Stabilizing Thin-Film Modules for Indoor Measurements

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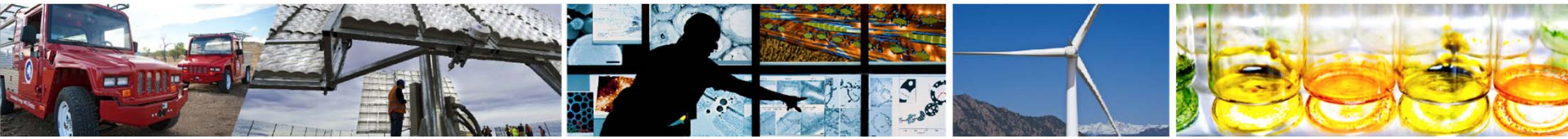
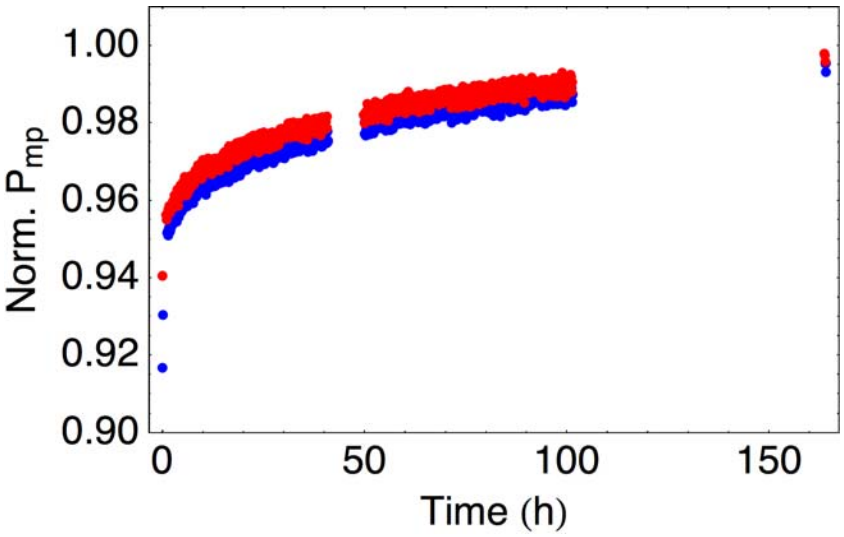
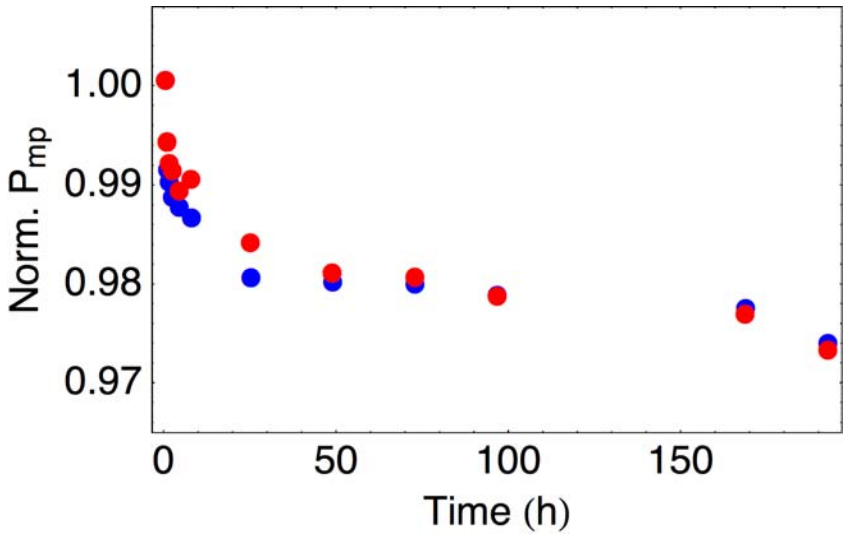


Metastable performance in thin-films

Light exposure (1000 W m^{-2}, 55°C)



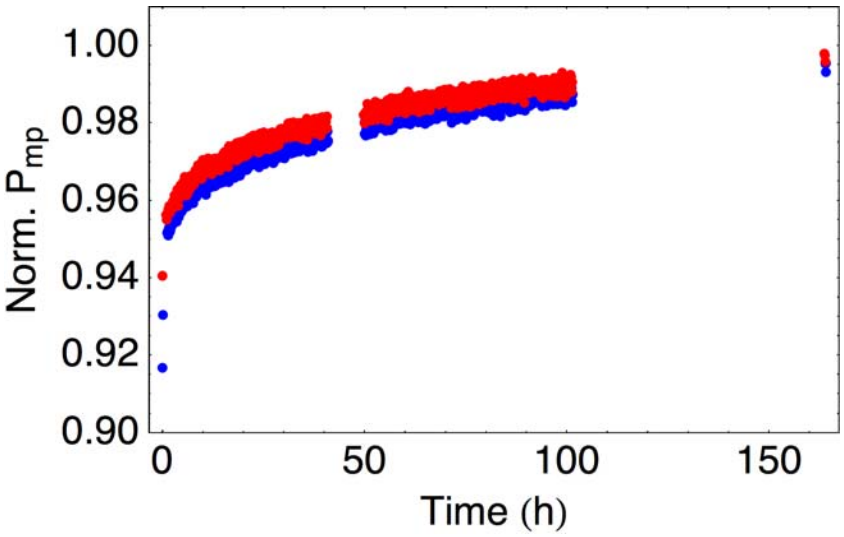
Storage at room temp.



Thin-film modules change performance upon exposure to light and storage in the dark

Metastabilities vs. permanent changes

Light exposure (1000 W m^{-2}, 55°C)



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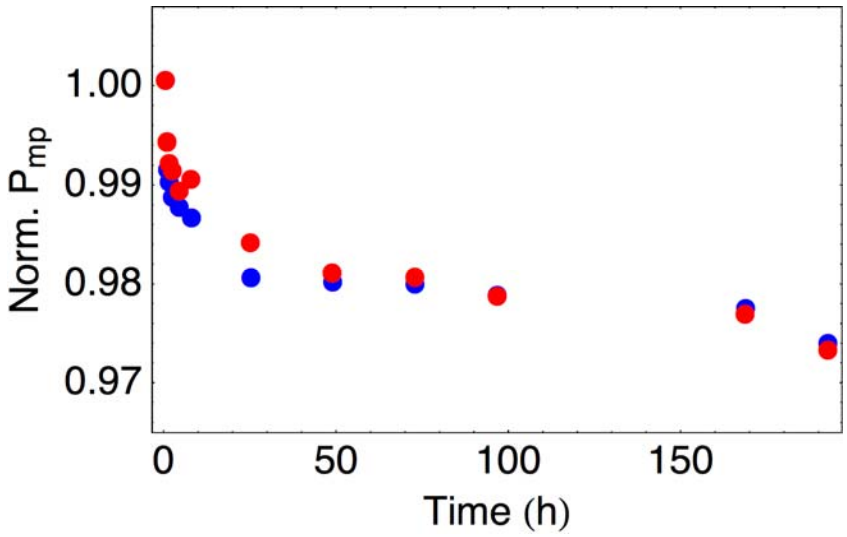

Changes are at often at least partially reversible, especially upon exposure to elevated temperatures

- Initial Norm. P_{mp}: 0.88
- After 165 hours at 55°C: 0.91

Metastabilities vs. permanent changes

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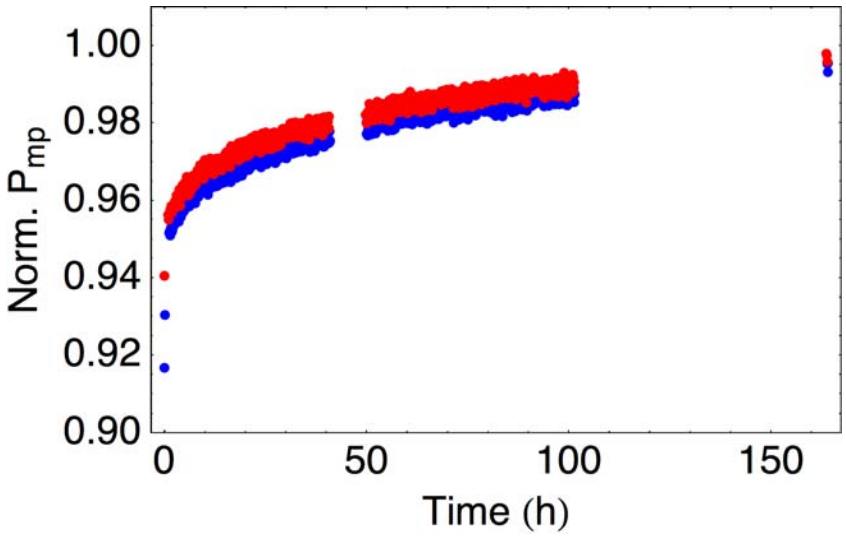
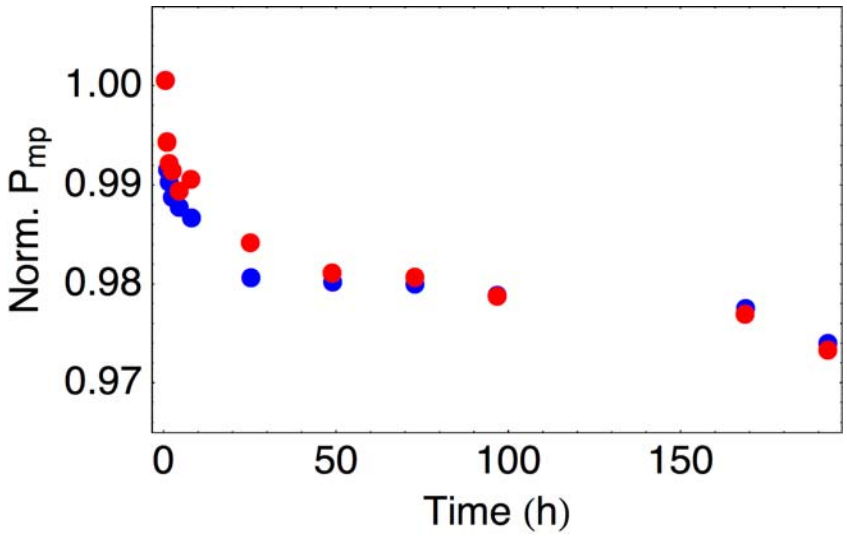


Storage at room temp.



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- Initial Norm. P_{mp}: 0.88
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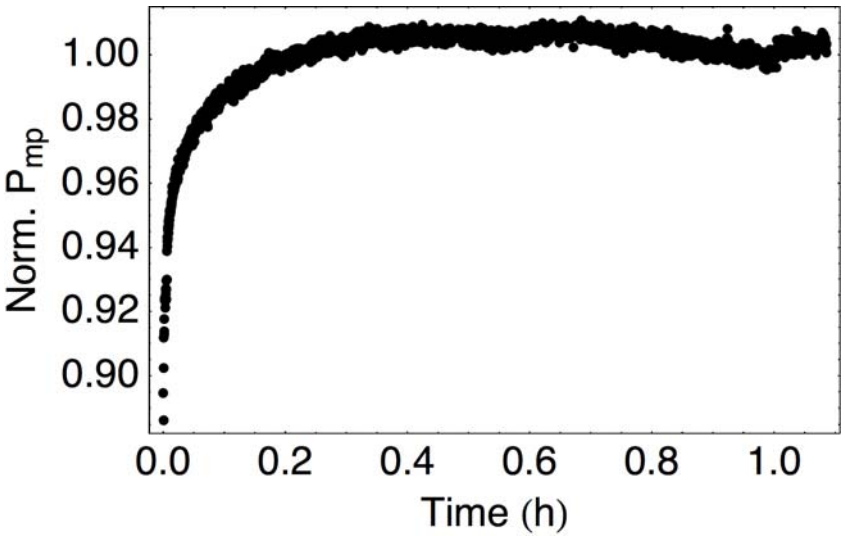
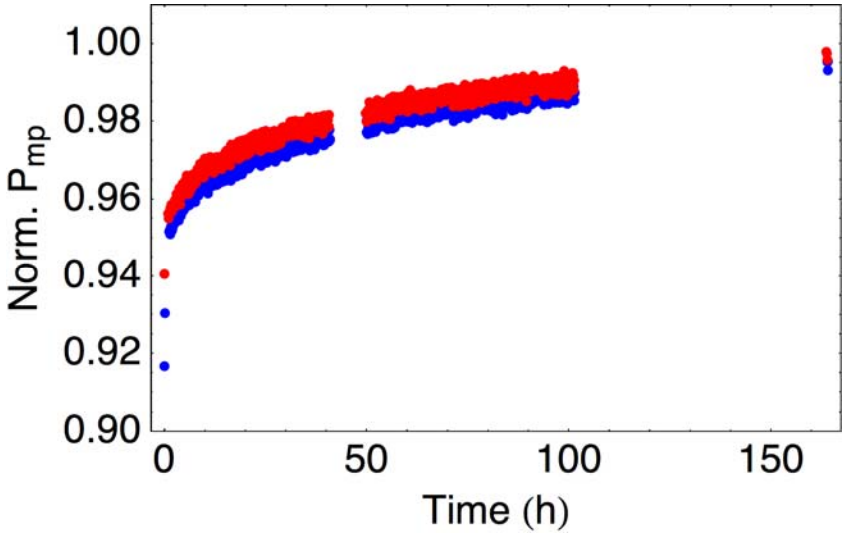
Metastabilities: reversible changes
Stabilization: Repeatedly achieving metastable state

Time scales of change

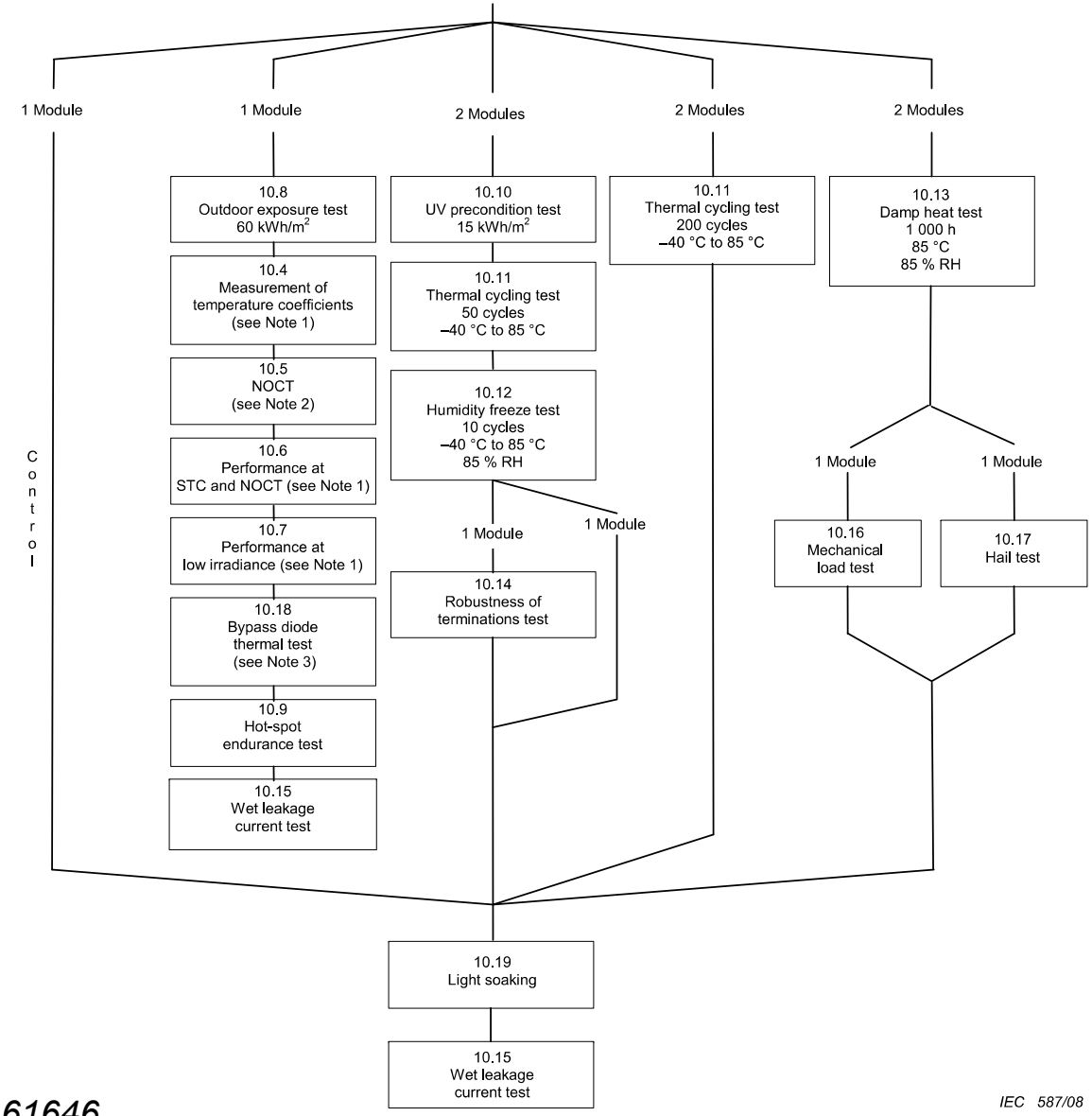
Transient changes in performance of two different types of CIGS modules





Changes can occur at different timescales for different modules

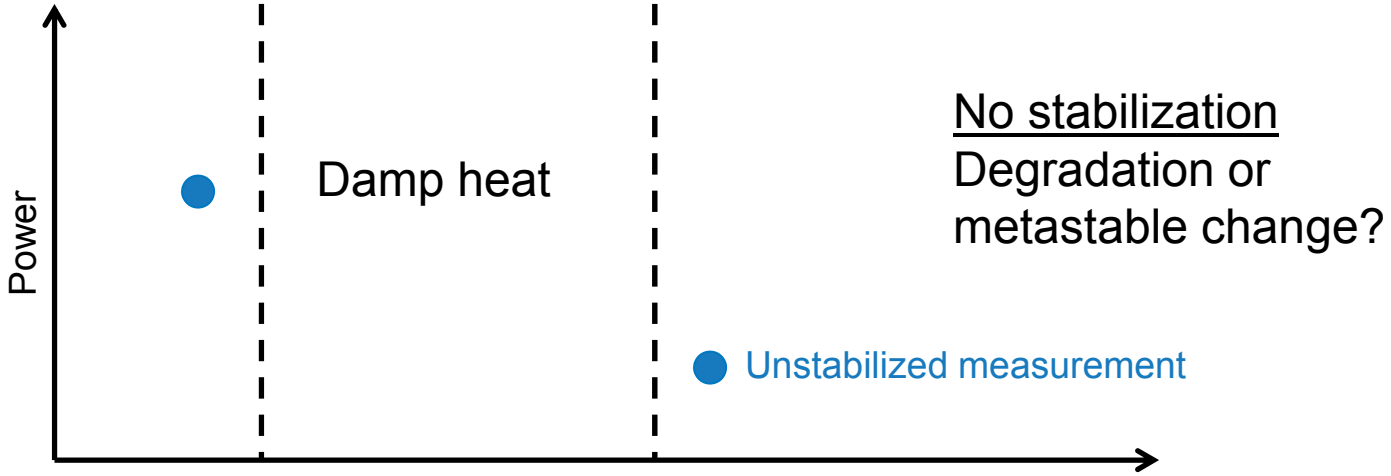
Importance to reliability



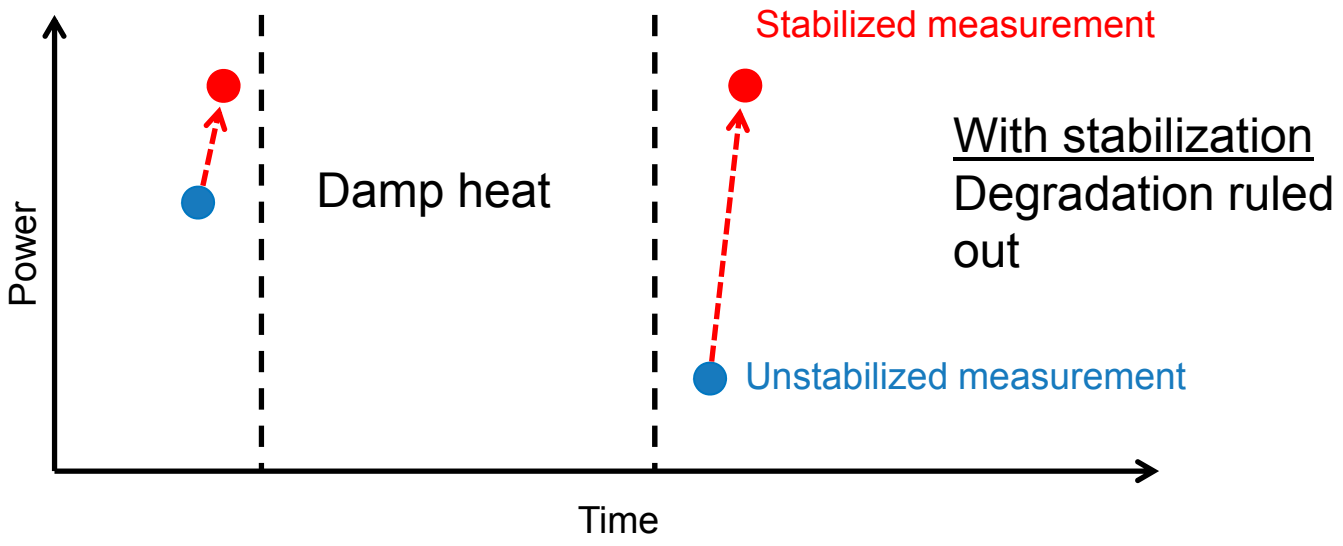
Important to differentiate between permanent degradation and reversible change

IEC 61646

Differentiating degradation



Differentiating degradation



Repeatable stabilization procedure needed before and after reliability test

NREL efforts

- CIGS: Round robin test of new light-soaking procedure - underway

- CdTe: Currently developing a stabilization procedure for upcoming round robin

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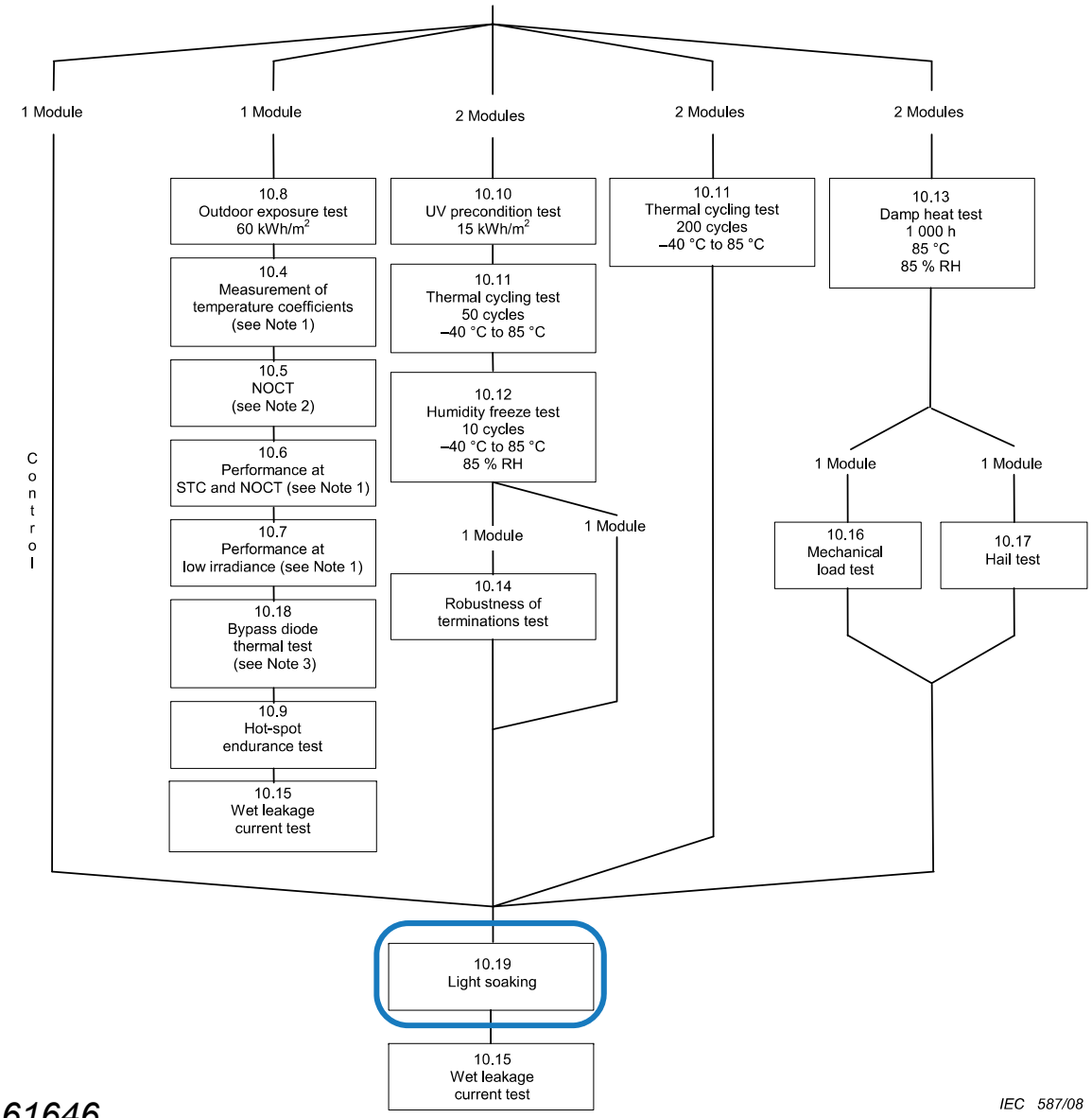
Current light soaking standard



Successive doses of 43 kWh m^{-2} until intermediate measurements are stable

Final power is compared to nameplate

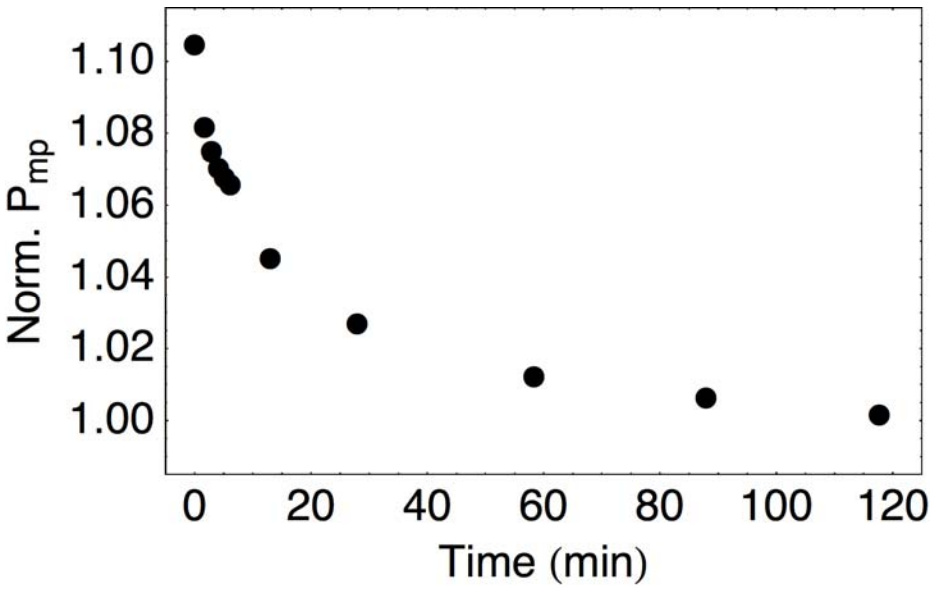
No prescribed time limit between end of light-soak segment and measurement

Note: Currently an effort underway to replace 61646 with new version of 61215 covering all technologies

IEC 61646

Improvements to current standard

Power measurements after CIGS module is brought indoors after light exposure (temperature corrected)



Current standard:

Successive doses of 43 kWh m^{-2} until intermediate measurements are stable

Final power is compared to nameplate

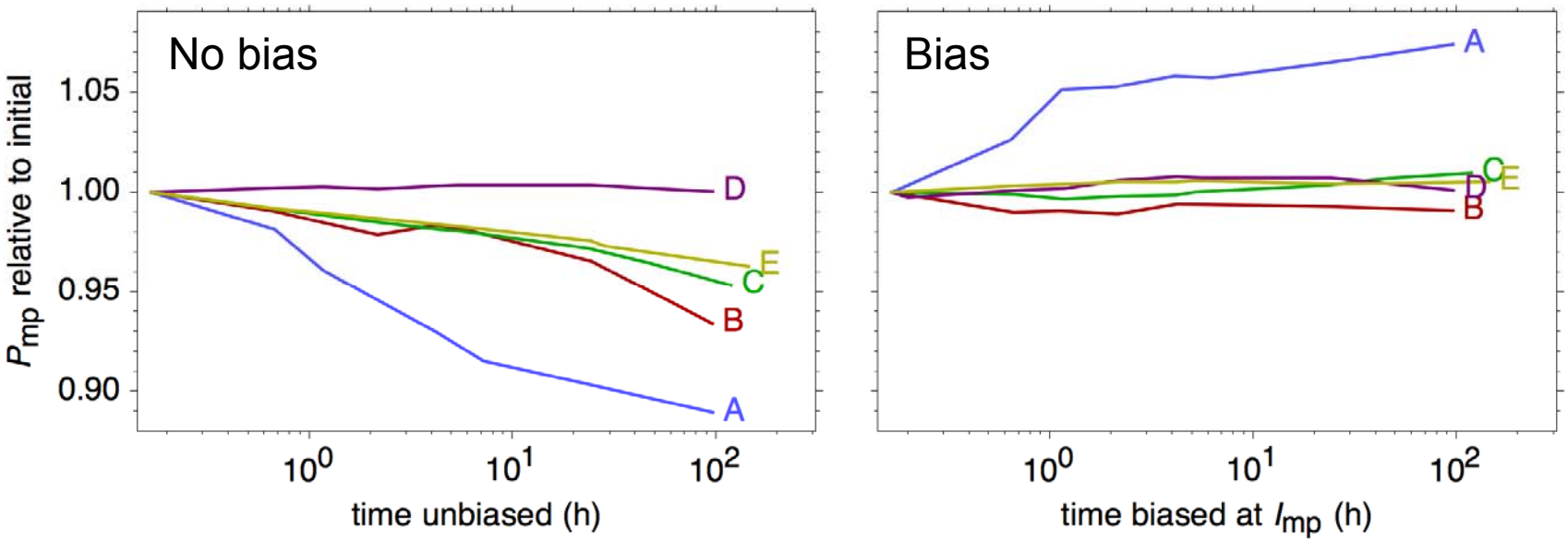
No prescribed time-limit between end of light-soak segment and measurement

- Important to measure promptly after light exposure

Deline, et al, Proc. SPIE 8472, 84720G (2012)

Improvements to current standard

Five different CIGS modules measured after outdoor light exposure, once with forward bias applied once without



- Important to measure promptly after light exposure
- Forward bias can help stabilize power after light exposure

Deline, et al, Proc. SPIE 8472, 84720G (2012)

Procedure for CIGS round robin

Purpose:

- Eliminate variations in measured power from metastable changes occurring in a day or less
- Yield STC performance of a module operating outdoors

Procedure

- Expose to light for 5-5.25 hours
- Measure IV curve within 1 minute, for diagnostic purposes
  - If > 1 min delay, forward bias the module until IV measurement
- Forward bias module as it cools to 25°C
- Measure second IV curve

NREL efforts

- CIGS: Round robin test of new light-soaking procedure - underway

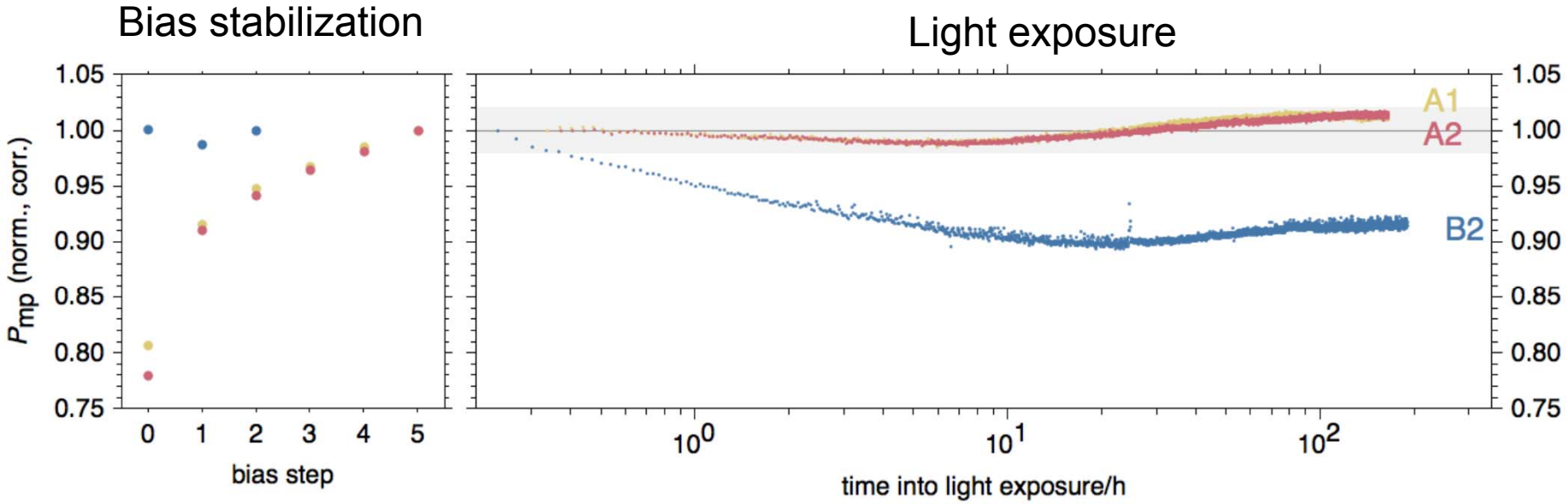
- CdTe: Currently developing a stabilization procedure for upcoming round robin
  - Possibility of stabilizing with forward bias instead of light

CdTe dark bias procedure

- Heat module to 85°C and bias at 90-100% of V_{oc} for 1.5 hours
- Repeat until three successive room temperature power measurements are stable
- Room temperature measurements made within 30 to 60 minutes of cooling down

Repeatable vs. outdoor stabilized

Two types of CdTe module were stabilized with the dark forward bias procedure, then placed in light-soak chamber

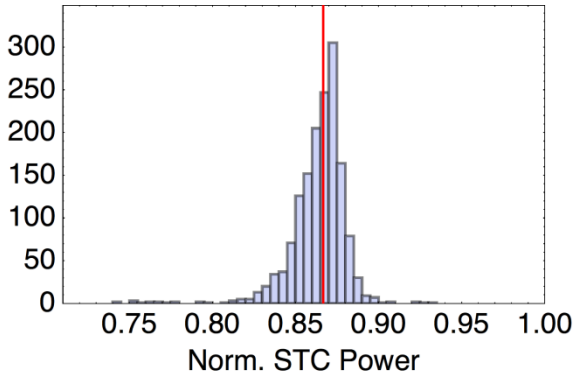


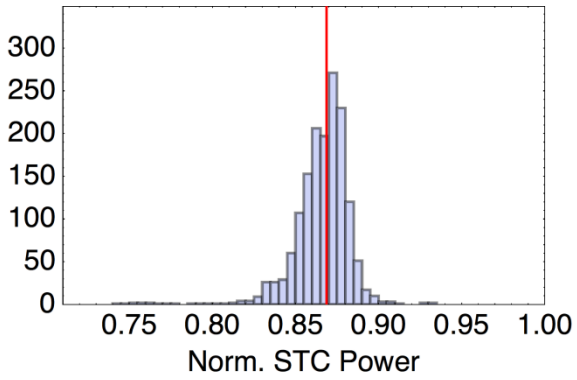
Are we interested in a repeatable measurement, or outdoor performance?

CdTe bias stabilization: outdoor results

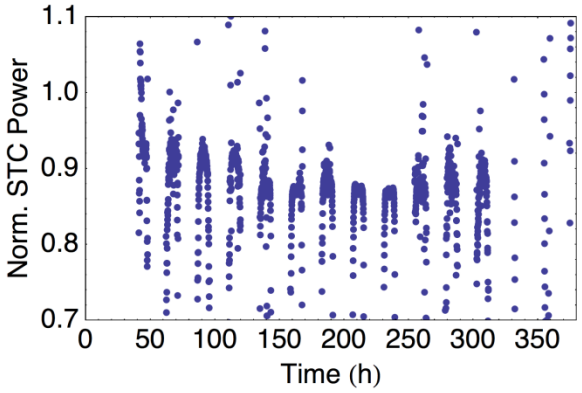
Two CdTe modules were bias stabilized and then deployed outdoors

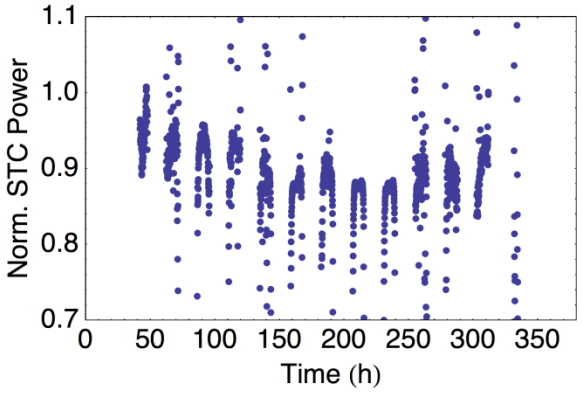
Capacity analysis





Power time series





Outdoor data shows evidence that bias stabilization results in different module state

Conclusion

- Thin-film modules undergo reversible changes in light and dark
- Controlling these changes is important for reliability testing and diagnostics
- Important questions:
  - Time-scale of any standardized procedure?
  - Repeatability vs. outdoor performance?

Acknowledgments

Thank you: Steve Rummel, Allan Anderberg, and Keith Emery (NREL)

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