# Long term performance of PV modules: System optimization through the application of innovative non-destructive characterization methods


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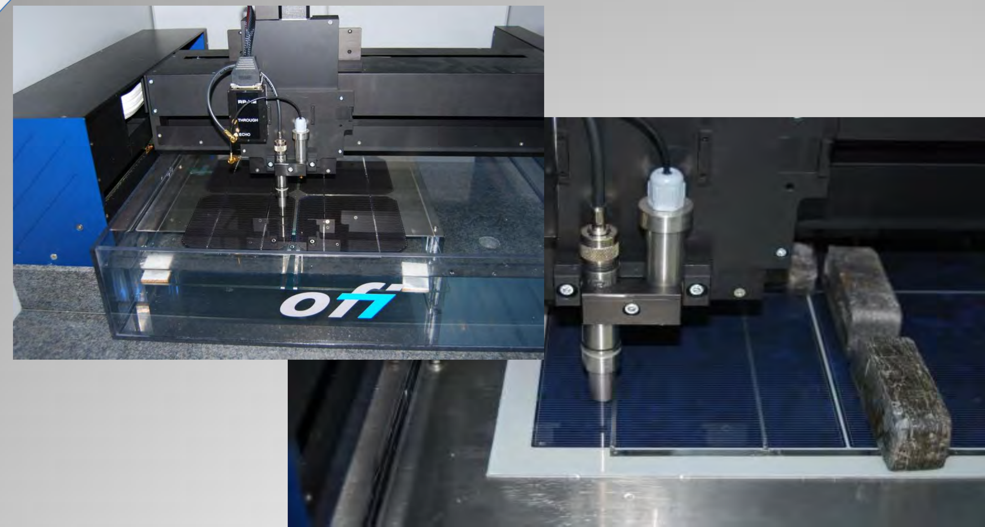
This work is funded by the Klima- und Energiefonds, "Neue Energien 2020"



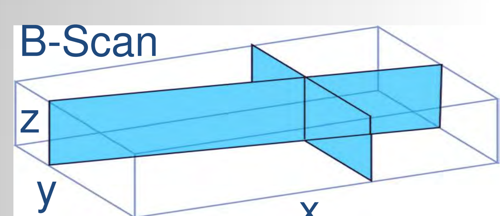
Reliability and long term performance of PV-modules over 20-25 years are key demands of the market to allow photovoltaic to play an increased role in the future energy supply system. Therefore, modules should be subject not only to electrical performance tests conforming to standards but also to quality assurance testing in regard to the chemical, optical and physical properties of the materials and material assemblies used. In reality, however, the characterization of materials already embedded in PV modules is a very demanding task as there are only limited tools available which allow non-destructive characterization of PV-modules and materials during production and operation. Thus, we focus our research activities on the development of innovative and sensitive analytical methods that allow for investigations of materials, PV-components and modules.

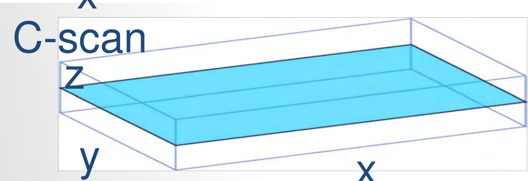

## Scanning Acoustic Microscopy (SAM)

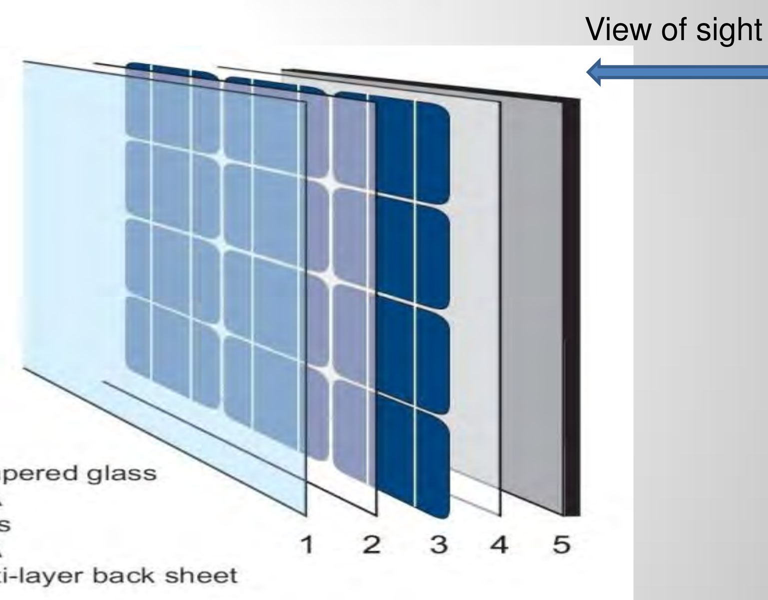


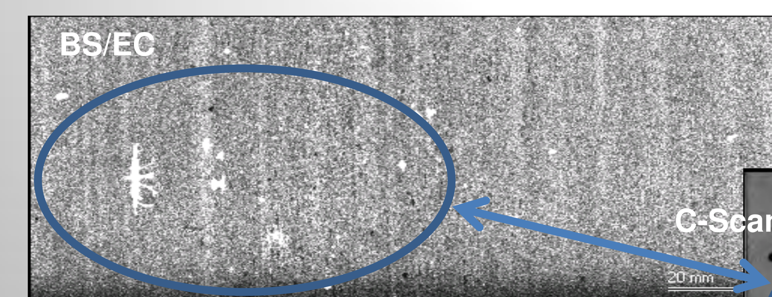
- detection and visualization of defects and delaminations
  - within the backsheet (BS),
  - the encapsulant (EC) and
  - between BS/EC and EC/wafer
- non destructive, no contact required

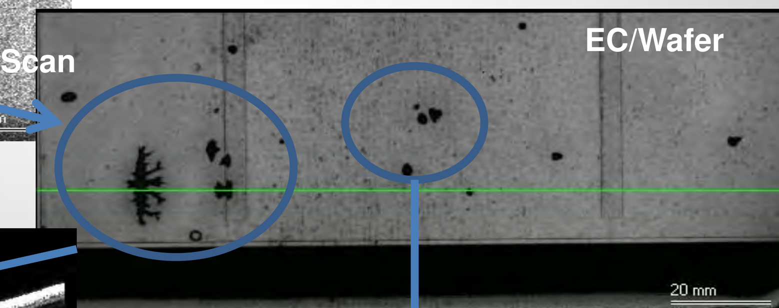
→ view through the backsheet of a module which has been in contact with air containing ammonia (0,5%) and water vapour for 1000h
→ voids are detected within the EVA

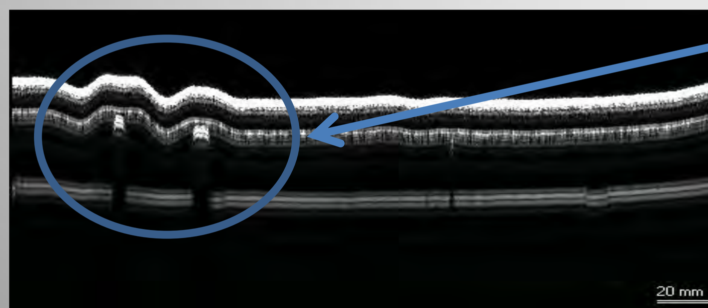


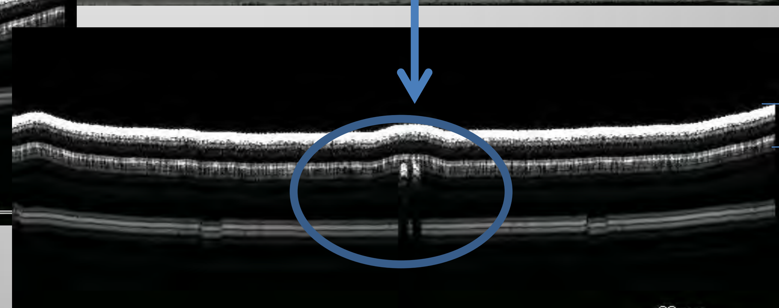



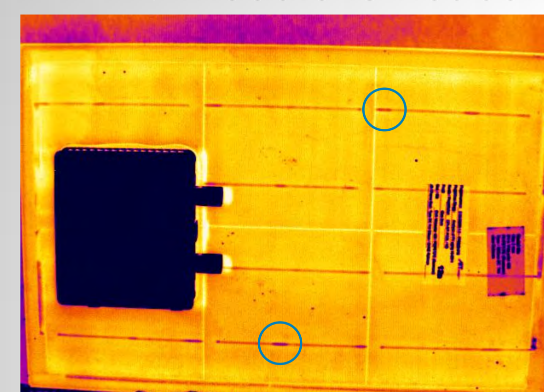



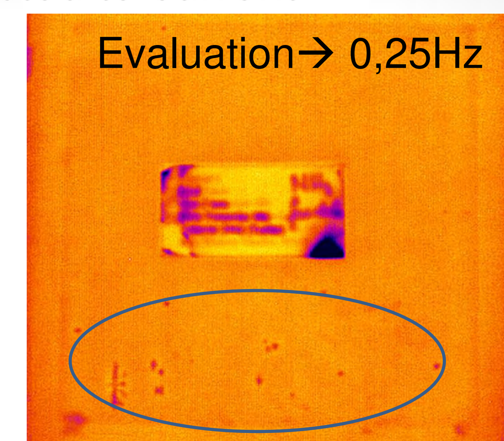



## Pulse Thermography

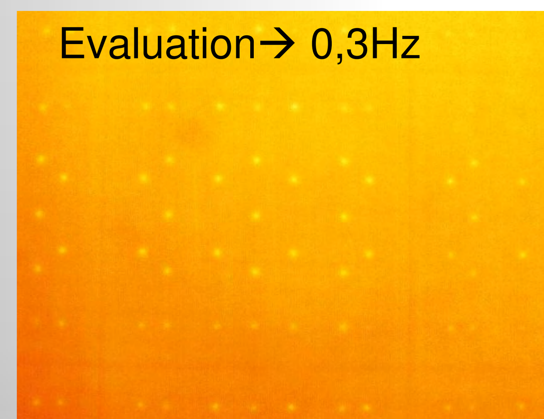
- visualization of defects and delaminations in materials and multilayer composites like PV-modules
- module is not connected to external current; detects differences in the thermal conductivity of the materials

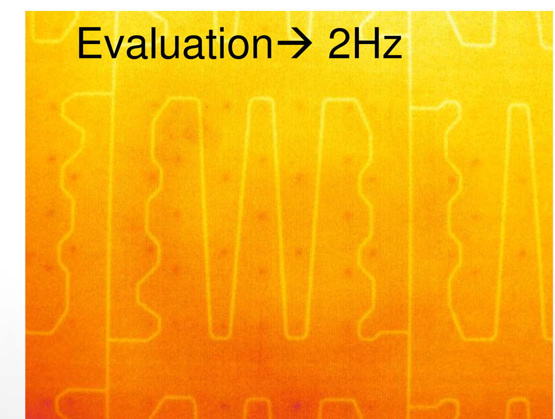
→ module is not connected to current





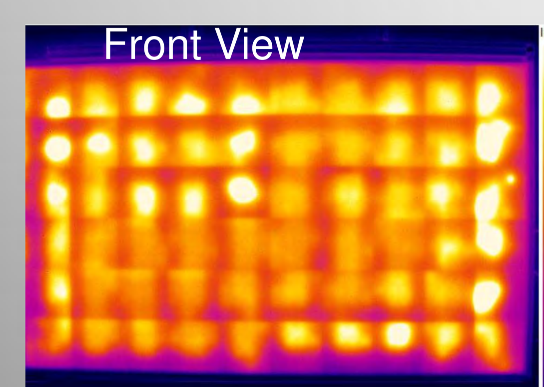

→ defects/delaminations within the BS and between BS/EC and EC/wafer detectable

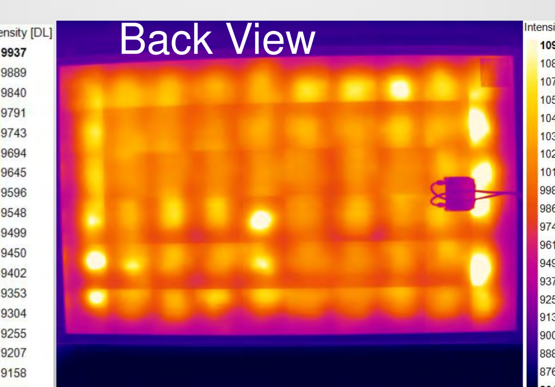



→ back-contacted pv-wafer
- visualization of interconnection;
- detection of defects/ delaminations between wafer and conductive foil

→ module is connected to current

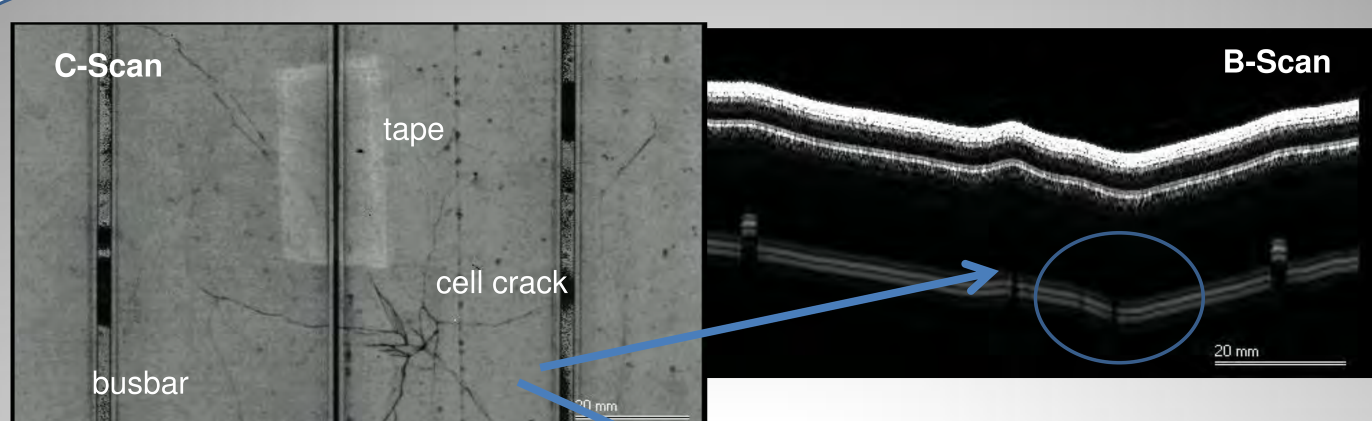


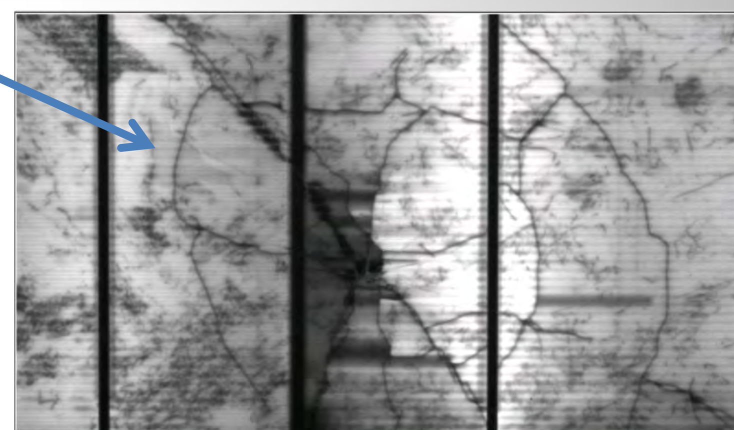

→ location of local hot spots, inactive wafer (parts), defect diodes

IR-Thermography

## Comparison SAM / Electroluminescence

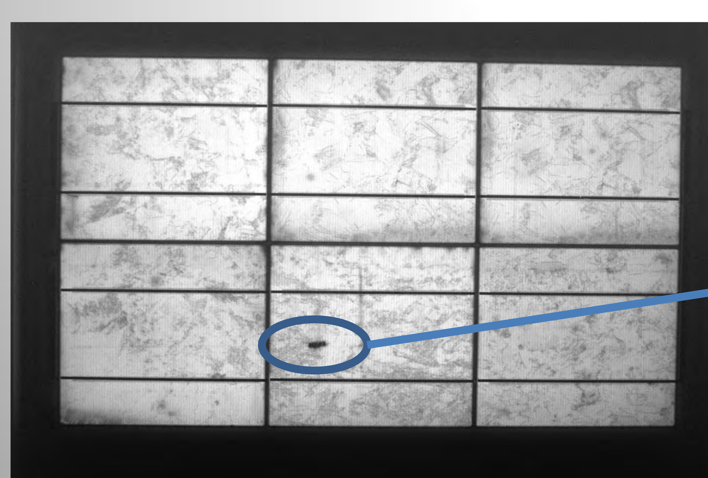



**SAM** (from back side)



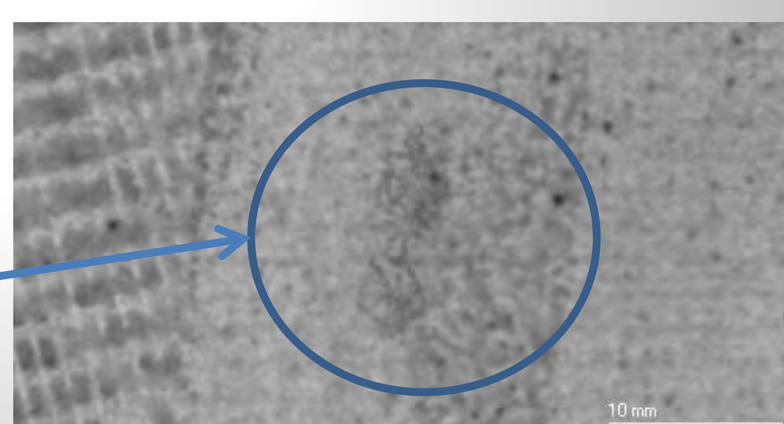
**Electroluminescence**
(from front side, mirrored)

**Electroluminescence**



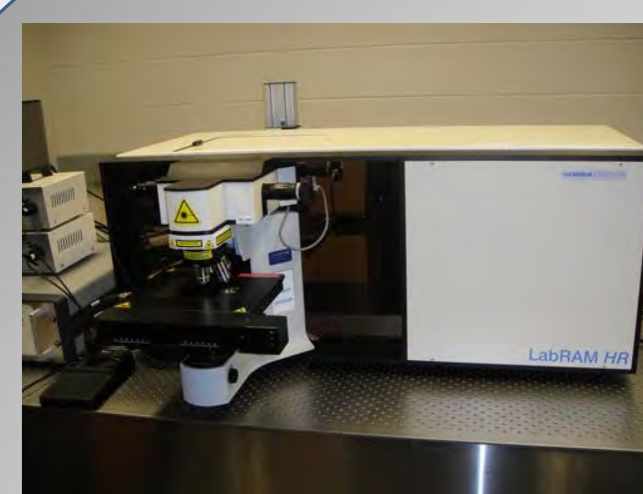
→ dark area in the wafer
→ crack ??

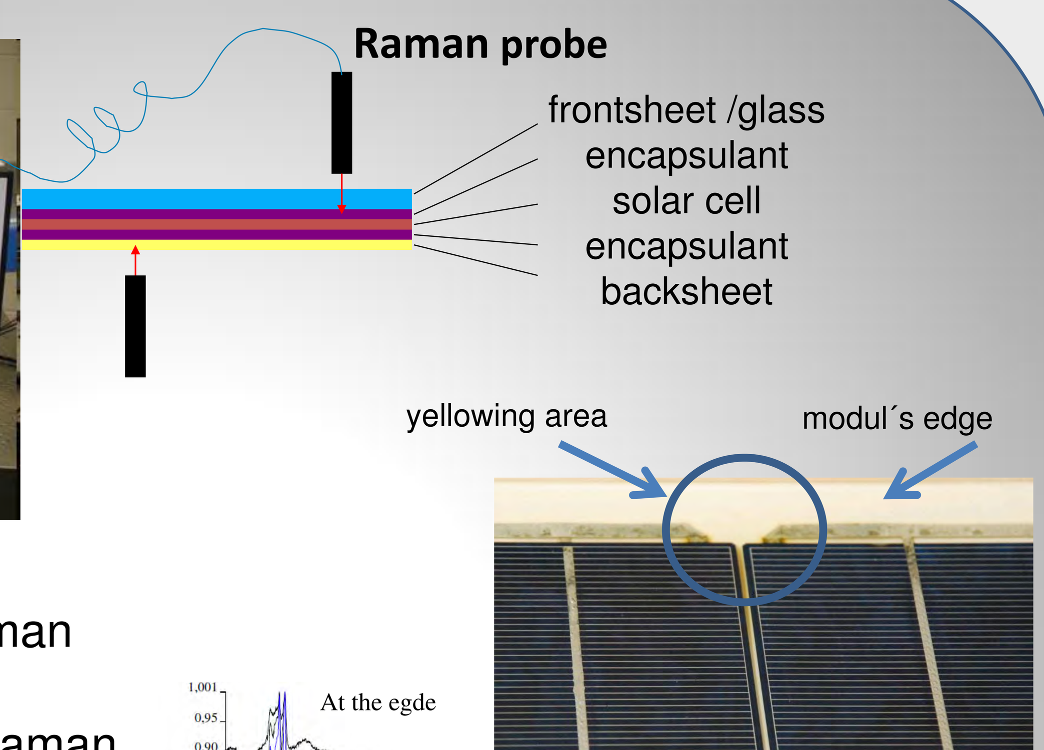
**SAM** (from back side)



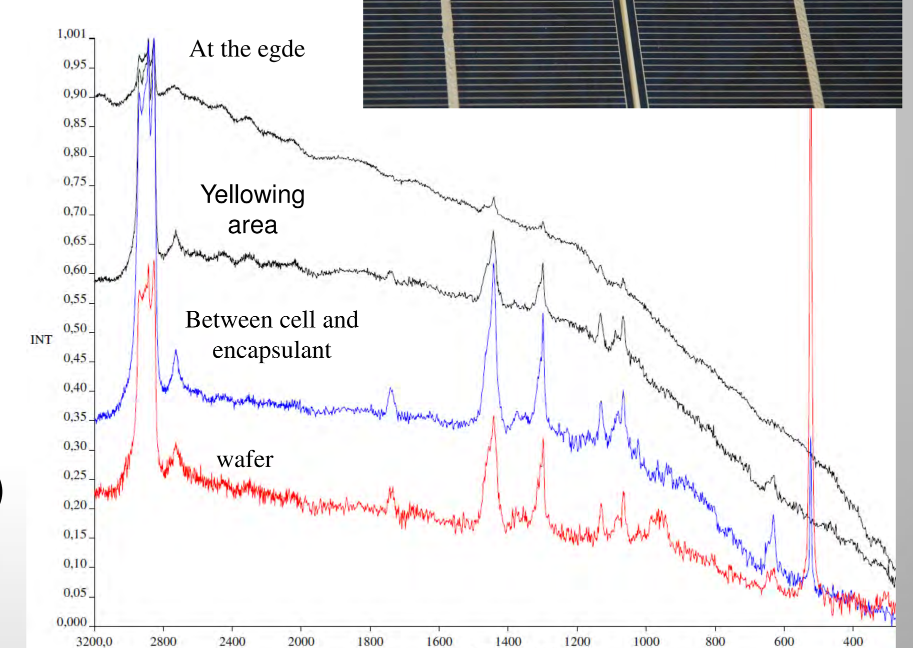
→ no crack in the wafer
→ structured wafer surface

## Confocal Raman Spectroscopy






- small samples -> confocal Raman Microscopy (Lab)
- PV-modules -> with external Raman probe (fibers 5 m -> 200 m)
- material identification through transparent layers (glass, polymers) possible
- no direct contact required
- suited for organic compounds (e.g. discolorations; degradation products) and semiconducting materials




→ Fluorescence is most pronounced at the modul´s edge
→ double bonds were not detected