

# LED'S MEASURE BIFACIAL

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# LED's INTRODUCE WAVELABS

## Facts & Figures

- Founded in 2011
- Headquarter, Production & Service in Leipzig, Germany
- R&D Center in Münster, Germany
- Product portfolio of solar simulators for PV cells and modules
- More than 70 employees
- World's largest producer of LED-based solar simulators for solar cells
- More than 700 tools in 24/7 operation
- More than 70 GW installed measurement capacity



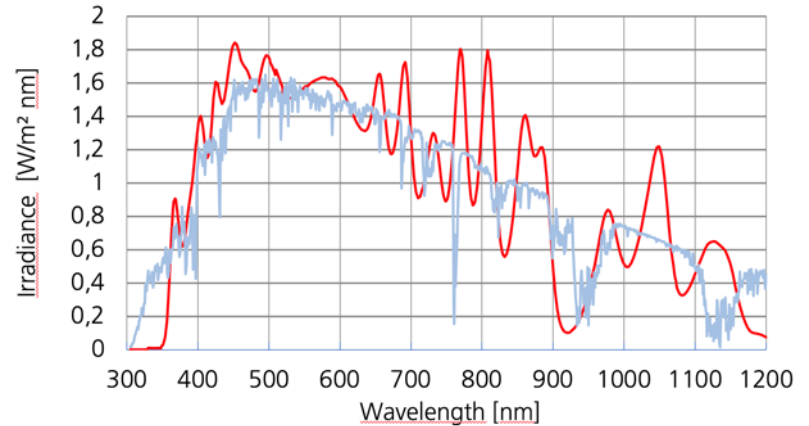
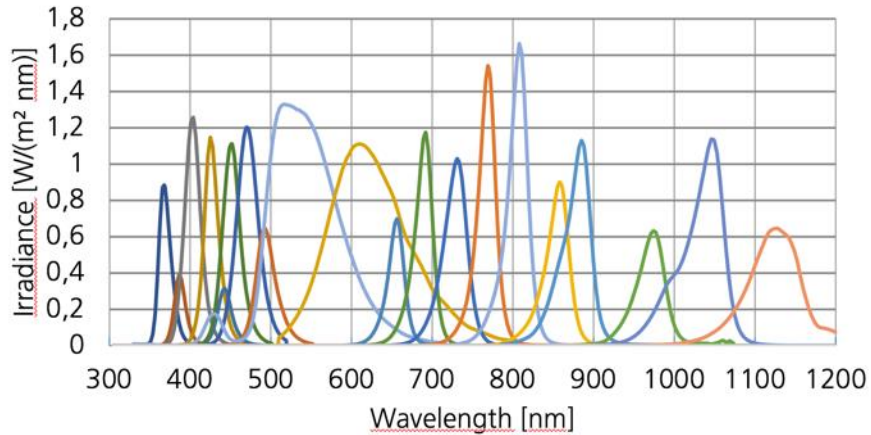
# LED's FLASH WORLDWIDE

## Think local, flash global!

- Customers from 29 countries trust WAVELABS
  - Sales and service support in many regions
  - Making **Waves** Outside The **Lab!**
- 
- Made in Germany



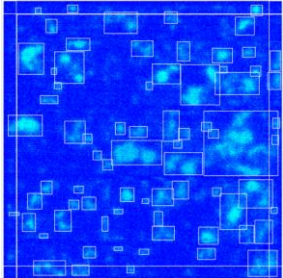
# LED's SHINE LIKE THE SUN



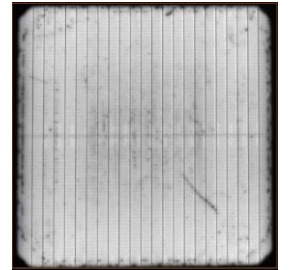
- Light engine with independent 20 LEDs
- All LEDs can be separately and easily tuned for user defined spectra
- Spectral match of class A++ acc. to IEC 60904-9 ed. 2 & ed. 3  $< \pm 5\%$
- Exposure times, from flashes (ms) up to continuous irradiation

# LED's PRESENT SINUS-300

## IR CAMERA



## EL CAMERA



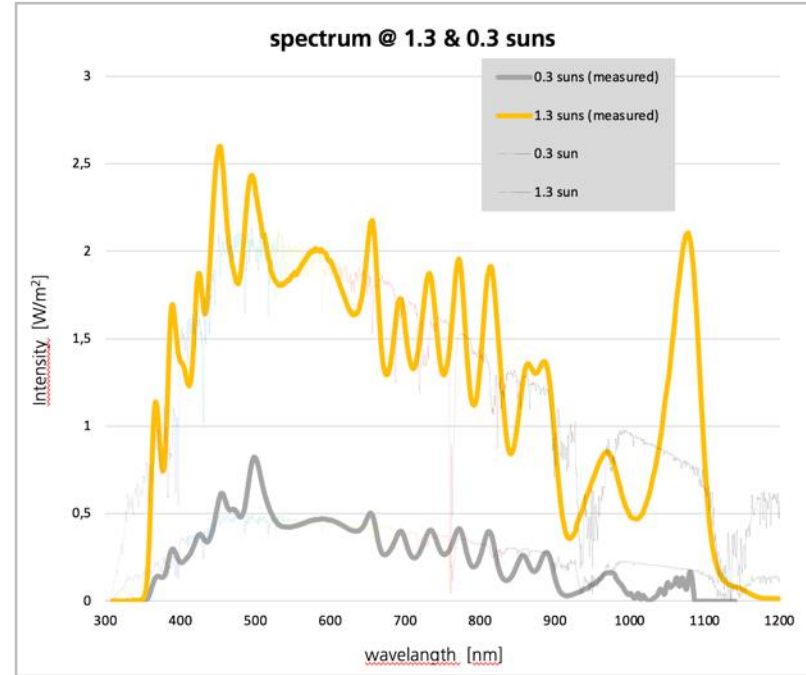
# LED's INTRODUCE RSF-300



- 238 RSF delivered
- 20 separate long lifetime LEDs
- Non-uniformity on 240x240 mm<sup>2</sup> < 2%
- LTI < 2%
- Simultaneous flashing with SINUS-300 at high throughput (~ 4000 cells/h)
- Red & blue in order to check the passivation quality of the cell's rear side

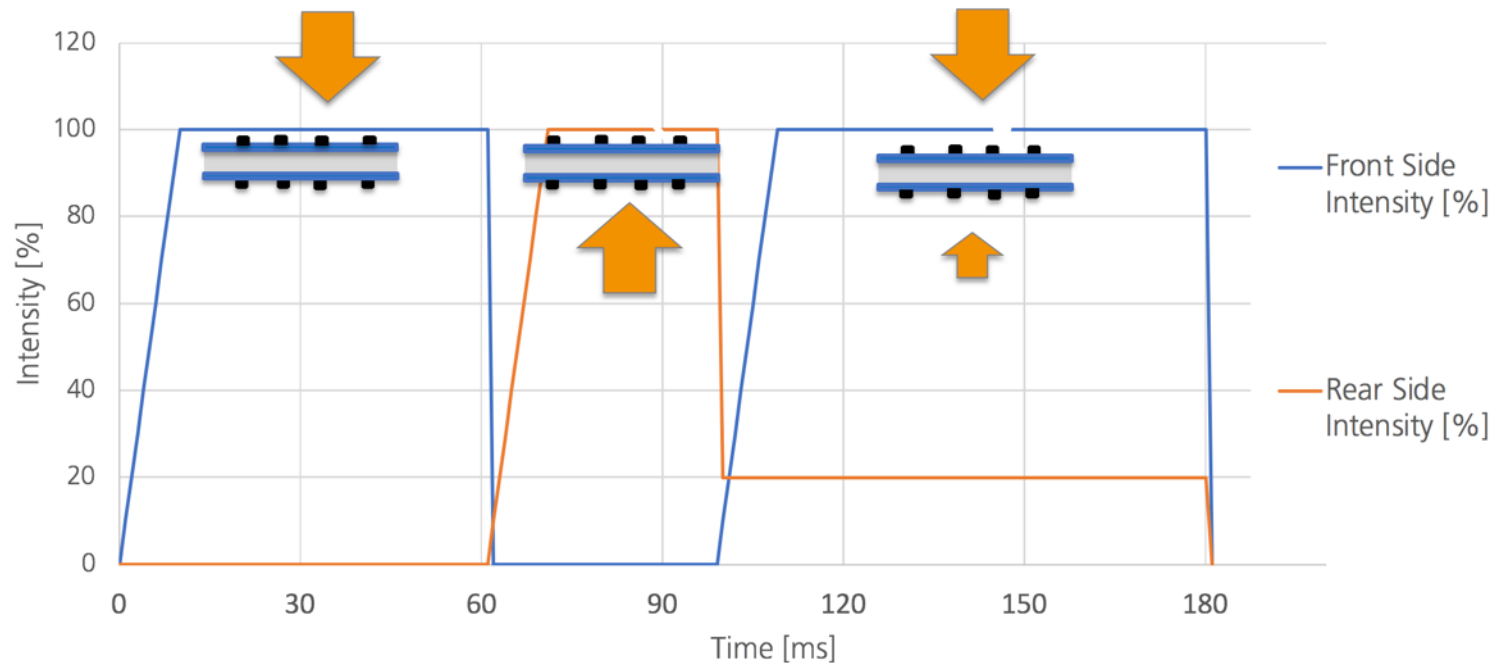
# LED's COPY THE SUN

- Multi color LED-based light source for perfect copy of the sun
- Class A+ @ 0.3 suns & 1.3 suns
- Perfect match for high & low intensities due to 20 individual LED channels



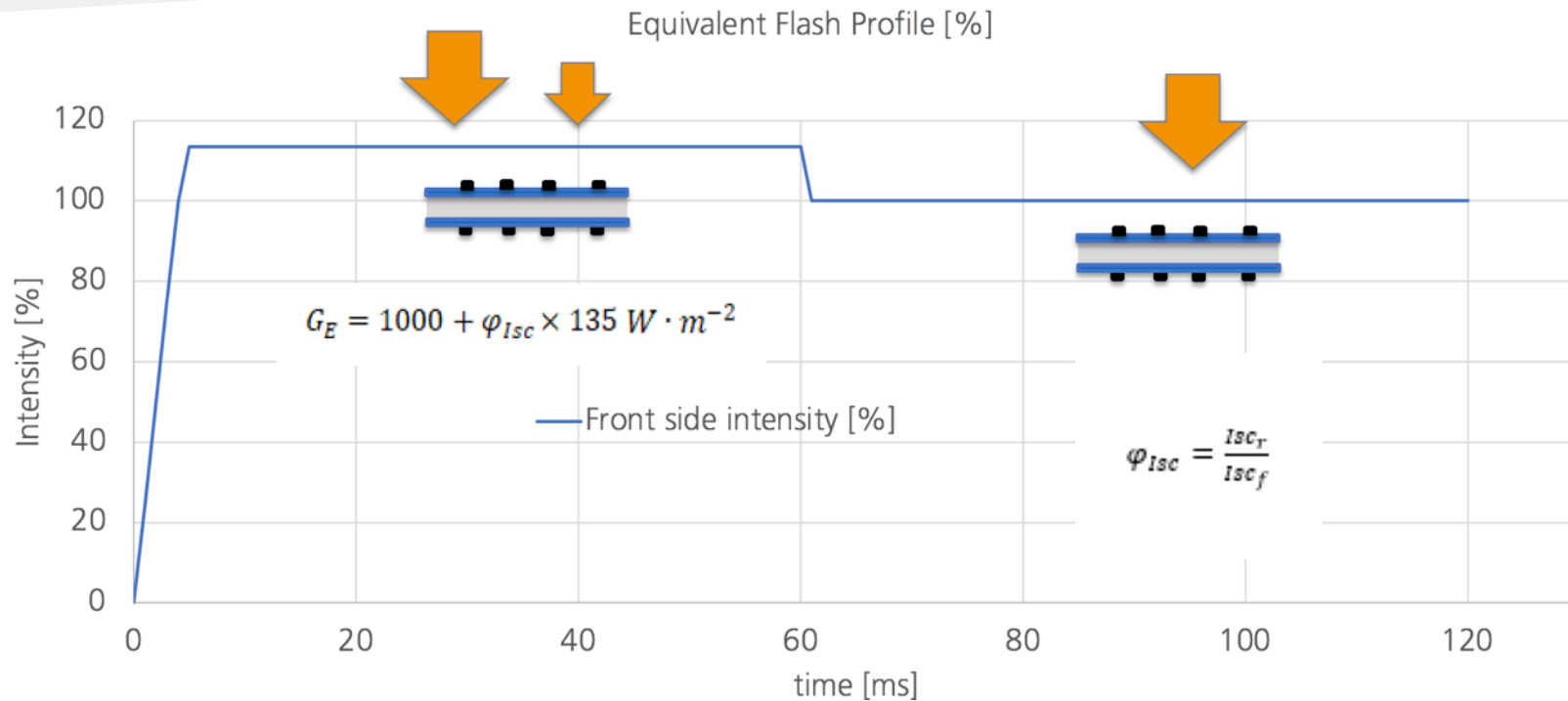
# LED's DO BIFACIAL MEASUREMENTS FOR – IEC 63202-3 (CD) - 1

Bifacial Flash Profile



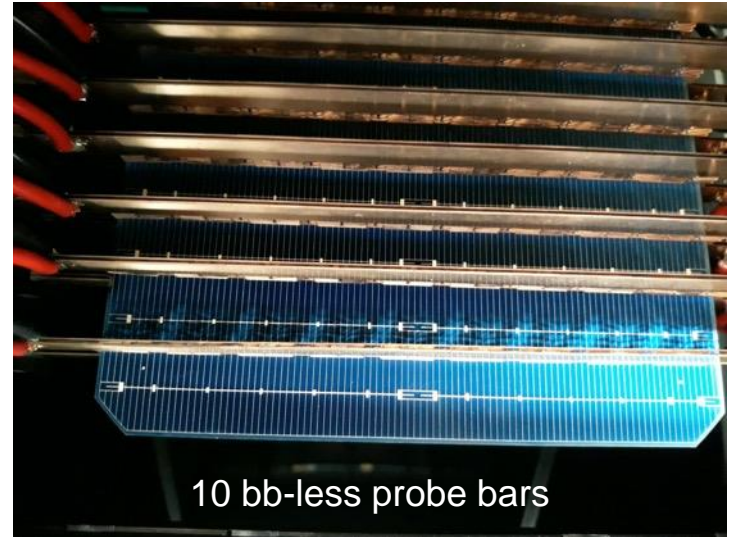


# LED's DO BIFACIAL MEASUREMENTS FOR – IEC 63202-3 (CD) - 2

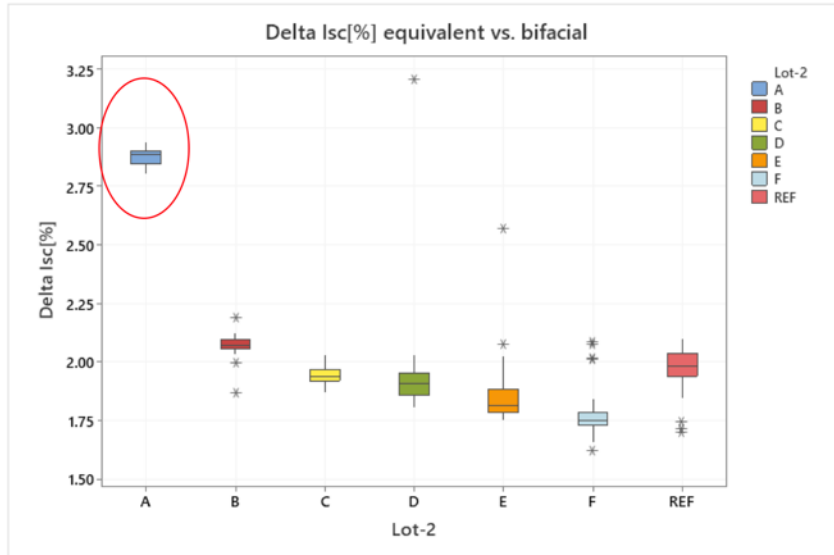


# LED's DO BIFACIAL MEASUREMENTS FOR – IEC 63202-3 (CD) - 3

- Measurement of 300 PERC solar cells sorted in 6 different batches ranging from 65% to 71% bifaciality
- Cells measured with 10 bb-less probe bars
- Recipe sequence included all steps in order to avoid recontacting



# LED's DO BIFACIAL MEASUREMENTS FOR – IEC 63202-3 (CD) - 4



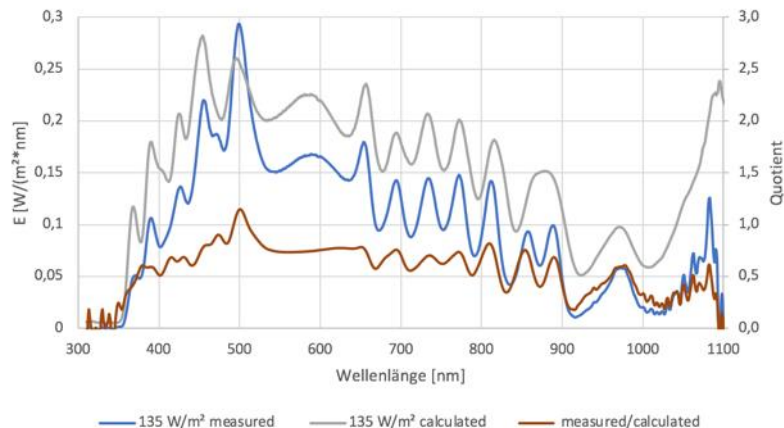
Possible origin of rel. deviation in Isc between **equivalent & bifacial measurement** :

- from spectral mismatch between measurement cell & intensity sensor/monitor cell
- Spectral distribution of the rear side flasher @135W/m<sup>2</sup>

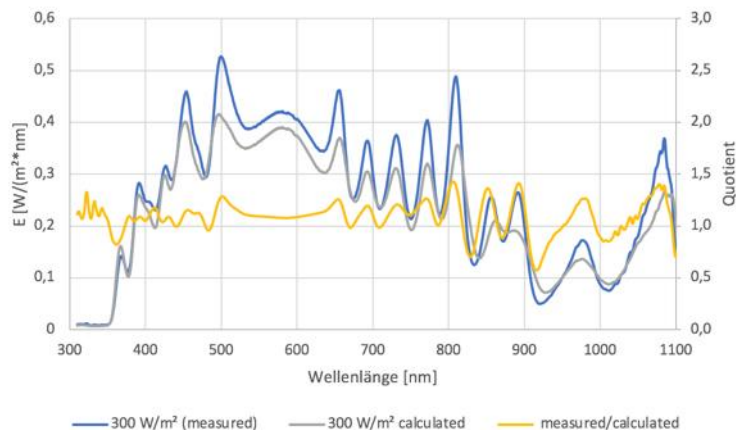
➤ Need of Isc calibration values of reference cells: a) 1000 W/m<sup>2</sup> front, b) 1135 W/m<sup>2</sup> front, c) 135 W/m<sup>2</sup> rear

# LED's DO BIFACIAL MEASUREMENTS FOR – IEC 63202-3 (CD) - 5

Measured vs. calculated spectrum @ 135W/m<sup>2</sup> & Quotient -  
before bugfix



Measured vs. calculated spectrum @ 300W/m<sup>2</sup> & Quotient -  
-after bugfix



- After bug fixing, the linearity of low light irradiance, the spectral distribution  $\approx 1000\text{W/m}^2$

# LED's DO BIFACIAL MEASUREMENTS FOR – IEC 63202-3 (CD) - 6

For bifacialities +/-3%

$$-0.1\% < \Delta I_{sc} < 0.1\%$$

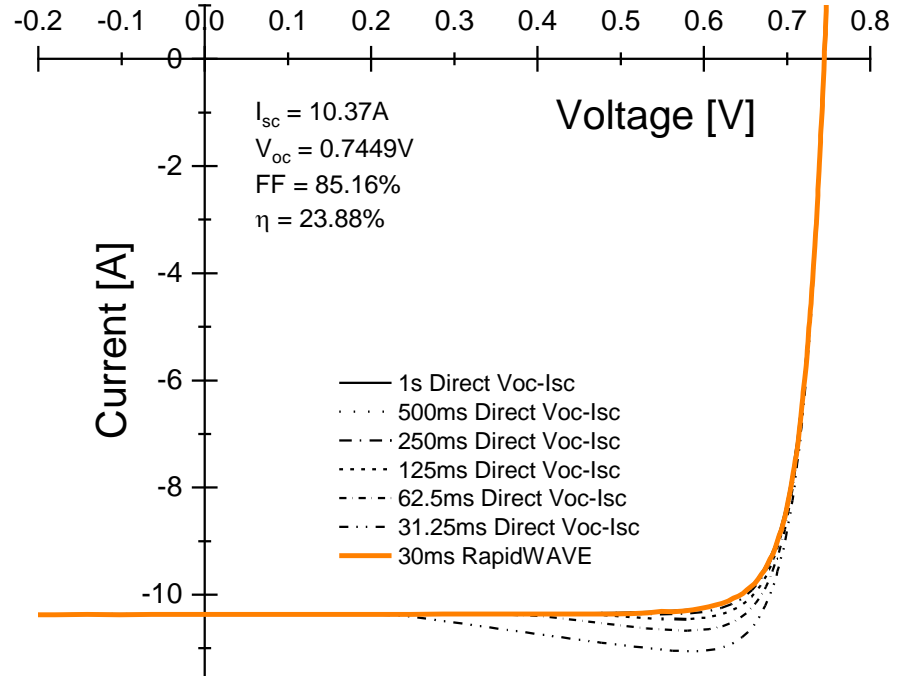
$$0.1\% < \Delta V_{oc} < 0.2\%$$

$$-0.3\% < \Delta FF < -0.1\%$$

- Equivalent vs. Bifacial shows good agreement for  $I_{sc}$ ,  $V_{oc}$  &  $FF$
- **But** rear side process problems can not be determined easily in case of process drift

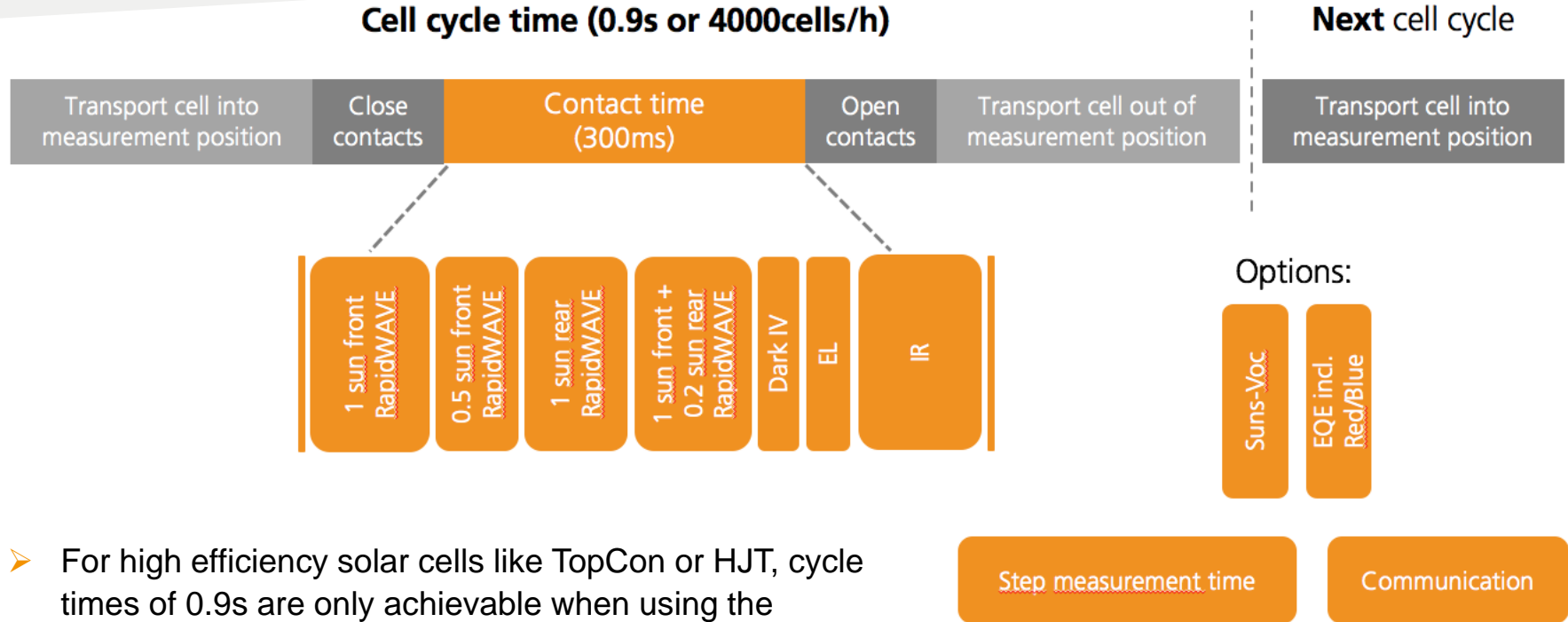
# LED's MEASURE BIFACIAL WITH RAPIDWAVE

- RapidWAVE function can reproduce a 1s IV curve for a HJT cell with a Voc of 744.9mV in 30ms



Accurate high throughput current-voltage classification of high efficiency silicon solar cells with RapidWave, B. Mitchell et al - EUPVSEC, Milano, 2022

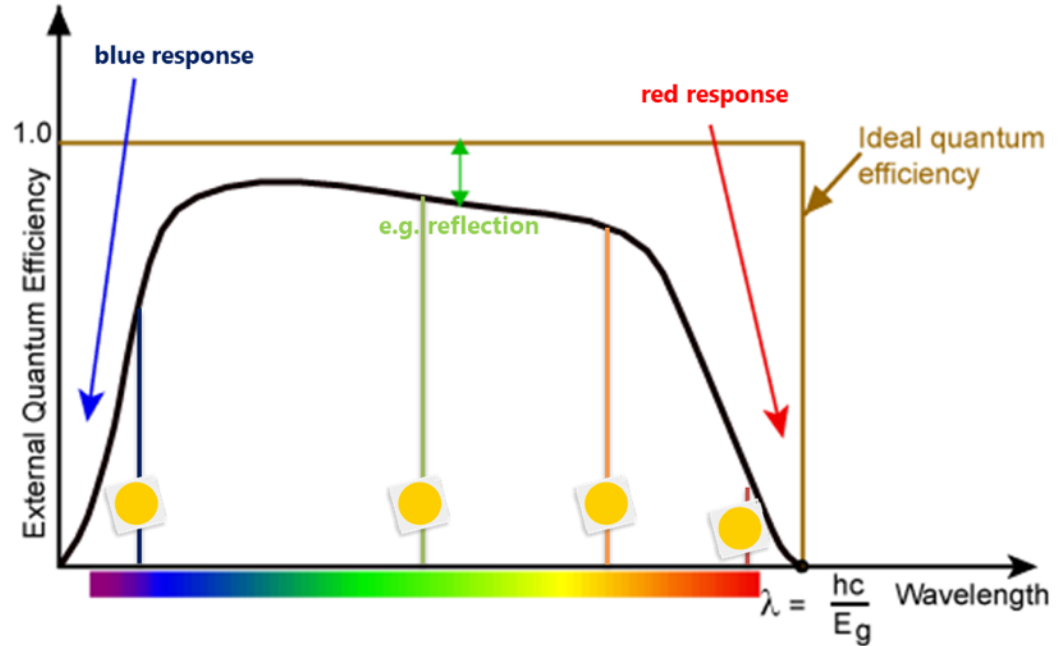
# LED's MEASURE BIFACIAL WITH RAPIDWAVE



- For high efficiency solar cells like TopCon or HJT, cycle times of 0.9s are only achievable when using the RapidWAVE

# LED's USE THE ADVANTAGE OF LEDs

- EQE describes how efficient the conversion of incoming light into charge carriers occurs
- Isc as function of LED wavelength
- Allows tracing and separation of process impacts on front and rear side of the solar cell

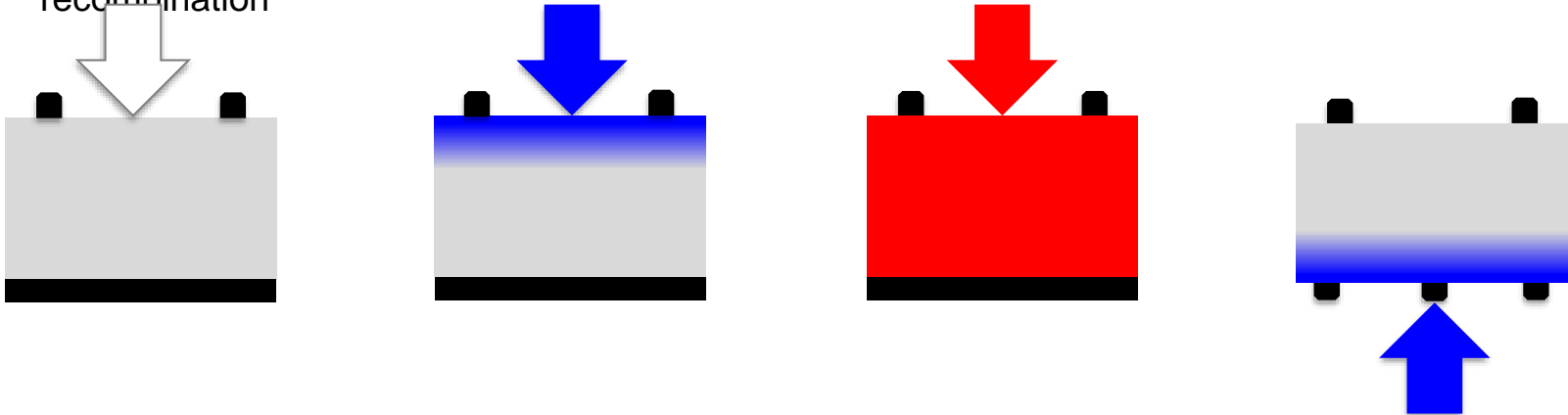




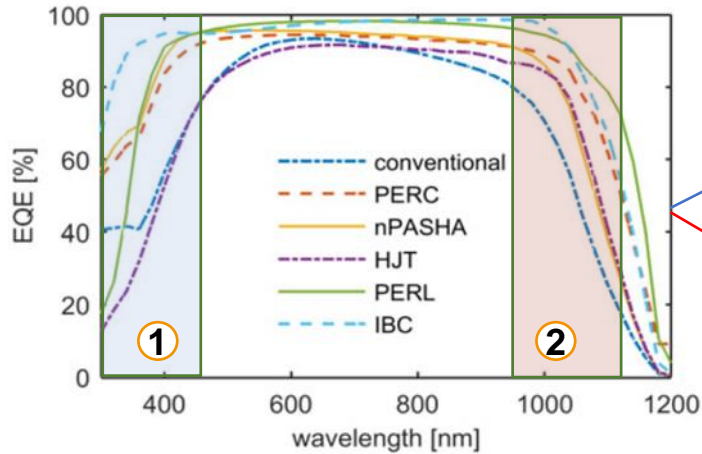
# LED's DO SPECIAL BIFACIAL THINGS

Use monochromatic light to improve your process control

- emitter quality & front reflection with blue light
- base material quality & rear passivation with red light
- for bifacial cells, rear side irradiance helps to distinguish between bulk & surface recombination

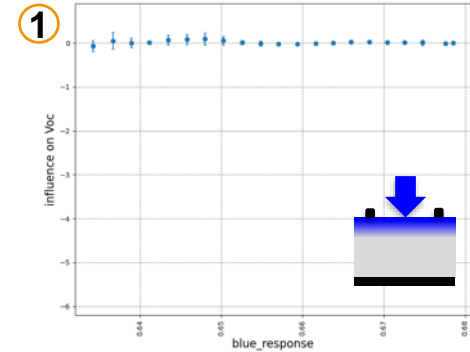


# LED's ANALYSE SPECIAL BIFACIAL THINGS

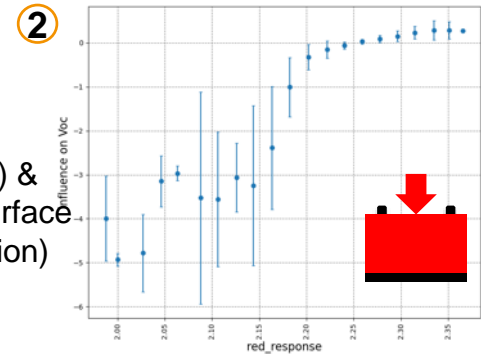


- Mean values of 60.000 cells averaged over the interval of blue & red Isc response
- Dependence of mean Voc on the material quality is measured by the red response

**1) Blue response:** dominated by carrier recombination in the front (emitter) region



**2) Red response:** mainly influenced by recombination in the bulk (material quality) & the rear side (rear surface and contact passivation)



# LED's SHINE BIFACIAL IN PRODUCTION



	SINUS-300	RSF-300
Spectral match better than class A+	++	+
Uniformity of light source class A	+	+
Temporal stability class A	++	++
0.2 to 1.3 suns irradiation possible for both light sources	+	+
Suitable for high-efficiency solar cells (RapidWAVE)	+	+
Flexibility of spectrum (e.g. red & blue measurement)	+	+
More than 2 years lifetime	+	+

# LED's SHINE BIFACIAL ON MODULES – LS-72

- Future modul flasher suitable for bifacial modules
- Fully customizable multi-wavelength spectrum (accord. to IEC 60904-9- Ed. 3)
- optimized for new module sizes (containing M12 cells)
- combining additional measurements steps like EL & HiPot Testing
- Fast cycle times down to ~ 20s
- High efficiency modules measuring with RapidWAVE







# LED's DO SOME SERIOUS NAME-DROPPING



# THANK YOU FOR YOUR ATTENTION



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