

Measurement of Bifacial Solar Cells with Single- and Both-sided Illumination at CalLab PV Cells

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MOTIVATION

- Bifacial solar devices market share: expected to increase to over 50% by 2029 [1]
- Missing standardized characterization method for evaluating bifacial solar devices performance hinders the mass production [2]

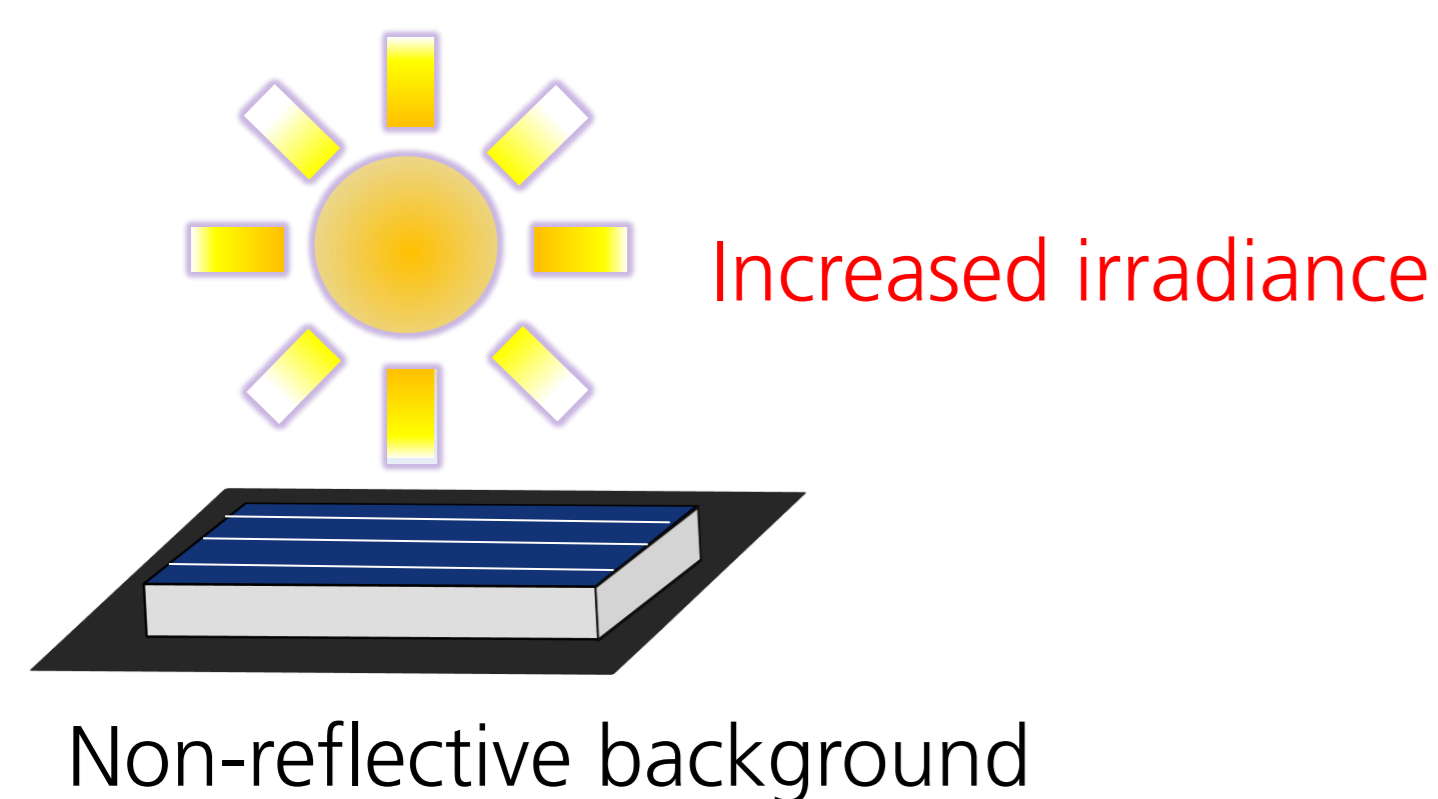
INTRODUCTION

Two different methods for indoor measurements proposed in the IEC technical specification 60904-1-2 [3]:

Single-sided illumination (G_E method)

$$\text{Front: } E_E = 1000 \text{ Wm}^{-2} + \frac{j_{sc, \text{rear}}}{j_{sc, \text{front}}} \cdot 100 \text{ or } 200 \text{ Wm}^{-2}$$

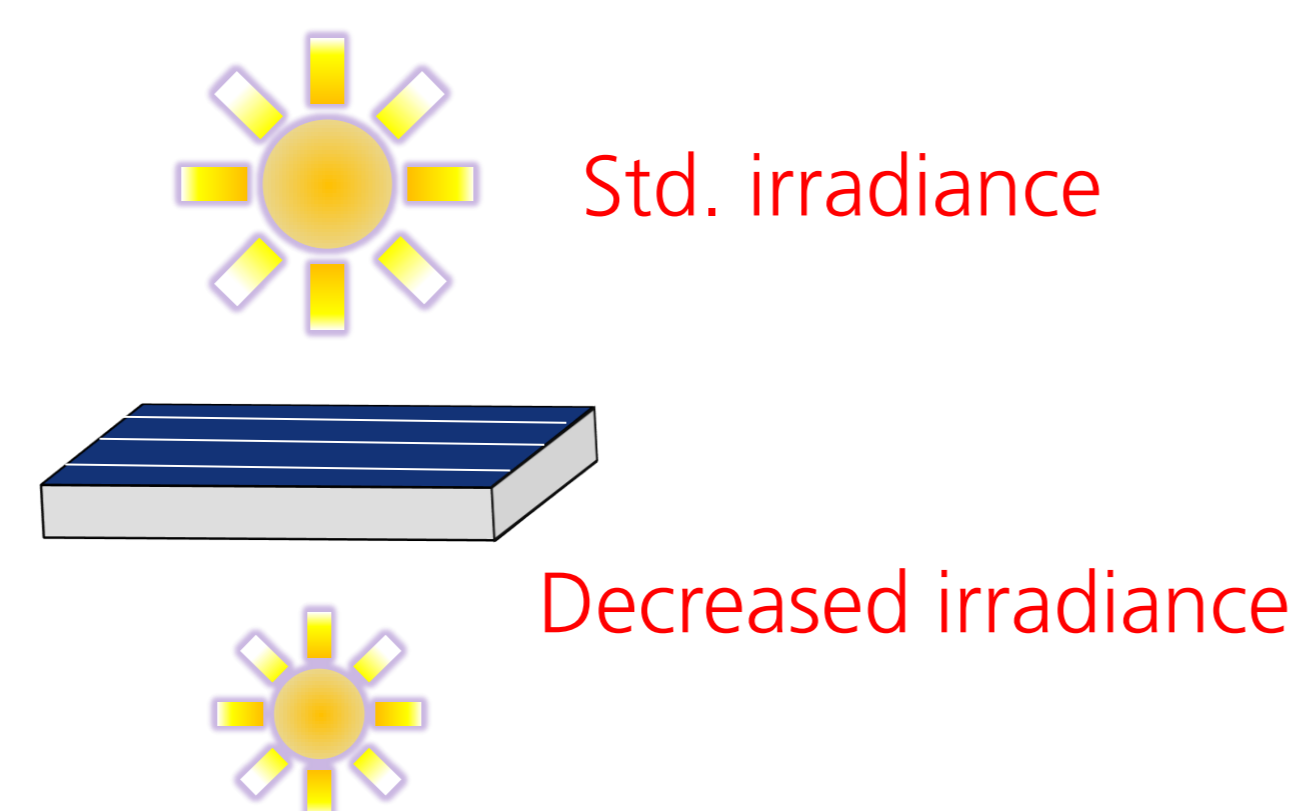
Bifaciality



Double-sided illumination (Bifacial method)

$$\text{Front: } E_{\text{front}} = 1000 \text{ Wm}^{-2}$$

$$\text{Rear: } E_{\text{rear}} = 100 \text{ or } 200 \text{ Wm}^{-2}$$



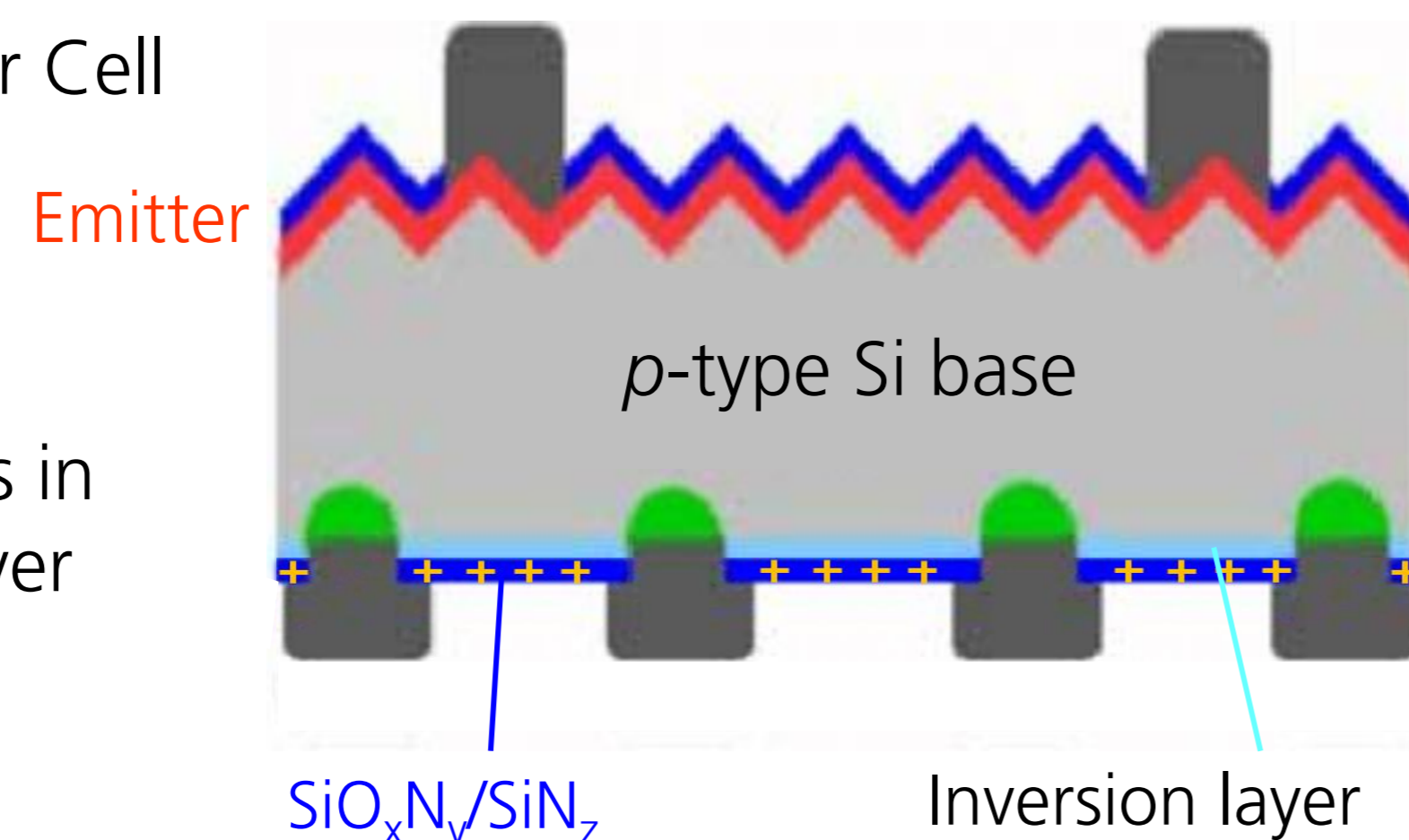
- Literature: agreement between both methods within $0.4 - 2 \%_{\text{rel}}$ [4-6]

Main aim: Quantitative comparison of Single- and Double-sided illumination methods, focus on nonlinear bifacial cell

NONLINEAR BIFACIAL PERC SOLAR CELL

Bifacial Passivated Emitter and Rear Cell (PERC):

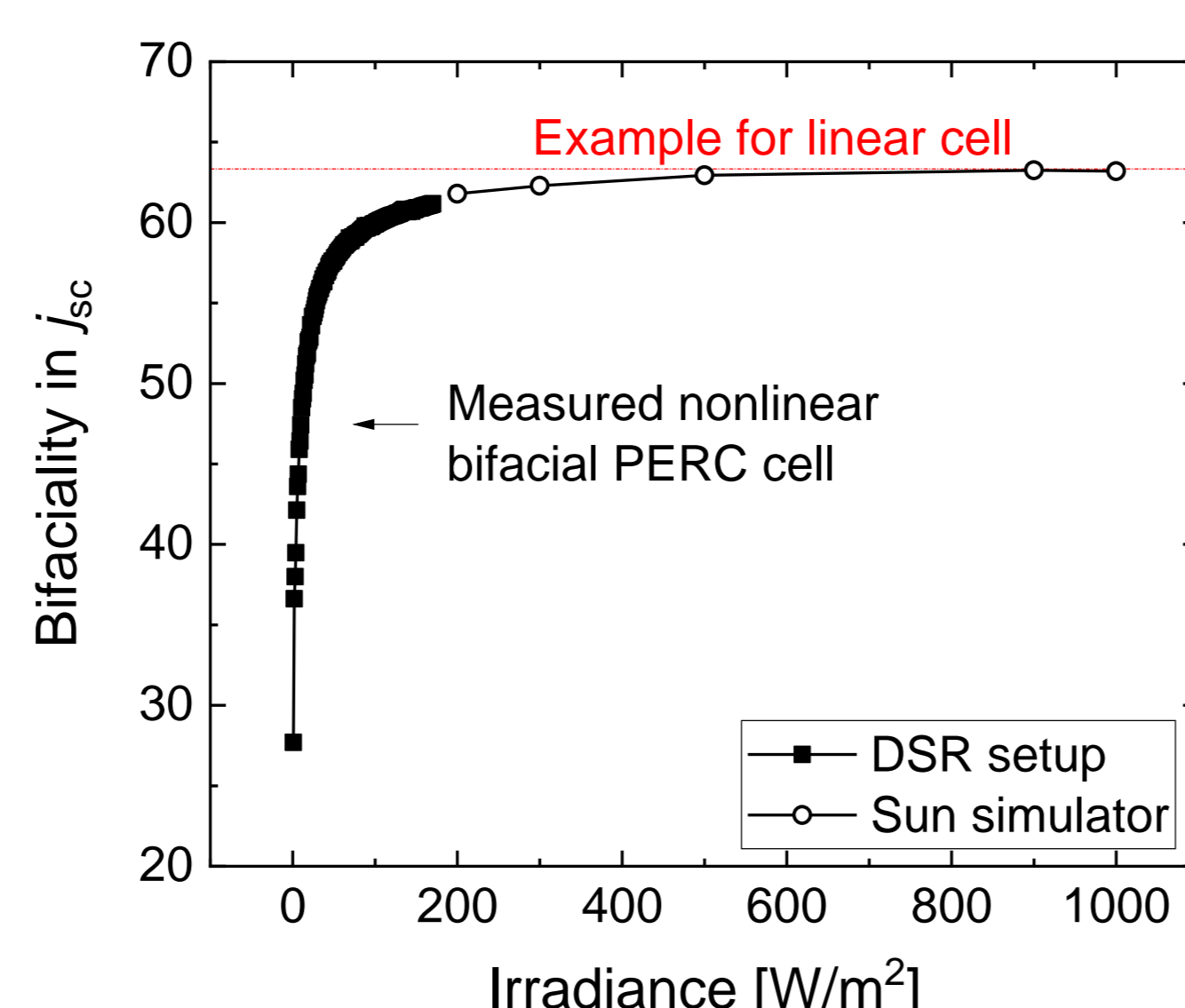
- Rear surface passivation with $\text{SiO}_x\text{N}_y/\text{SiN}_z$ [7]
- High density of positive charges in $\text{SiO}_x\text{N}_y/\text{SiN}_z$ creates inversion layer that is shunted at the local aluminum-alloyed contacts [8-9]



- Nonlinear $J_{sc}(E)$ relation:
 - Bifaciality strongly dependent on irradiance

Theory: Different photogeneration depth profiles between Bifacial and G_E methods [10]

→ **Difference between two methods possible for nonlinear bifacial cells**



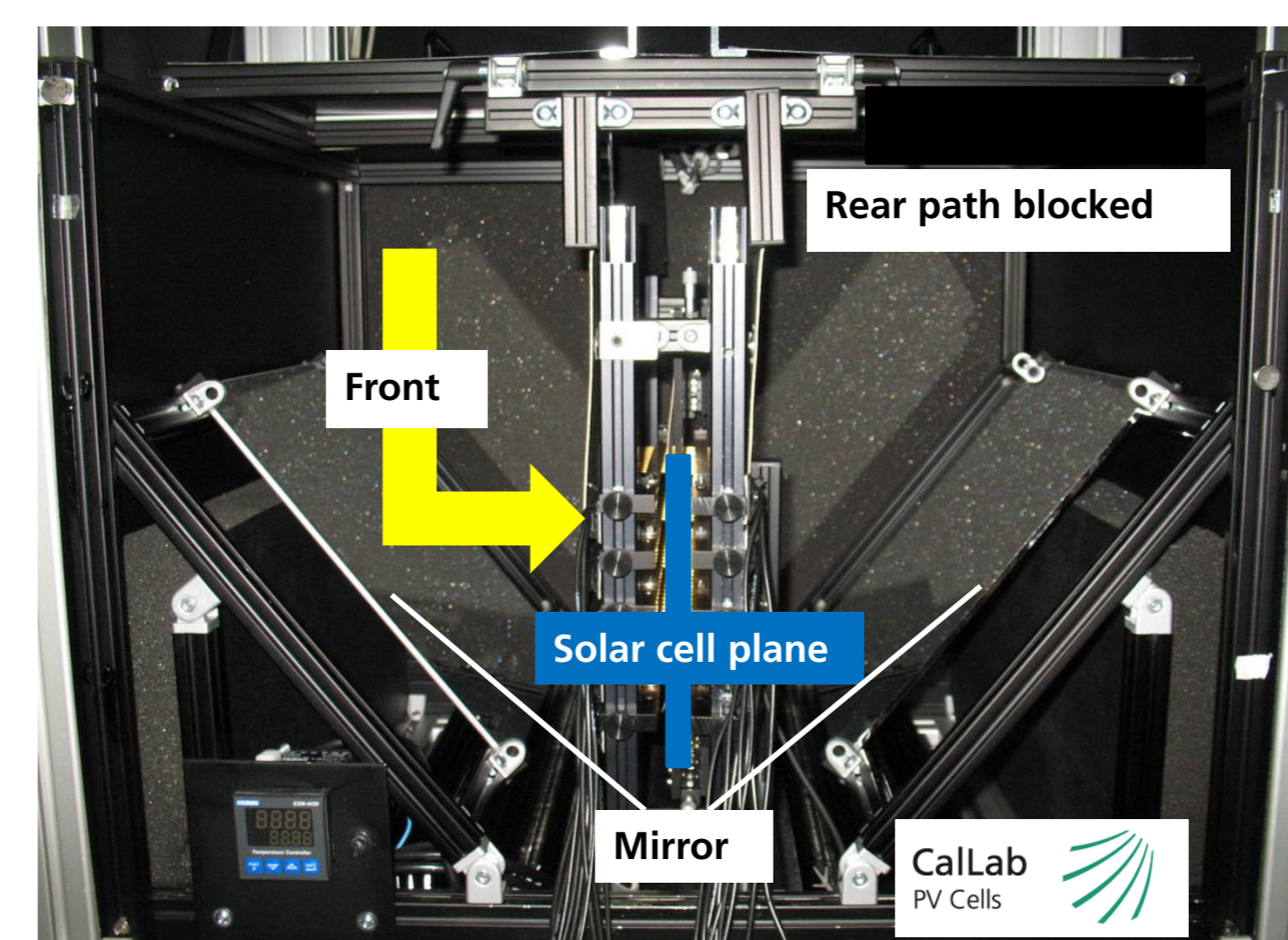
EXPERIMENTAL

(i) Advanced two-mirror setup at CalLab PV Cells

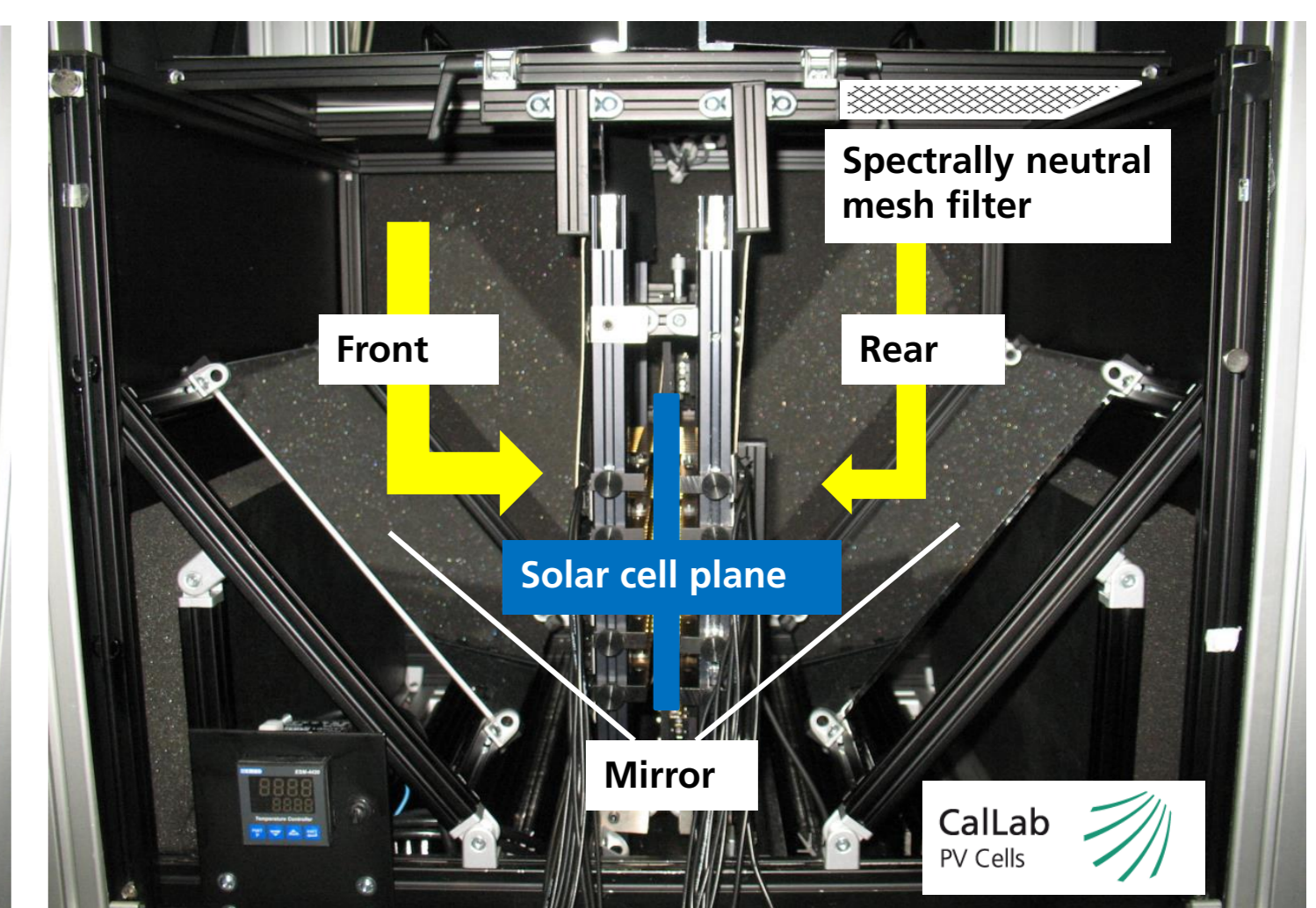
- Spectral distribution at front and rear: Class A
- Irradiance uniformity at front and rear: Class A
- Light transmission from one side to the other minimized
- Precise temperature control within $25.0 \pm 0.3 \text{ } ^\circ\text{C}$

(ii) I-U (Current-Voltage) measurement of a nonlinear bifacial PERC cell

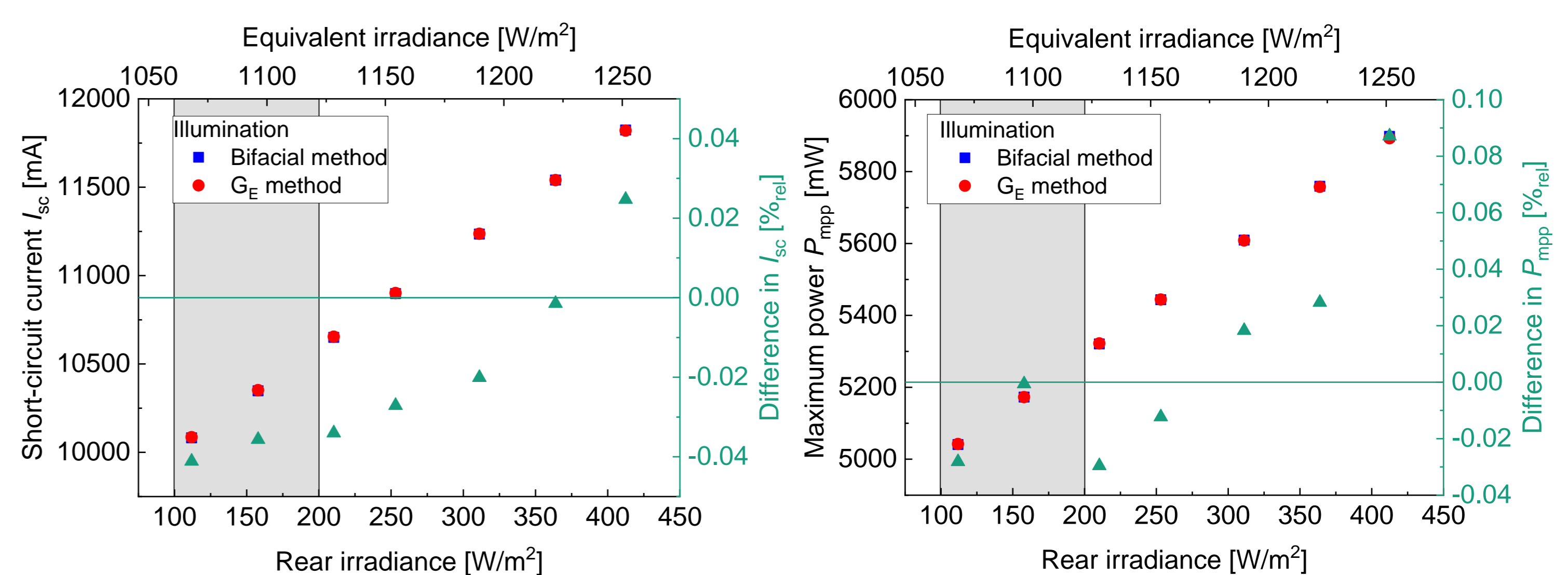
G_E method:



Bifacial method:



(iii) Quantitative comparison between Bifacial and G_E methods



- ΔJ_{sc} between two methods: $< 0.05 \%_{\text{rel}}$
- ΔP_{mpp} between two methods: $< 0.1 \%_{\text{rel}}$

→ **Bifacial and G_E methods are consistent for nonlinear bifacial PERC cell**

SUMMARY

- Difference in IU parameters between Bifacial and G_E methods for nonlinear bifacial PERC cell below $0.1 \%_{\text{rel}}$
- Bifacial and G_E methods proposed in IEC technical specification 60904-1-2 have shown good agreement, even for strong nonlinear bifacial cells
- CalLab PV Cells provides calibration services for bifacial solar cells using the advanced two-mirror setup

REFERENCES

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