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IEC 60904-1-2: Measurement of current-voltage characteristics of bifacial photovoltaic devices

V. Fakhfouri, bifiPV workshop, October 2017, Konstantz (DE)

Outline

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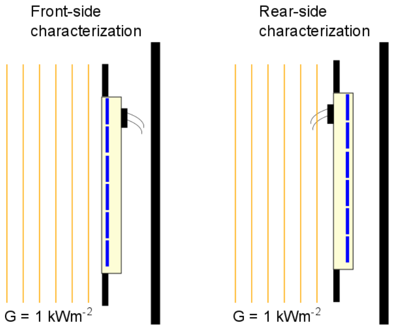
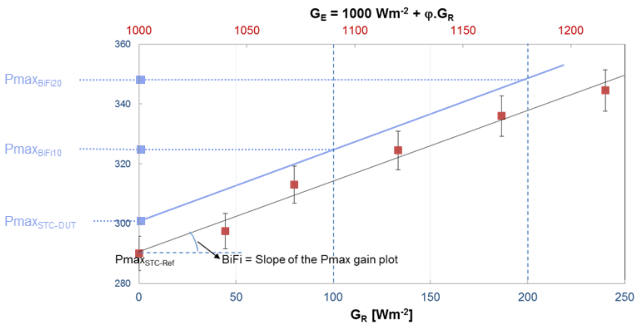
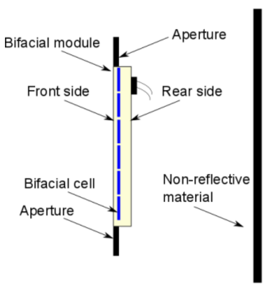


1. IEC BiFi Standard; project status
2. Standard I-V measurement of Bifacial devices
3. I-V measurement challenges





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IEC BiFi project status

On 26th October 2017

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Project Reference	Document Reference	Init. Date	Current Stage	Next Stage	Working Group	Project Leader	Fcst. Publ. Date
IEC TS 60904-1-2 ED1 Photovoltaic devices - Part 1-2: Measurement of current-voltage characteristics of bifacial photovoltaic (PV) devices	82/1289/CD 476 kB	2016-02	ADTS 2017-08	TDTS 2018-02	WG 2	Vahid Fakhfouri	2018-03

Stage	Decision date	Target date
PNW Proposed New Work	23 Oct. 2015	
ANW Approved New Work	05 Feb. 2016	Mar. 2017
ACD Approved for Committee Draft	06 Feb. 2016	Feb. 2017
ADTS Approved for Draft Technical Specification	31 Mar. 2017	Apr. 2017
A2CD Approved for 2nd Committee Draft	05 May 2017	May 2017
CD Committee Draft	12 May 2017	May 2017
PCC Preparation of CC Document	04 Aug. 2017	Aug. 2017
ADTS	11 Aug. 2017	Feb. 2018
TDTS Translation of DTS		Feb. 2018

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IEC BiFi standard method at a glance

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	Analogy: T° coefficients	Measurement	Device	Output
Laboratory	Determination of α, β, κ	Bifaciality measurement	Reference device	Bifaciality coefficients
		Bifacial gain determination	Reference device	Bifaciality gain factor
Production	$Pmax_{DUT\text{-}T°}$ measurement $Pmax_{STC}$ (calculated)	STC measurement	Production batch (of the **same BOM** as the Reference)	$Pmax_{STC}$ $Pmax_{BiFi}$ (Calculated)

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Step 1: Bifaciality measurement

…In PV laboratory

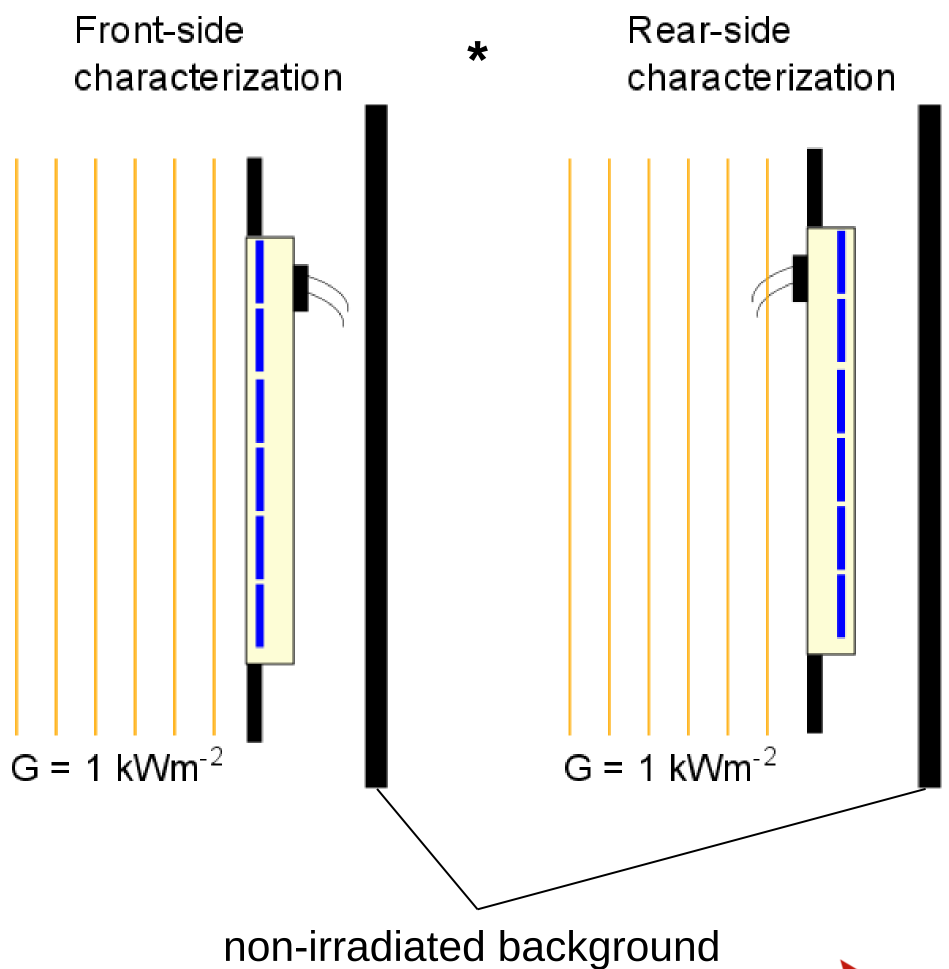
- Bifaciality coefficients:

$$\varphi_{Isc} = \frac{Isc_r}{Isc_f}$$

$$\varphi_{Voc} = \frac{Voc_r}{Voc_f}$$

$$\varphi_{Pmax} = \frac{Pmax_r}{Pmax_f}$$

$$\varphi = Min(\varphi_{Isc}, \varphi_{Pmax})$$



** Applies also for cells.*

Step 2: Bifacial gain determination

…In PV laboratory

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- Outdoor or Indoor with double-side illumination:

  at 1sun on the front side and G_{R_i} on the rear side (at least 3 levels)

- Indoor:

  at equivalent 1-side irradiance levels G_{E_i} (at least 3):

$$G_{E_i} = 1000Wm^{-2} + \varphi \cdot G_{R_i};$$

$$i = 1, 2, 3, \ldots$$

$$\varphi = Min(\varphi_{Isc}, \varphi_{Pmax})$$

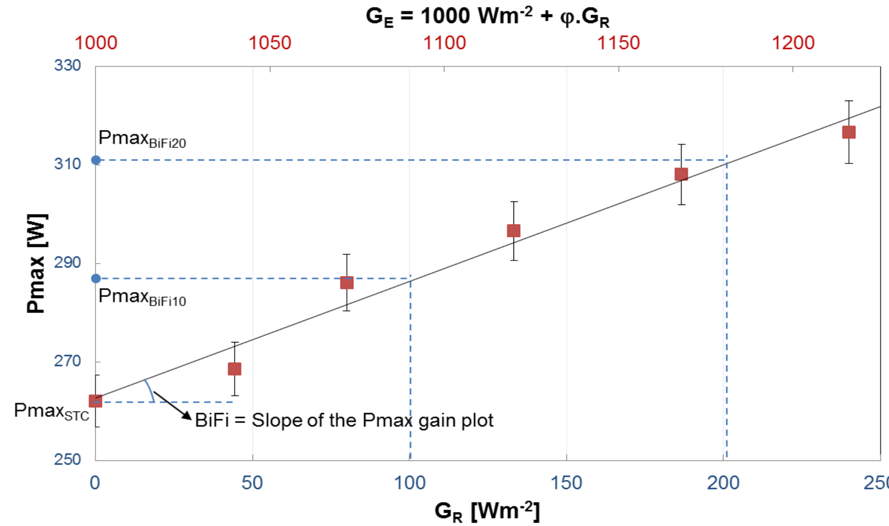
Example: For $\varphi = 80\%$,

$$G_{R_1} = 100Wm^{-2}$$

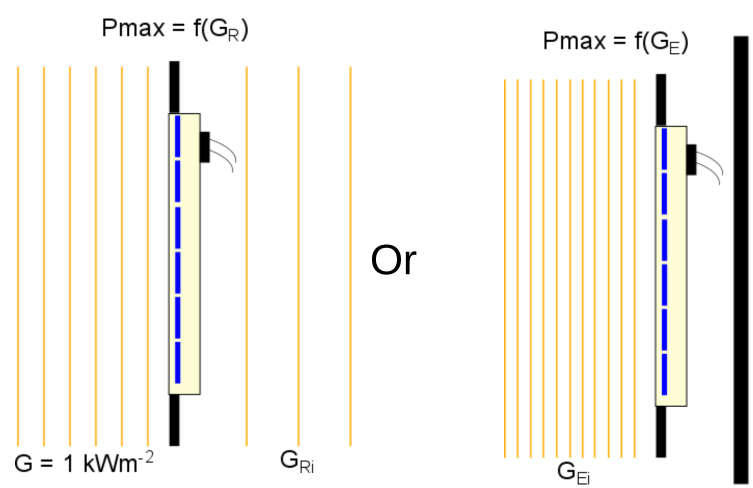
$$G_{R_2} = 200Wm^{-2}, \ldots$$

$$\rightarrow G_{E_1} = 1080Wm^{-2}, G_{E_2} = 1160Wm^{-2}$$

- Pmax reporting with 2 specific bifacial gains:
  - *$Pmax_{BiFi10}$* with 1kWm^{-2} on the front and G_R=100Wm^{-2} or at G_E = 1kWm^{-2} + φ . 100Wm^{-2}
  - *$Pmax_{BiFi20}$* with 1kWm^{-2} on the front and G_R=200Wm^{-2} or at G_E = 1kWm^{-2} + φ . 200Wm^{-2}



Examples of Pmax as a function of irradiance level on the rear side G_R (for outdoor or double-side illumination) or its 1-side equivalent irradiance G_E



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Power rating of Bifacial PV devices

In practice

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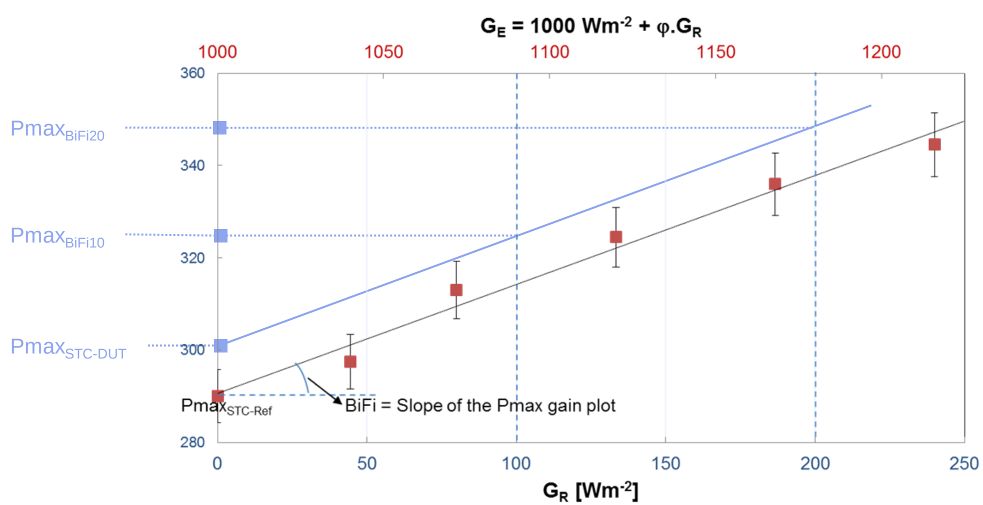
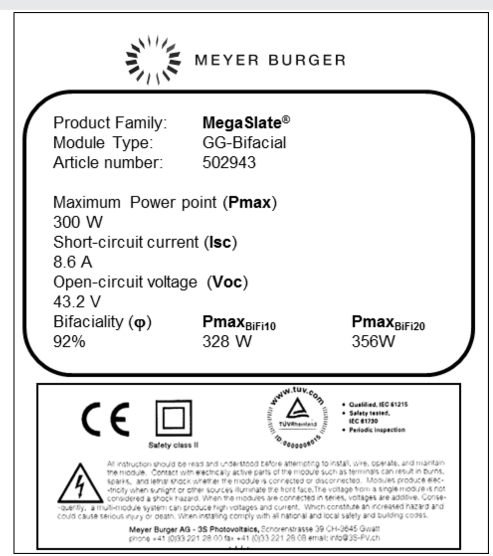
	Modules	Cells
PV Laboratories	• STC (monofacial) measurement of the key data → Reference module • Bifaciality coefficients measurement • Bifacial gain determination	• STC (monofacial) measurement of the key data → Reference cell • Bifaciality coefficients measurement • Bifacial gain determination
PV Production	• Calibration using the Reference module • IV measurement of each device at STC, $Pmax_{STC}$ reporting • $Pmax_{BiFi10}$ and $Pmax_{BiFi20}$ calculation and reporting (based on $Pmax_{STC}$ and BiFi gain factor)	• Calibration using the Reference cell • IV measurement of each device at STC, $Pmax_{STC}$ reporting • Bifaciality coefficients and Bifacial gain reporting (datasheet)

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Product Family: MegaSlate®
Module Type: GG-Bifacial
Article number: 502943

Maximum Power point (Pmax)
300 W
Short-circuit current (Isc)
8.6 A
Open-circuit voltage (Voc)
43.2 V

Bifaciality (φ)	$Pmax_{BiFi10}$	$Pmax_{BiFi20}$
92%	328 W	356W

CE

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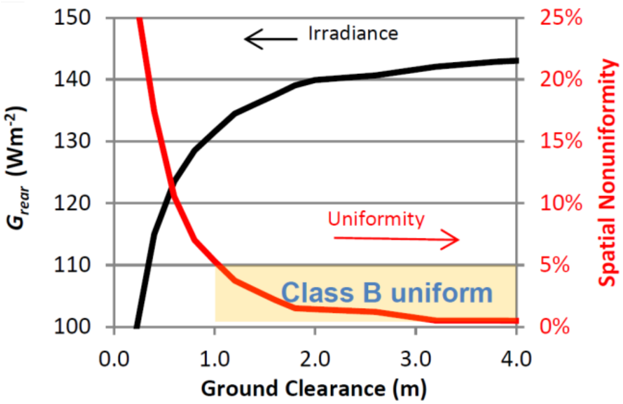
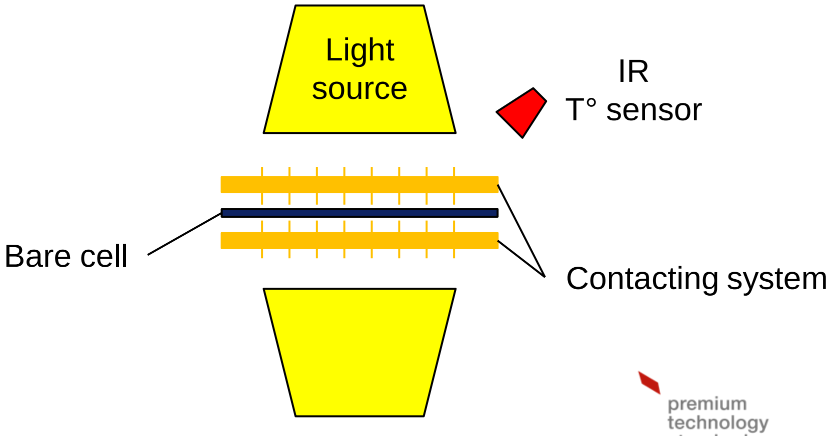
Challenges

For Outdoor and Double-side illumination

- Non-uniformity of irradiance on the rear-side:
  - NU<5% indoor; <10% outdoor
  - Measured when the test area is simultaneously illuminated on both sides
  - Measured at all of the irradiance levels used
- Bare Cells contacting, with double-side illumination and different front- and the rear-side metallization
- Bare Cell's temperature measurement, with double-side illumination



C. Deline et al., (43rd IEEE PVSC): Simulated average rear irradiance and Non-uniformity across the module (right axis) on a module deployed at 37° tilt angle over light soil (0.21 albedo). NU reduces as z increases.



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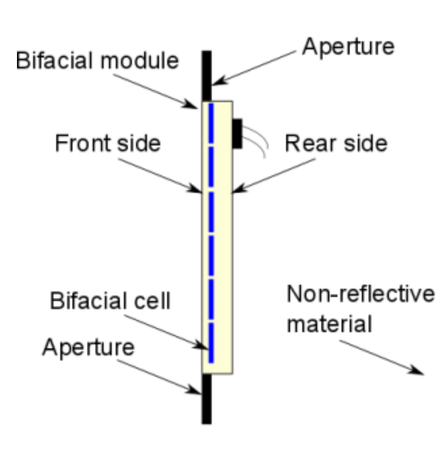
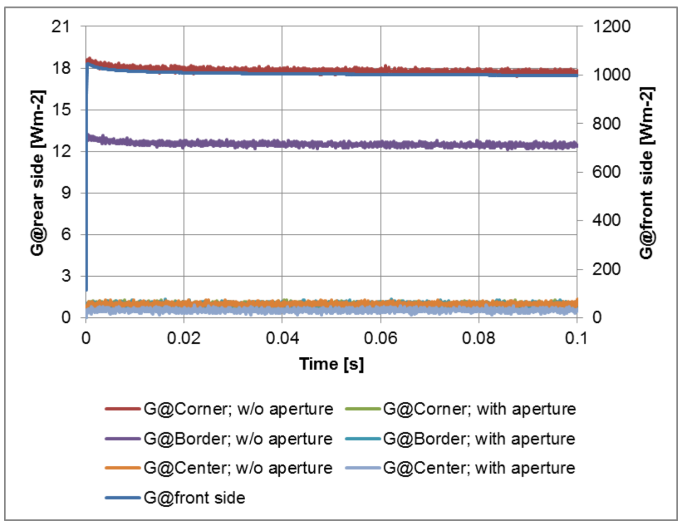
Challenges

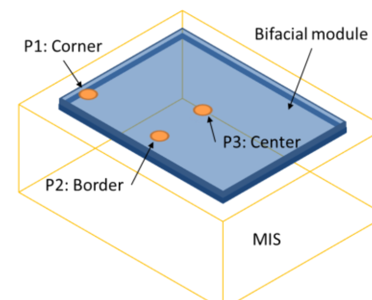
Non-irradiated background (for G_E method)

- Irradiance on the non-exposed side: < 3 Wm^{-2}
- Use of apertures for Module testing strongly recommended





Pasan's Module Inspection System, MIS, and its bifacial-compatible black hood



Irradiance measurement positions on the rear-side

Irradiance measurements on the front- and the rear-sides							
	Front-side (reference)	Corner; w/o aperture	Corner; with aperture	Border; w/o aperture	Border; with aperture	Center; w/o aperture	Center; with aperture
Avg. G [Wm^{-2}]	1000.32	17.84	0.96	12.52	0.97	0.98	0.56

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Challenges

Non-irradiated background for cell testing (1/3)

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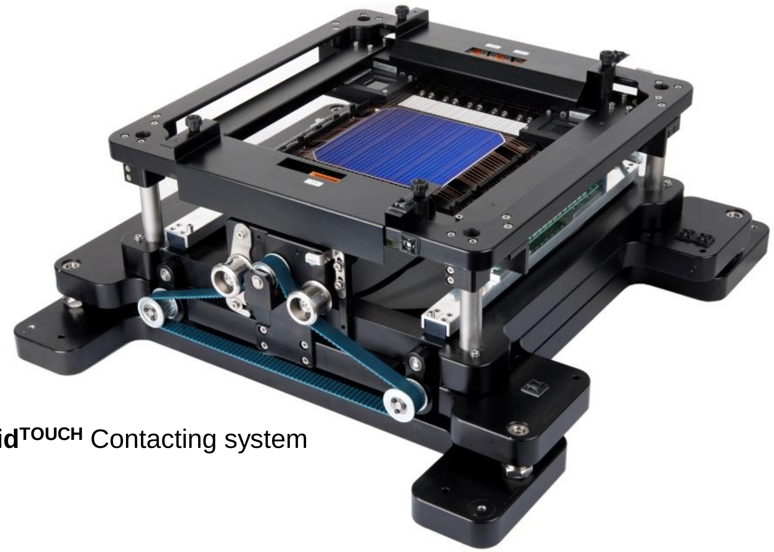
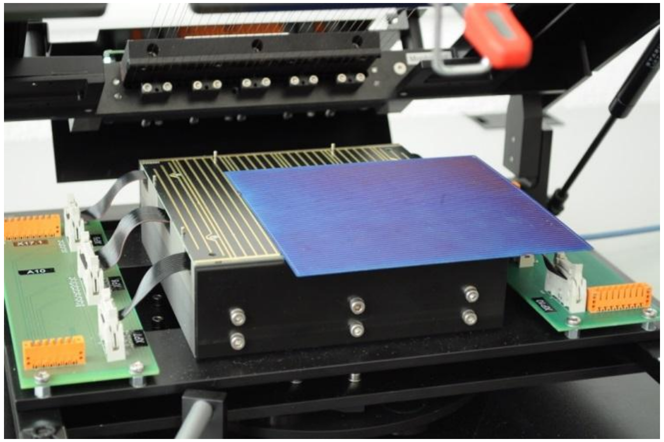
Hohl-Ebinger et al.: Mounting chucks for bifacial solar cells

- Irradiance on the non-exposed side: < 3 Wm^{-2}
- Background compensation by extrapolation of $Isc=f(Reflectivity_{chuck})$ acceptable by the standard

→ Contacting solutions evaluation by J. Levrat et al.



Pasan's **Grid**TOUCH Contacting system



Pasan's **PCB**TOUCH Contacting system

csem

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Challenges

Non-irradiated background for cell testing (2/3)

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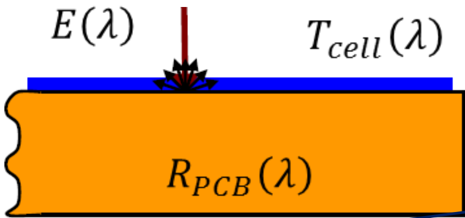
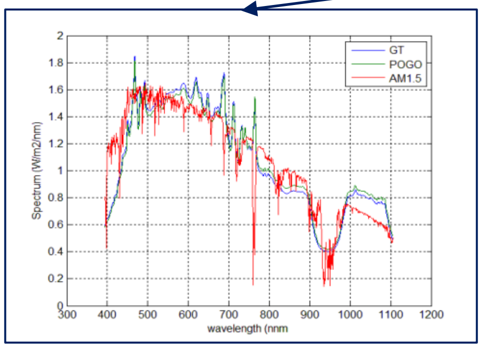
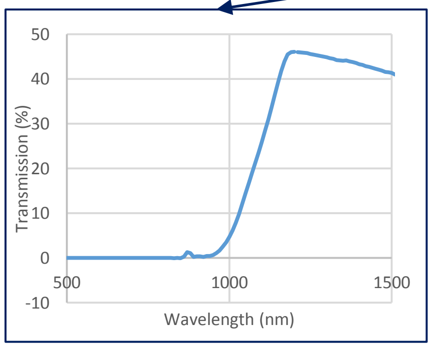
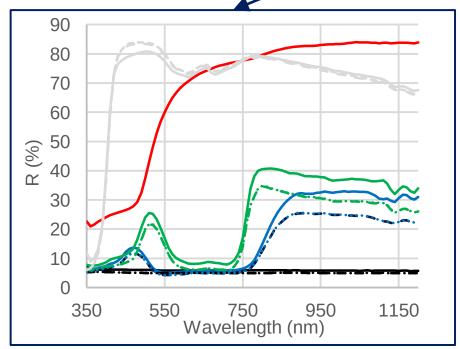


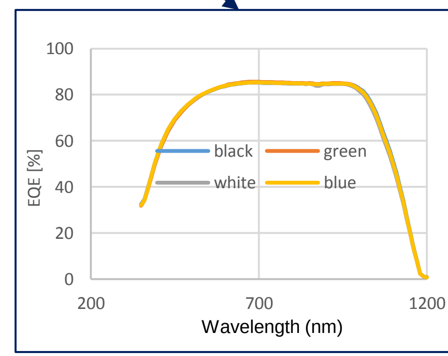
$$SR_{meas}(\lambda) = SR_{front}(\lambda) + T_{cell}(\lambda)R_{PCB}(\lambda)SR_{back}(\lambda)$$

$$\Delta I_{back}(\lambda) = \int E(\lambda)T_{cell}(\lambda)R_{PCB}(\lambda)SR_{back}(\lambda)d\lambda$$

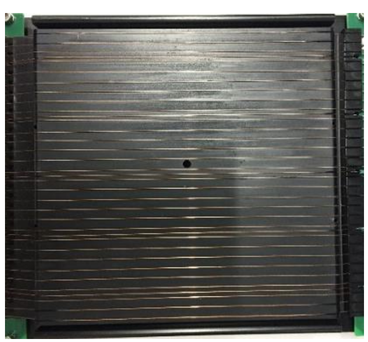


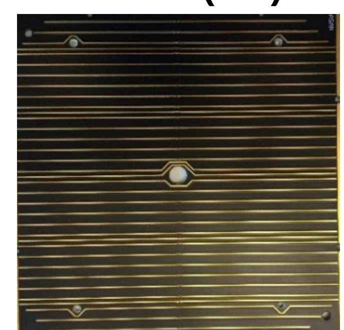






White	Grid[TOUCH]	CSEM dev. platf.	PASAN (old)	PASAN (std)

R=20.7%

Mean R=65.2%	Mean R=4.96%	Mean R=22.2%	Mean R=16.2%

csem

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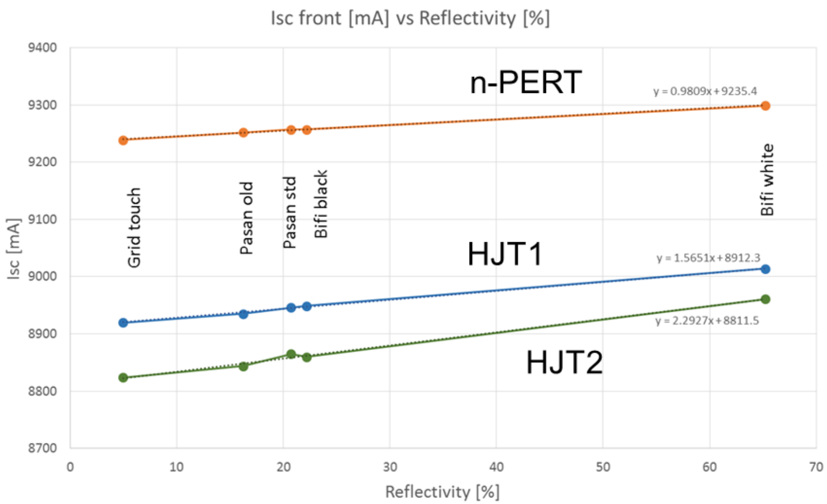
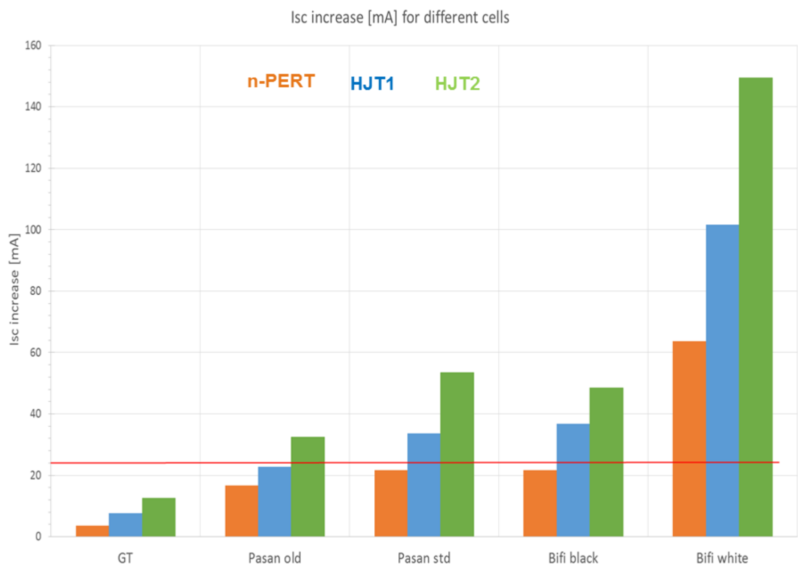
Challenges

Non-irradiated background for cell testing (3/3)

- Isc_0 determined by linear regression
- Possibility to reach the standard requirement for the Chuck reflectivity or to compensate it



	Isc_0 [mA]
n-PERT	9235.4
HJT 1	8912.3
HJT 2	8811.5



	Isc_0	***allowed energy increase***	***Bifaciality***	***Isc increase max***
n-PERT	9235.4	0.30%	0.87	24.1
HJT1	8912.3	0.30%	0.91	24.3
HJT2	8811.5	0.30%	0.92	24.3

Conclusion

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- IEC 60904-1-2: I-V measurement of BiFi devices
  - Standard project in a very advanced stage
  - Reproducible method to assess bifacial devices and to value the bifacial gain
  - No requirement for new measurement equipment in PV productions
- BiFi measurement challenges
  - Uniformity of irradiance on the rear-side (outdoor, double-side illumination)
  - Bare cells contacting and temperature measurement (double-side illumination)
  - Background compensation (achievable)

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Thank you for your attention

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Pasan's new BiFi-compatible module tester; <0.5% non-uniformity

Meyer Burger's n-type HJT bifacial modules with busbarless cells; CSEM's façade