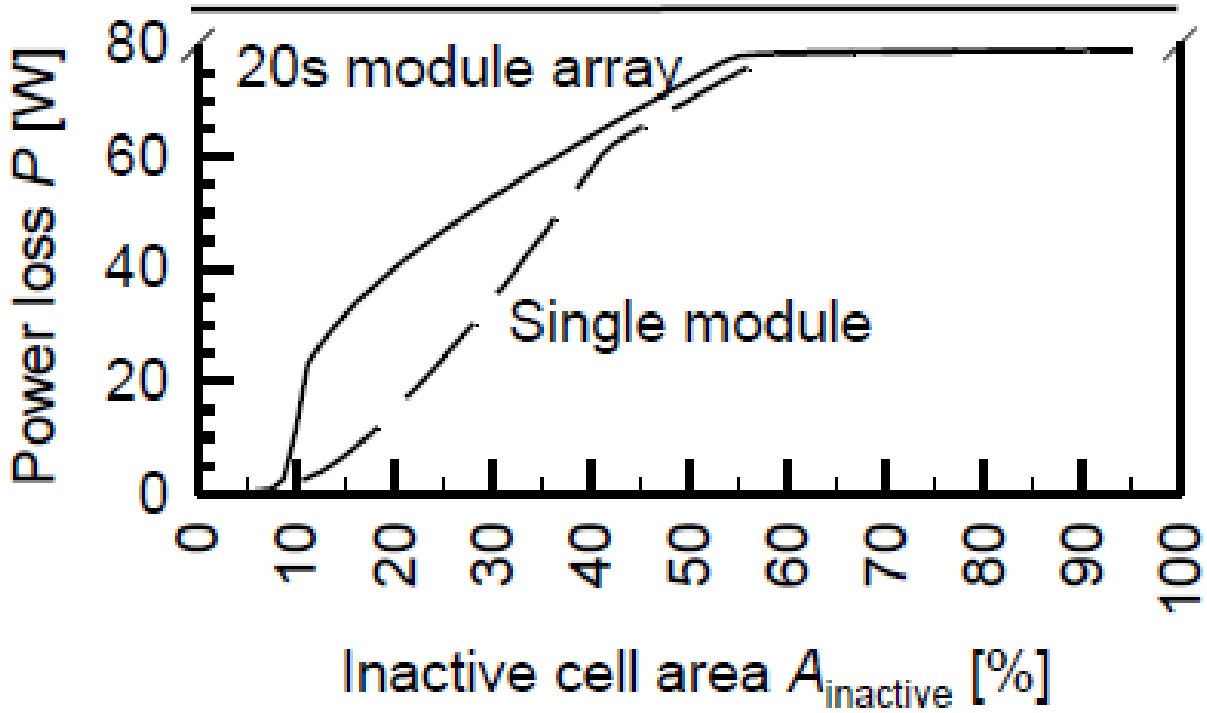
Luminescence



	UV - Fluorescence	**Thermography**	**Luminescence**
Pro	Cracks visible	Power loss	All defects
	Cost effective	Cost effective	Identification
Con	**Night**	**Irradiance**	**Night**
			Generator
	Well aged cracks	Identification	Expensive

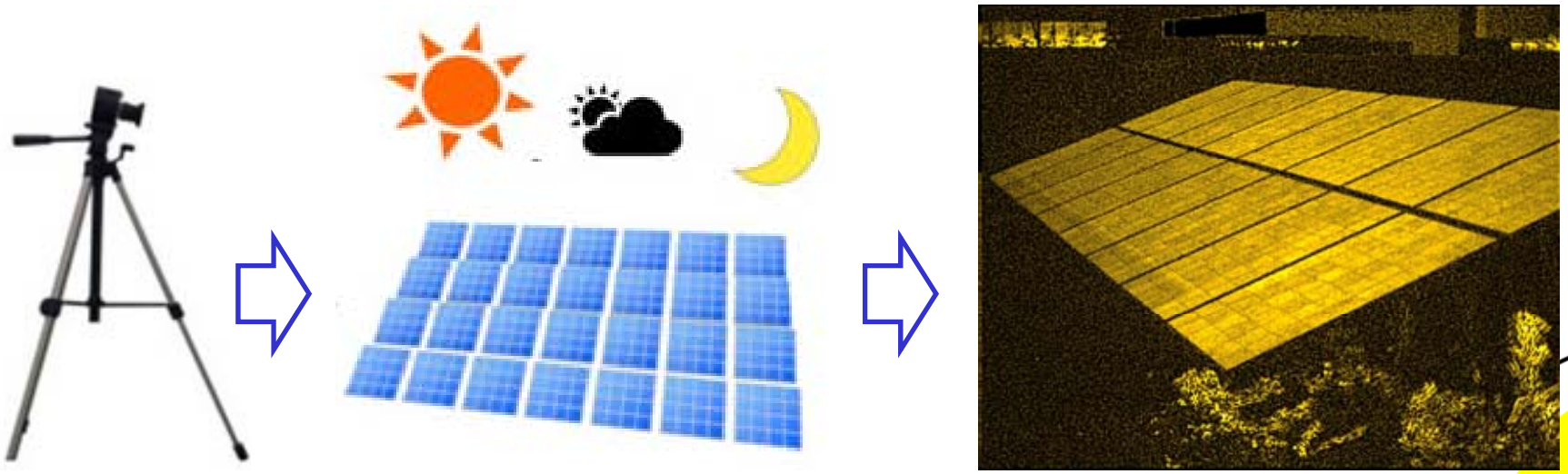
What we do about it?

- Hot spot
  - How hot? Remove, replace or just observe…
- EL cell damage
  - How severe? How to judge?

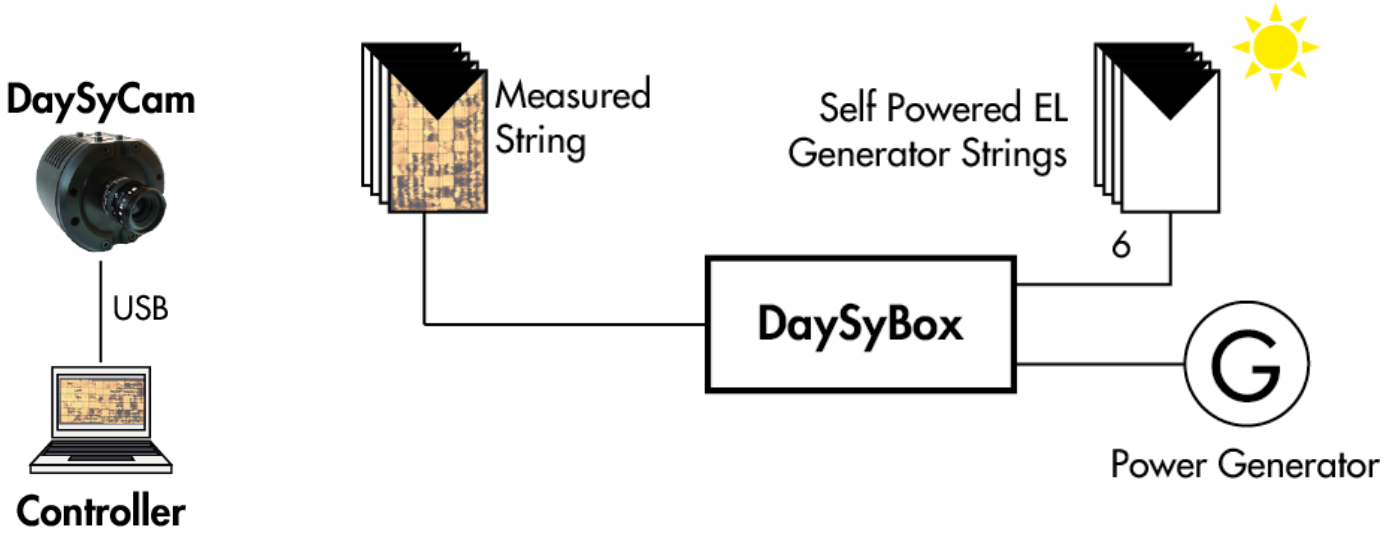


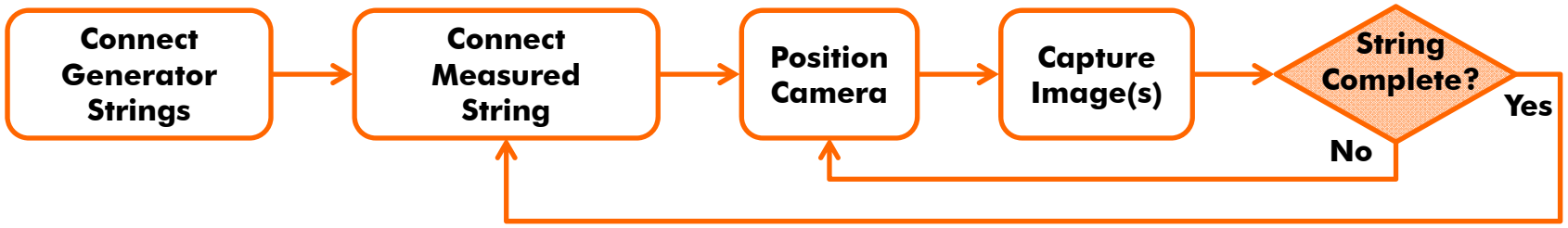
Novel Method: DaySy

- Electro (EL)- and photoluminescence (PL) characterization
  - In full daylight
  - Independent of surrounding light
  - On mounted modules and full strings
  - Using either the PV-plant or a DC source as power supply



Measurement Procedure





Service Availability: Sunny Day

Measure when YOU want: 100% availability day and night

DaySy – Self Powered EL

DaySy – EL with Power Generator

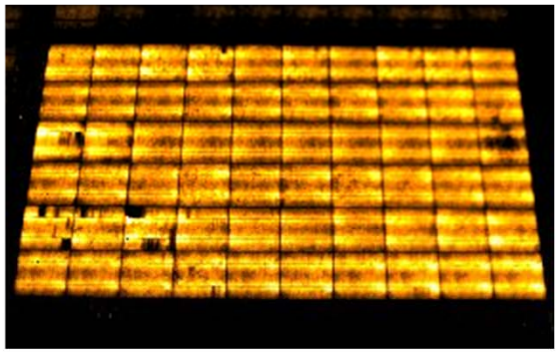
Night -EL **Night -EL**

Thermography

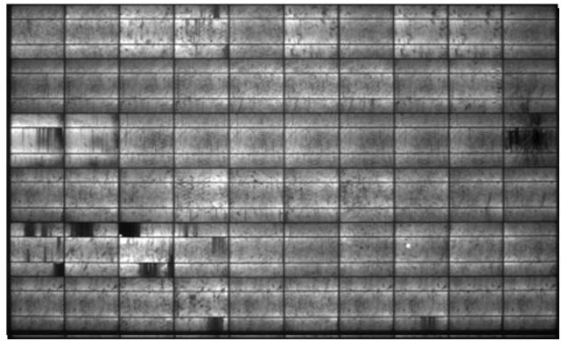
0 100 700 700 100 0

Daytime Irradiance [W/m²]

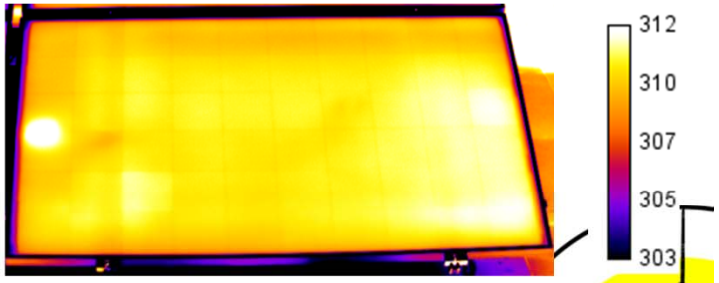
DaySy EL



8 MP Dark-Box EL

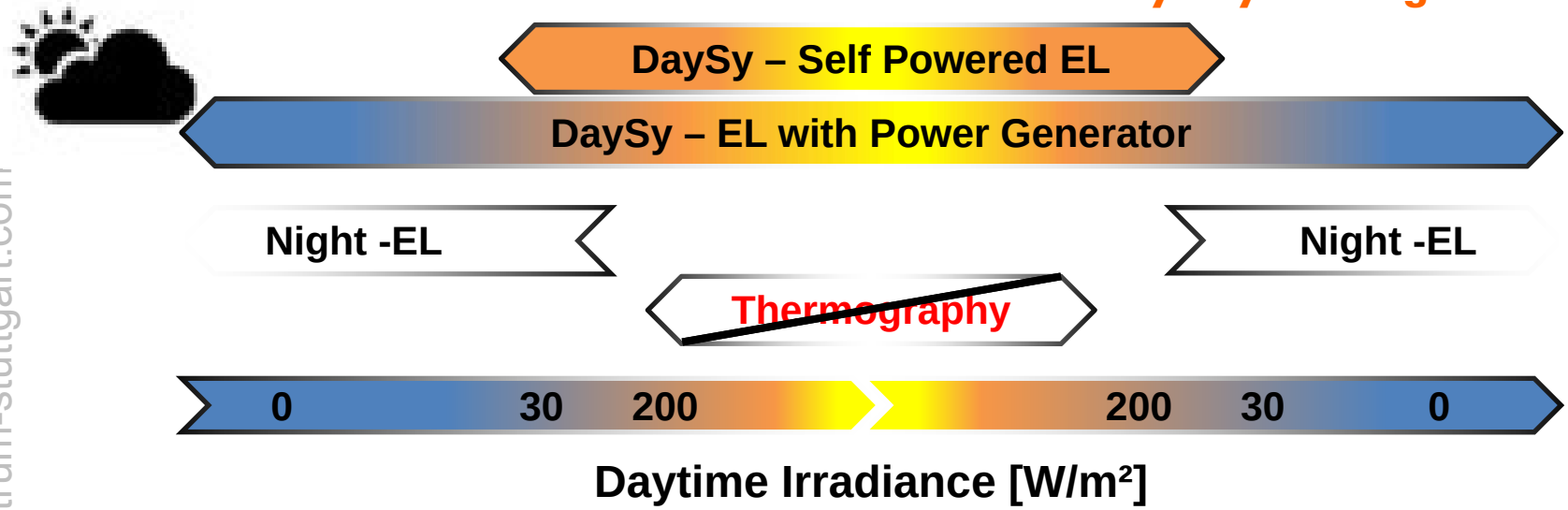


MPP Thermography

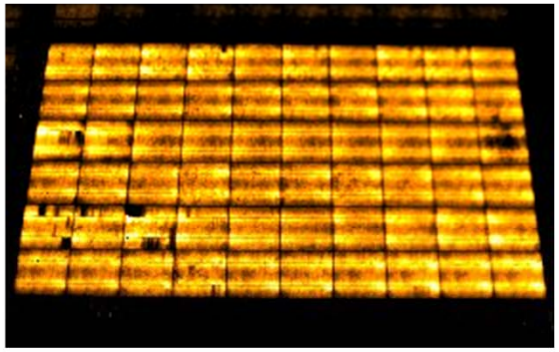


Service Availability: Cloudy Day

Measure when YOU want: 100% availability day and night



DaySy EL



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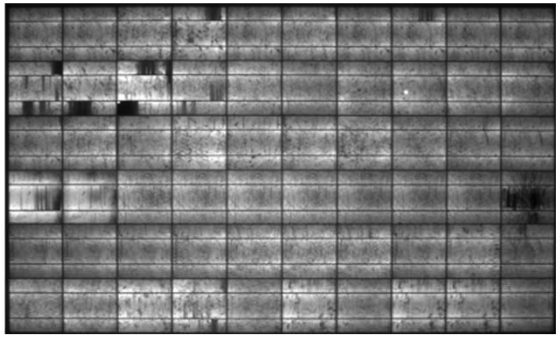
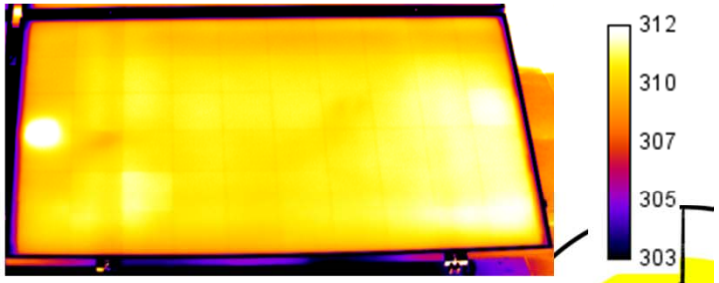
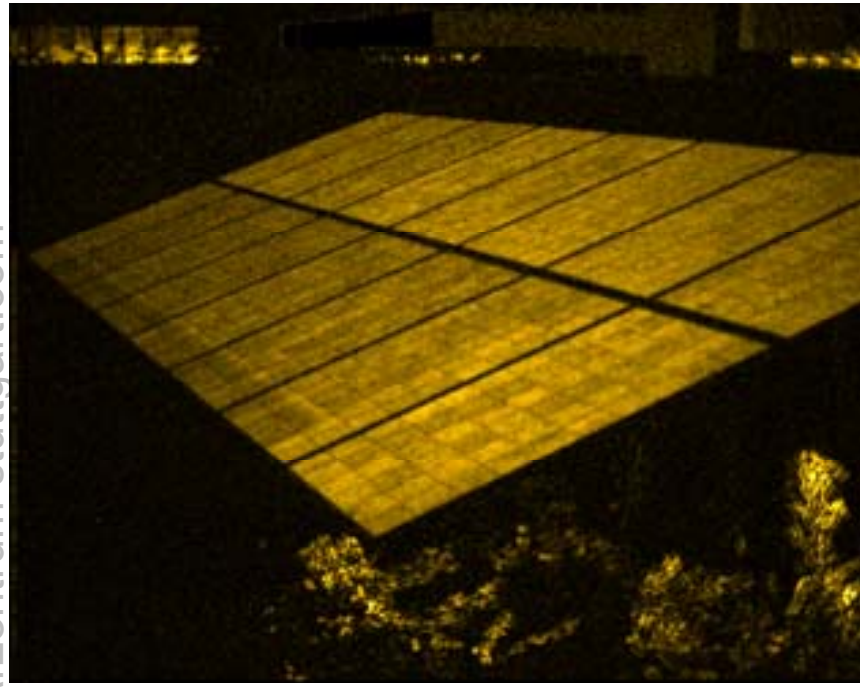
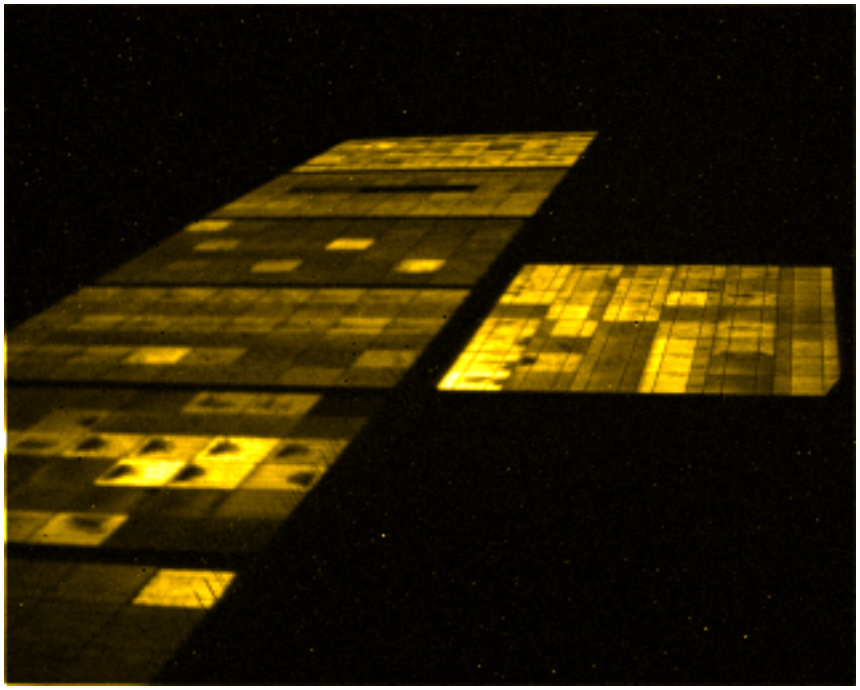


MPP Thermography



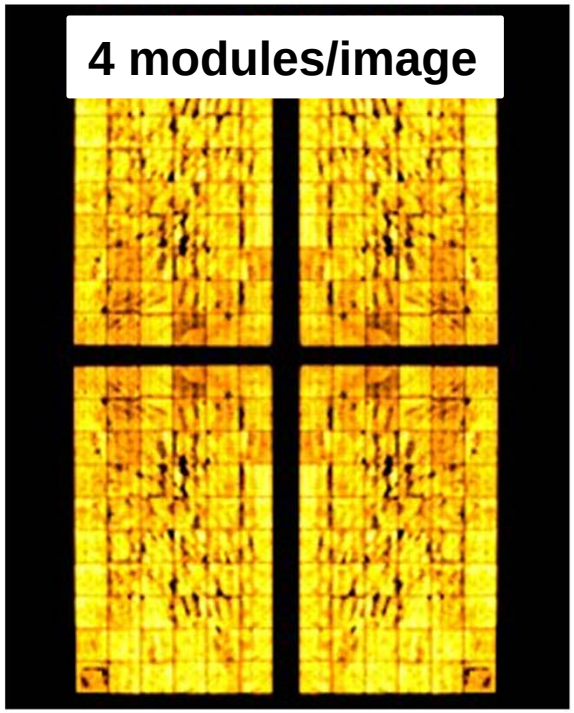
Whole String Imaging



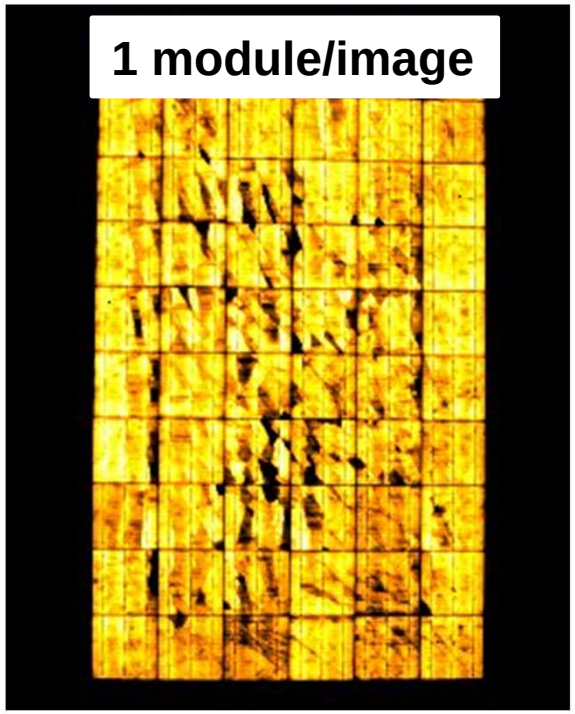


- ✓ Potential induced degradation (PID)
- ✓ poor low light response
- ✓ damaged areas
- ✓ groups of broken fingers
- ✓ Very high throughput possible

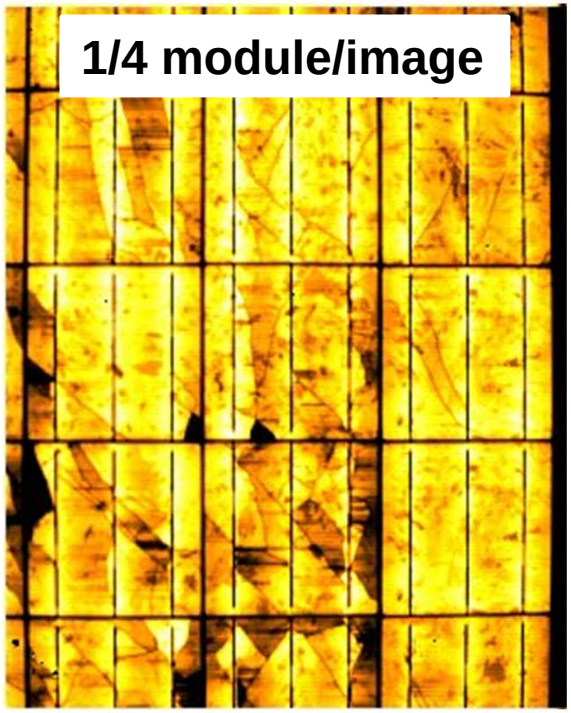
Detection Limit



- ✓ potential induced degradation (PID)
- ✓ damaged areas
- ✓ groups of broken fingers
- ✓ poor low light response

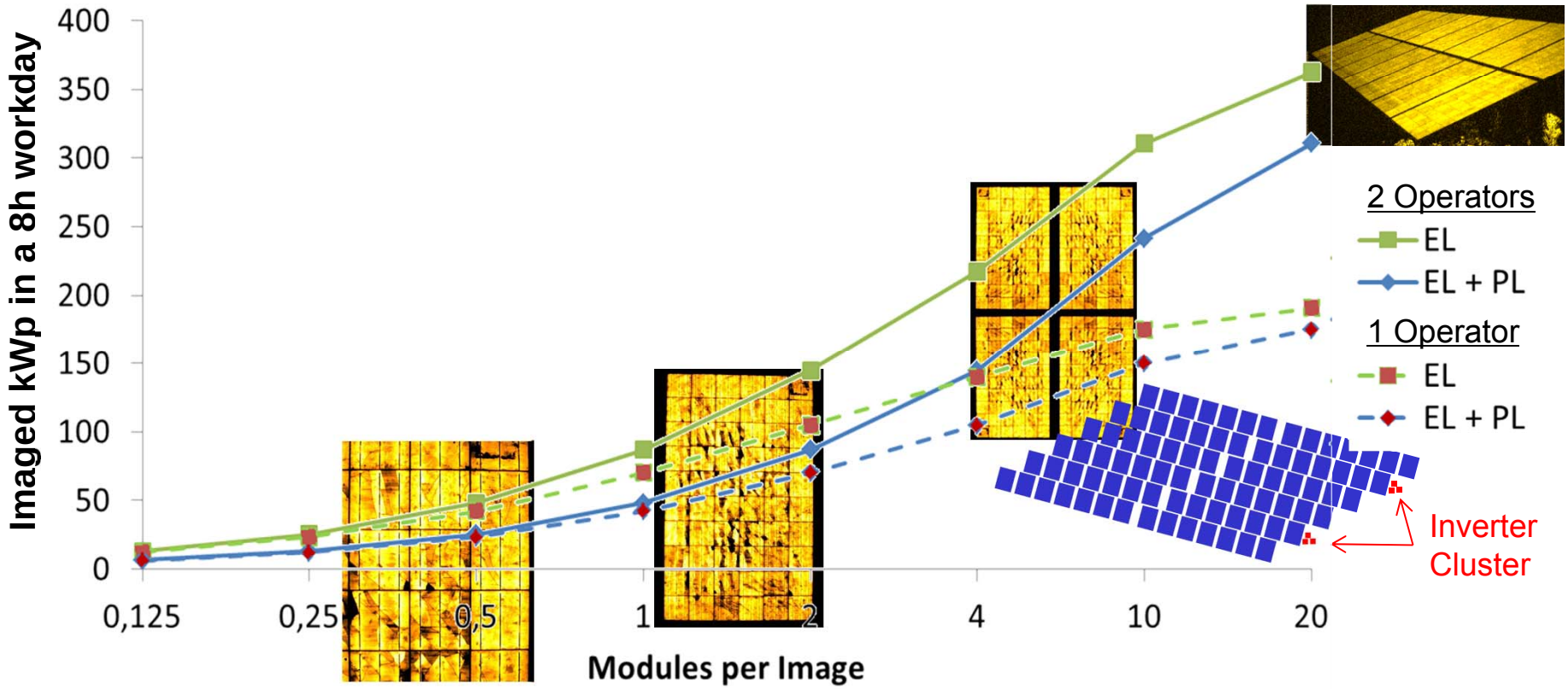


- ✓ groups of broken fingers



- ✓ micro-cracks
- ✓ broken fingers

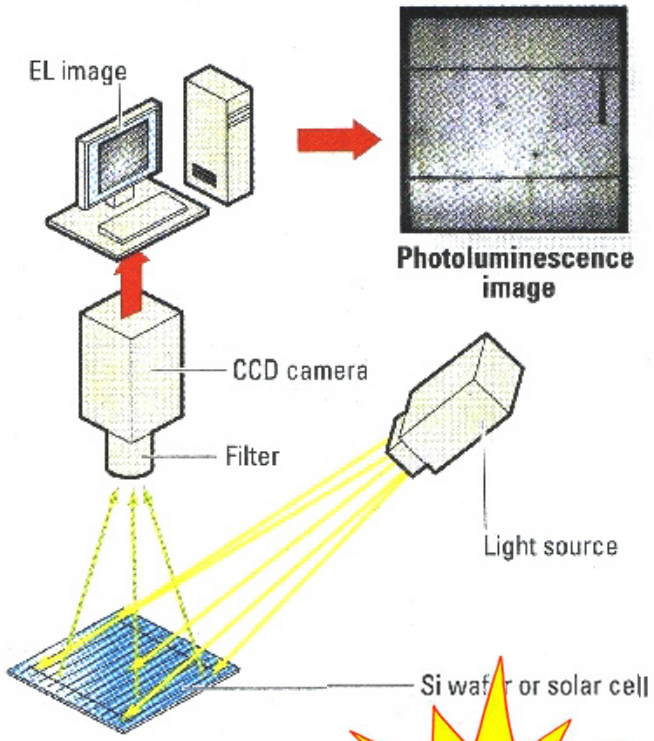
Throughput



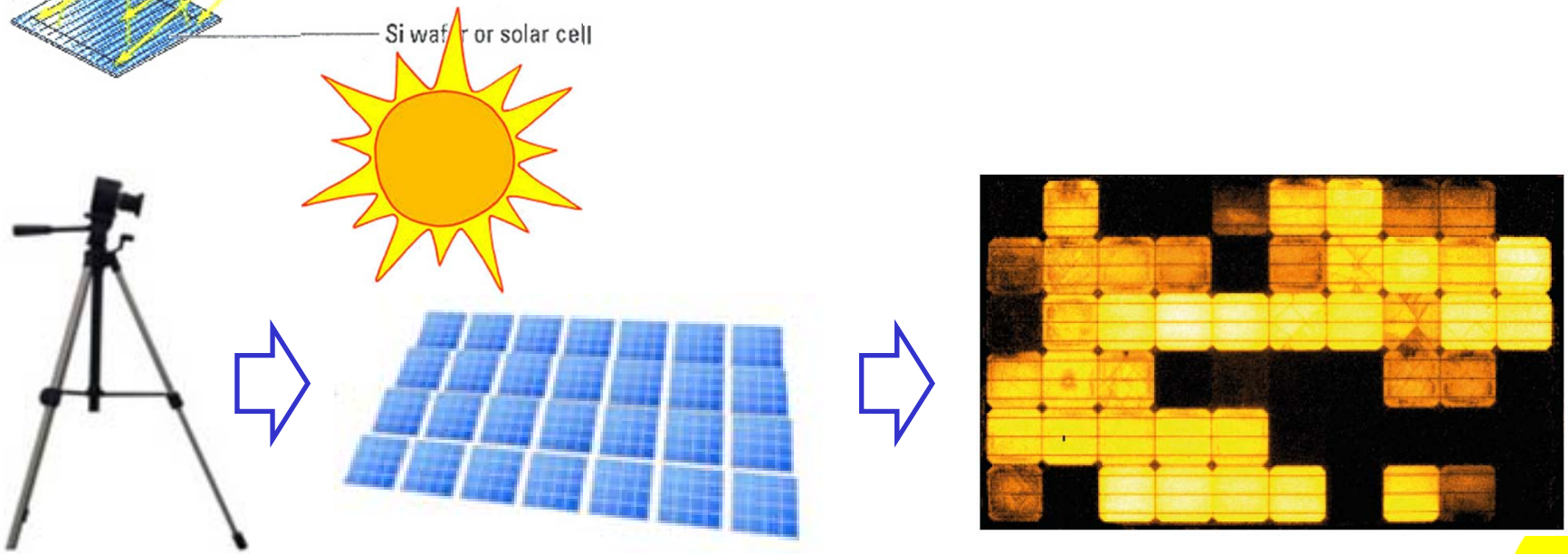
Scenario:

- Field PV installation with clustered string inverters, 250W_p modules, 20 modules/string
- Unpacking & Setup: 30 minutes; Wrap up: 15 minutes / operator
- Location of PV strings is unknown and has to be discovered: 10 min / string / operator
- 1 minute for a EL image; 2 minutes for a EL+PL image

Photoluminescence on module level

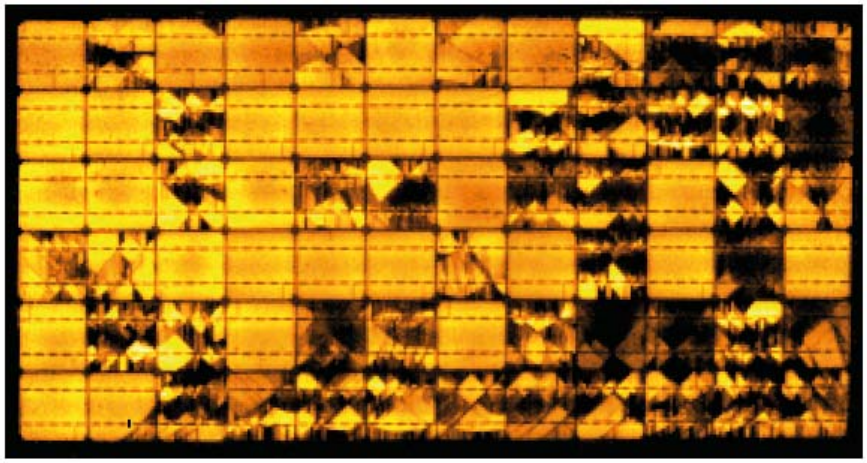


	EL	PL	Example
Ohmic	++	--	Broken fingers
R_P	--	++	PID, low light

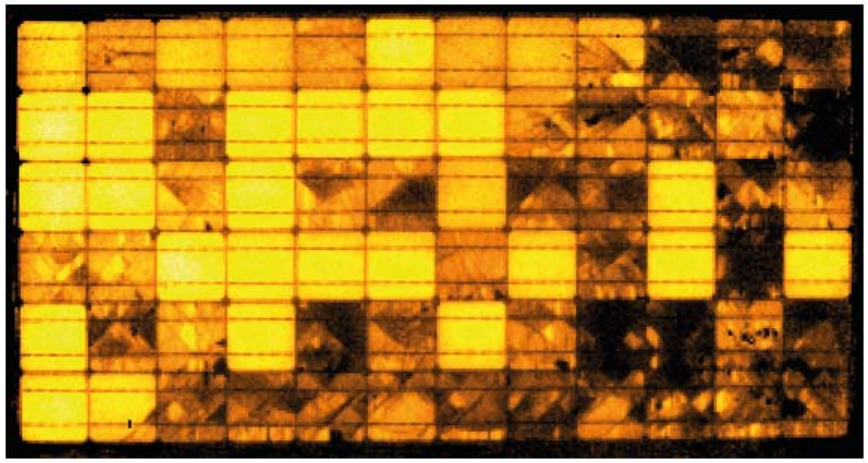


Defective Modules: Broken Cells

Electroluminescence (EL)



Photoluminescence (PL)

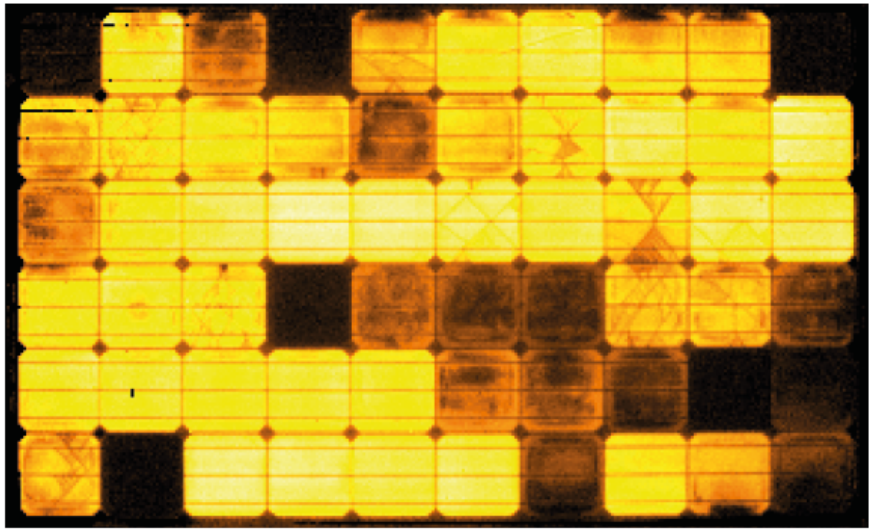


Badly damaged module

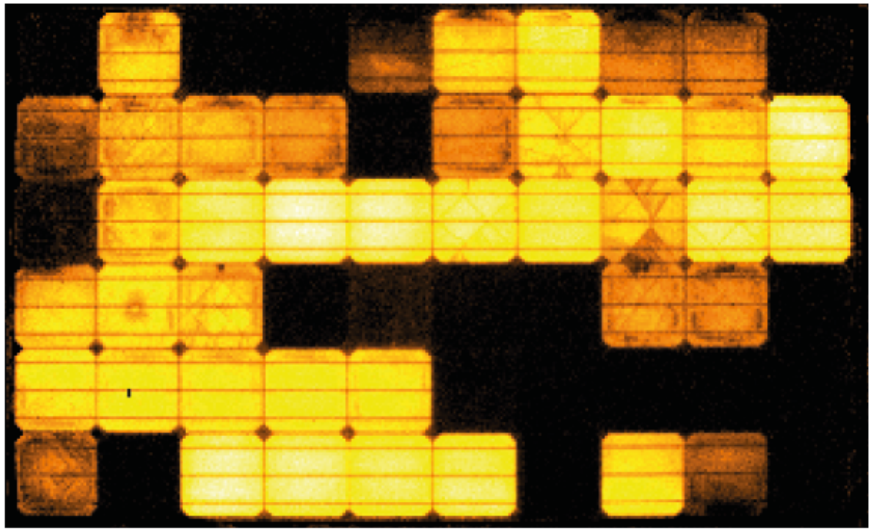
- Dead areas: Black EL & black PL
- High series resistance: Dark EL & regular PL
- Low parallel resistance: Dark EL

Defective Modules: PID

Electroluminescence (EL)



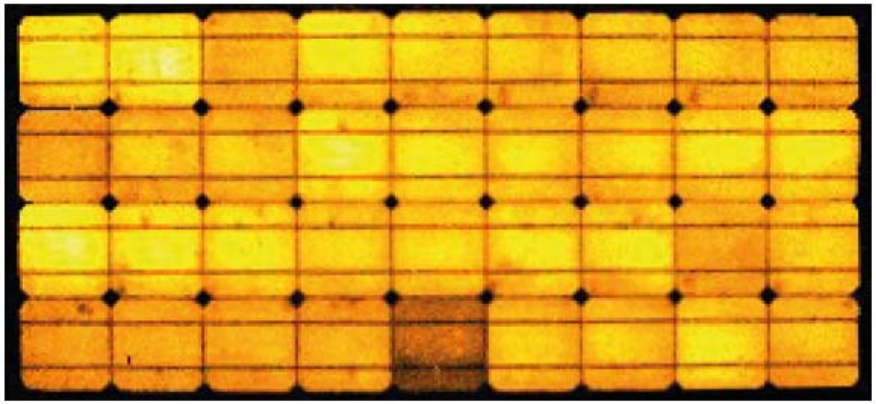
Photoluminescence (PL)



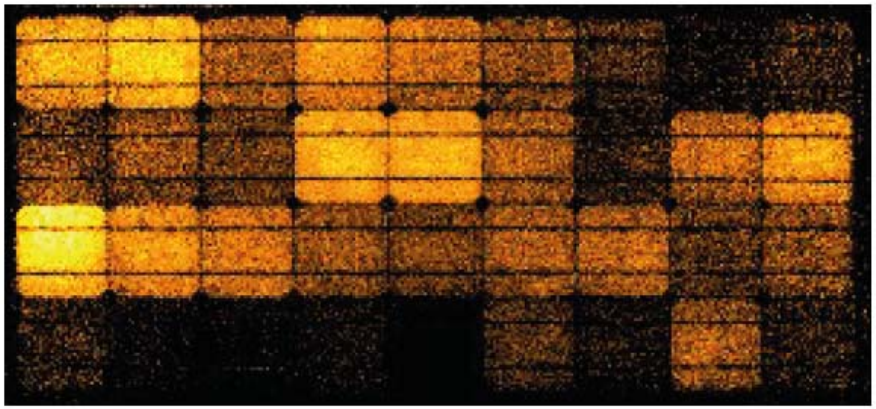
Potential Induced Degradation (PID)
Chessboard pattern with darker EL and black PL due to low parallel resistance.

Degraded Low-Light-Response

PL at 800 W/m²



PL at 80 W/m²

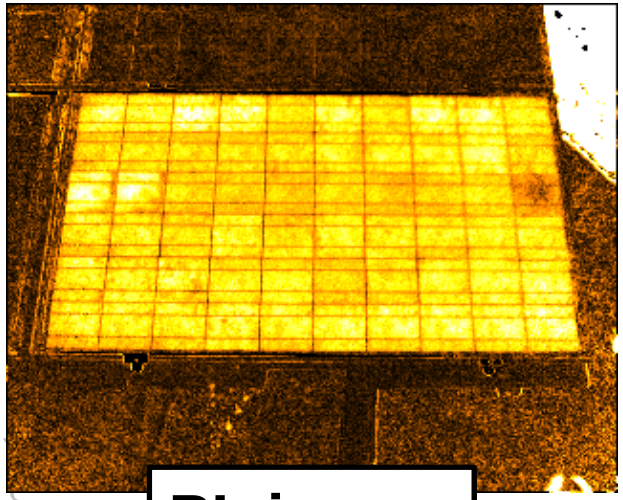


Degraded low light response

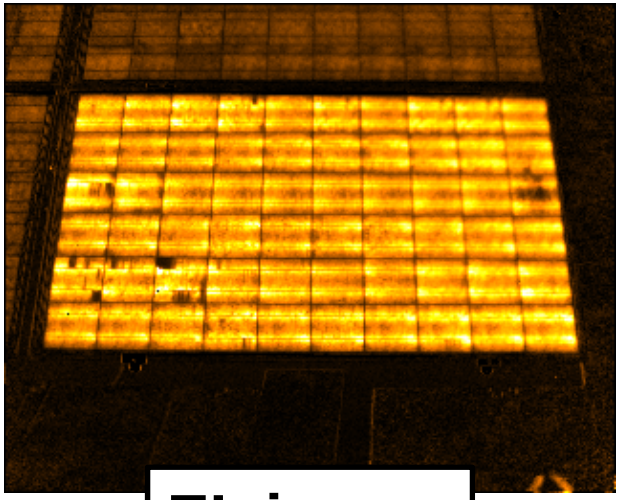
Low parallel resistance reduces the open circuit voltage at low light intensities

→ Dark cells appear in low light PL image (right).

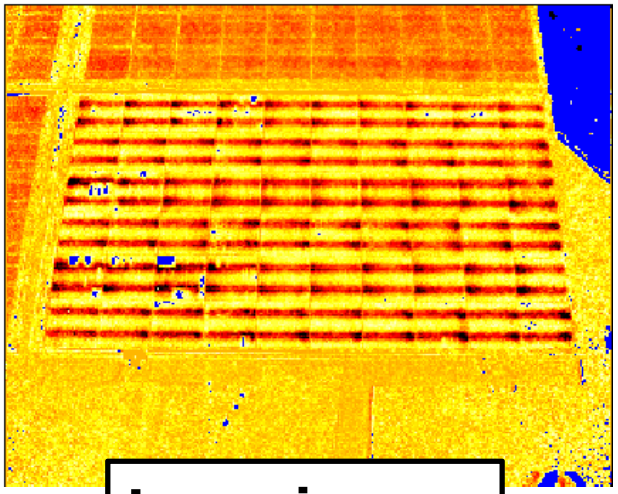
Automated Image Analysis



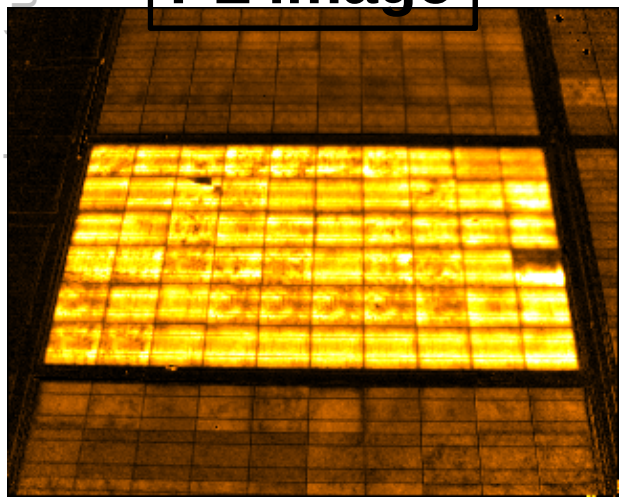
PL image

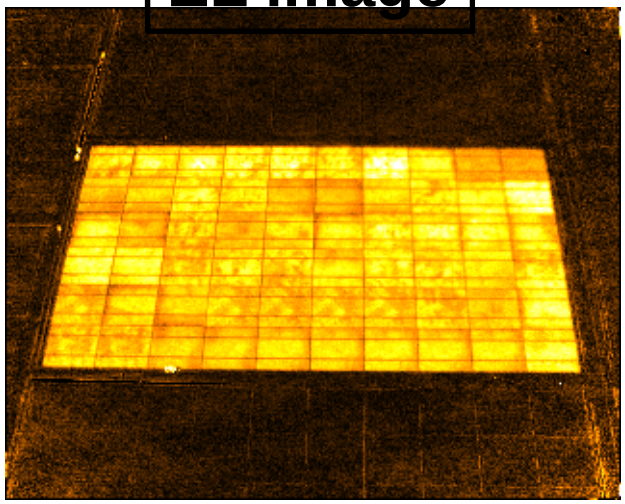


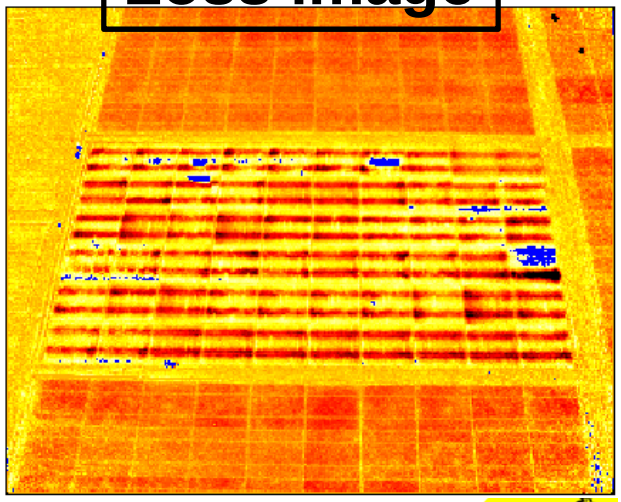
EL image



Loss image



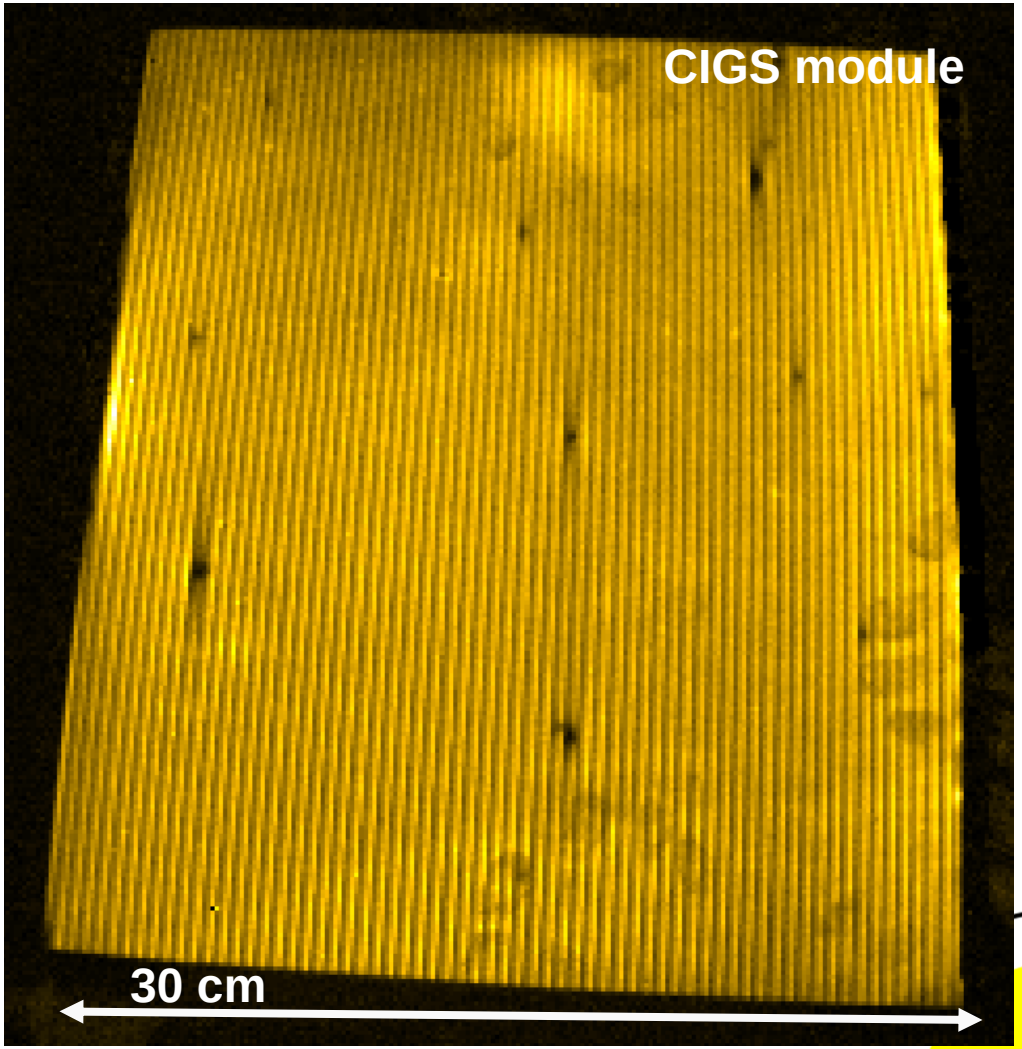




Thin film module

- a-Si
- CIGS

- CdTe coming soon…



Thanks for your attention!