Modern PV Module Quality Testing

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with special thanks to
Michael Reuter,
Liviu Stoicescu,
Jürgen Werner.

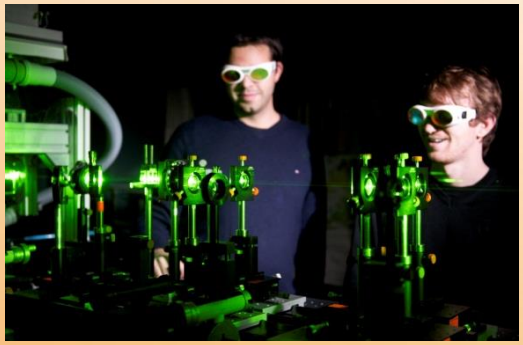
ipv

Institute for Photovoltaics - *ipv*

- director Jürgen H. Werner
- 4+1 work groups
- new group *Energy Storage* (Peter Birke)
- 25 coworkers, including 10 PhD candidates

Technology

Industrial solar cells



Laser processes

Sensor technology

Birgitt Winter

Renate Zapf-Gottwick

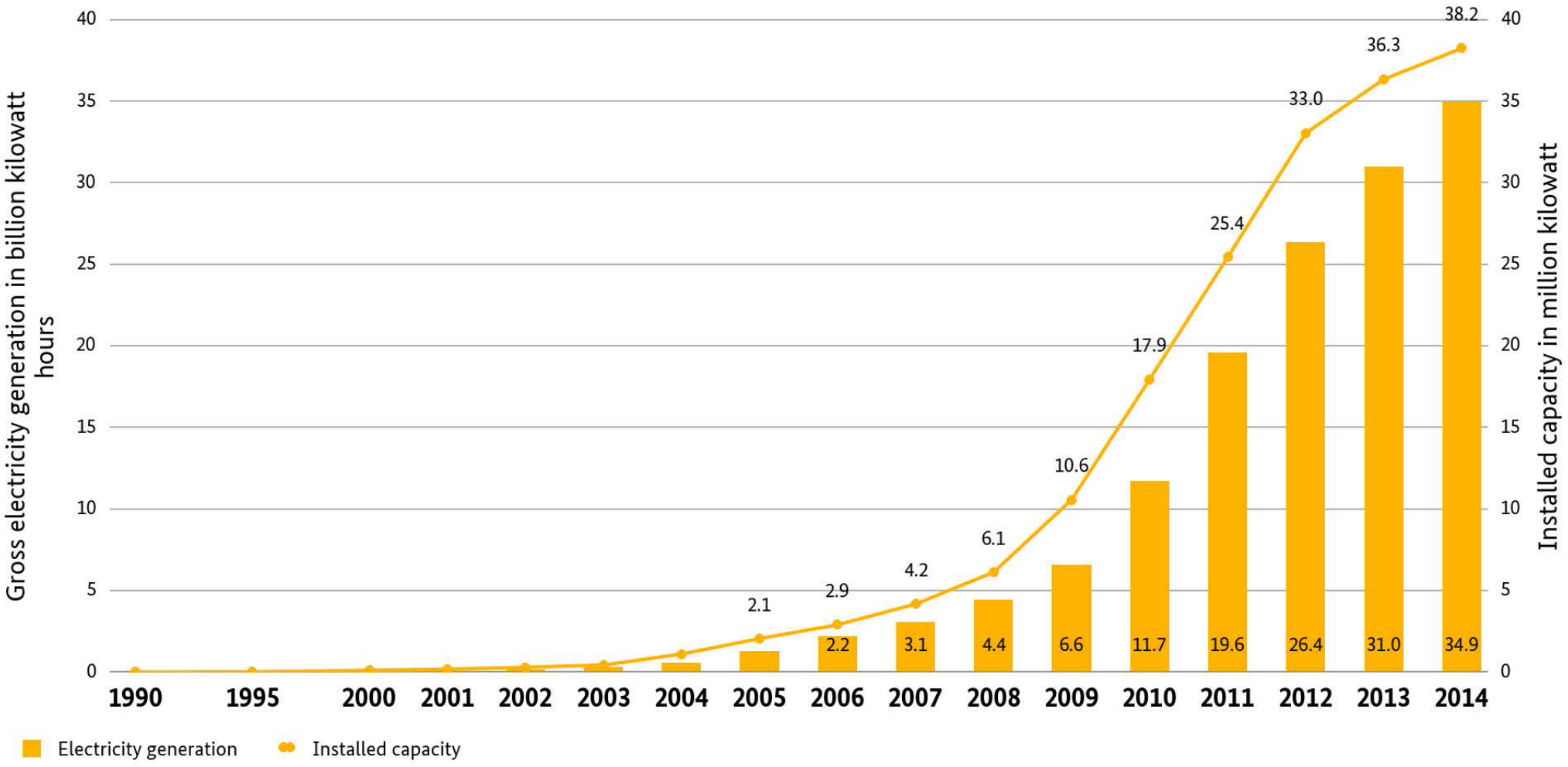
Jürgen Köhler

Markus Schubert

Outline

- Quality Assurance in PV - why?
- Common methods
- Imaging techniques
- Daylight Luminescence System (DaySy)
- DaySy - a very good option!

Motivation: keep 38 GW alive!

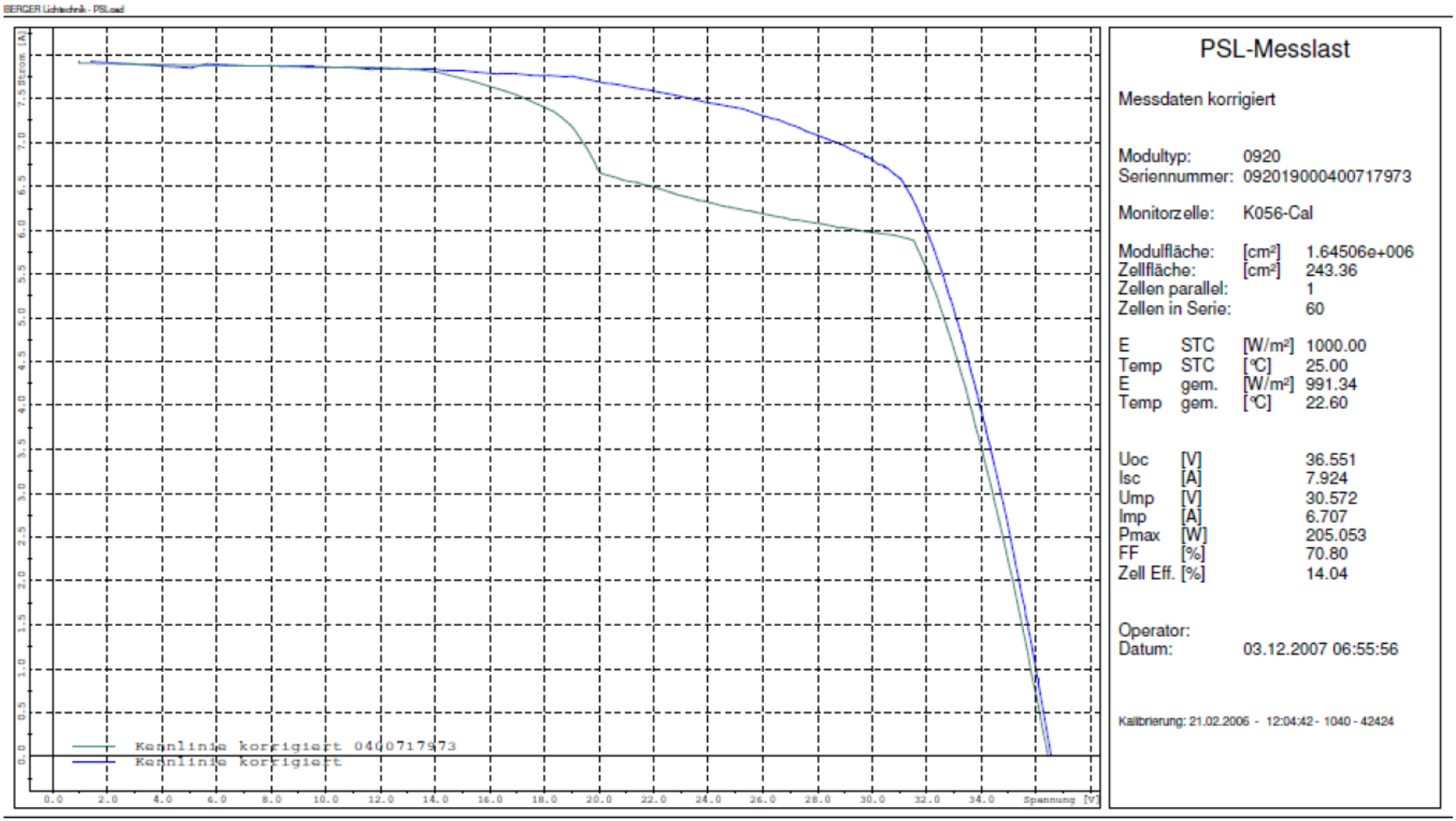


38 GW PV installed in Germany
all cells/modules series-connected !!

Only few methods for troubleshooting

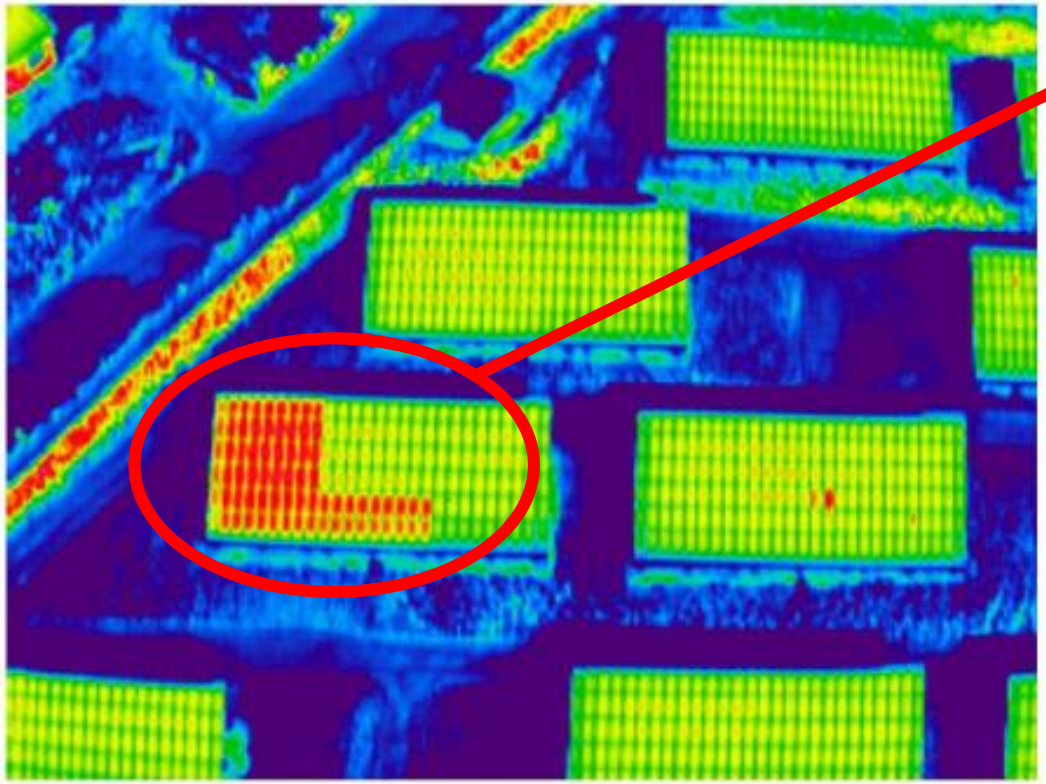
- compare strings (big PV plants)
- analyse string or module *I/V*
- outdoor thermography
- electroluminescence
- dismantle and check indoor

Dismantle and check indoor



Indoor flasher measurement: effect of broken cell after 5 years of outdoor operation [courtesy of Peter Bentz, Solarfabrik Freiburg]

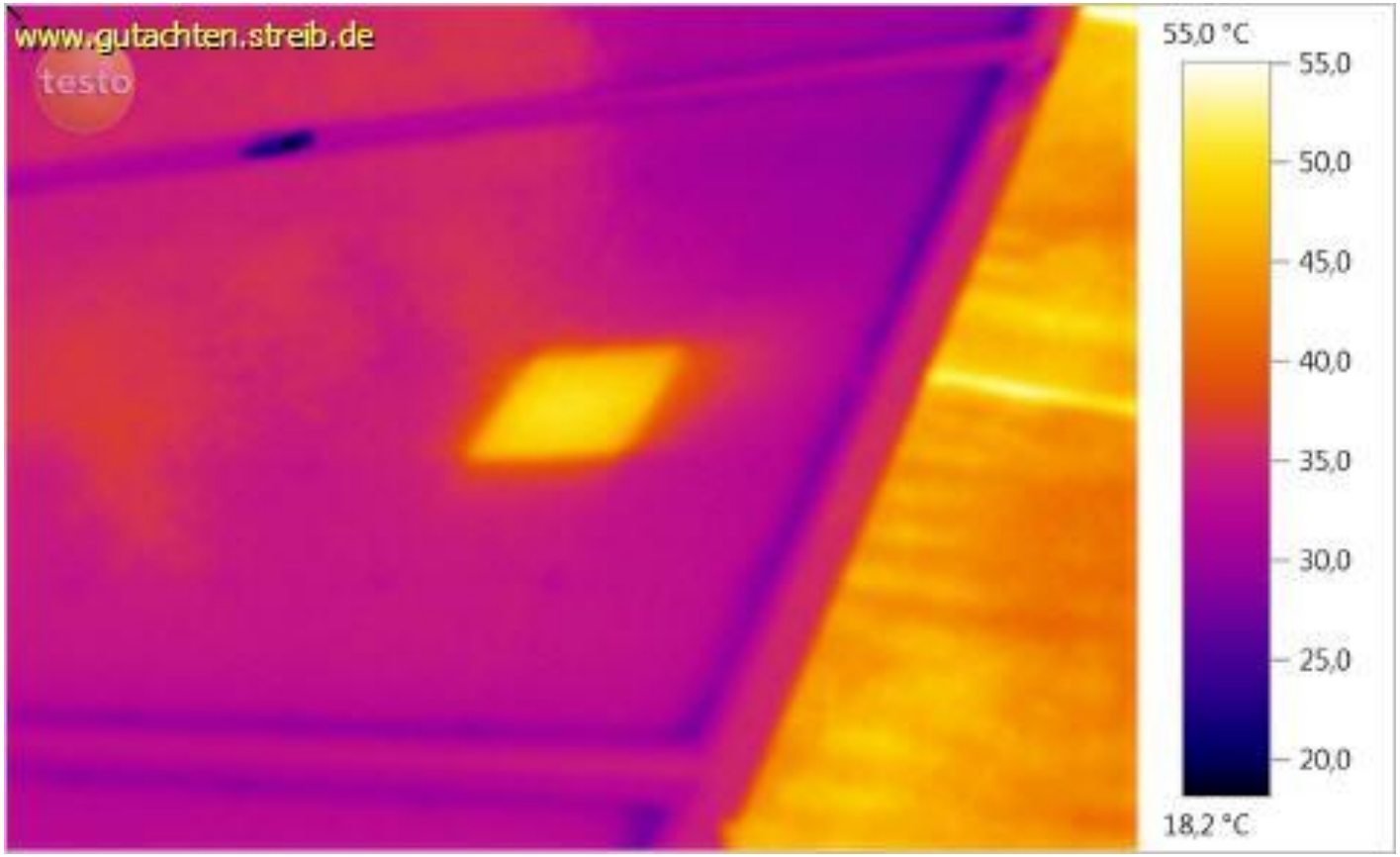
Thermography of complete PV park



failure of one inverter

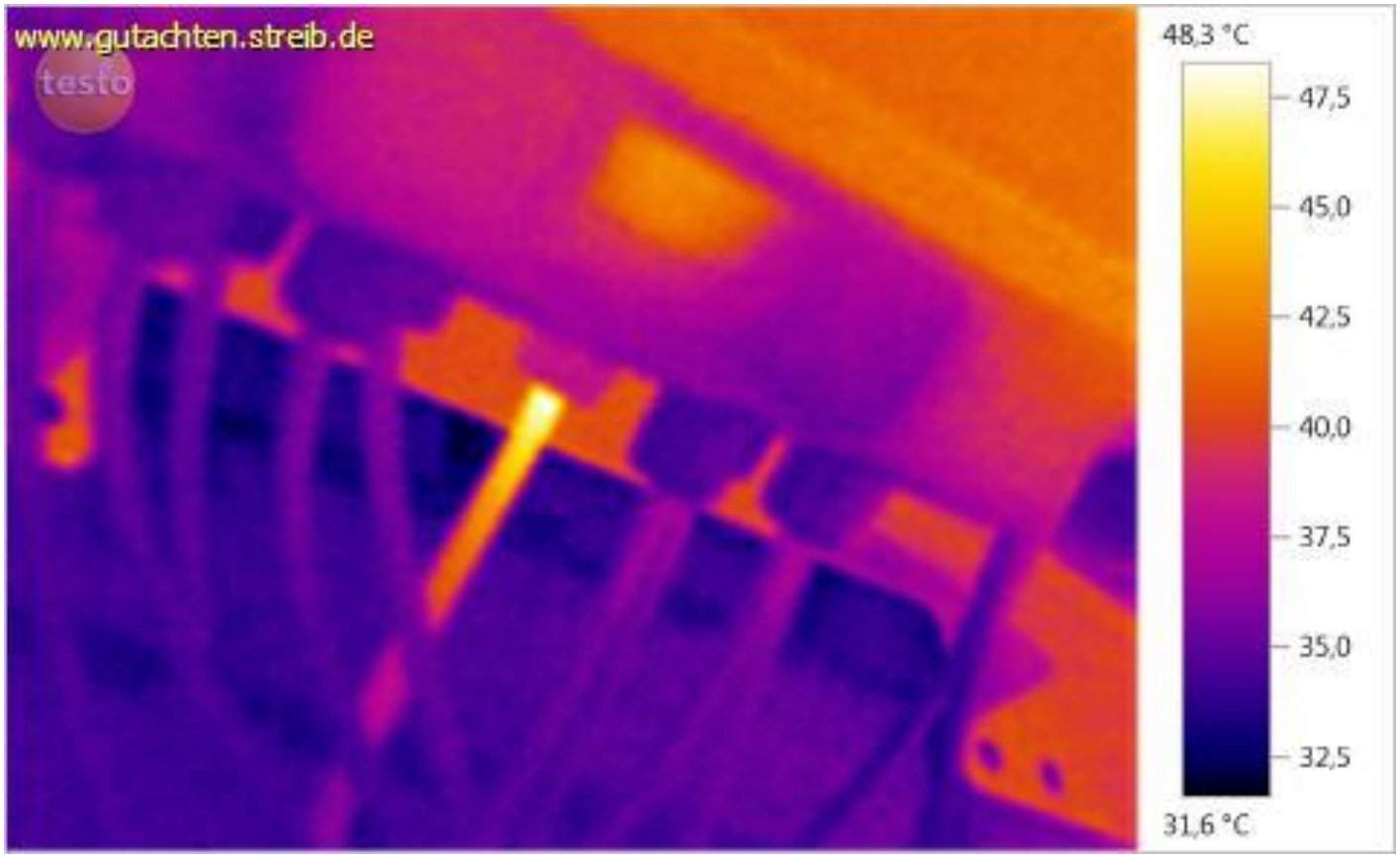
Infrared imaging of PV Parks
[courtesy of C. Buerhop, ZAE Bayern]

Typical thermography image



hot spot, probably due to broken cell

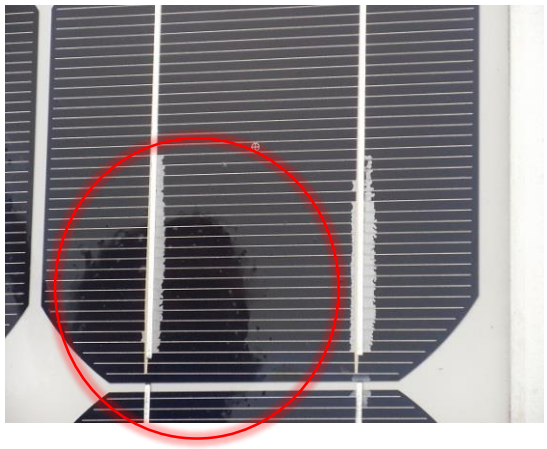
Thermography



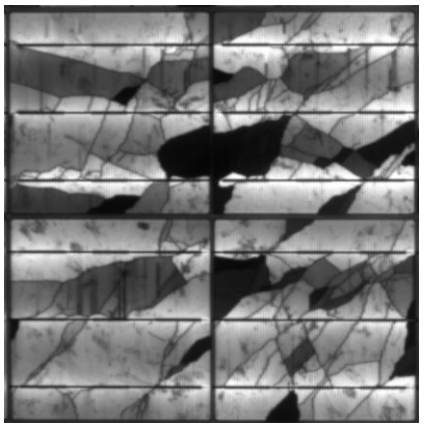
poor cable connection, wrong connector type?

Module Failure Modes

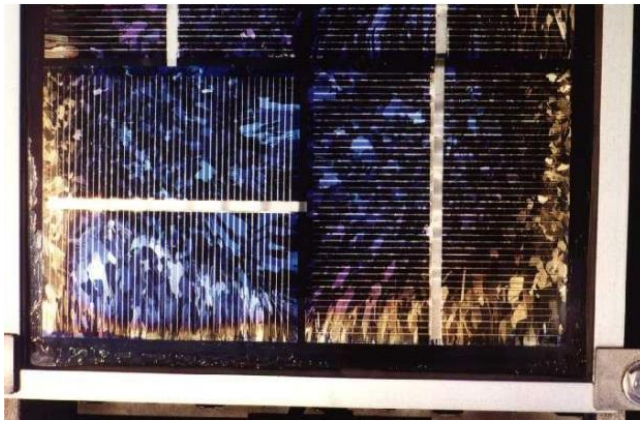
Delamination



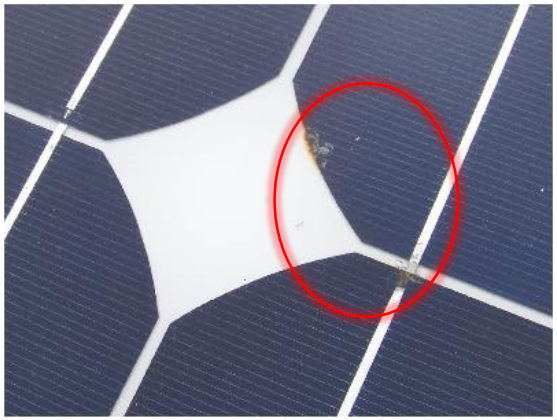
Microcracks, broken cells, finger interruptions

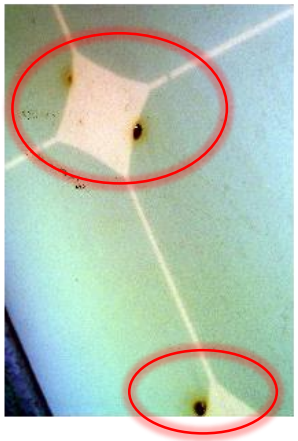


Browning

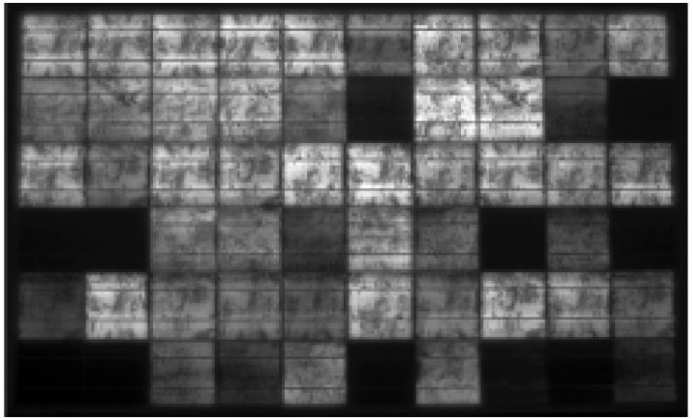


Hot spots



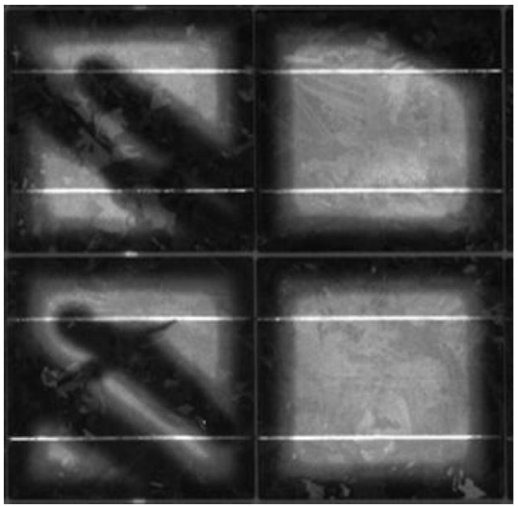


Potential induced degradation (PID)



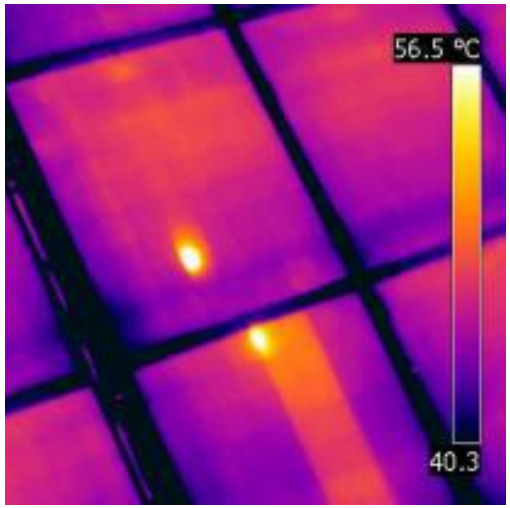
Optical Characterization Methods

UV - Fluorescence



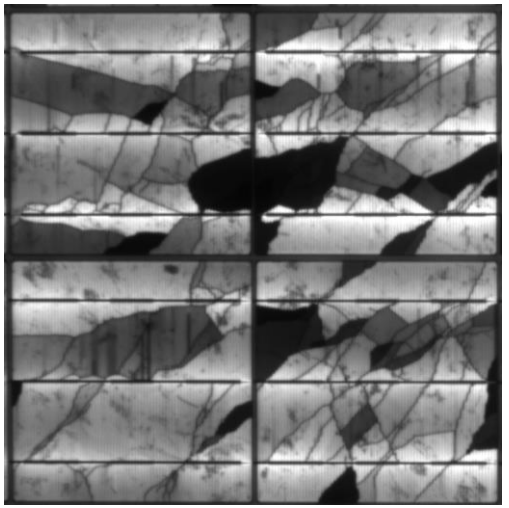
Irradiate module with UV light and visually inspect the response

Thermography



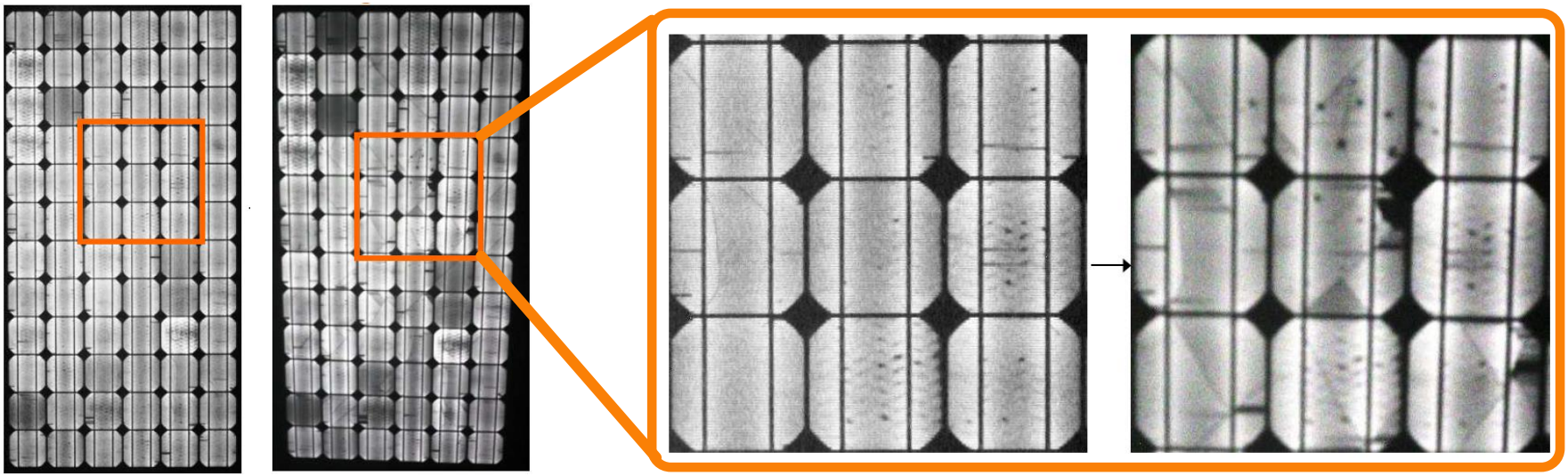
Detect heat where it is now…

Luminescence



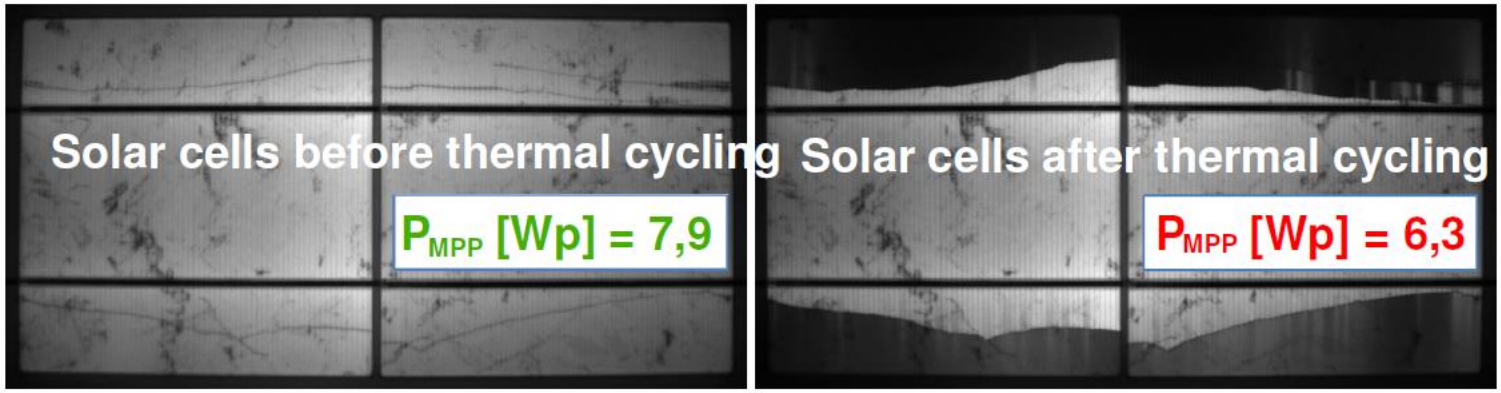
Use solar cells as light emitting diode and see where the current is going..

Electroluminescence of transport damage



transport

transport damage



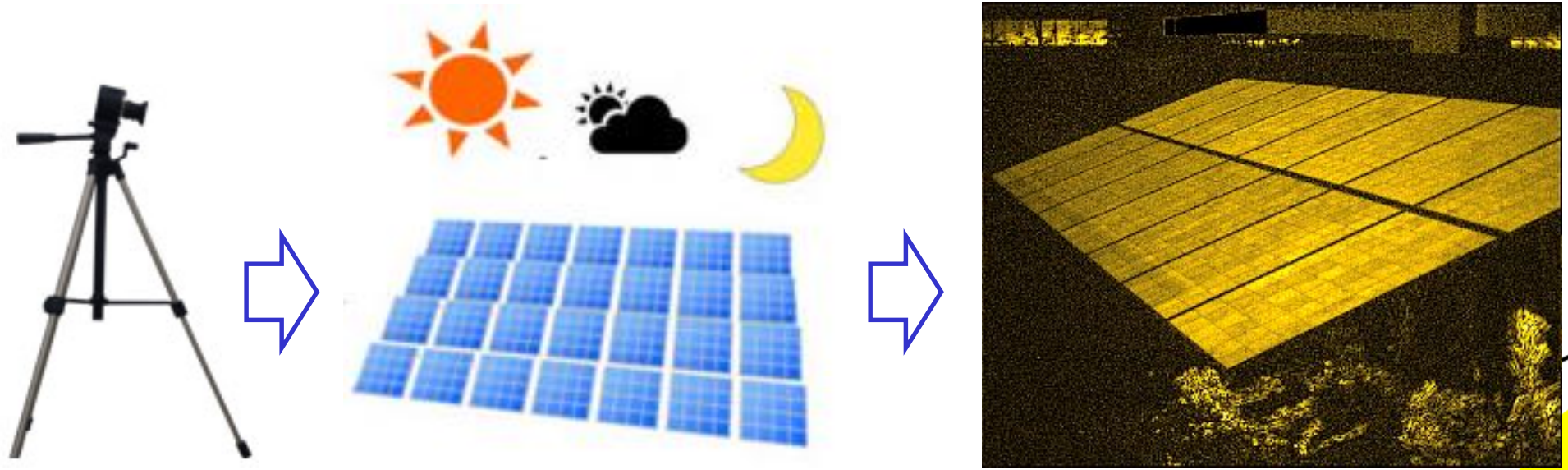
aging after 200 cycles in climatic chamber:

power loss!

The DaySy Method

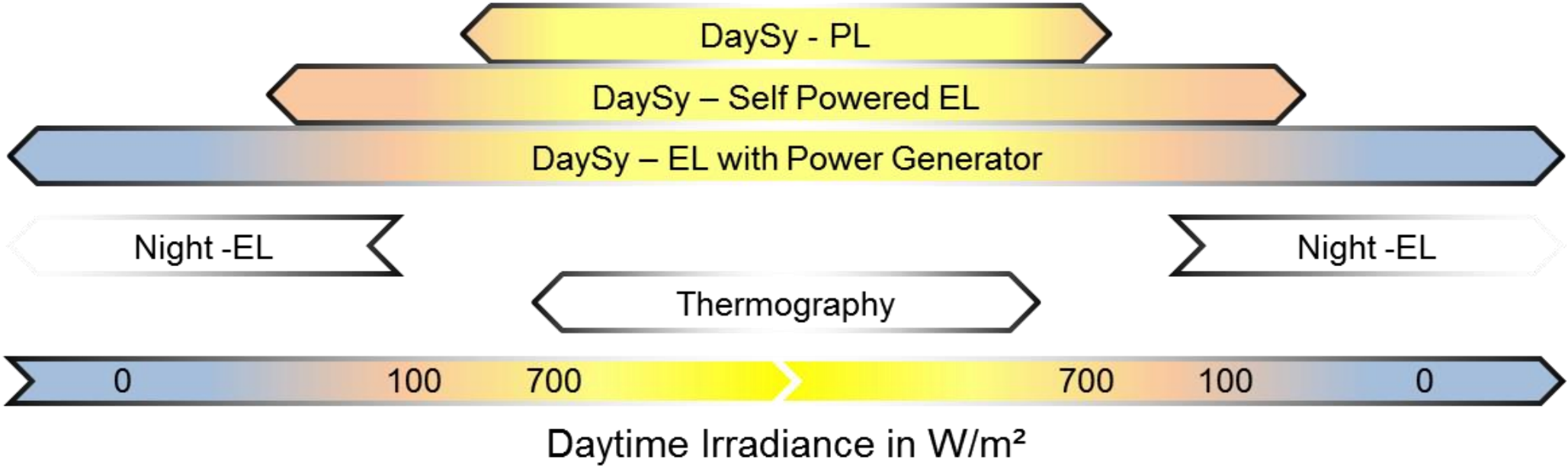
- Electro (EL)- and photoluminescence (PL) characterization
  - In full daylight → Independent of surrounding light
  - On mounted modules and full strings
  - Using either the PV-plant or a DC source as power supply

  → From an overview to detail images!

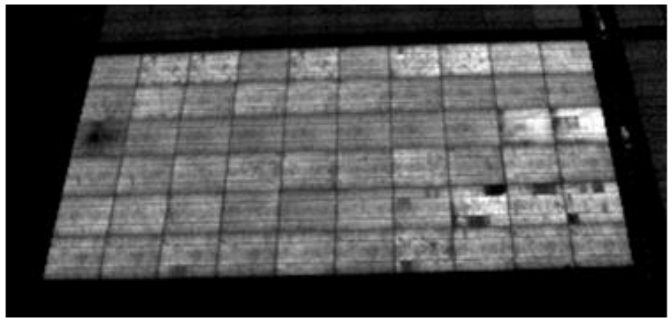


Availability of outdoor imaging methods

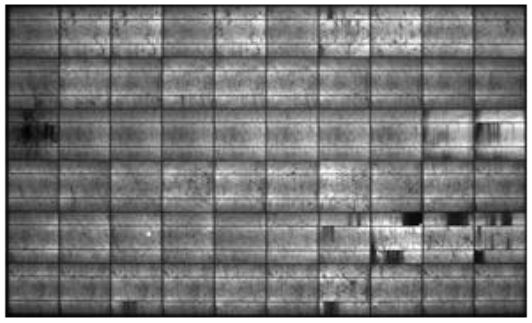
Measure when YOU want: 100% Availability Day and Night



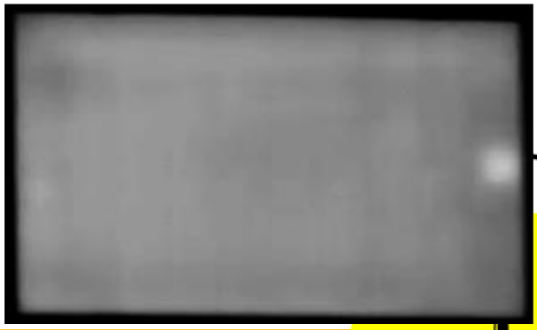
DaySy EL of installed Module



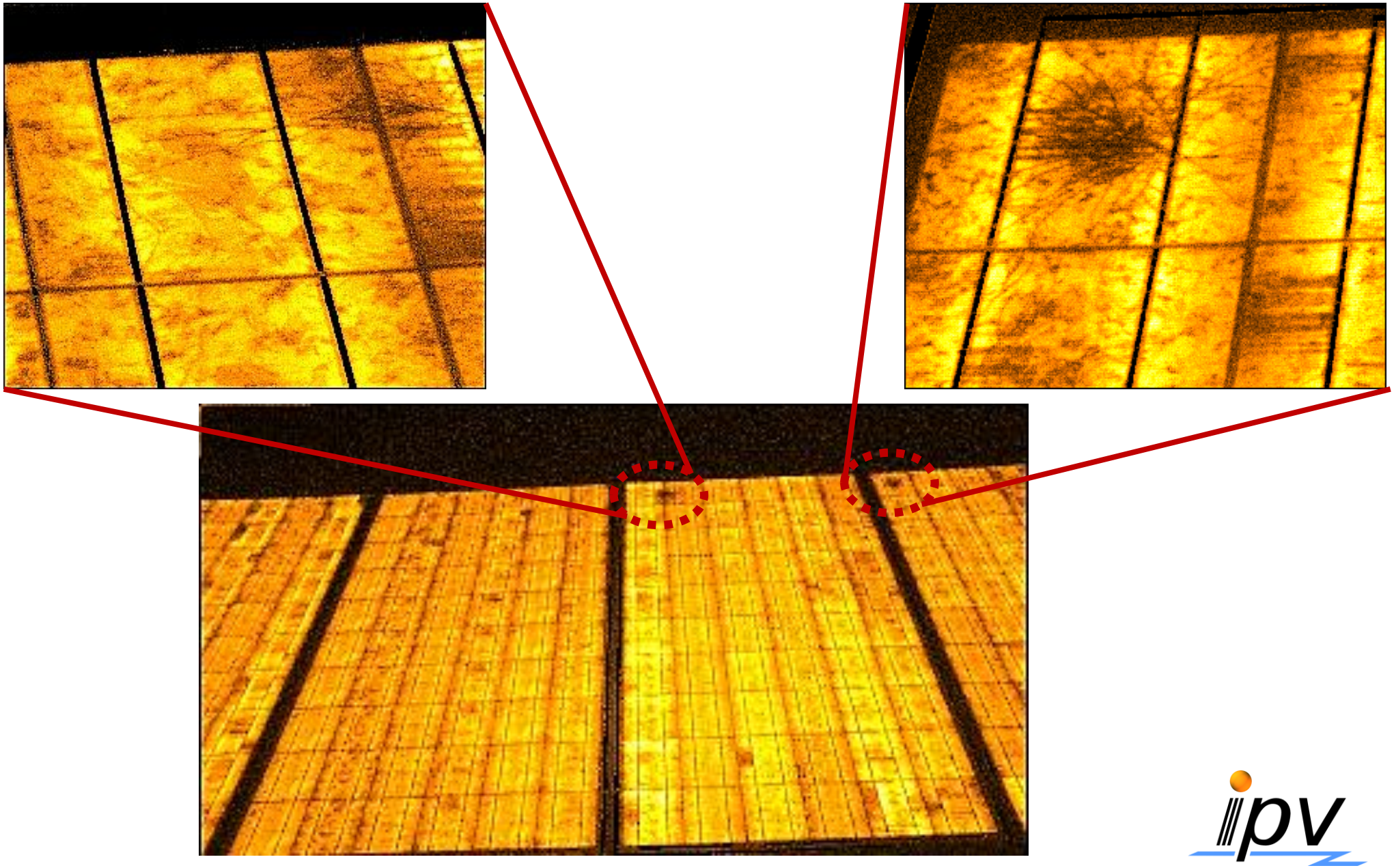
8 MP Dark-Box EL



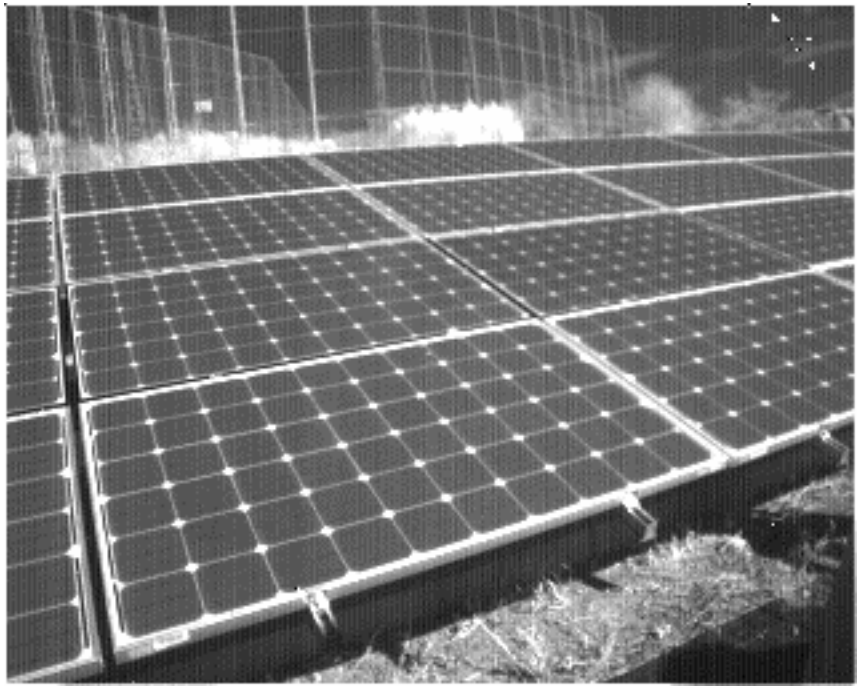
MPP Thermography

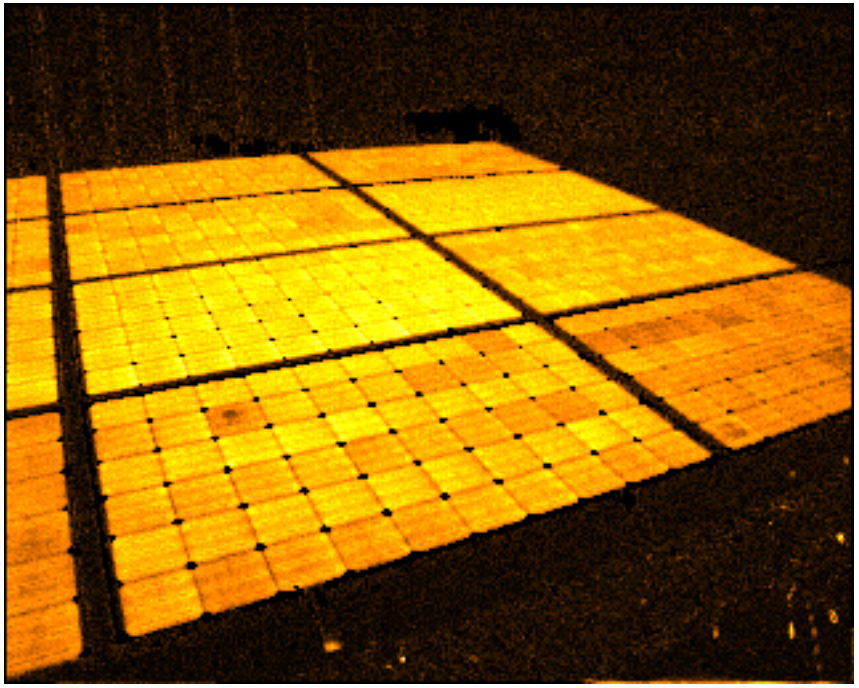


Hail on c-Si Modules



'Angry birds'

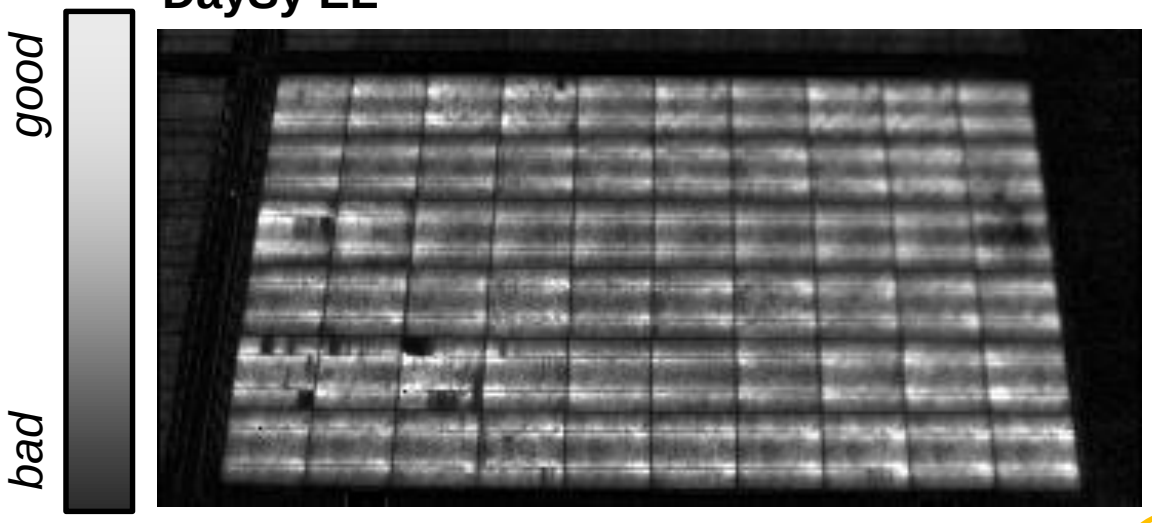




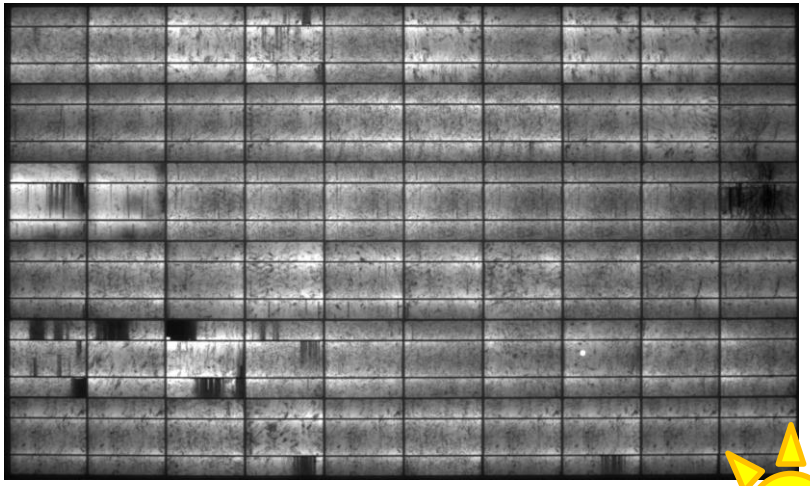
Damage detected in Japan near golf course at coastline.

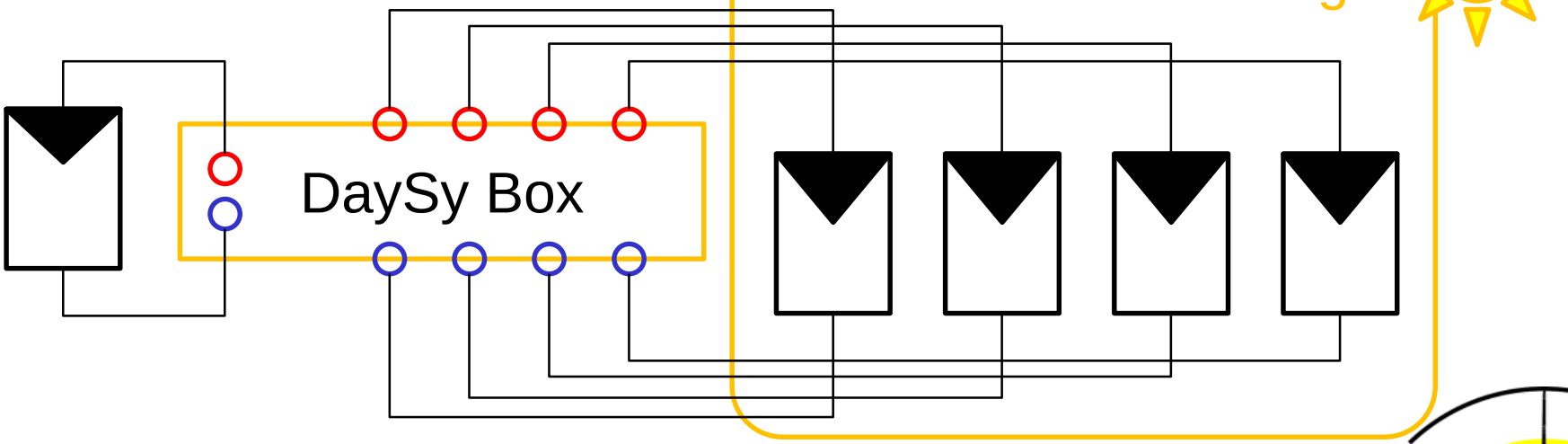
DaySy –EL (self-powered)

DaySy EL

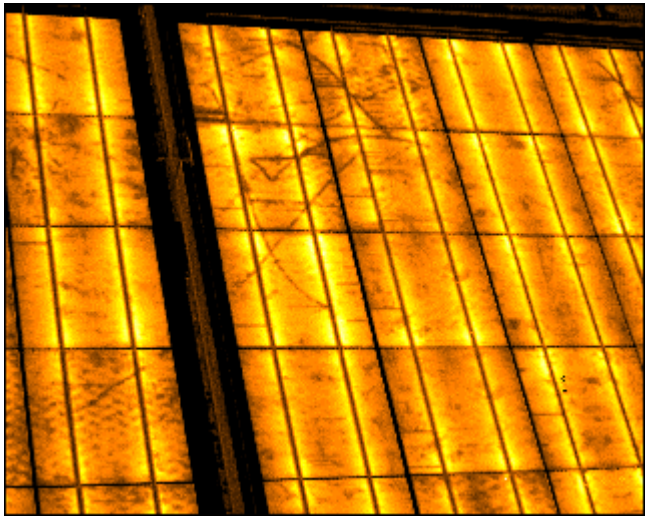


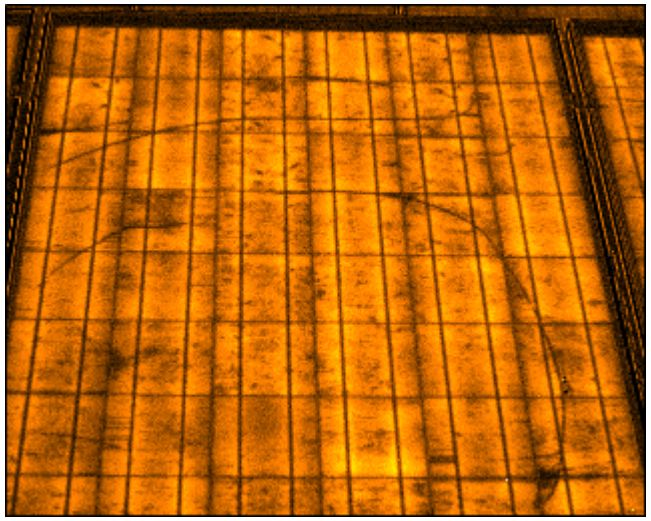
Dark Box EL @ 10 A





Do NOT "Kärcher" your PV !

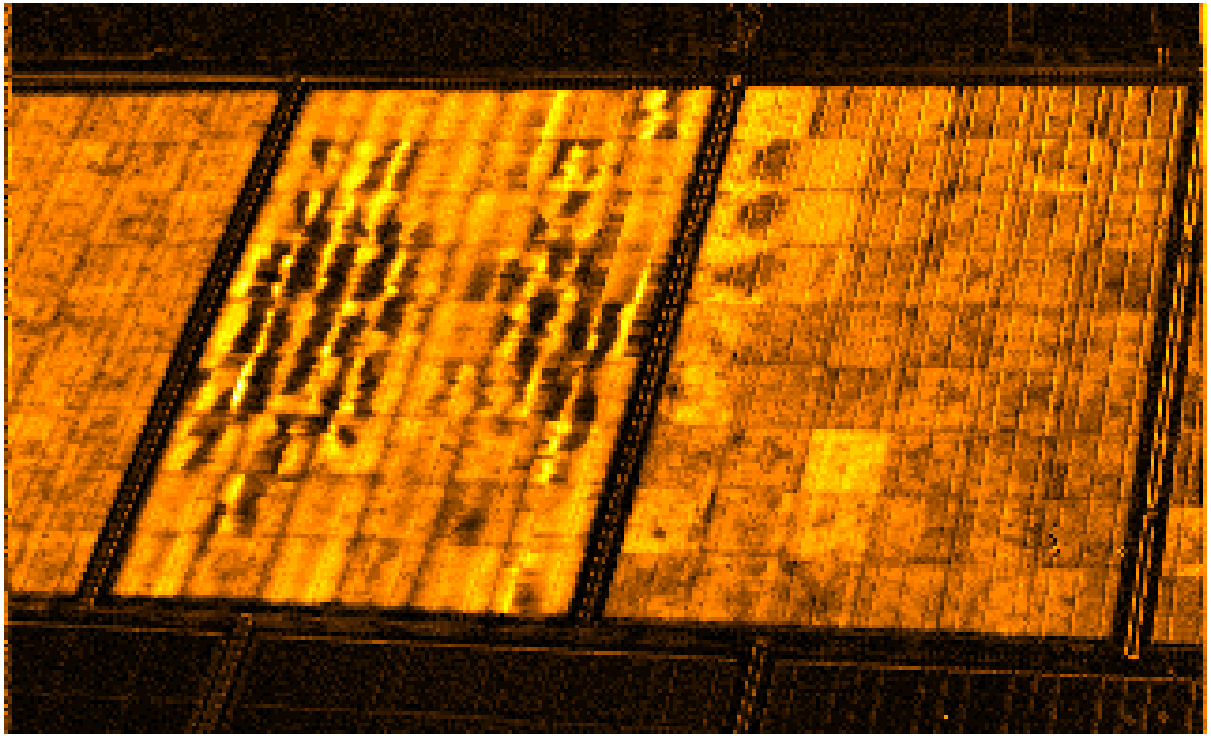




Severe damage due to high-pressure cleaning

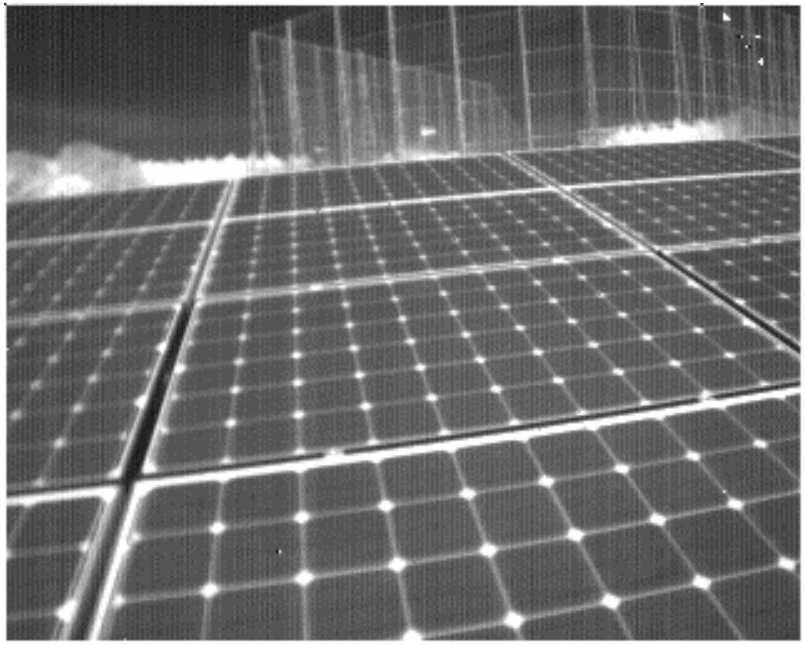
https://www.kaercher.com/de/inside-kaercher/sponsoring.html

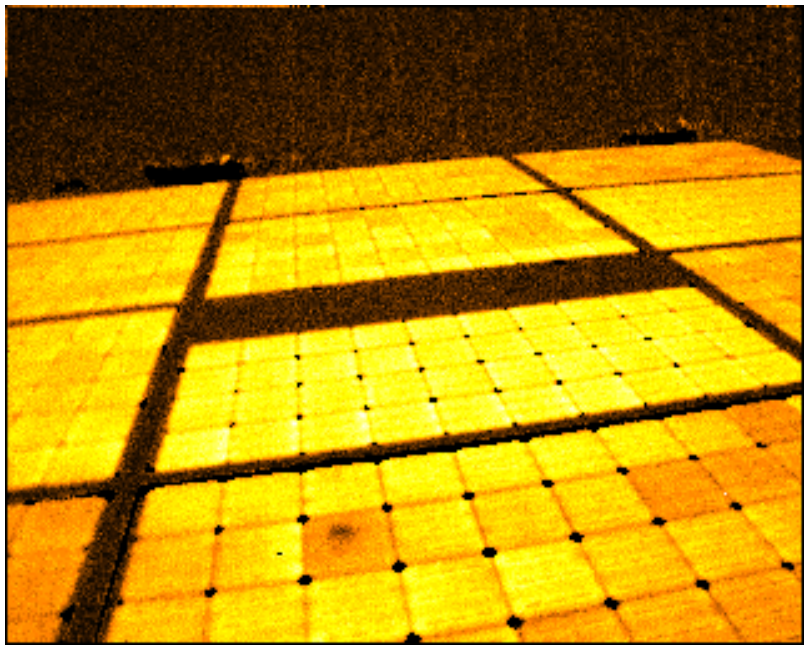
Do NOT drop PV modules from the truck



ONE broken module will kill the performance of your complete string (until bypass diodes will take effect).

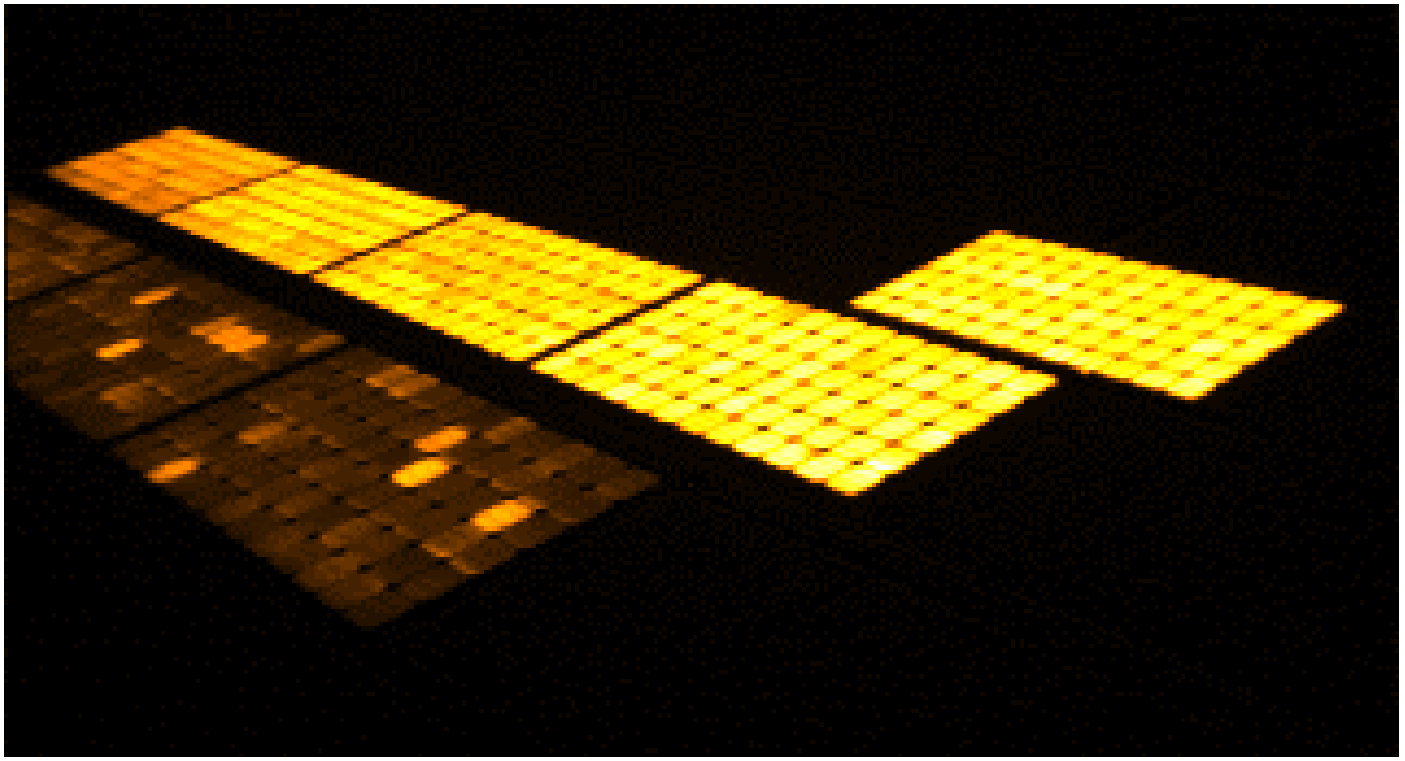
Broken bypass diodes - very common!





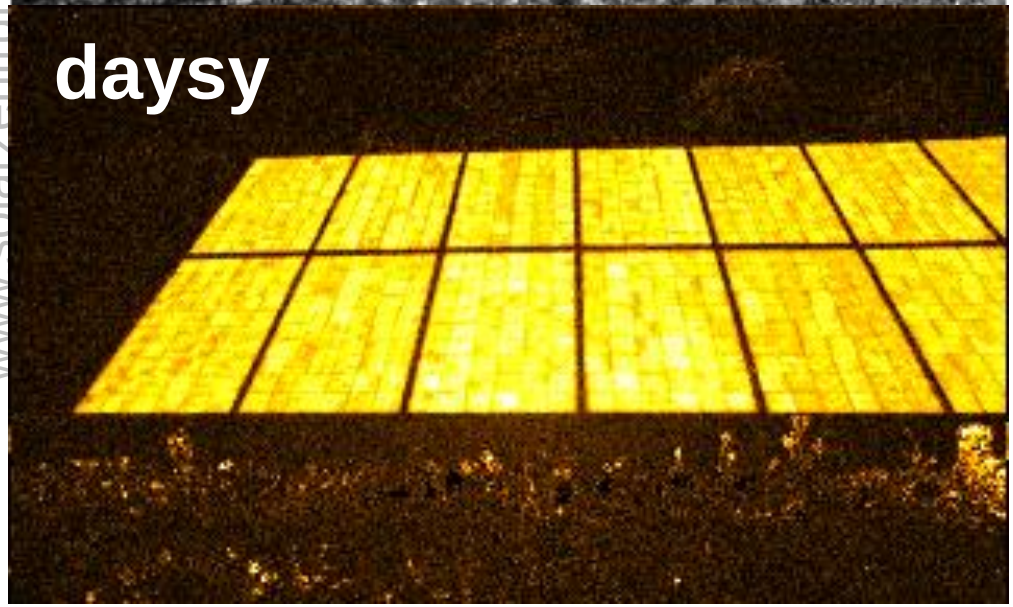
- easily detected by DaySy, if in short-circuit
- not so easy in *I/V*
- almost no chance, if in open-circuit

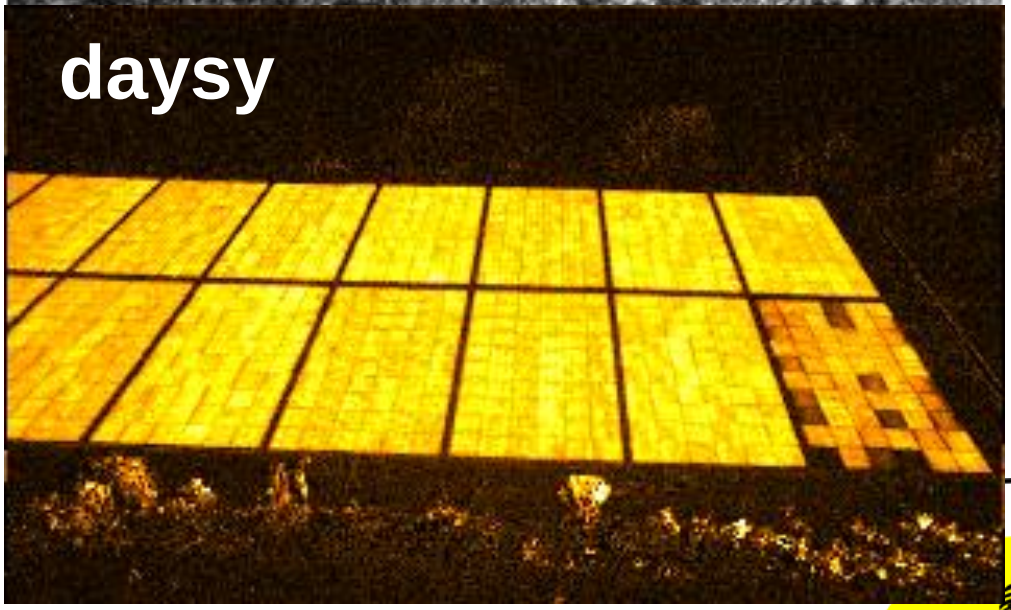
Polarization of long strings (PID)



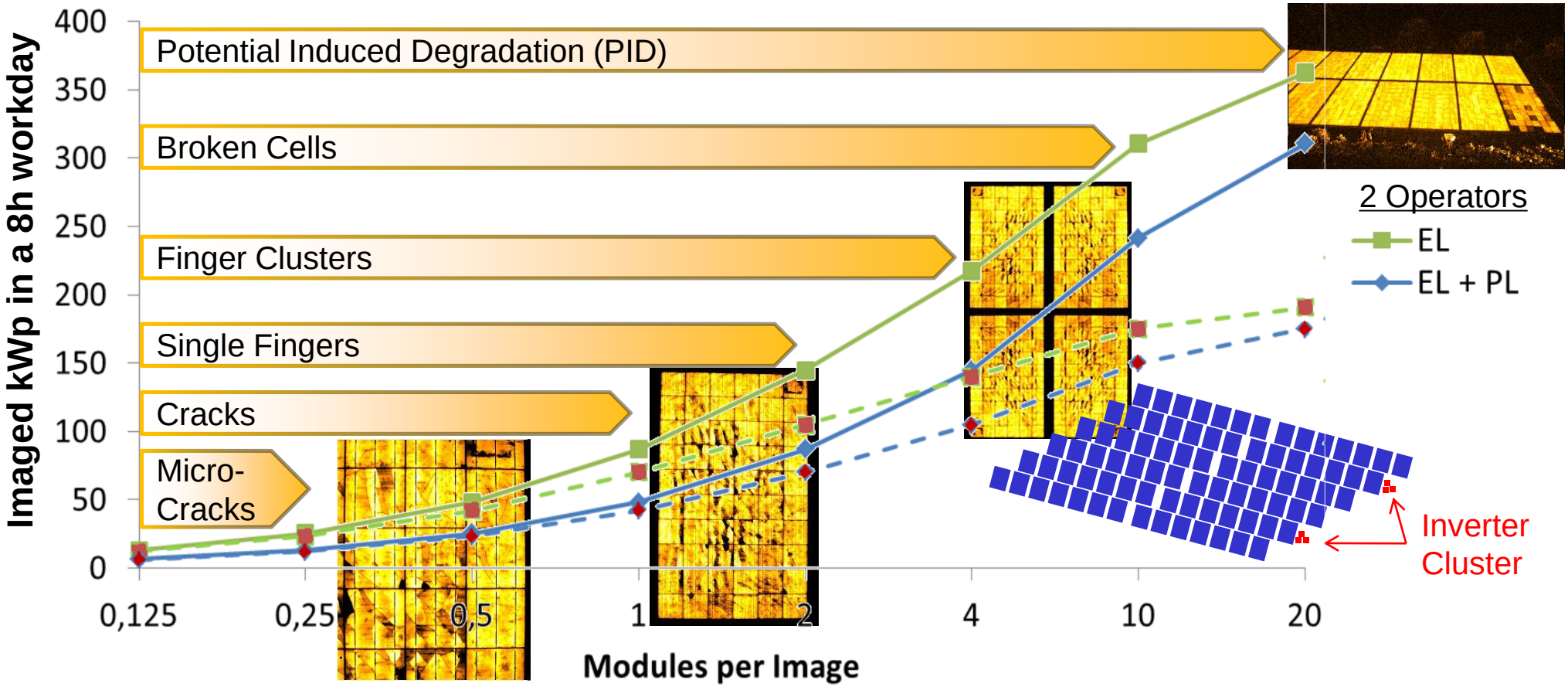
Polarization of Sunpower modules
towards high-voltage end of string.

Whole string imaging





Throughput



Scenario

- Field PV installation, 250W_p modules, 20 modules/string
- Unpacking & Setup: 30 minutes; Wrap up: 15 minutes
- Location of PV strings is known (good documentation) 10 min / string / operator
- 1 minute for a EL image; 2 minutes for a EL+PL image

Conclusion

DaySy detects

- transport damage
- wrong handling during installation
- installation / maintenance faults
- module damage during operation
  (thermal stress, mechanical strain, aging ..)
- failures (bypass diodes, cell contacts, PID ..)

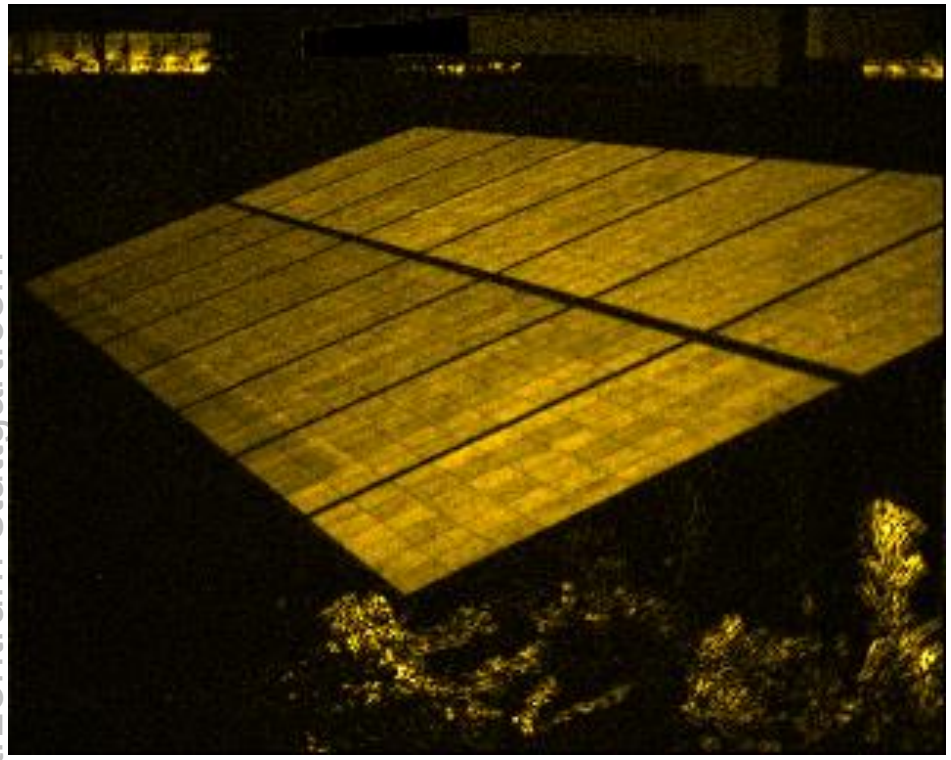
DaySy

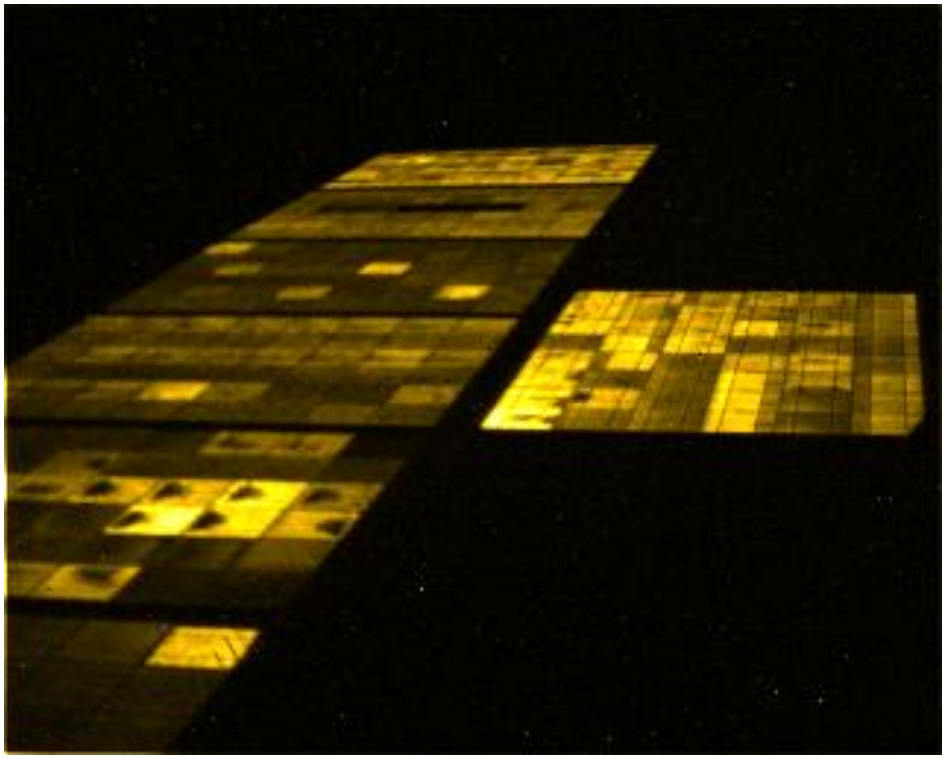
- helps training installers / PV companies
- is THE good option for PV in Cyprus!

bonus track

for Questions & Discussion

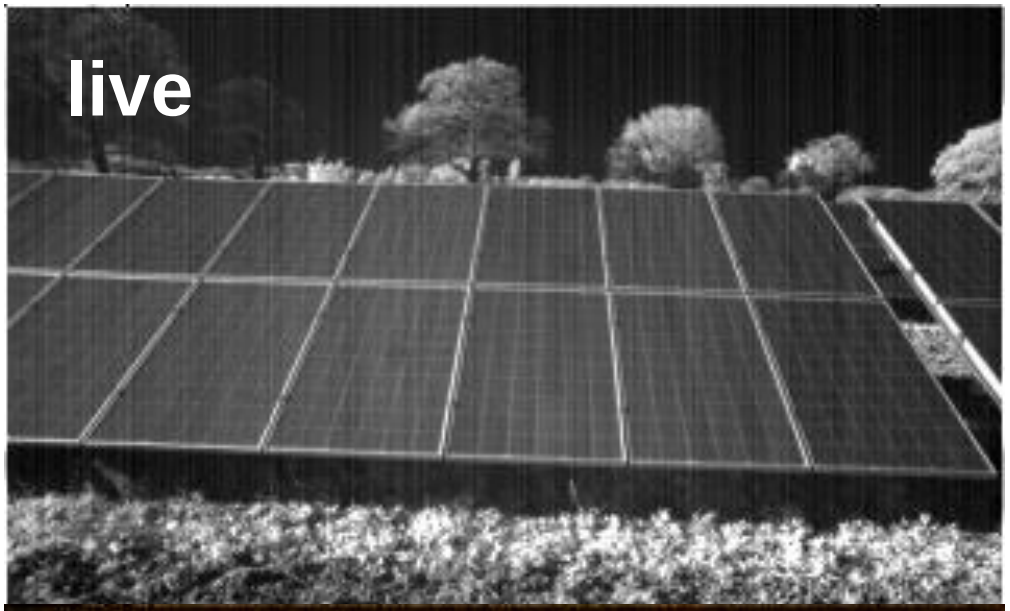
Whole String Imaging (1)

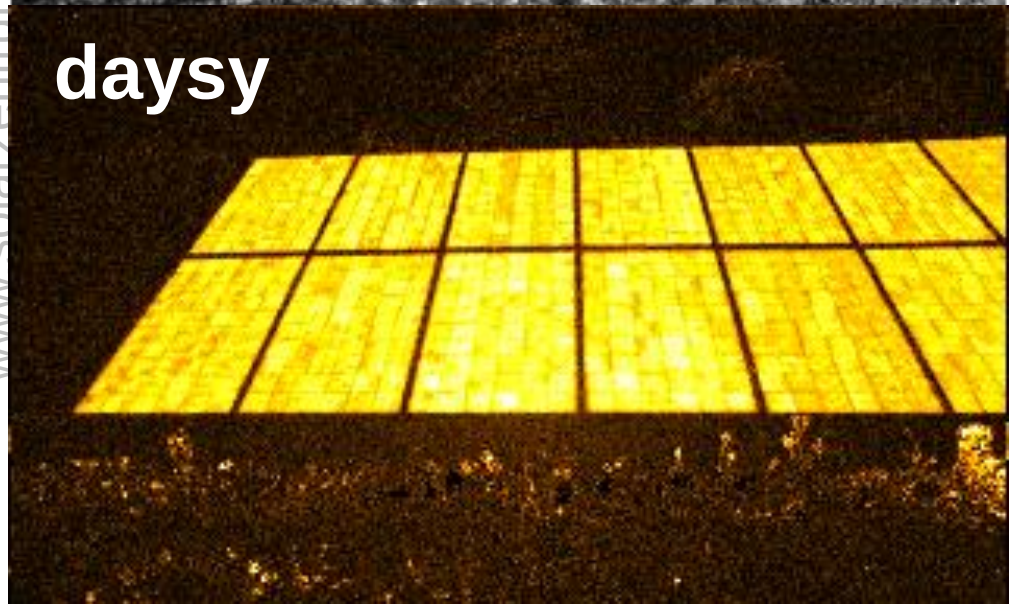


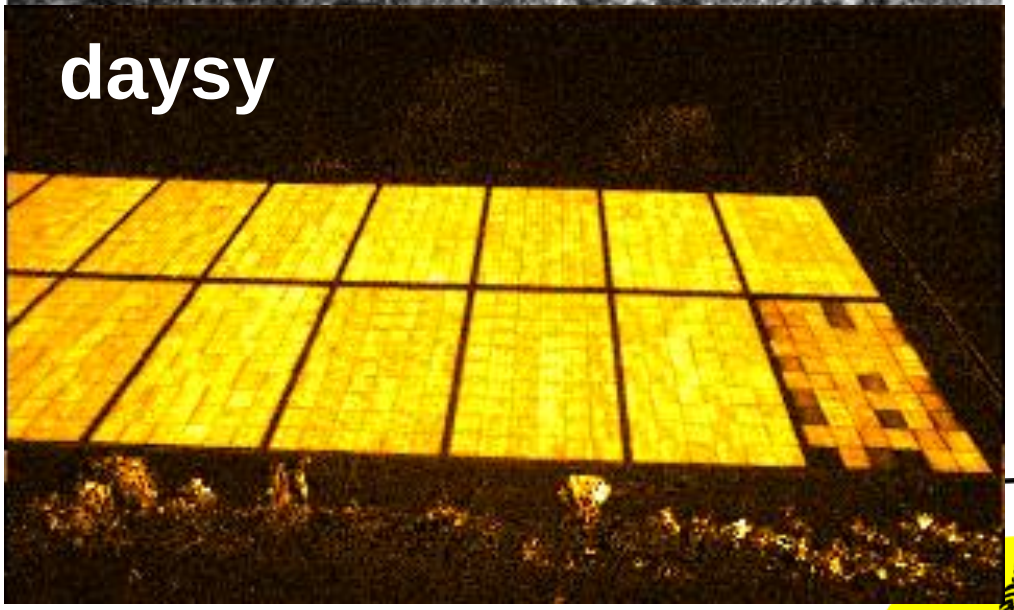


- ✓ Potential induced degradation (PID)
- ✓ poor low light response
- ✓ damaged areas
- ✓ groups of broken fingers
- ✓ Very high throughput possible

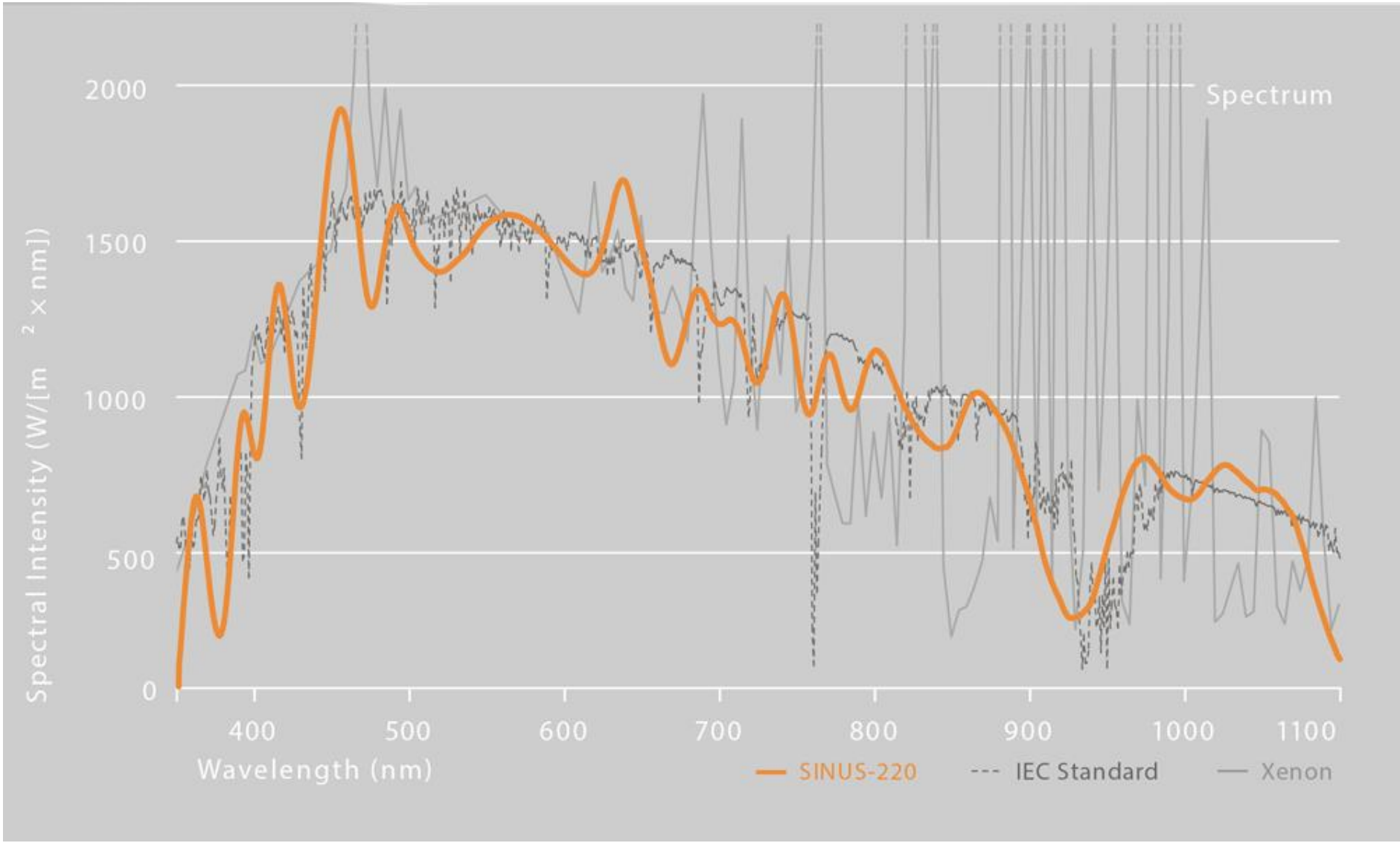
Whole String Imaging 2







LED Flasher



source: http://www.wavelabs.de

everything connected in series