Toward the standardisation of the power rating of bifacial solar devices

BifiPV workshop 2018, Denver, Colorado

G. Arnoux[1,*], N. Bassi[1], V. Fakhfouri[1], R. Ambigapathy[1], J. Levrat[2], J. Geissbühler[2], M. Despeisse[2], C. Ballif[2] and the IEC TS 60904-1-2 project team.

[1]PASAN SA (Meyer Burger), Rue Jaquet-Droz 8, 2000 Neuchâtel, Switzerland

[2]CSEM, PV-Center, Rue Jaquet-Droz 1, CH-2002 Neuchâtel, Switzerland,

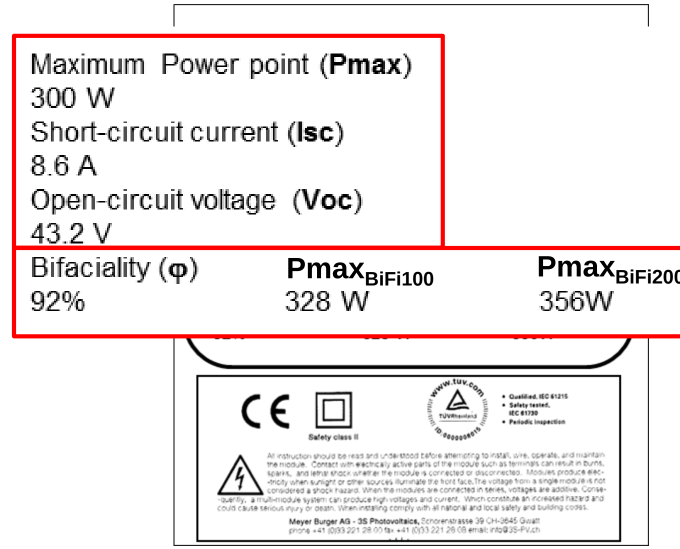
Technical specification (TS) IEC 60904-1-2

MEYER BURGER

- Status of the TS
  - May 2018 : Committee draft (CD) submitted and accepted (with comments) by national committees (100% of the 22 voters accepted)
  - July 2018 : Comments addressed and TS circulated within WG2
  - September 2018 : Last comments from WG2 received.
  - October 2018 : Formal approval of TS by project team
  - Submission to the IEC office and initiation of publication process
  - Publication foreseen January 2019 (no delay expected)
- No significant changes of the content since Vahid's presentation [bifiPV workshop 2017]

IEC TS 60904-1-2 at a glance

MEYER BURGER

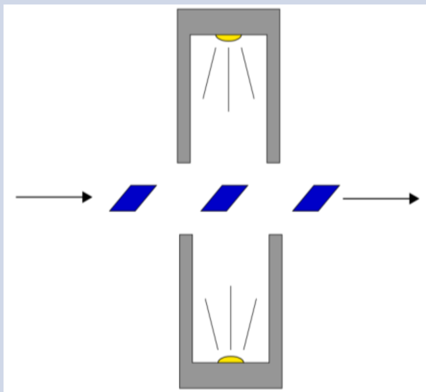
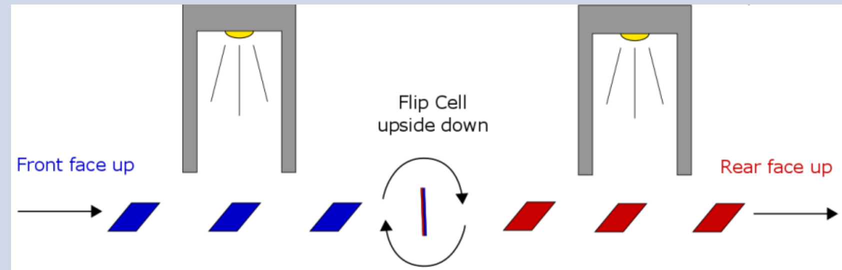


- What shall be reported
  - Key data at STC conditions (IEC 60904-1)
  - Bifaciality
  - $P_{max,BiFi100}$ and $P_{max,BiFi200}$
- Can be derived from a reference device
  - I-V characteristics at STC (IEC 60904-1)
  - Calculate $P_{max,BiFi100}$ and $P_{max,BiFi200}$
- Full characterisation of bifacial devices
  - Bifaciality: $\boldsymbol{\varphi} = \min\{\varphi_{Isc}\ ;\ \varphi_{Pmax}\}$ at STC
    - $\varphi_{Isc} = I_{sc,rear}/I_{sc,front}$
    - $\varphi_{Pmax} = P_{max,rear}/P_{max,front}$
  - Rear irradiance driven power gain yield: ***BiFi*** [W/(Wm^{-2})]
    - Additional peak power per irradiance unit at the rear side (eg 0.28 W/(Wm^{-2}))
- Indoor full characterisation proposes two methods
- An example case study: full characterisation of bifi cells in production

premium technology standard by pasan

Illuminating front and back

MEYER BURGER

Double, simultaneous illumination	Single, sequential illumination
	

Get bifaciality: $\varphi = \min\{\varphi_{Isc} \, ; \, \varphi_{Pmax}\}$

Front and rear at STC (1000 W/m^2)

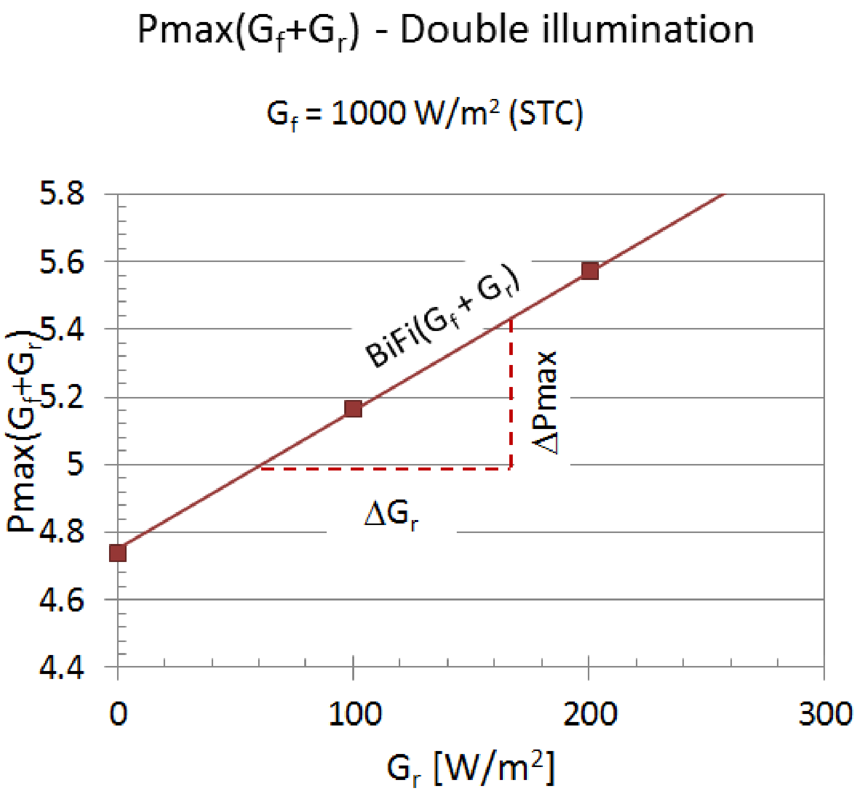
Get rear irradiance driven power gain yield: *BiFi*

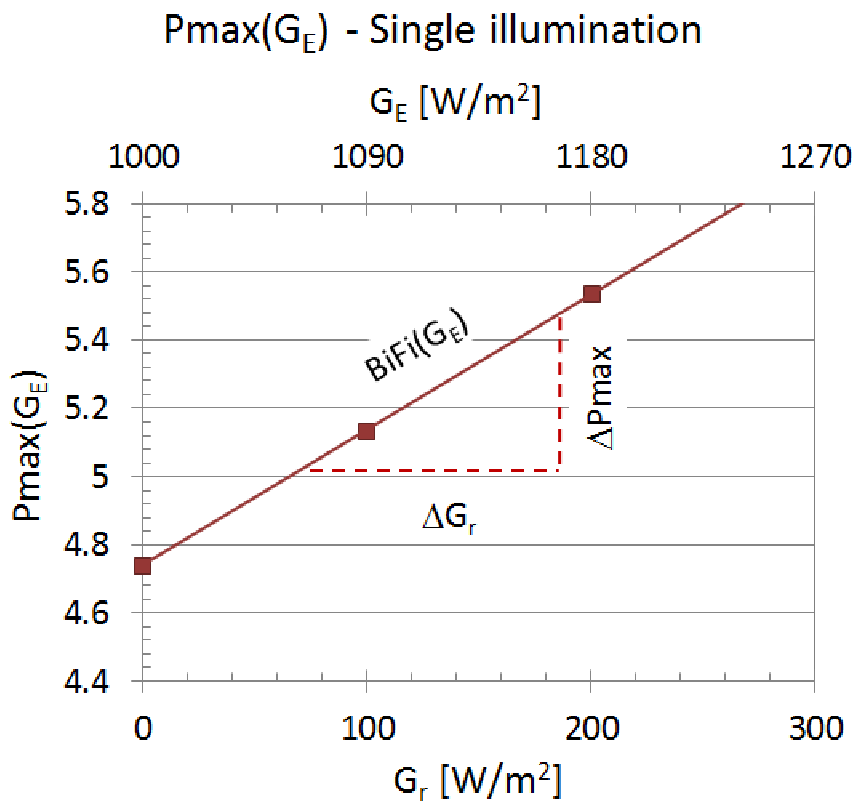
Front at STC and 2 rear illuminations	Front at STC and 2 equiv. irradiances: G_{Ei}
• Two rear illuminations: • $G_{r,1}$ and $G_{r,2}$	• Two equivalent irradiances: • $G_{Ei} = 1000 + \varphi \bullet G_r$ • With: $G_r = G_{r,1}$ and $G_{r,2}$

y

REAR IRRADIANCE DRIVEN POWER GAIN YIELD

MEYER BURGER



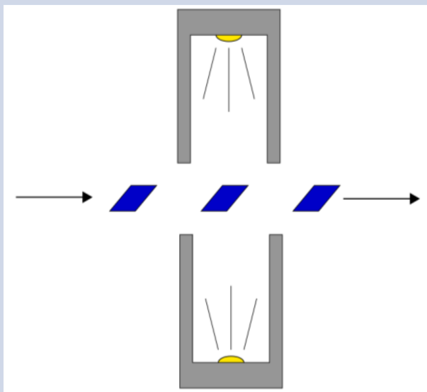


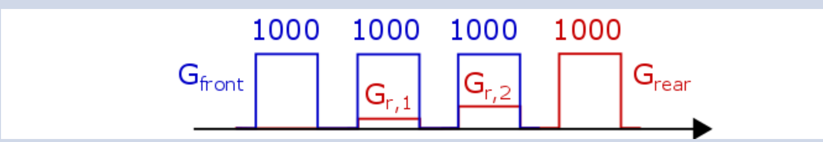
- *BiFi* [mW/(W/m^2)] = slope of linear fit of *Pmax*(G_{rear}):
- Provides the gain on Pmax by irradiance unit on the rear side compared to STC conditions

ILLUMINATING FRONT AND BACK

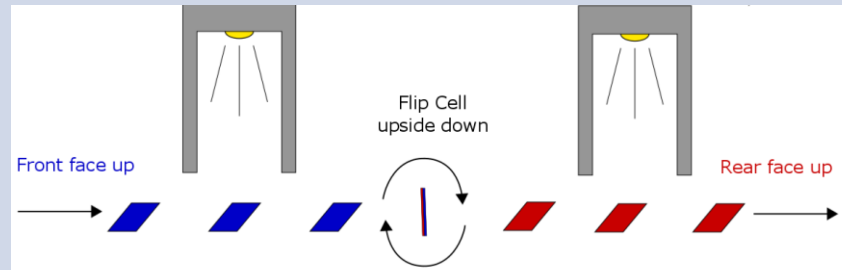
MEYER BURGER

Double, simultaneous illumination





Single, sequential illumination



ILLUMINATING FRONT AND BACK - METROLOGY

MEYER BURGER

	Double, simultaneous	Single, sequential illumination
Advantages	- The closest to real situation	- No shadowing of belts (cell production)* - Irradiance compensation IEC 60891 - Use existing contacting systems for BB0 cells
Disadvantages	- Shadowing of belts (for cell production)* - Undefined irradiance and temperature compensation	- Requires equivalent irradiance method (G_E).

*Cell shadowing leads to FF underestimate **(~ -0.5% with 5%** of shadowing)
[J. Levrat et al, white paper, CSEM]

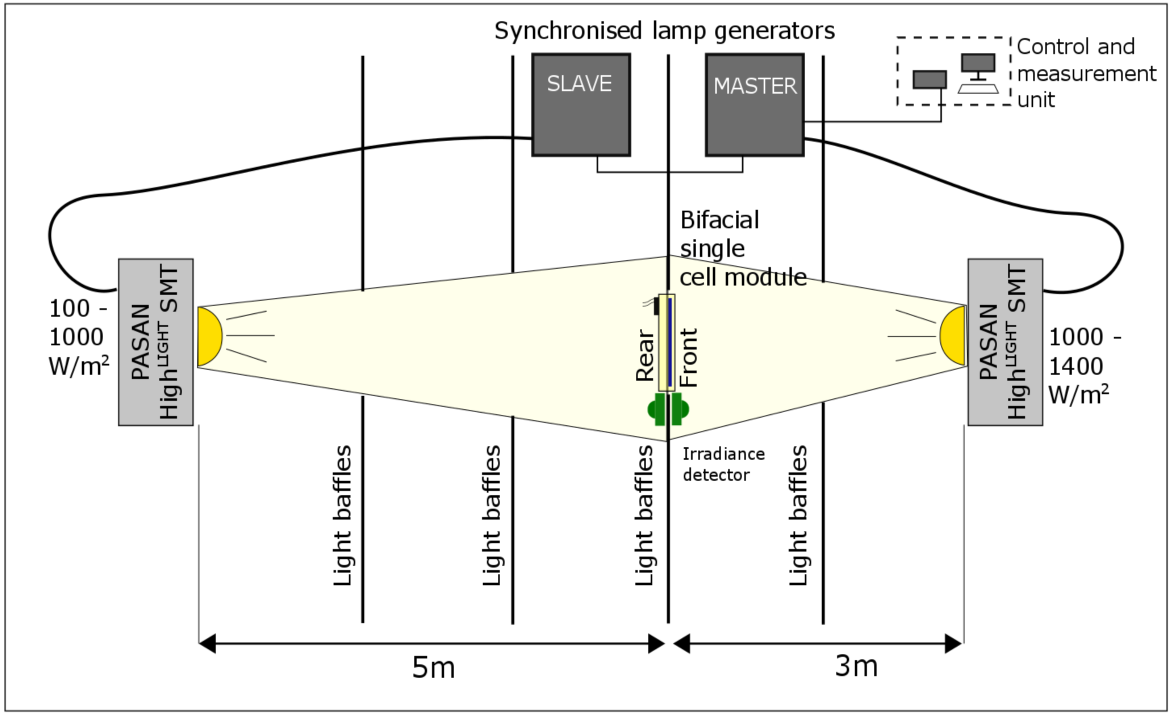
Is G_E method equivalent to simultaneous illumination?

premium technology standard by pasan

EXPERIMENTAL SETUP

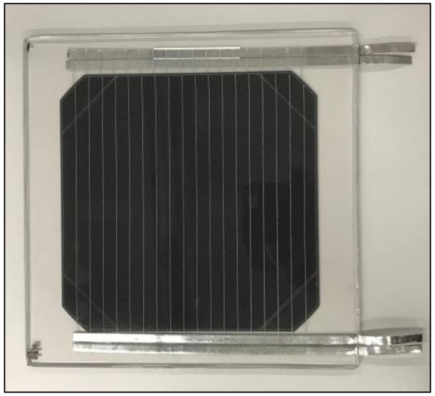
MEYER BURGER

PASAN Bifacial double source solar simulator



Single cell module

Front



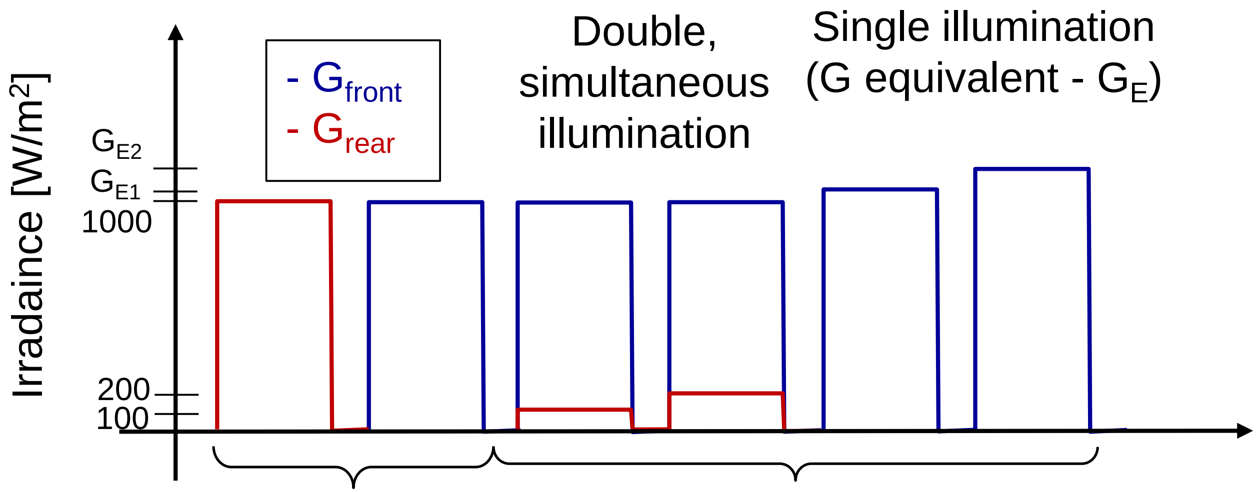
Rear

Single, encapsulated (glass/glass), BB0 cell + SWTC®

premium technology standard by pasan

EXPERIMENTS

MEYER BURGER



bifaciality

Rear irradiance driven power gain yield: *BiFi*

$$\varphi_{I_{sc}} = \frac{I_{scr}}{I_{scf}} \qquad \varphi_{Pmax} = \frac{P_{maxr}}{P_{maxf}}$$

Double illumination

Single, sequential illumination

$$\varphi = \min\{\varphi_{I_{sc}}; \varphi_{mpp}\}$$

BiFi (G_{front} + G_{rear})

BiFi (G_E)

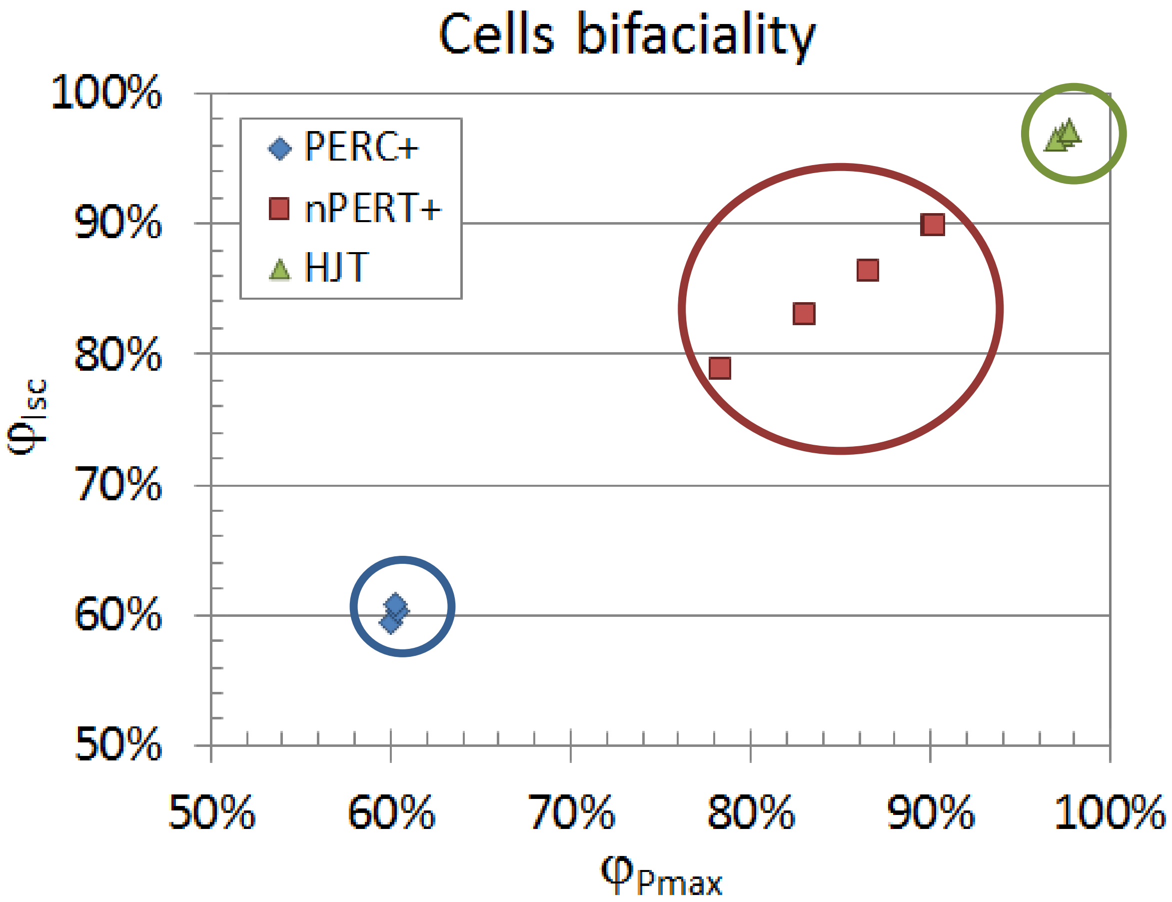
Equivalent irradiance

$$G_E = G_{front} + \varphi G_{rear}$$

premium technology standard by pasan

REPRESENTATIVE SAMPLES

MEYER BURGER

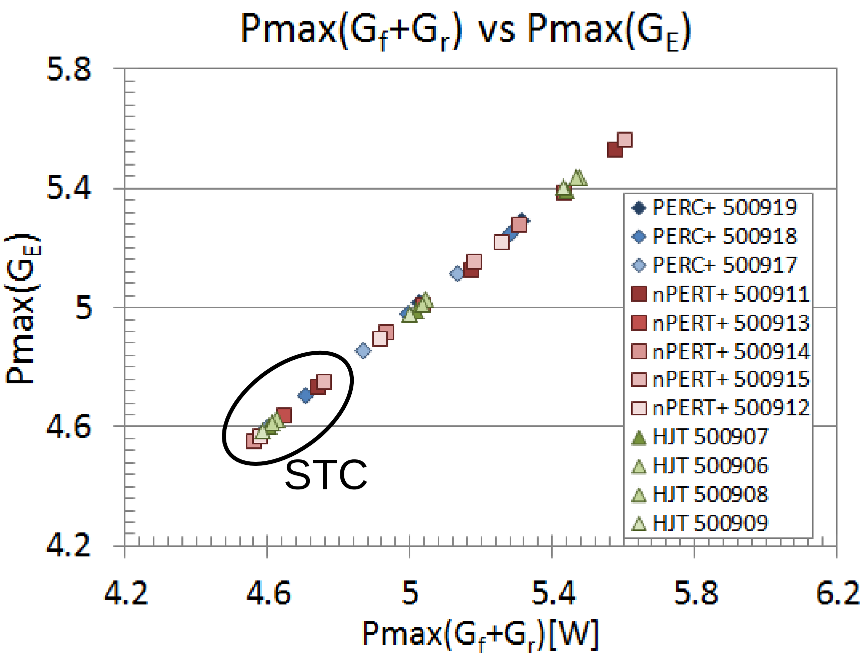


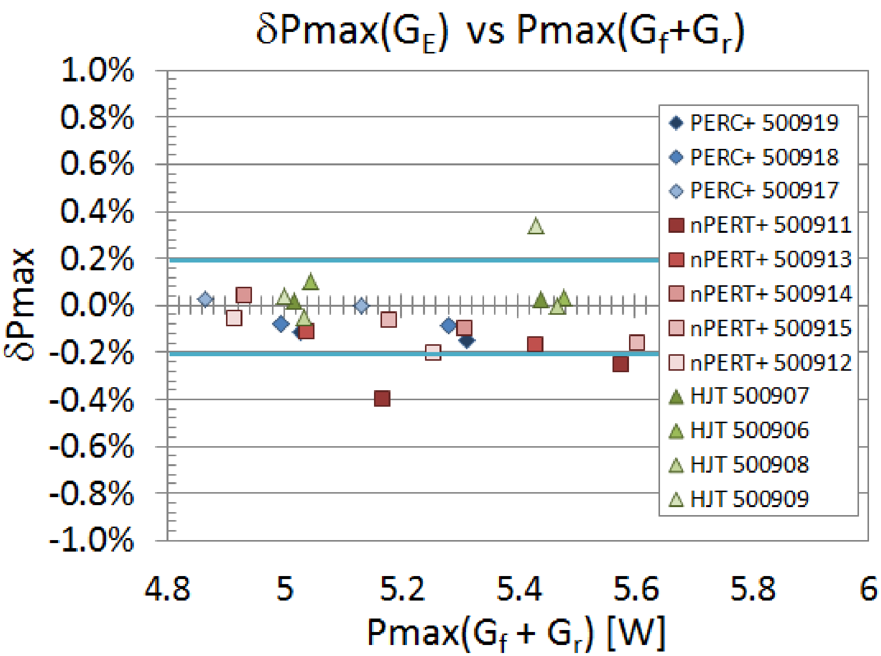
- 12 DUT samples:
  - 3x PERC+
  - 5x nPERT+
  - 4x HJT

premium technology standard by pasan

Pmax MEASUREMENTS

MEYER BURGER



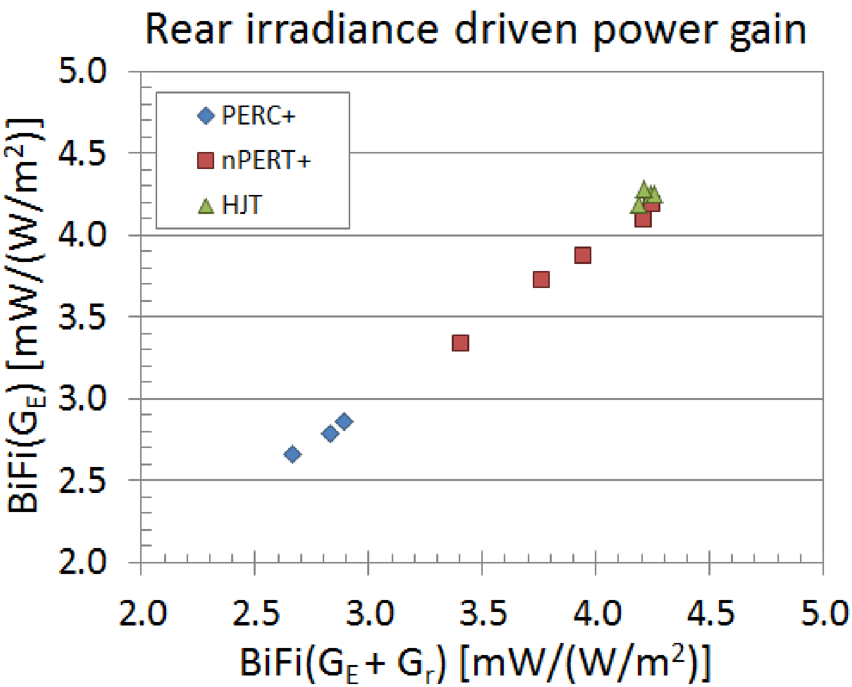


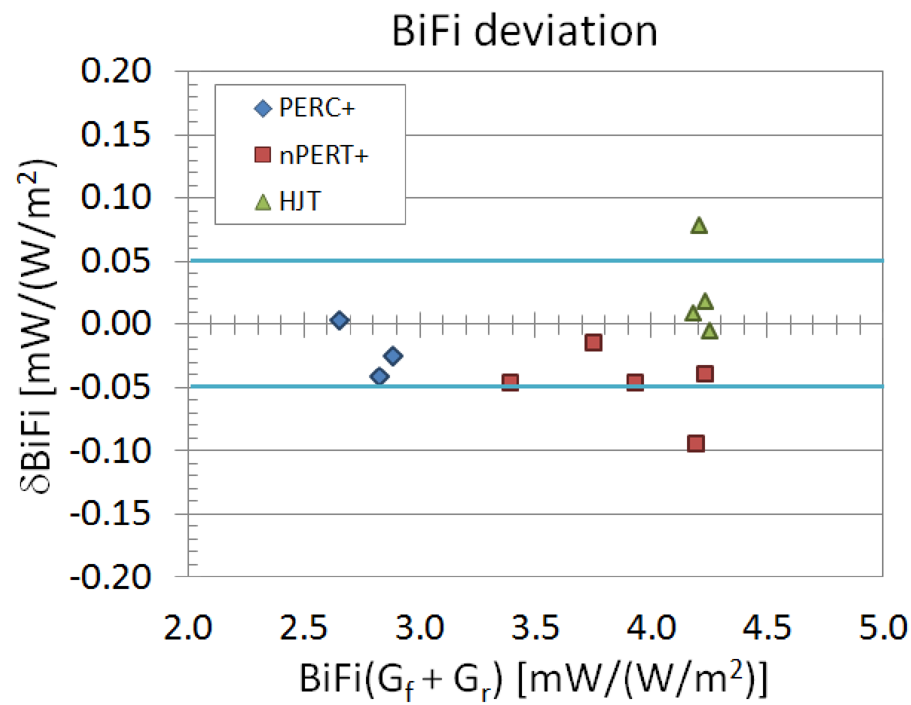
- Quantify deviation between methods: $\delta Pmax = \dfrac{Pmax(G_E)}{Pmax(G_f + G_r)} - 1$
  - $|\delta Pmax| < 0.2\%$ for 85% of the measurements
  - Independent of cell technology or rear irradiance level (up to G_r = 200 W/m^2)

premium technology standard by pasan

MEYER BURGER

REAR IRRADIANCE DRIVEN POWER GAIN YIELD





- Difference between methods: $\delta BiFi = BiFi(G_E) - BiFi(G_f + G_r)$
  - $|\delta BiFi| \leq 0.05$ mW/(W/m2) (for 83% of the samples)
  - For example: error on $Pmax_{BiFi200}$ < ±10mW (0.2% on a 5W cell)

CONCLUSION

MEYER BURGER

Is G_E method equivalent to double illumination?

- The simple answer is YES in the context of our study.
- Each approach has its advantages.
- The G_E is more suitable for BiFacial – Busbarless cells.
- Next steps compare the two methods in real world conditions.
- With experience TS 60904-1-2 can become a real standard

MEYER BURGER

Thank you for you attention

gilles.arnoux@meyerburger.com

premium technology standard by pasan

MEYER BURGER

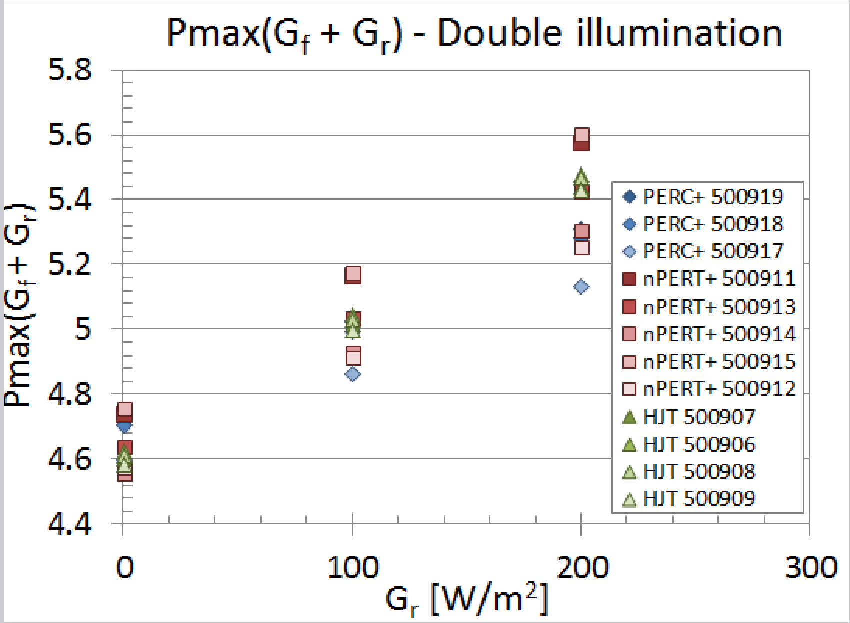
Supplementary material

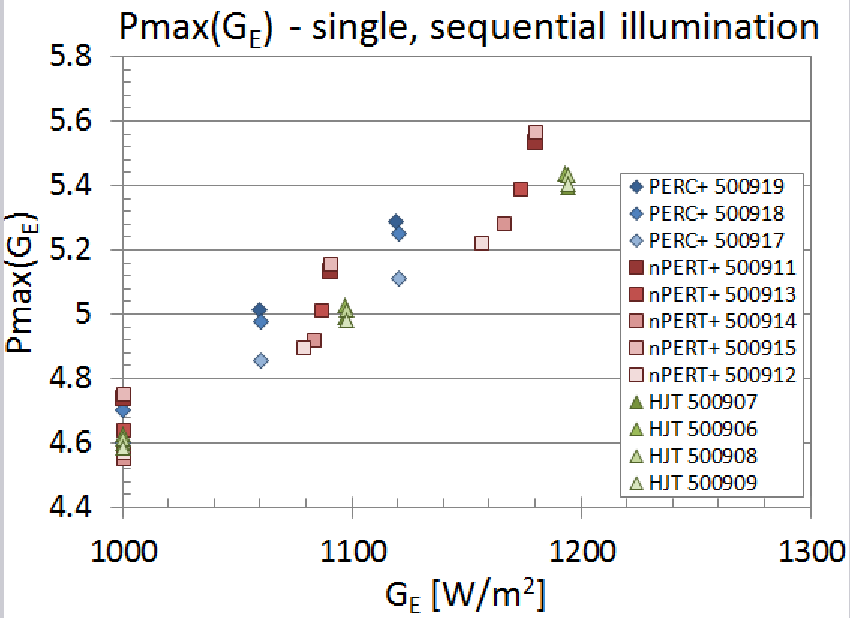
premium technology standard by pasan

POWER RATING MEASUREMENTS

MEYER BURGER

Double, simultaneous illumination	Single, sequential illumination



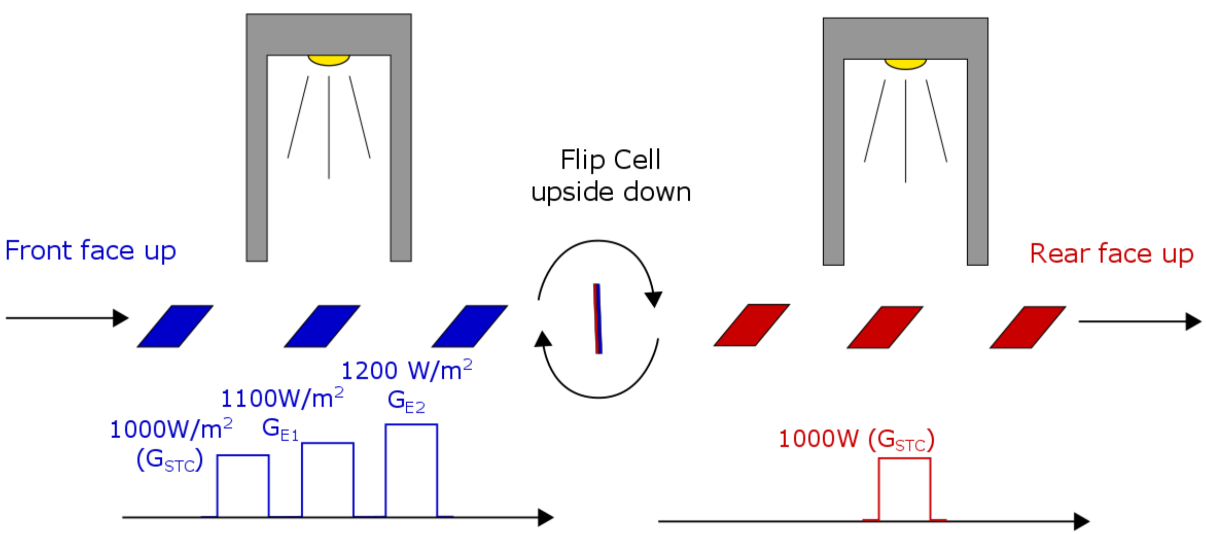


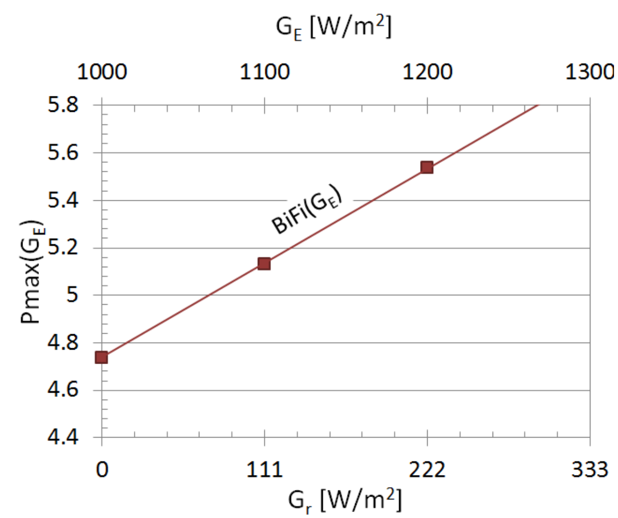
premium technology standard by pasan

Sequence Face Up first

MEYER BURGER

- Bifaciality not known upfront → Fixed equivalent irradiance
  - $G_{E,1}$ = 1100 W/m^2
  - $G_{E,2}$ = 1200 W/m^2
- Determine corresponding rear irradiance: $G_{r,i} = (G_{E,i} - 1000)/\varphi$
- *BiFi* can be determined independently of what face is up first





premium technology standard by pasan

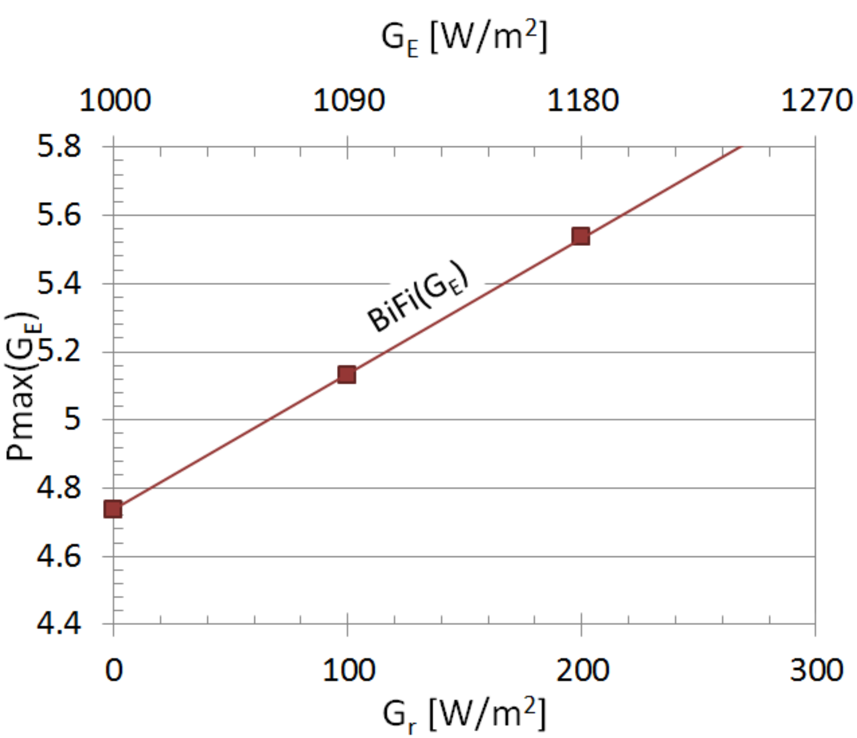
Face up/down first: differences

MEYER BURGER

Face down first

$G_{E,i}$ calculated upfront

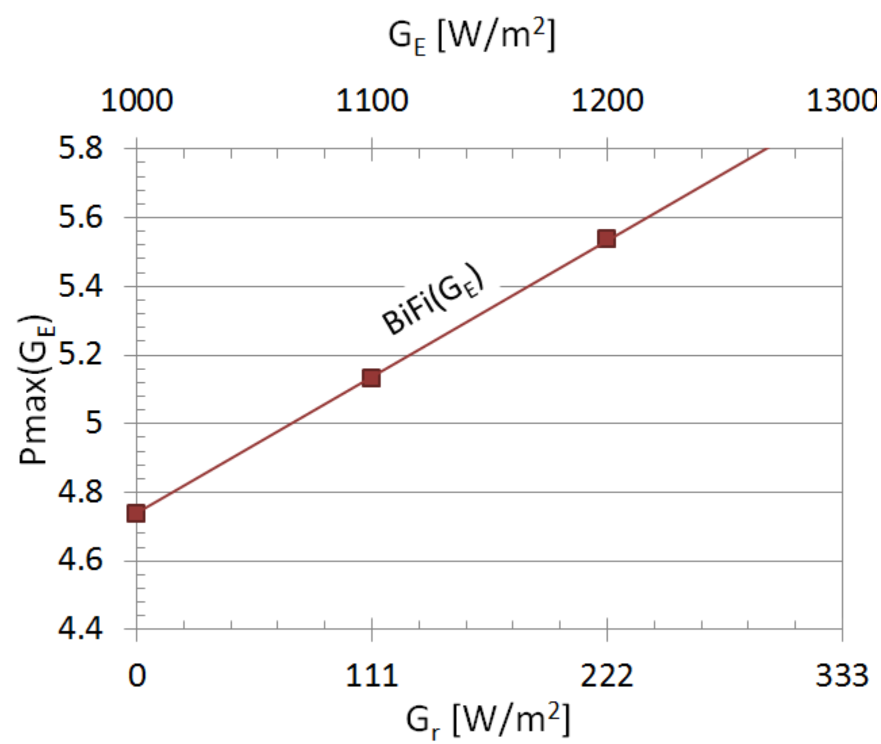
$G_{r,i}$ is fixed (100 and 200 W/m^2)



Face up first

$G_{E,i}$ fixed upfront (1100 and 1200 W/m^2)

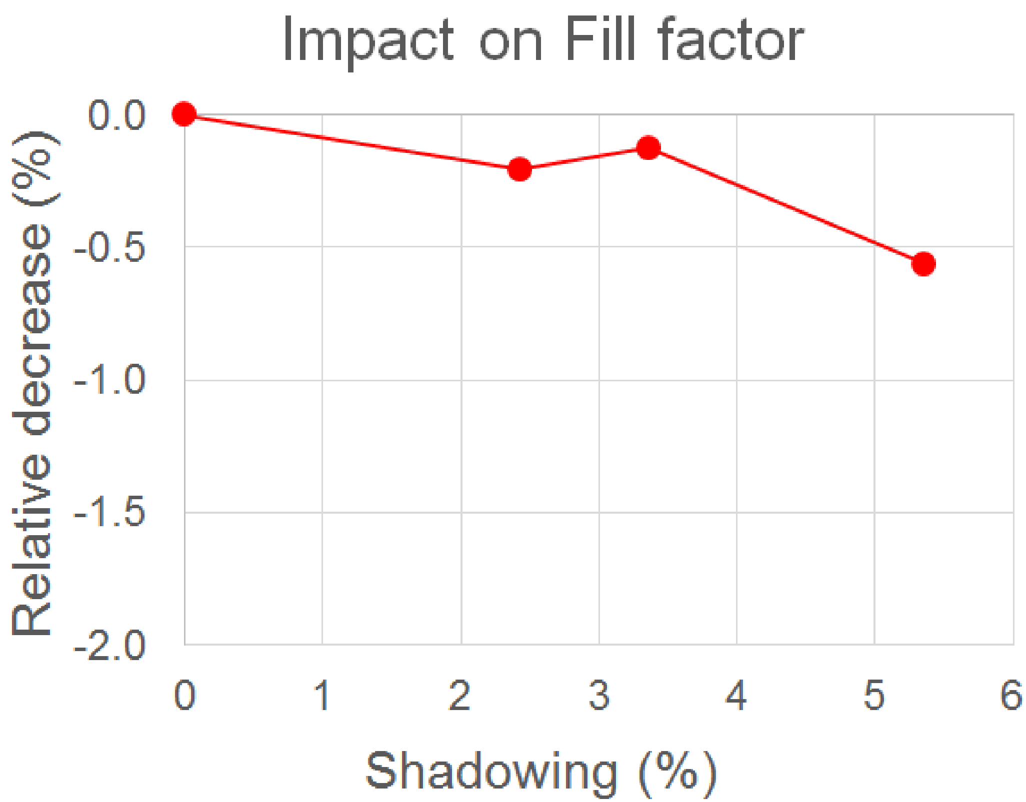
$G_{r,i}$ derived postprocess



In both cases BiFi is determined

premium technology standard by pasan

Impact of shadowing

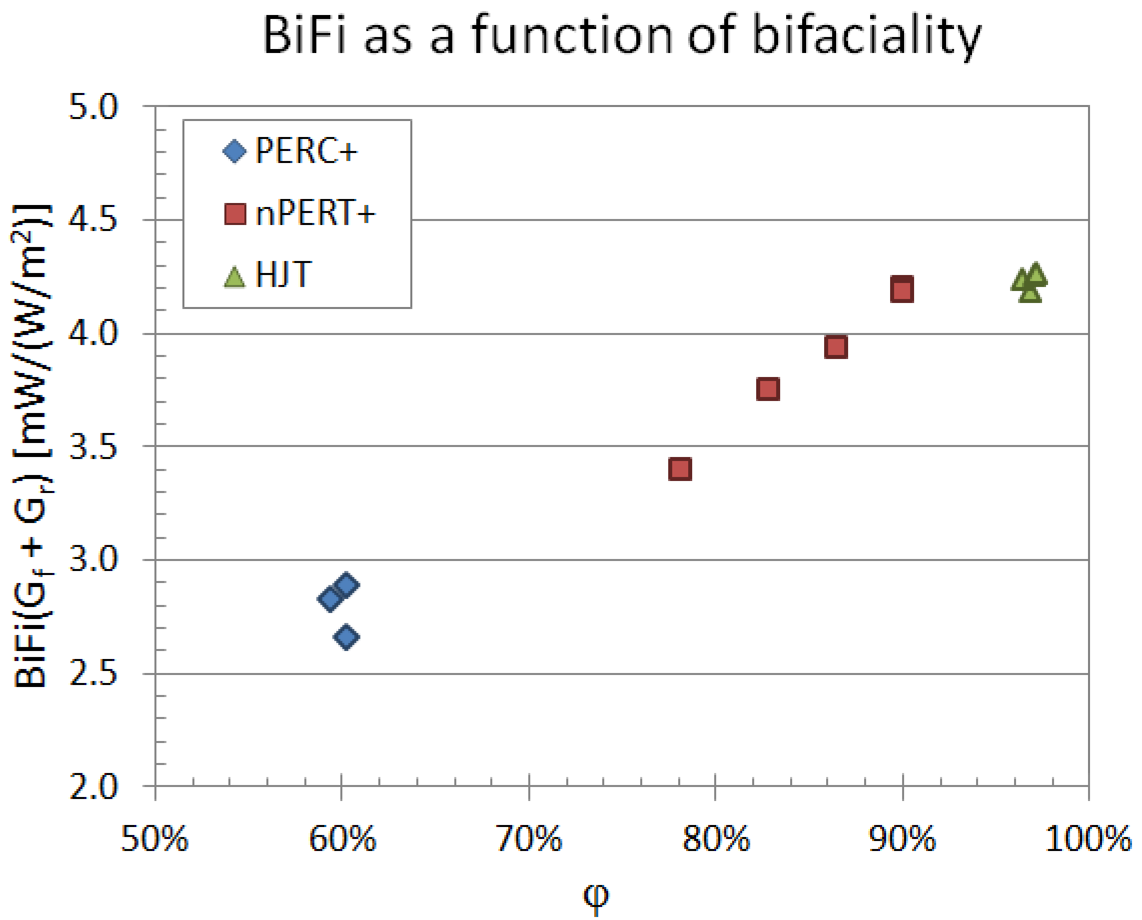


J. Levrat et al., CSEM, not published (2018)

premium technology standard by pasan

BiFi DEPENDENCE ON BIFACIALITY

MEYER BURGER



premium technology standard by pasan