# LeTID AND THE FUTURE OF MODULE DEGRADATION TESTING

## CONTROL FOR DEFECTS TO DELIVER LOWER LCOE

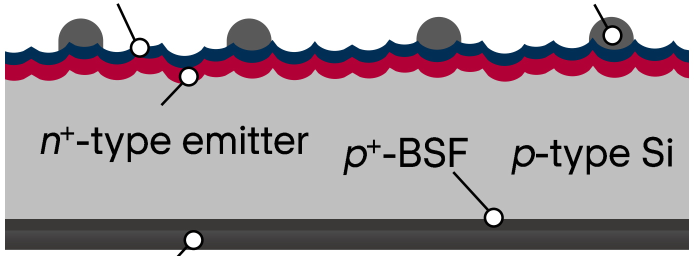
F. Kersten, F. Fertig, R. Lantzsch, F. Frühauf, J. Lindroos, N. Buschmann, A. Szpeth, Y. Neumann, K. Petter, B. Klöter, M. Schaper and J. W. Müller

Hanwha Q CELLS GmbH | Sonnenallee 17-21 | 06766 Bitterfeld-Wolfen, Germany

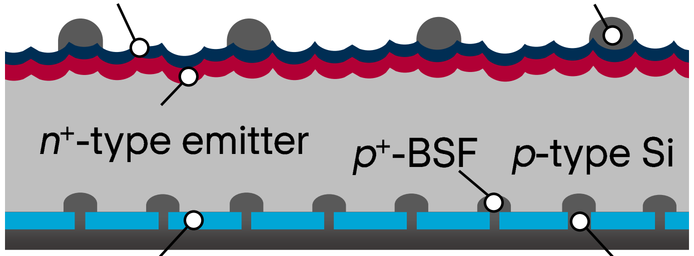
LeTID webinar pv-magazine | October 18, 2019

# DEVELOPMENT OF SOLAR CELLS DESIGN

## Al-BSF solar cell




## powered by Q.ANTUM technology [1,2]




- PERC-like structure with additional features
- Lean & cost-effective process (HE, ARC module optimized, w/o oxidation or anneal, single screen print, 6BB layout)
- Efficiency increase of 0.5 - 0.6 $\%_{abs.}$ per year
- Q.ANTUM efficiency potential of > 24 $\%_{abs.}$
- Quality assured by Yield Security system

Q CELLS
YIELD SECURITY
- ANTI PID TECHNOLOGY (APT)
- HOT-SPOT PROTECT (HSP)
- TRACEABLE QUALITY (TRA.Q™)
- ANTI LID TECHNOLOGY (ALT)


[1] P. Engelhart *et al.*, in Proc. 26th EU PVSEC, 821-826, Hamburg, Germany, 2011.
[2] A. Mohr *et al.*, in Proc. 26th EU PVSEC, 2150-2153, Hamburg, Germany, 2011.

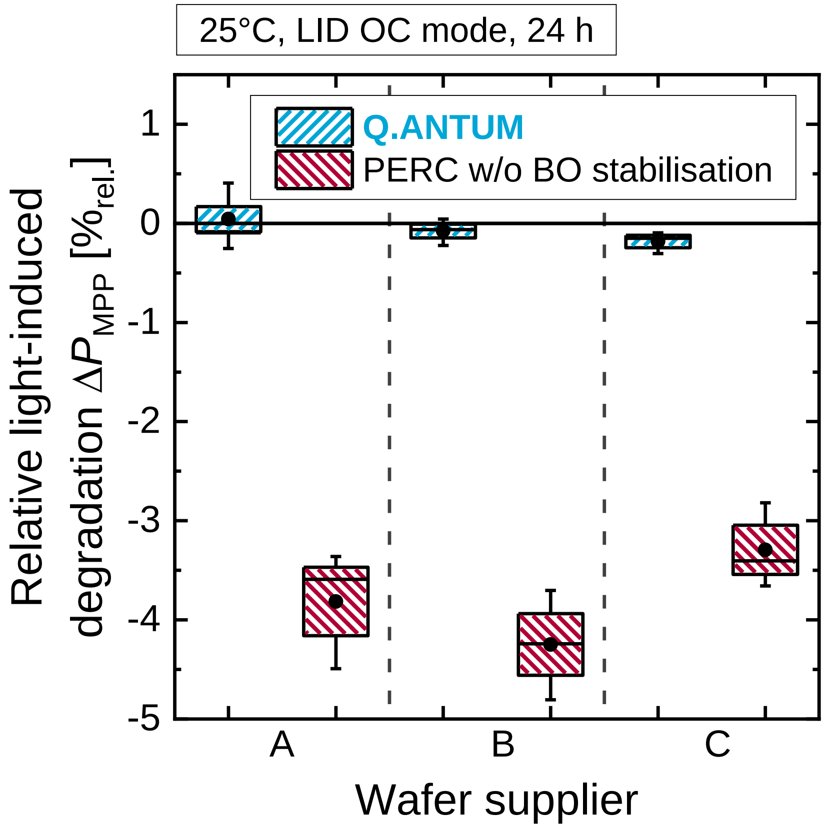
# DEVELOPMENT OF SOLAR CELLS DESIGN

Q CELLS

## LID due to Boron-Oxygen (BO) complex

- First observed in the 70s [4]
- Most prominent LID mechanism in commercial Cz-silicon
- Possibility to permanently deactivate has been first presented in 2006 [5]
- Intensively researched by many groups
- Solutions for mass production commercially available

- Q.ANTUM suppresses LID due to BO complex



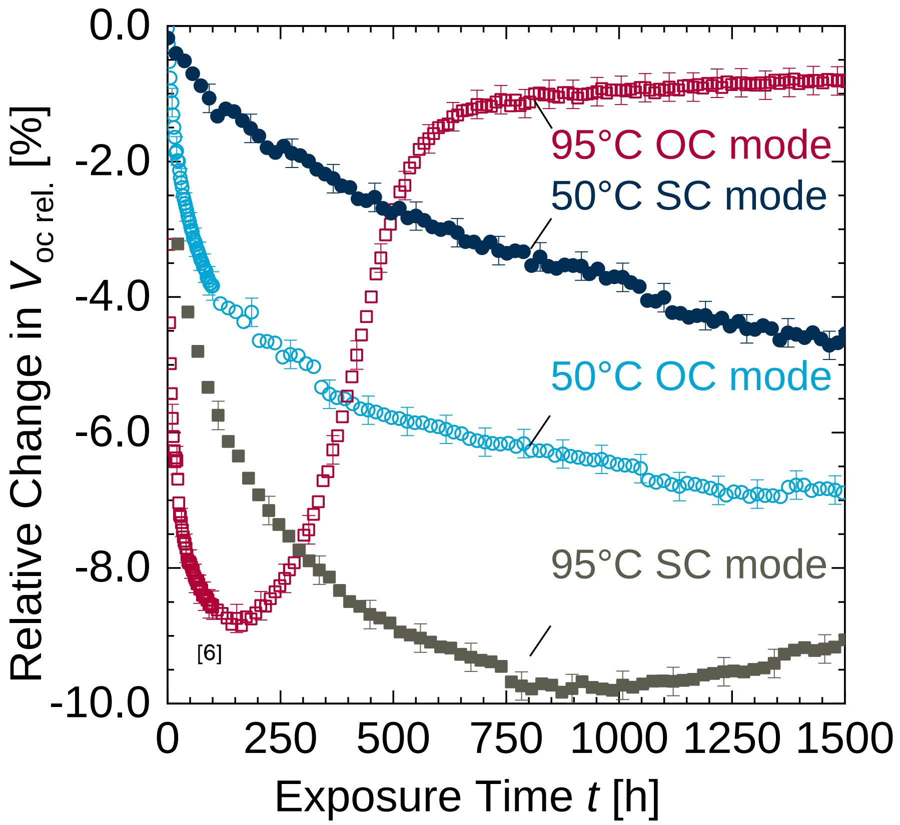

## New degradation effect of c-Si at elevated temperature

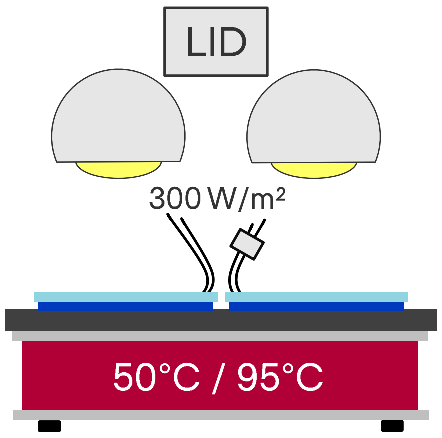
- Light and elevated Temperature Induced Degradation (LeTID) [6] ▸ today's webinar

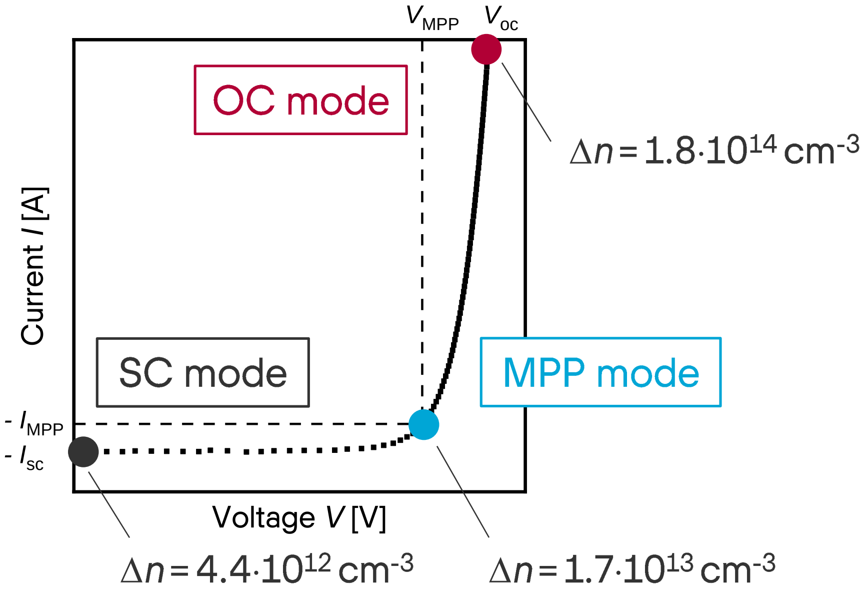

[3] F. Fertig *et al.*, Energy Procedia **124**, 338–345, 2017.
[4] H. Fischer and W. Pschunder, in Proc. 10th IEEE PVSC, 404-411, Palo Alto, USA, 1973.
[5] A. Herguth *et al.*, in Proc. 4th WCPEC, 940-943, Hawaii, USA, 2006.
[6] F. Kersten *et al.*, Sol. Energ. Mat. Sol Cells **142**, 83–86, 2015.

# LeTID CHARACTERISTICS ON SOLAR CELLS

- Injection and temperature dependence ▸ $\Delta n$ and $T$ on cell level



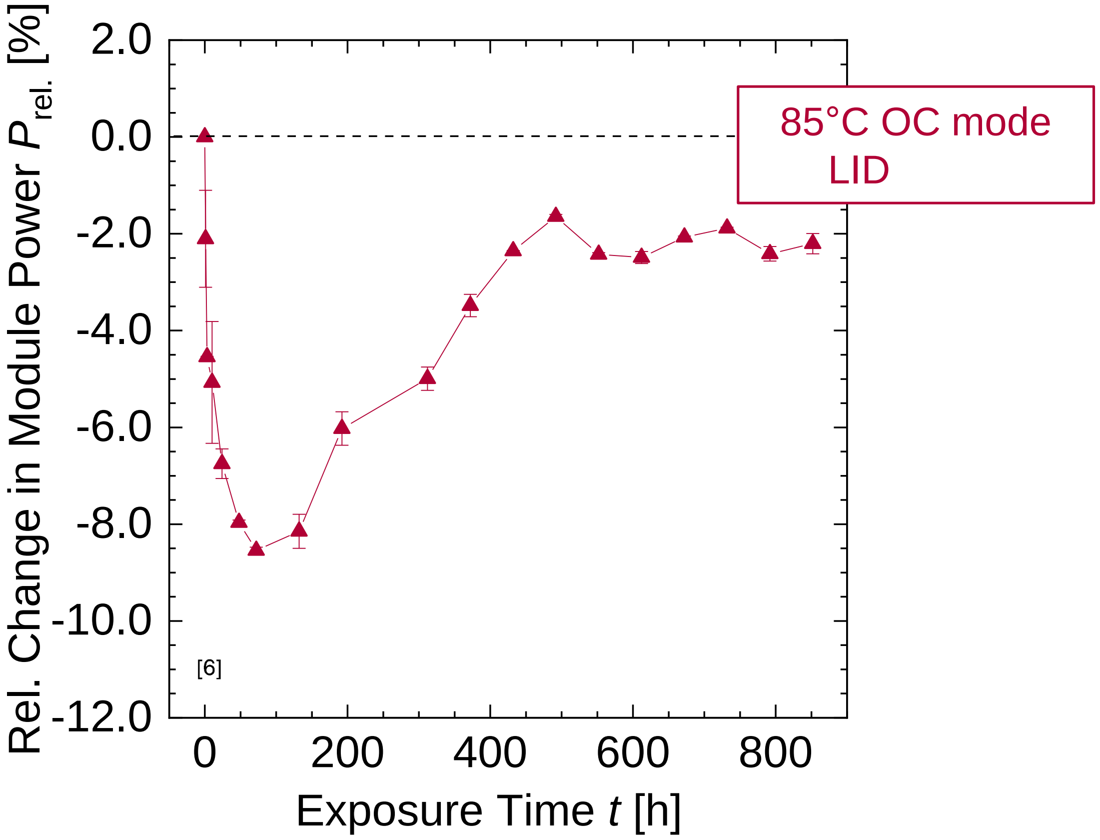



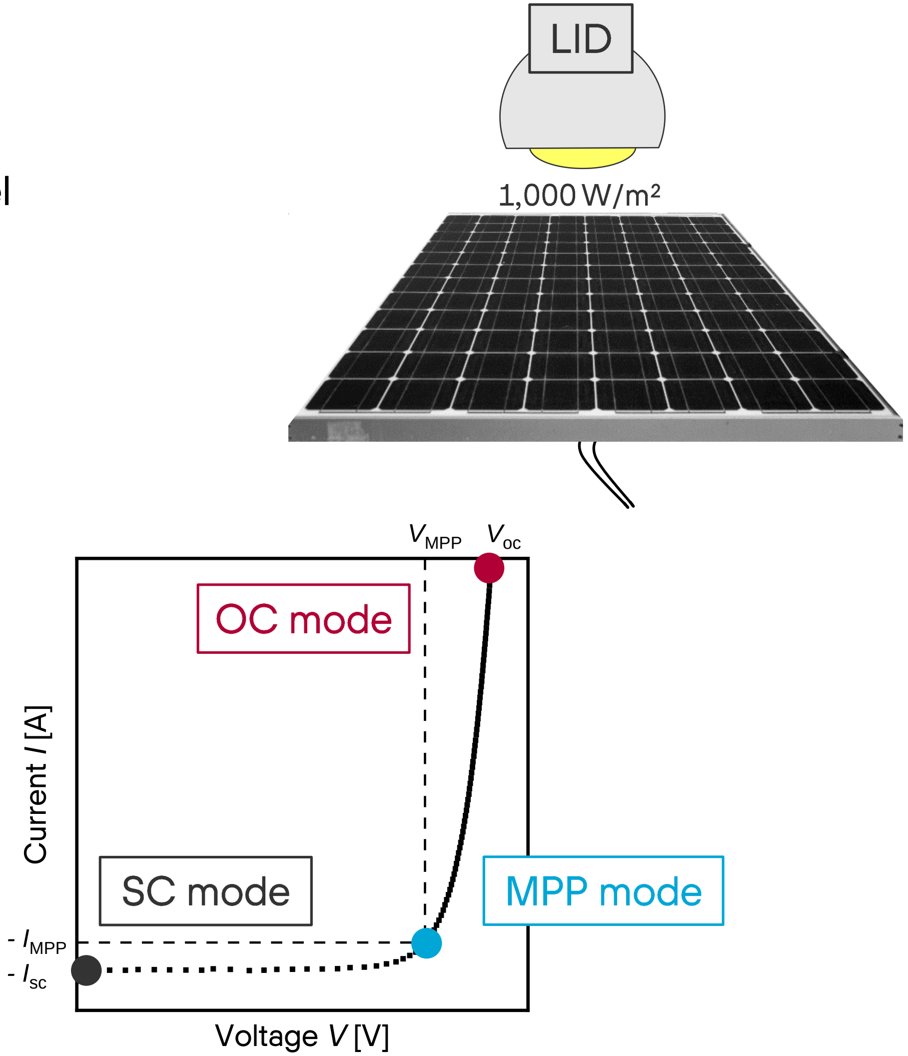

[6] F. Kersten *et al.*, Sol. Energ. Mat. Sol Cells **142**, 83–86, 2015.

$\Delta n$ ... calculation with PC1D at 95°C and 300 W/m²

# LeTID CHARACTERISTICS ON MODULES

- Injection and temperature dependence ▸ $\Delta n$ and $T$ on module level




[6] F. Kersten *et al.*, Sol. Energ. Mat. Sol Cells **142**, 83–86, 2015.

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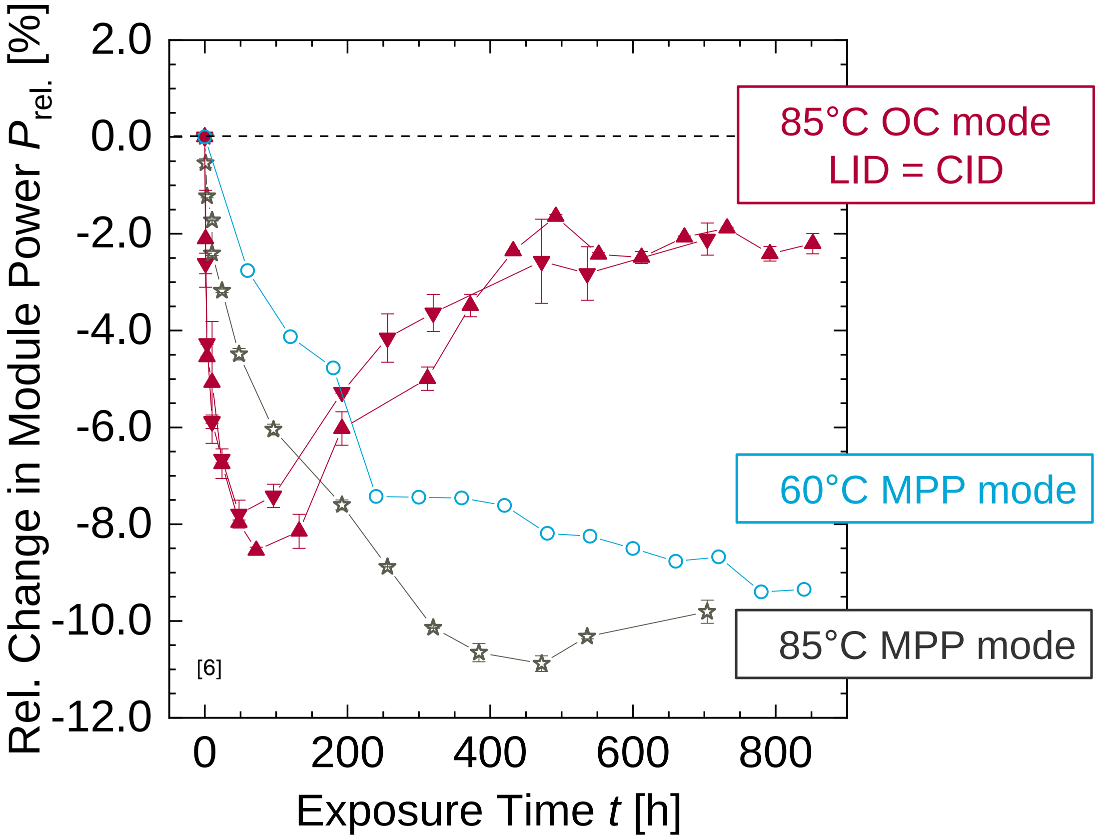
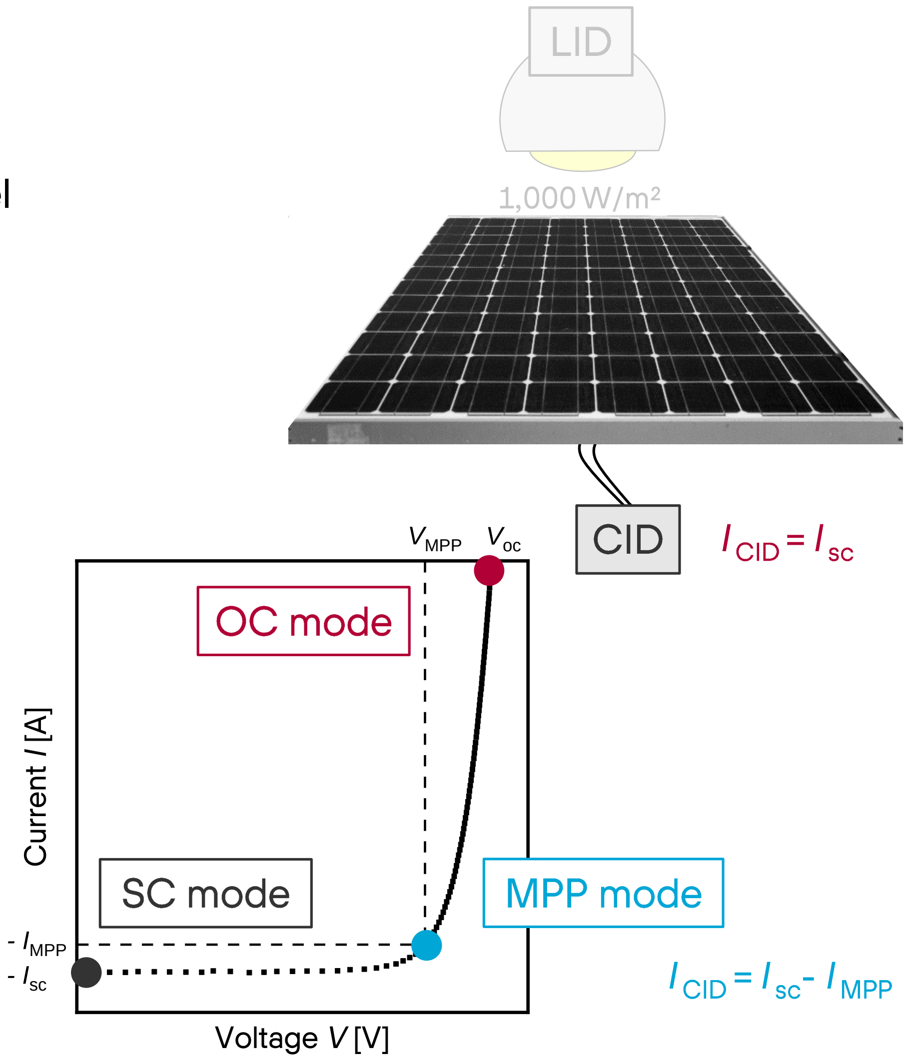



[6] F. Kersten *et al.*, Sol. Energ. Mat. Sol Cells **142**, 83–86, 2015.

# LeTID PERFORMANCE LOSS

- LeTID-sensitive PERC and Q.ANTUM modules on industrial mc-Si [1,7]

- Module degradation experiments in lab:
  - in climate chamber at 75°C
  - excess carriers being injected by current (CID)
  - current correlates to the excess carrier density as for field operation in MPP mode

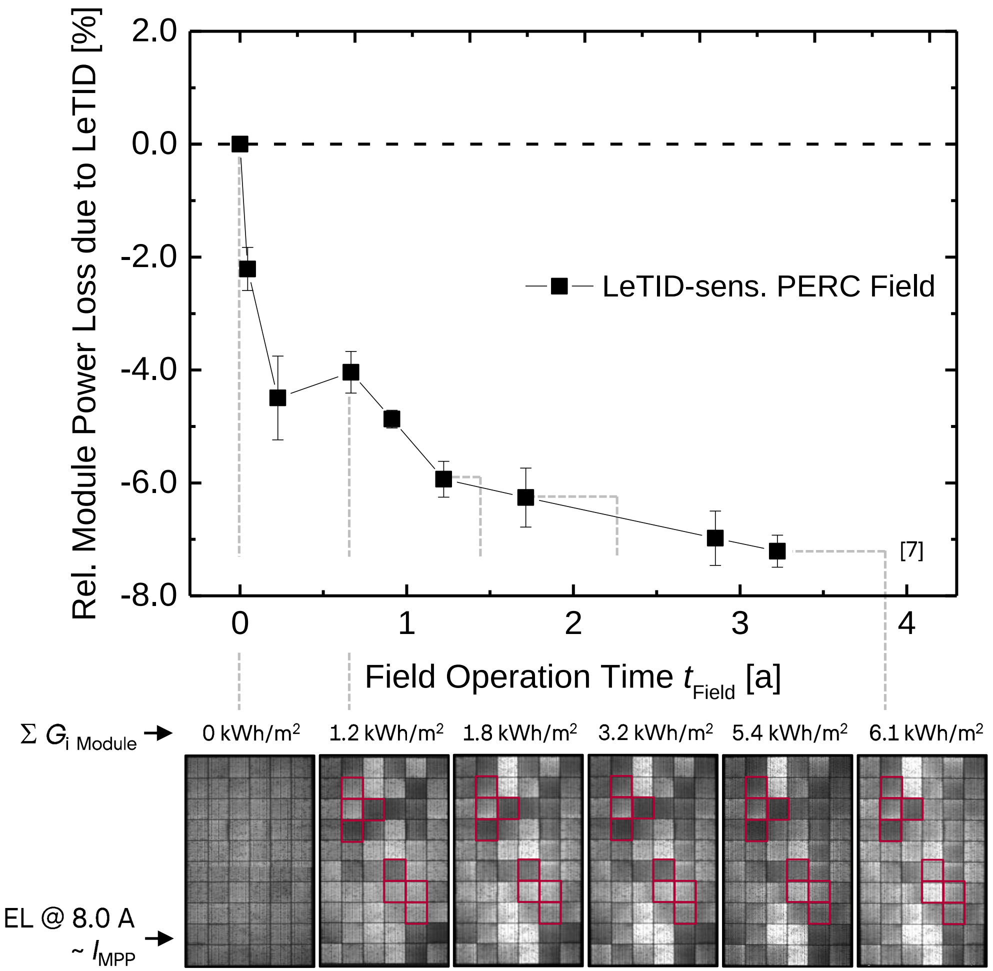
- LeTID-sensitive PERC and Q.ANTUM modules
  installed on outdoor test fields in Germany and Cyprus

- Module degradation experiments in field:
  - continuous logging of irradiance ($G_{\text{i Module}}$),
    module temperature ($T_{\text{Module}}$) and energy yield
  - quarterly the modules at both locations
    removed for IV- and EL-measurement
  - re-installation after each test cycle in outdoor systems


[1] P. Engelhart *et al.*, in Proc. 26th EU PVSEC, 821-826, Hamburg, Germany, 2011.
[7] F. Kersten *et al.*, Energy Procedia 124, p. 540, 2017.

# LeTID PERFORMANCE LOSS

- Field installation in Cyprus (MPP mode)
- Quarterly removal for IV- and EL-measurement
- EL-image evolution vs. cumulative energy yield
- Inhomogeneous EL-image due to degradation
  → different degradation rate of each cell
- Rel. module power loss up to 8% after 3 years




[7] F. Kersten *et al.*, Energy Procedia 124, p. 540, 2017.

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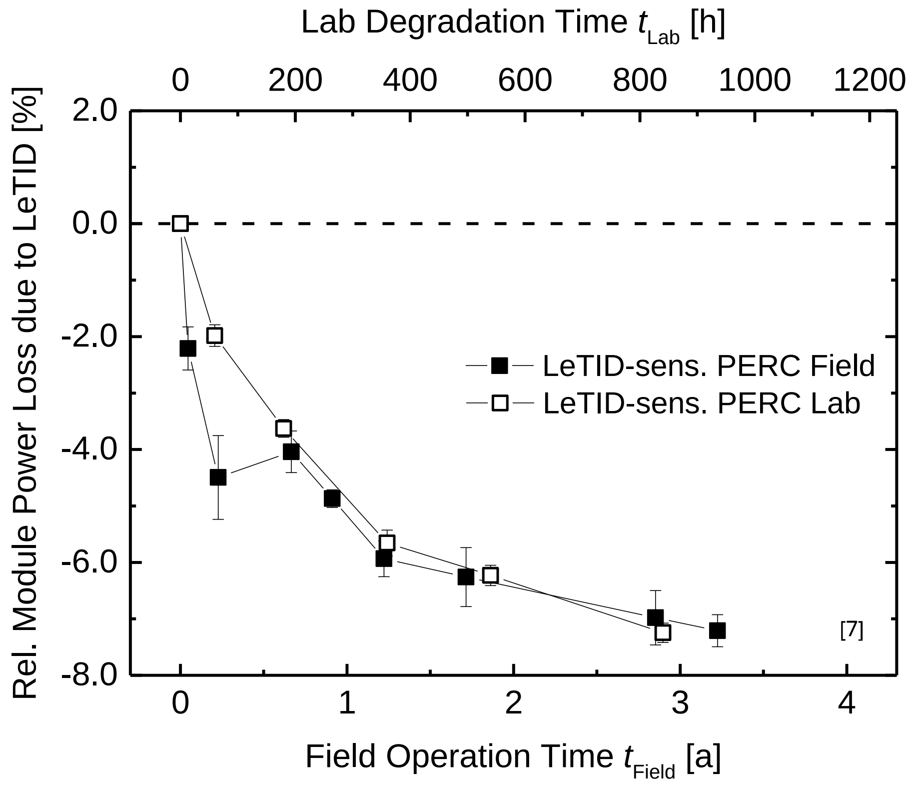
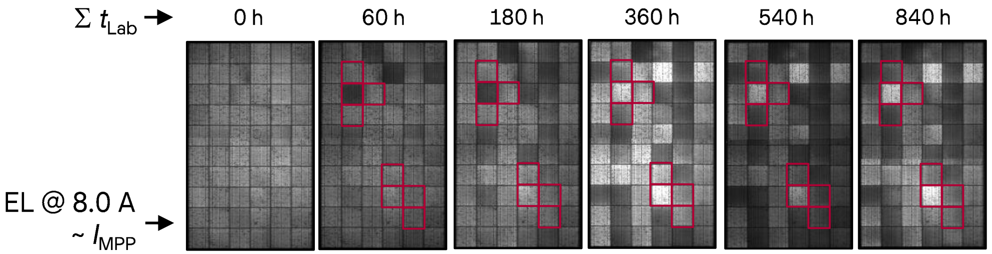
- Climate chamber degradation:
  CID at 75°C in MPP mode ($I_{SC}$- $I_{MPP}$)
  → near to field conditions

- Same degradation behavior field = lab

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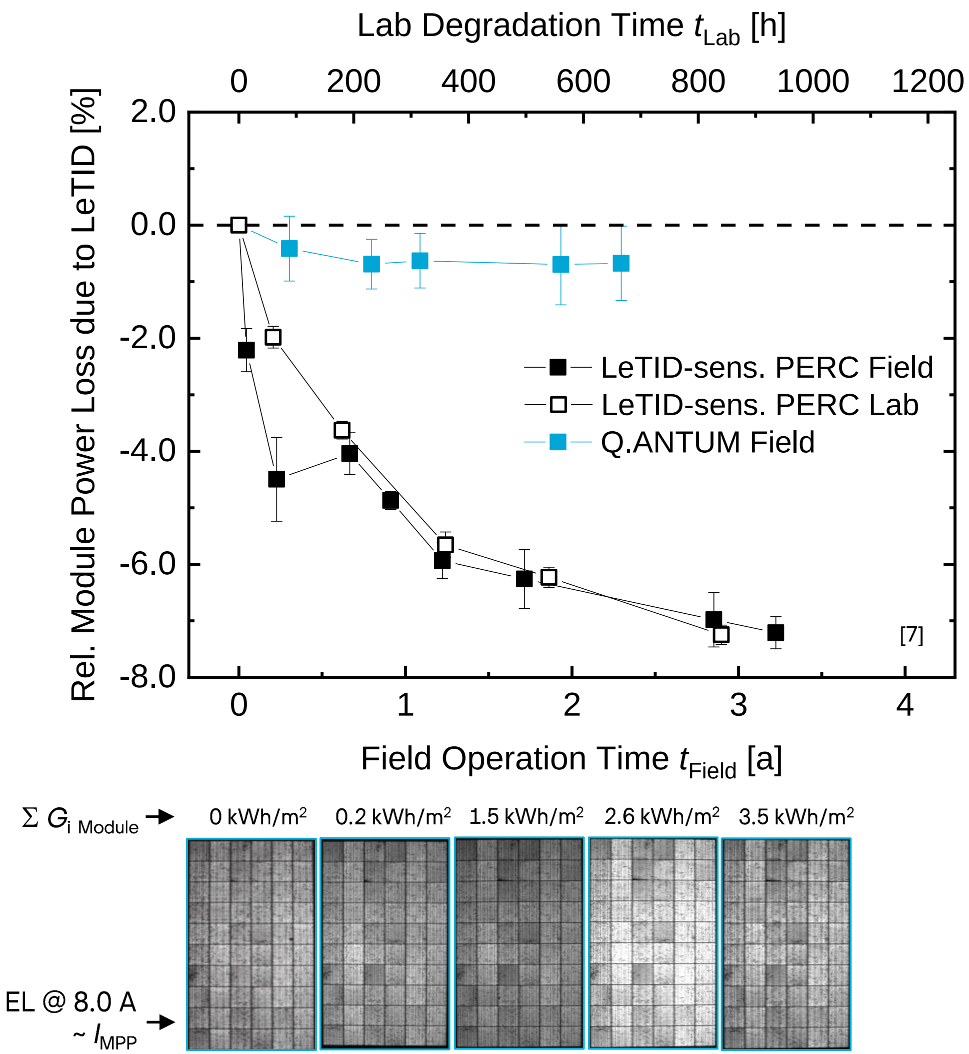
- Same degradation behavior field = lab
- Q.ANTUM suppressed any LeTID in field




[7] F. Kersten *et al.*, Energy Procedia 124, p. 540, 2017.

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- Climate chamber degradation:
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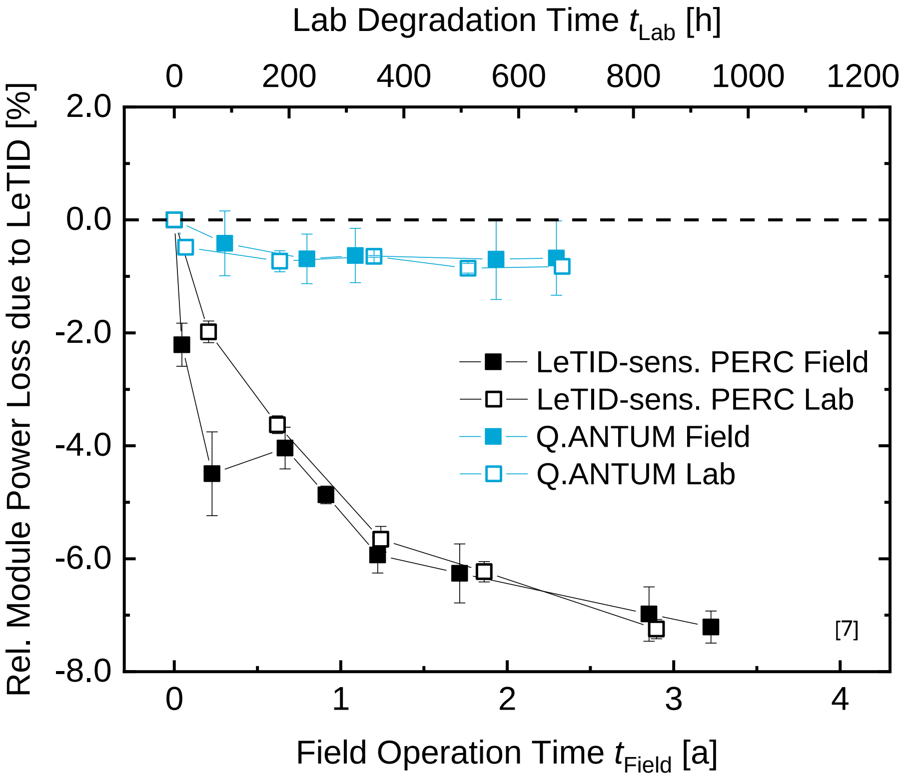
  → near to field conditions

- Same degradation behavior field = lab
- Q.ANTUM suppressed any LeTID in field and lab degradation test

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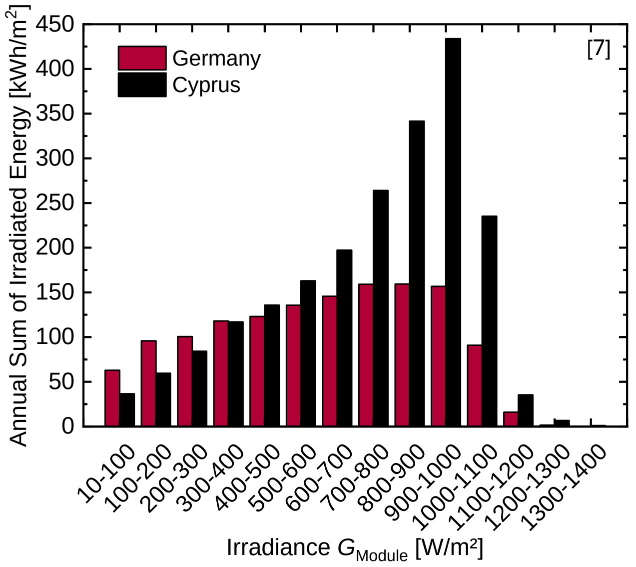
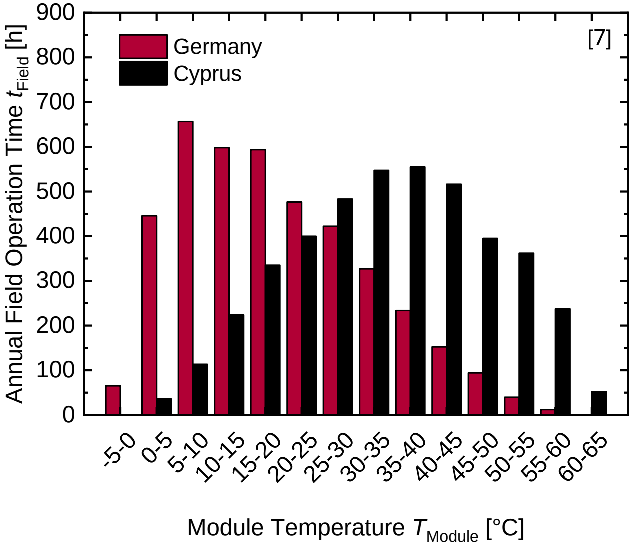
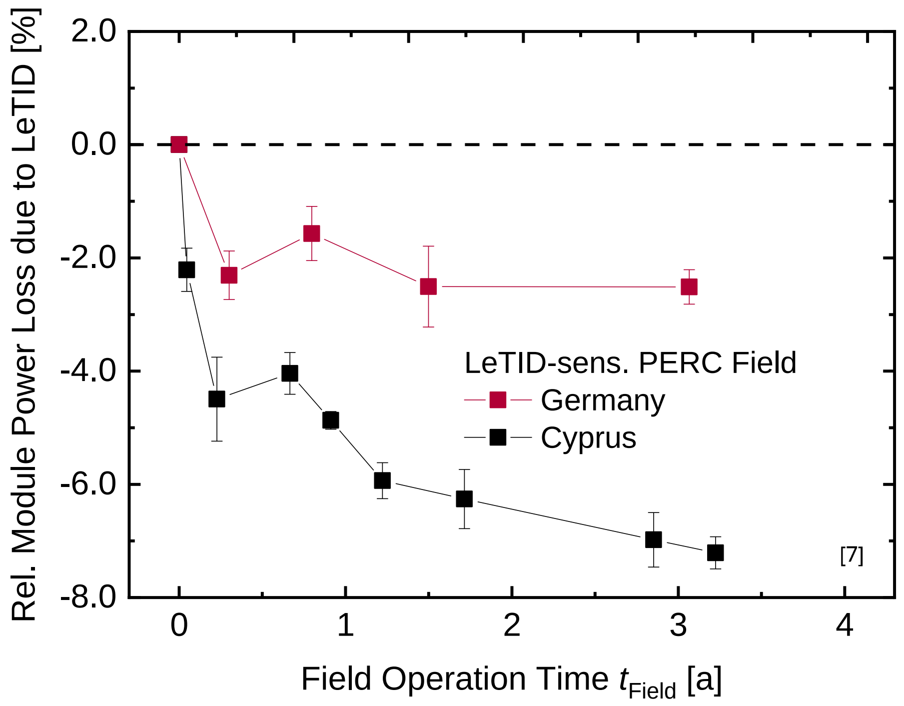


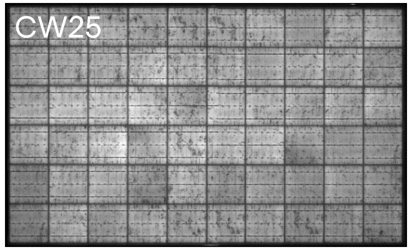




- Well suited LeTID conditions in Cyprus
- Slow degradation rates in Germany

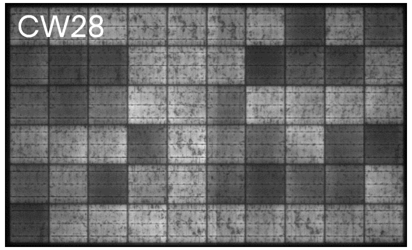

[7] F. Kersten *et al.*, Energy Procedia 124, p. 540, 2017.

# LeTID PERFORMANCE LOSS

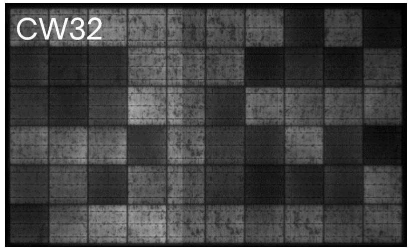
- Accelerated LeTID in Germany [6]:
  1. OC mode
  2. Module rear side isolated with Styrofoam ($T_{\text{Module max.}}$ +20 K)



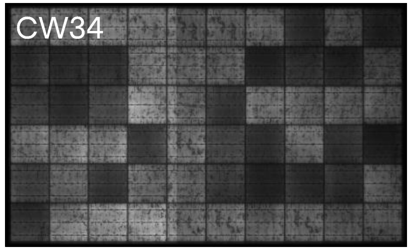

Module power: 100 %



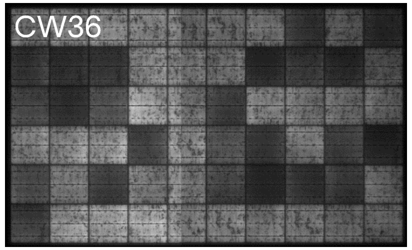

106 kWh -5.2 %



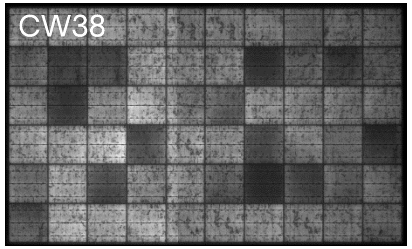

203 kWh -7.5 %



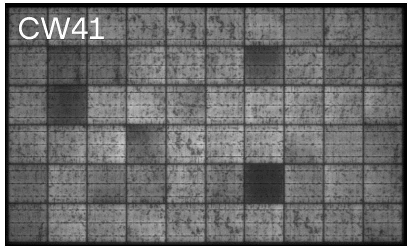

320 kWh -7.0 %



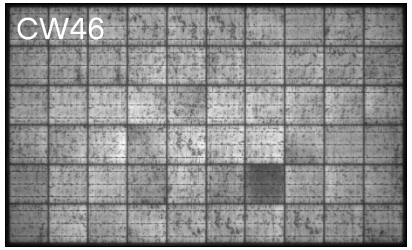

364 kWh -6.1 %




397 kWh -2.4 %




455 kWh -1.4 %




520 kWh -0.8 %

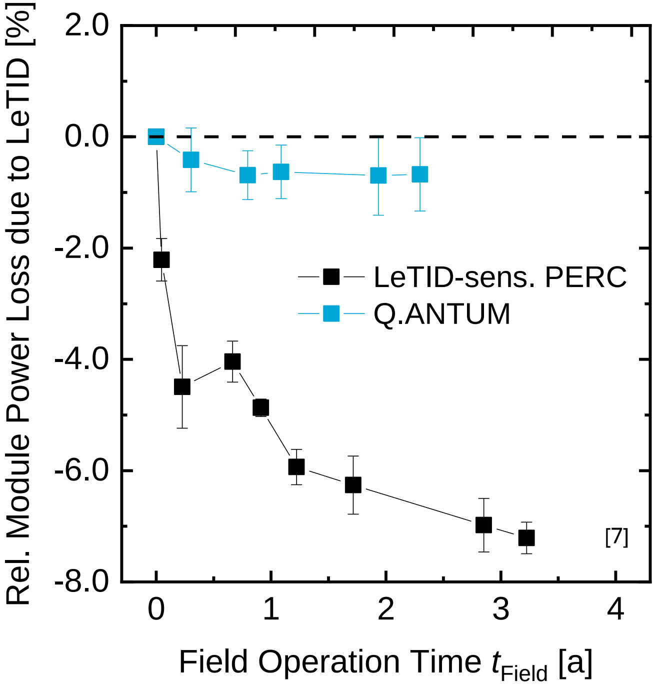
- Under “real field conditions”: LeTID + regeneration cycle takes several years (> 10 years in Germany)

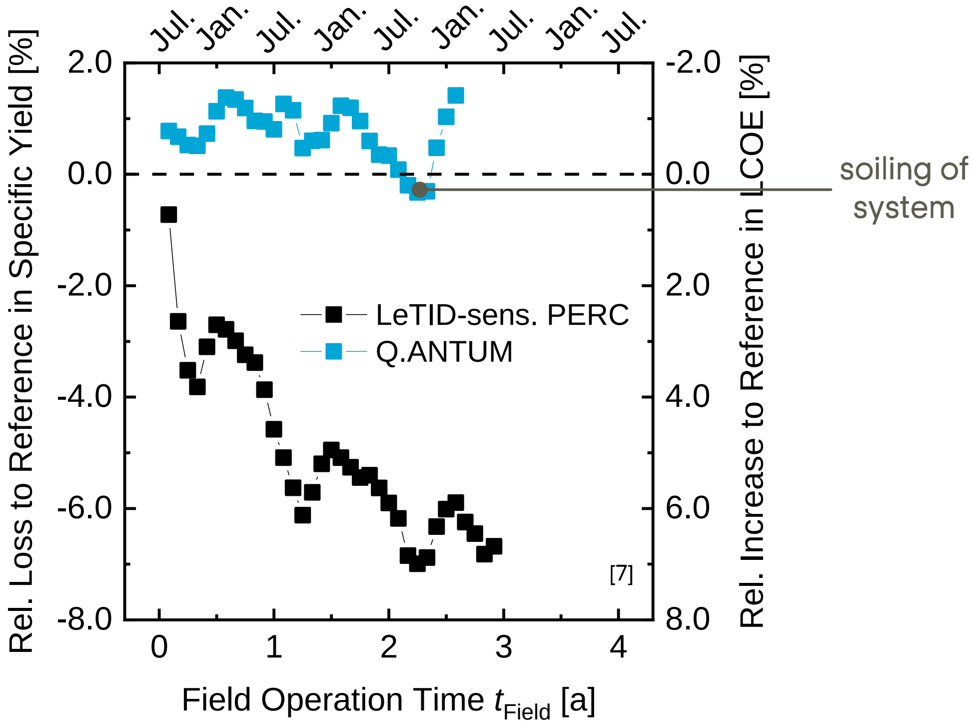
[6] F. Kersten *et al.*, Sol. Energ. Mat. Sol Cells **142**, 83–86, 2015.

# SYSTEM PERFORMANCE LOSS DUE TO LeTID

Q CELLS

- LeTID arises in the field and significantly reduces energy yield
- Q.ANTUM Technology suppresses LeTID in the field



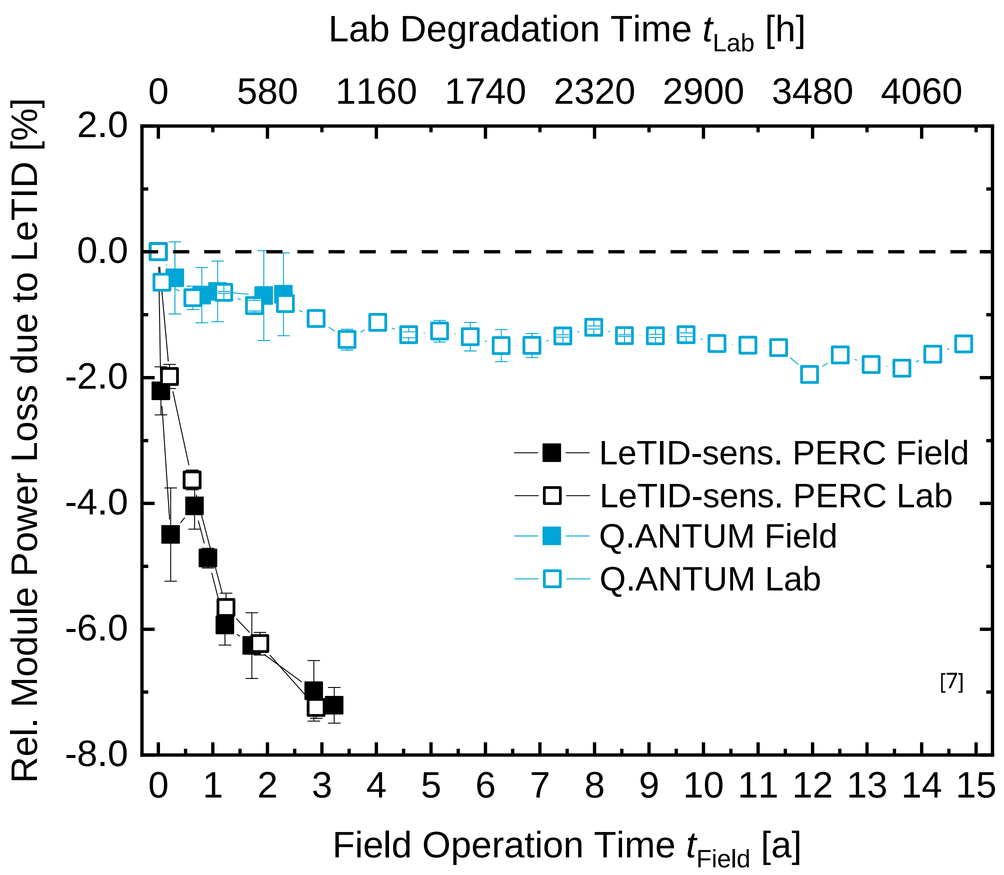



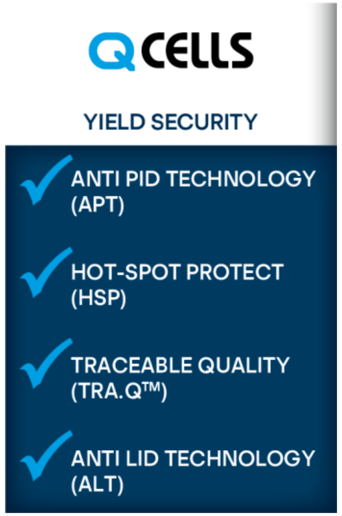

- Loss in module power one-to-one to energy yield and revenue (after 3 years installation-time relative increase in LCOE of 7% to reference w/o LeTID)

[7] F. Kersten *et al.*, Energy Procedia 124, p. 540, 2017.

# Q.ANTUM LONG-TERM DEGRADATION BEHAVIOR

- Q.ANTUM Technology suppresses LeTID in the lab in 4,000 hours long-term climate chamber test with CID at 75°C in MPP mode (correlates to ~15 years in Cyprus field installation)



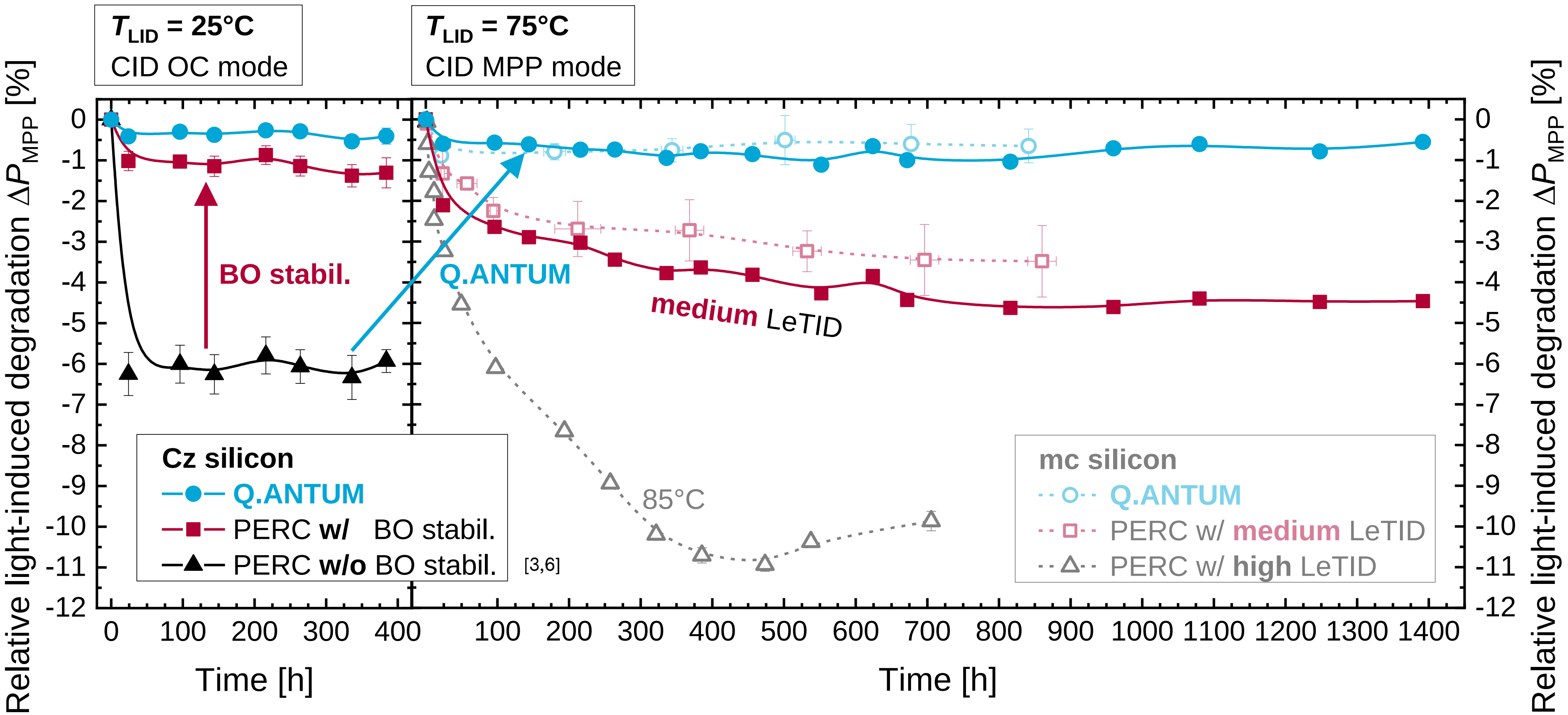

▸ **What about LeTID in Cz silicon PERC?**

[7] F. Kersten *et al.*, Energy Procedia 124, p. 540, 2017.

# LeTID IN Cz SILICON PERC

Q CELLS

- LeTID also occurs in Cz silicon PERC




- Q.ANTUM suppresses LeTID in mc and Cz silicon


[3] F. Fertig *et al.*, Energy Procedia **124**, 338–345, 2017.
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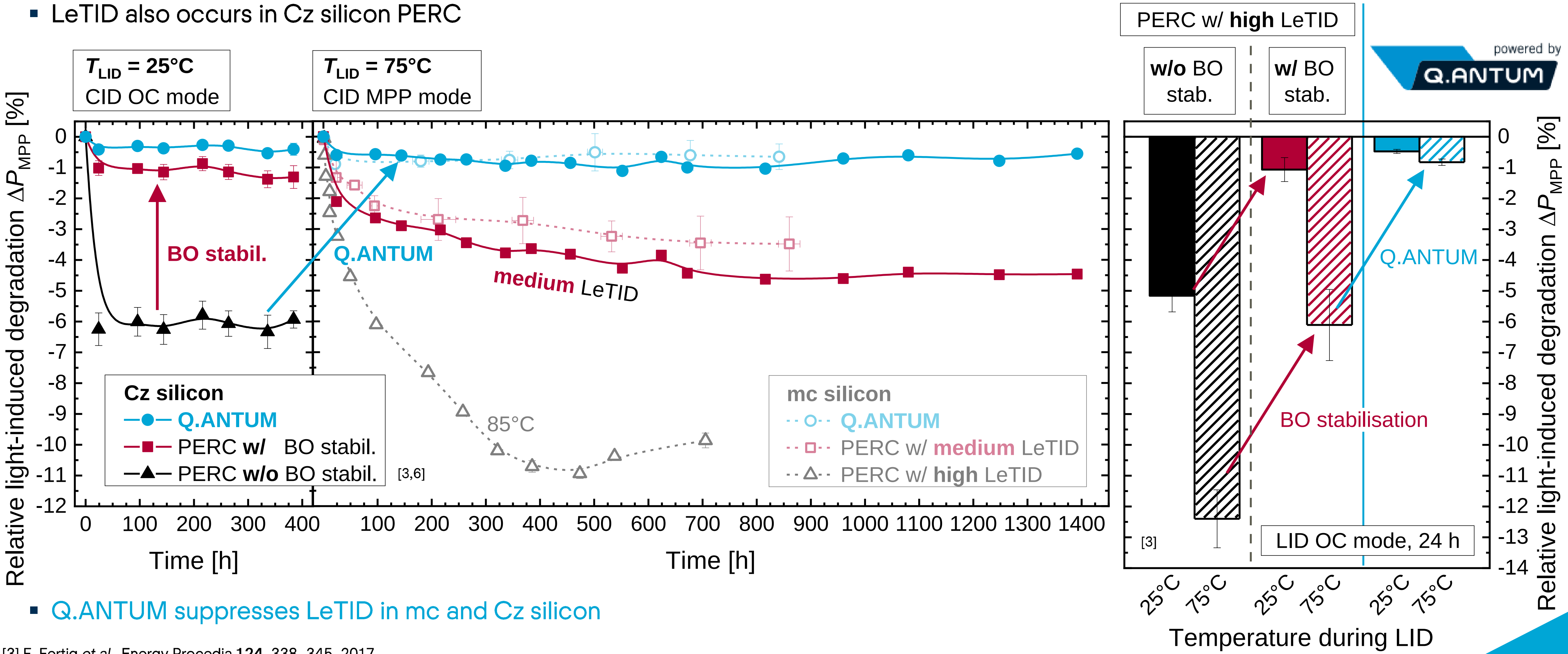


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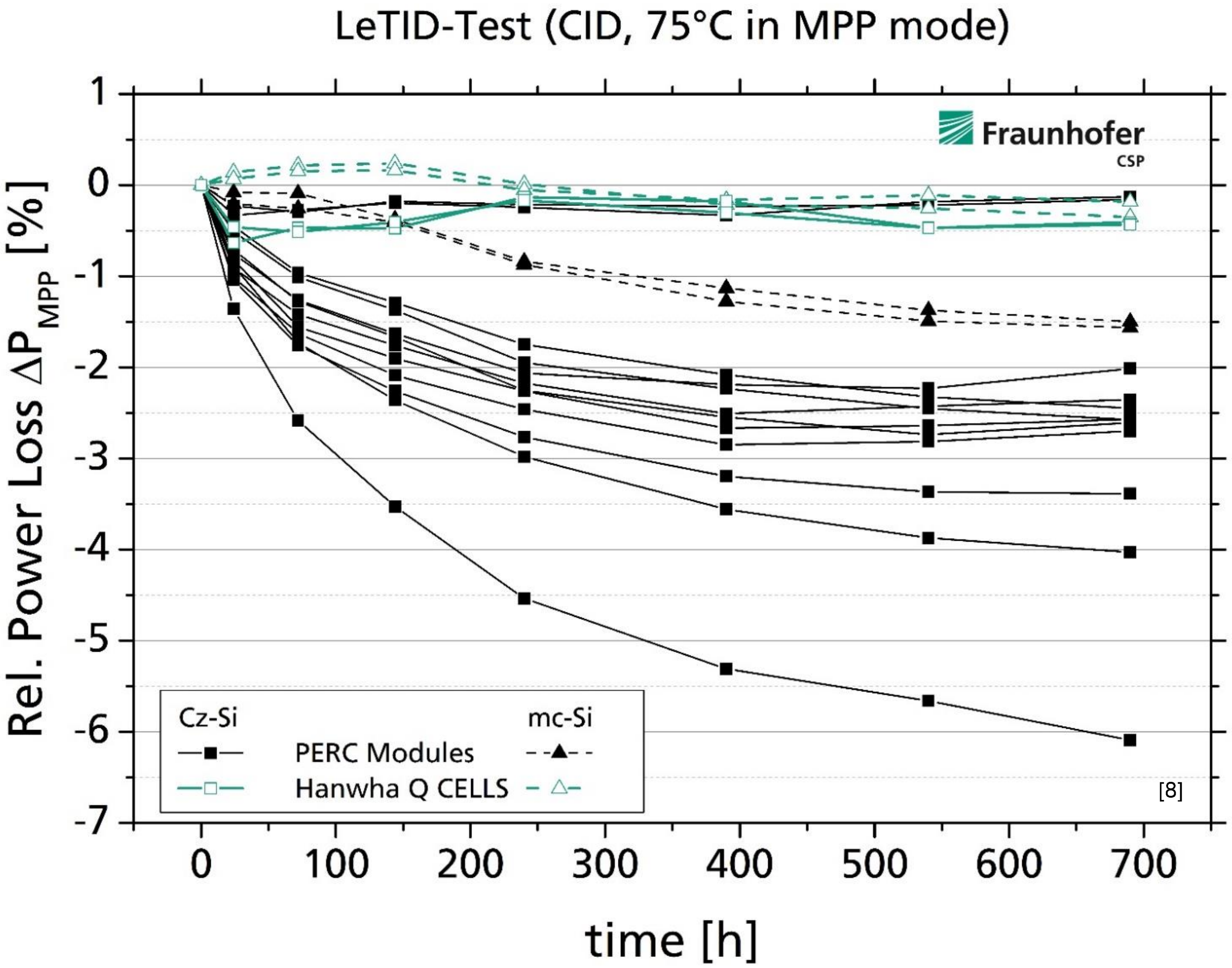
[3] F. Fertig *et al.*, Energy Procedia **124**, 338–345, 2017.
[6] F. Kersten *et al.*, Sol. Energ. Mat. Sol Cells **142**, 83–86, 2015.

# EXTERNAL LeTID TESTS

Q CELLS

- Independently confirmed by different institutes Fraunhofer CSP [8], TÜV Rheinland [9], VDE




- Q.ANTUM suppresses LeTID in mc- and Cz-Si

[8] M. Pander et al., in Proc. 35th EU PVSEC, 1265-1268, Brussels, Belgium, 2018.
[9] LeTID testing standard (2 PfG 2689/04.19) TÜV Rheinland 2019.

# Hanwha Q CELLS QUALITY ASSURANCE

Q CELLS

## THE STRICTEST QUALITY ASSURANCE FOR ULTIMATE RELIABILITY

**1 // Certification Testing**

- Approvals from IEC, CSA/UL, MCS, JET, and KEMCO
- Ensures safety of module design

**2 // Yield Security**

- Guaranteed PID resistance
- Hot-Spot Protect
- Assurance of authenticity
- Minimized LID

**3 // VDE Quality Tested**

- 3rd party supervision
- Goes beyond standard testing
- Quarterly inspections for consistent quality

**4 // Q CELLS Quality Program**

- Global Production Site Management to ensure comparable, high quality
- Test thoroughly, continuously & more realistically

# SUMMARY

- LeTID test proposal: CID at 75°C in MPP mode
  - Reaches full LeTID at a reasonable speed in both multi and mono PERC modules
  - Can predict field performance
  - Works also on modules from other manufacturers
- Q.ANTUM technology suppresses ...
  - Boron-Oxygen (BO) and
  - Light and elevated Temperature Induced Degradation (LeTID)
  - In both multi and mono silicon solar cells and modules

# THANK YOU

Friederike Kersten | Thalheim | October 18, 2019
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Q CELLS
Engineered in Germany