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Optimization of the shunt resistance of Cu(In,Ga)Se₂ cells for indoor applications

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Maya El Khoury, Matthieu Moret, Antoine Tiberj, Wilfried Desrat. Optimization of the shunt resistance of Cu(In,Ga)Se₂ cells for indoor applications. 13èmes Journées Nationales du Photovoltaïque (JNPV 2023), Dec 2023, Dourdan, France. . <hal-04810791>

HAL Id: hal-04810791

<https://hal.science/hal-04810791v1>

Submitted on 29 Nov 2024

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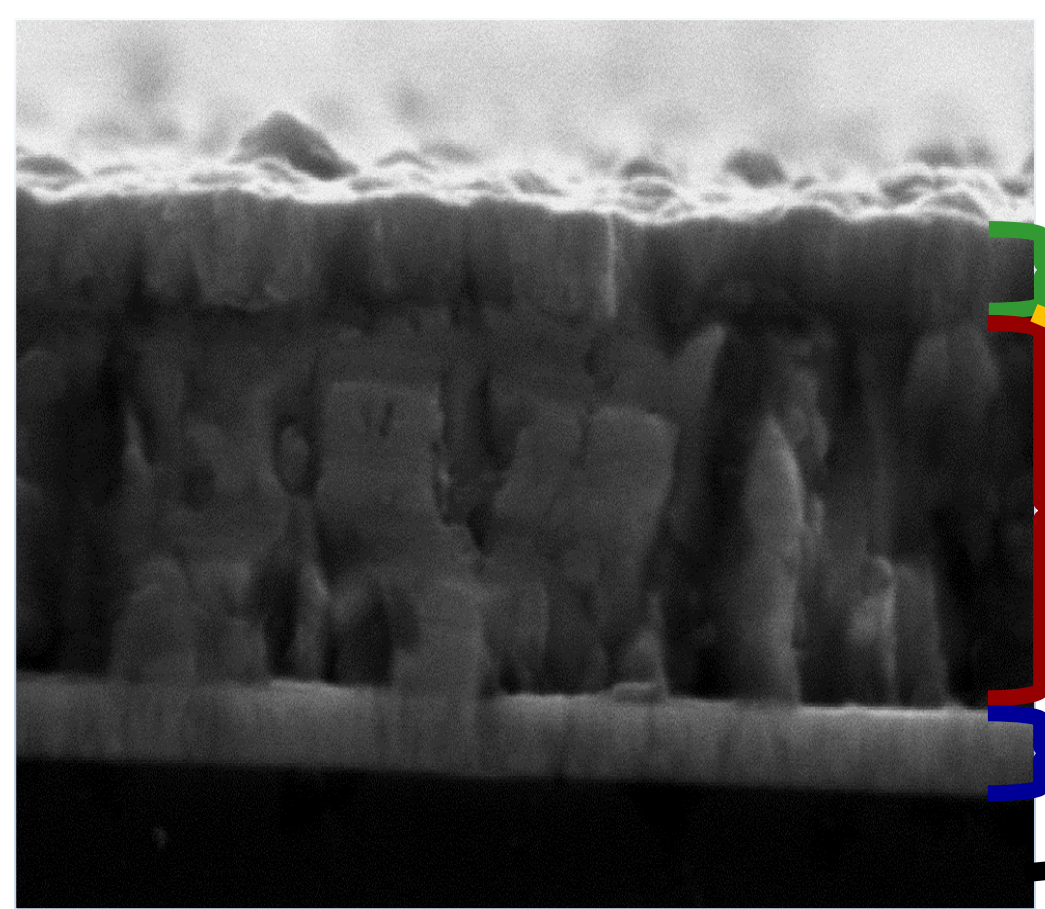
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Abstract

With the rise of Internet of Things (IoT), a sustainable and efficient power source for electronic devices, such as indoor photovoltaics, is essential [1]. Copper poor and gallium rich CIGS photovoltaic cells, marked by a high parallel resistance, hold promise for these applications, yet they have not received thorough exploration in the past [2].

In this poster we present an extended analysis of the I-V electrical characteristics of several CIGS solar cells, with different gallium and copper contents, measured with a white LED from 45000 lx down to extremely low illumination (~50 lx). Notably, regardless of the gallium content, copper poor cells with a CGI between 0.45 and 0.5 exhibited the highest shunt resistance. This resulted in a remarkable increase of the P_{max} by a factor of one thousand when compared to conventional copper-rich CIGS solar cells when tested under low light conditions (50 lx).

Structure of a CIGS cell



ZnO/ZnO:Al (n)
CdS (n)
CIGS (p)
Mo
SLG

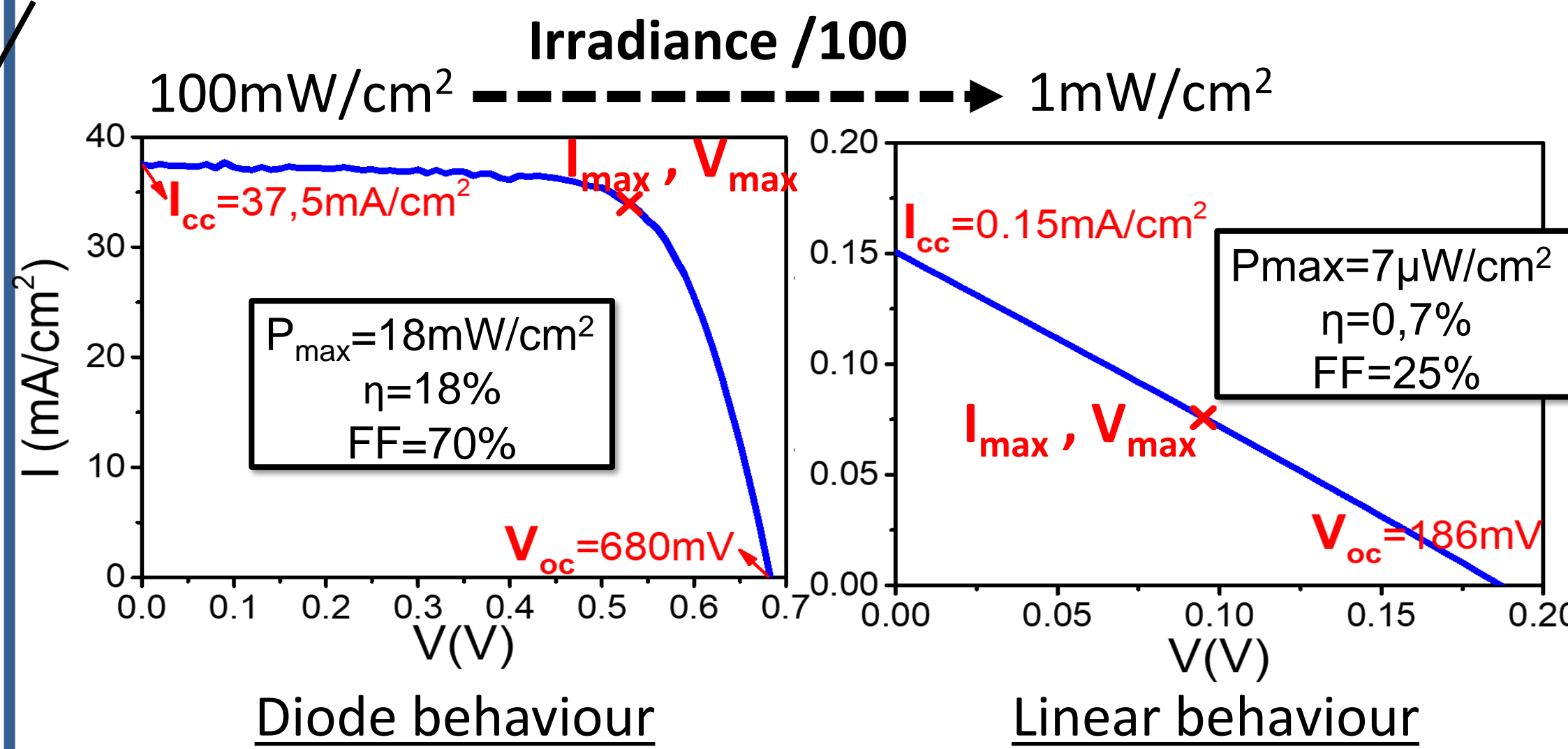
$$CGI = \frac{Cu}{In+Ga} = 0.93$$

$$GGI = \frac{Ga}{In+Ga} = 0.28$$

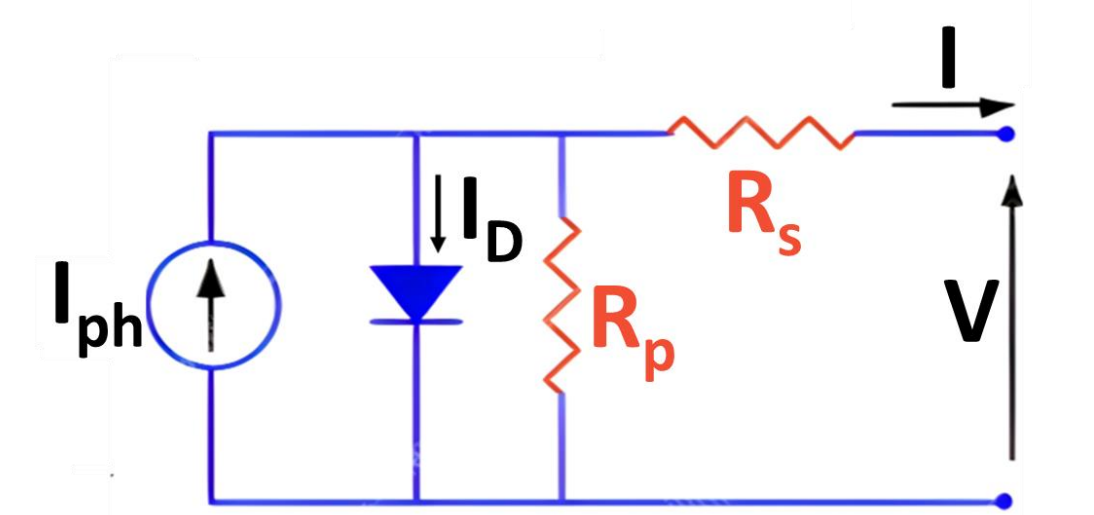
This work focuses on optimizing only the CIGS absorber layer

Cu(In,Ga)Se₂ cell measured with different irradiance levels: Outdoor vs indoor

Standard cell I-V measurements

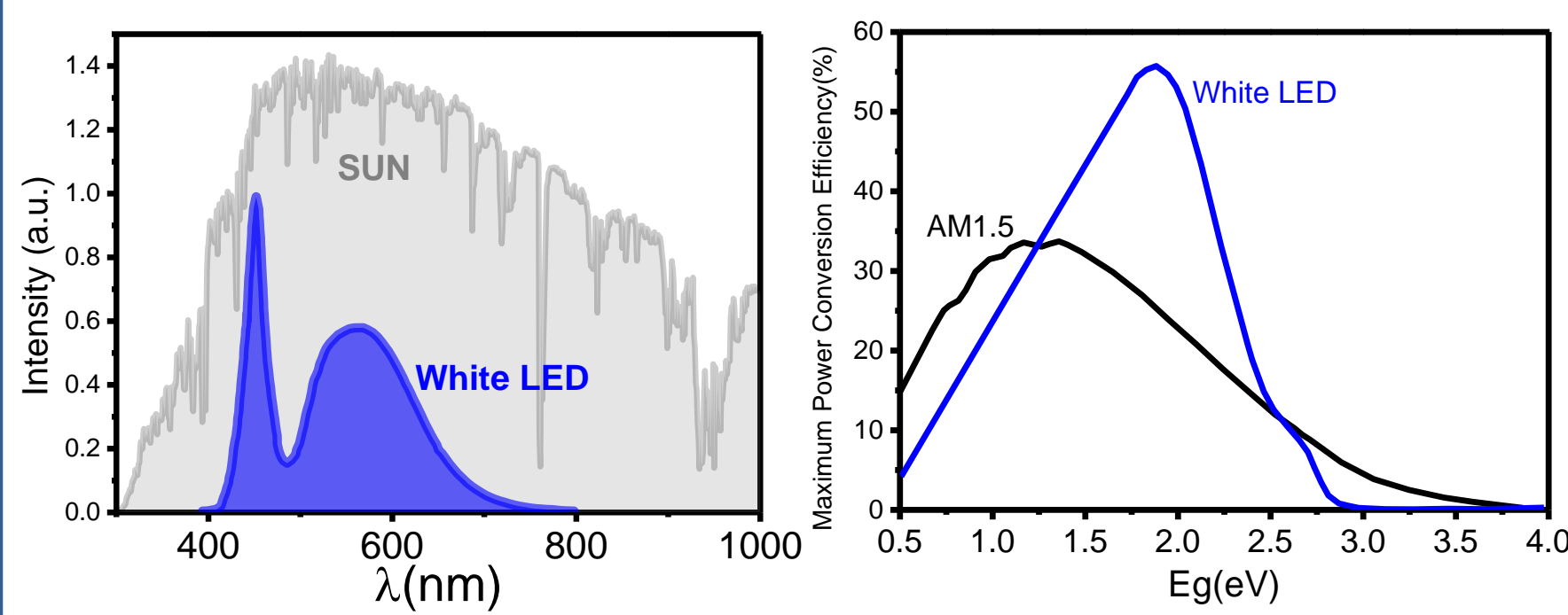


At low irradiance levels, CIGS cells optimized for traditional use (outdoor) have linear behavior. This is due to their low shunt resistance (R_p) that presents an undesired pathway for the current to bypass the diode.



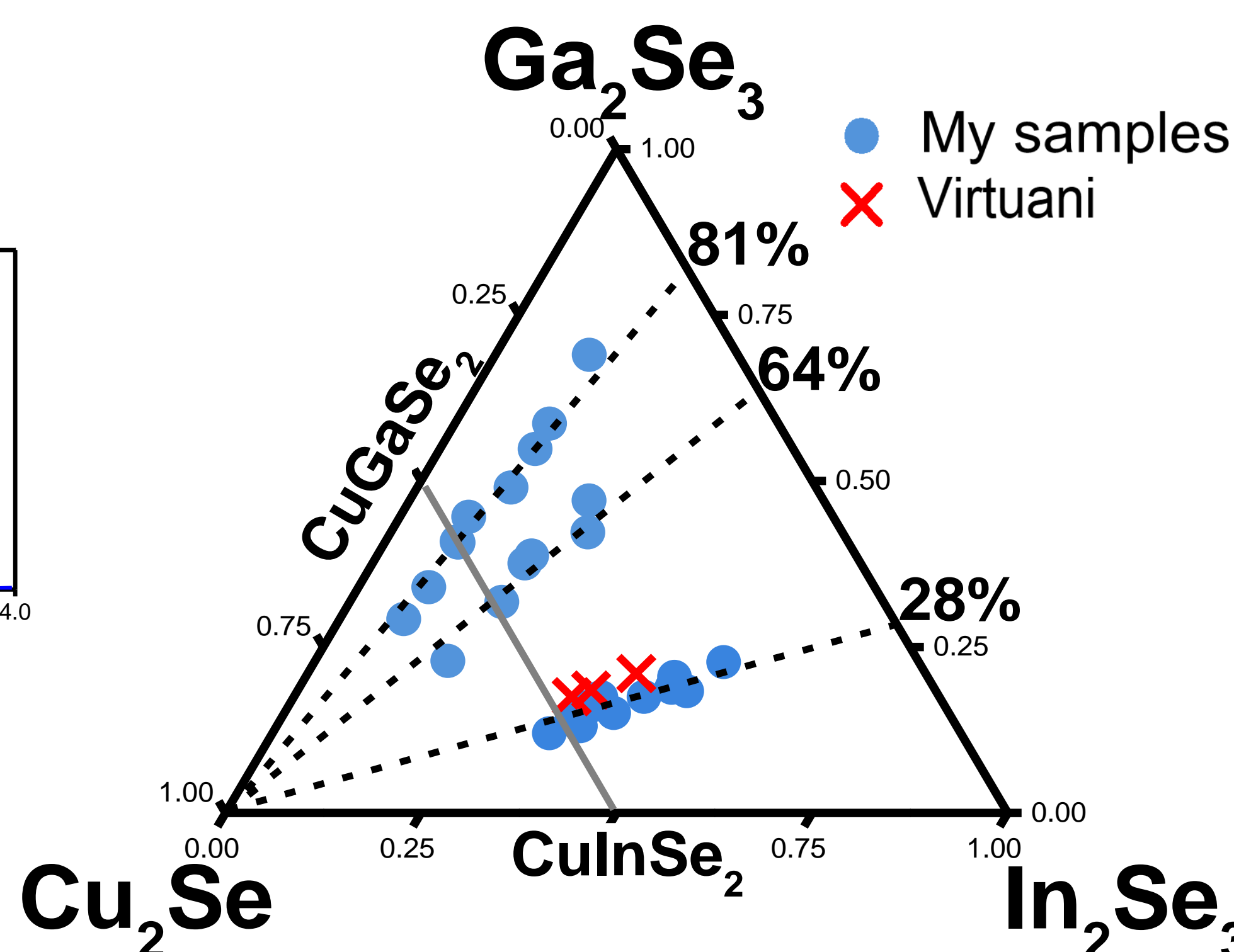
Copper poor and Gallium rich CIGS for indoor applications

Virtuani et al. demonstrated that **copper-deficient CIGS** cells marked by a high parallel resistance perform better under low irradiance conditions (dimmed solar spectrum). We want to evaluate these cells using a **white LED** (indoor conditions).



The spectral differences between the sun and the LED implies the need for a wider band gap ~ 1,8 eV for maximum absorption. That is why we extended our analysis to **Gallium rich** (wider band gap) and **copper poor** compositions.

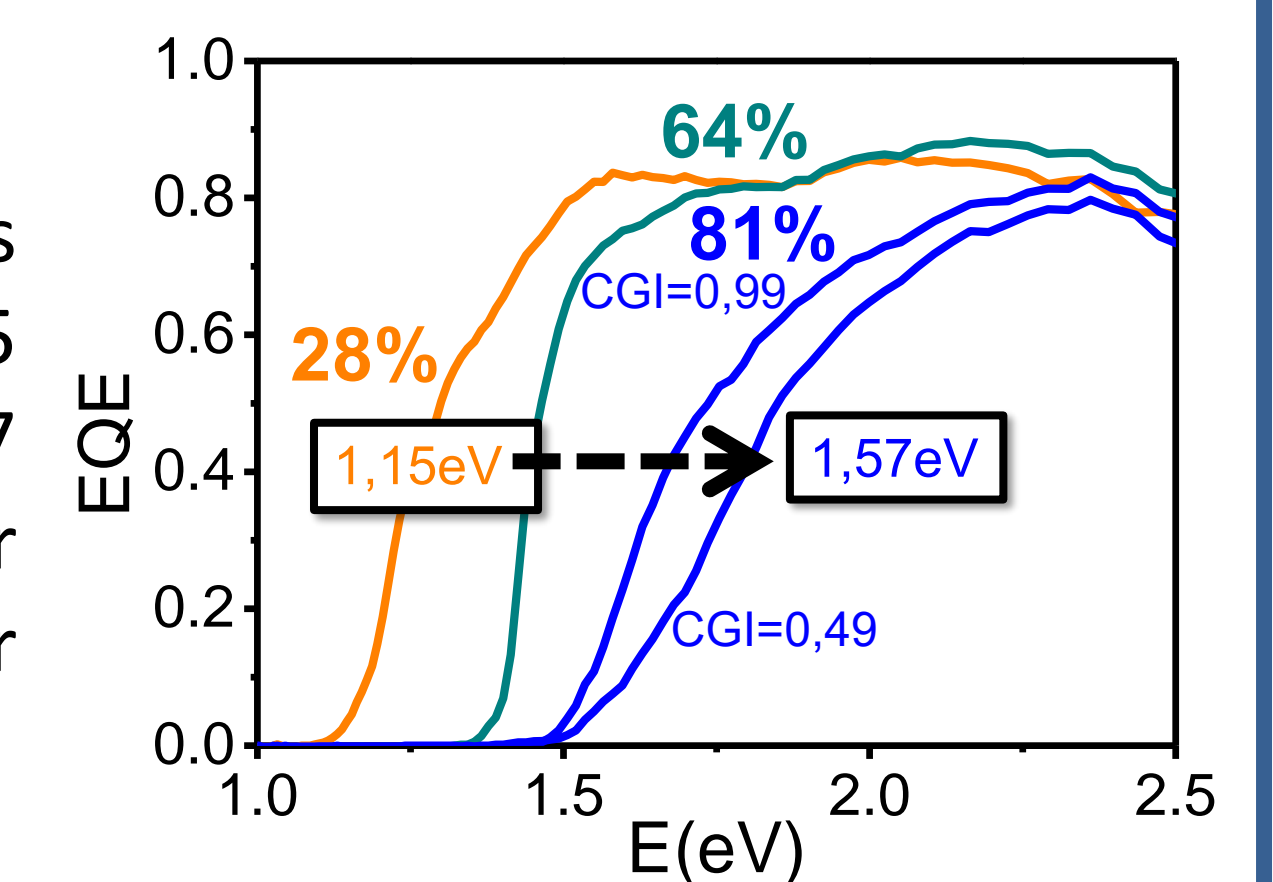
Composition of the samples elaborated in my thesis at L2C



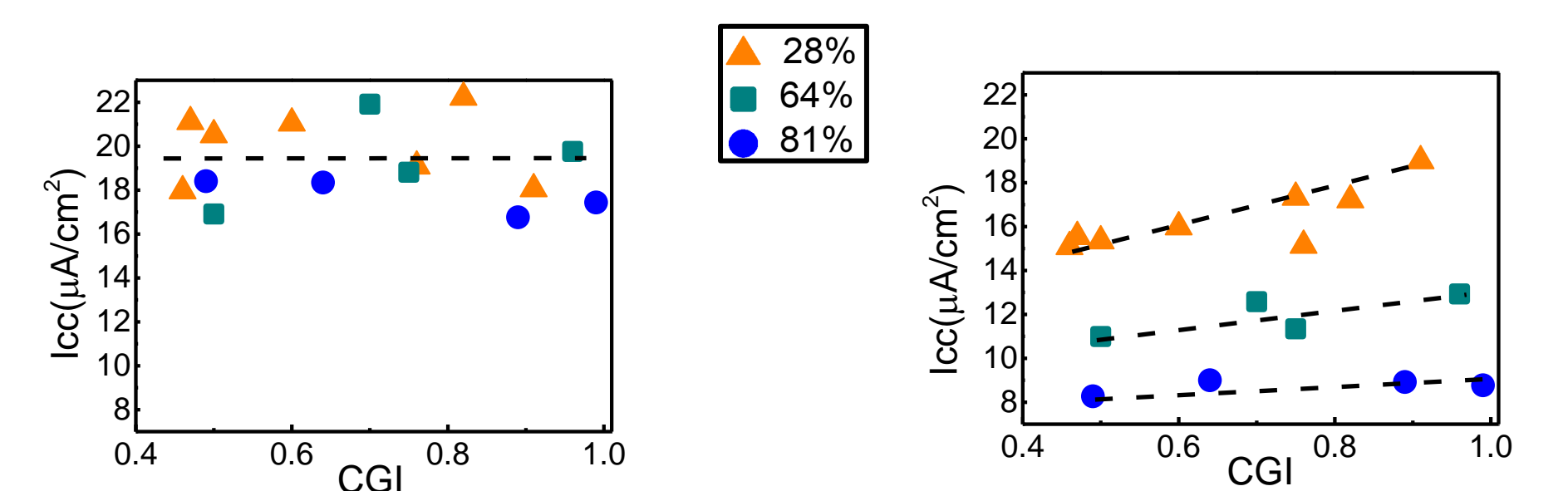
Effect of the Gallium content

EQE measurements:

The band gap was optimized from 1,15 eV (28%, CGI=0,94) to 1,57 eV (81%, CGI=0,49) for Gallium rich and copper poor CIGS cells.



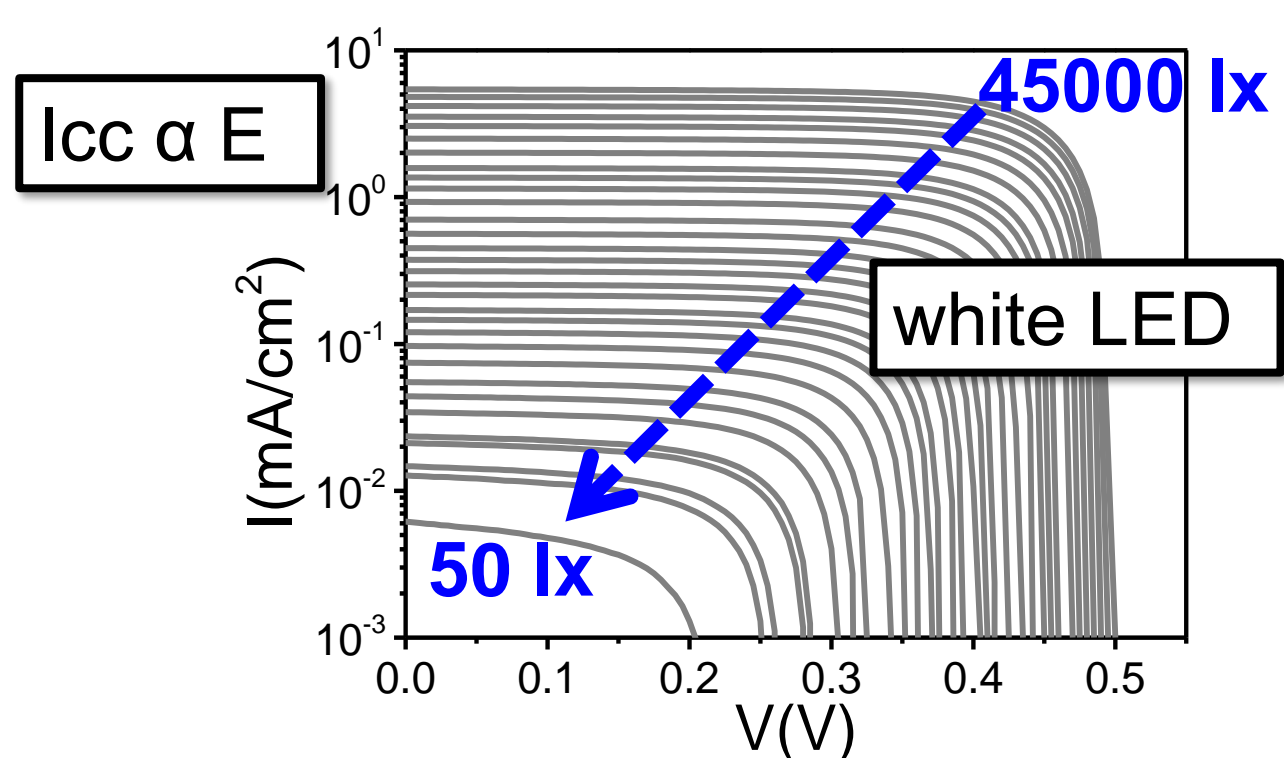
I_{cc} Measured at 200lx (LED) Vs dimmed solar spectrum



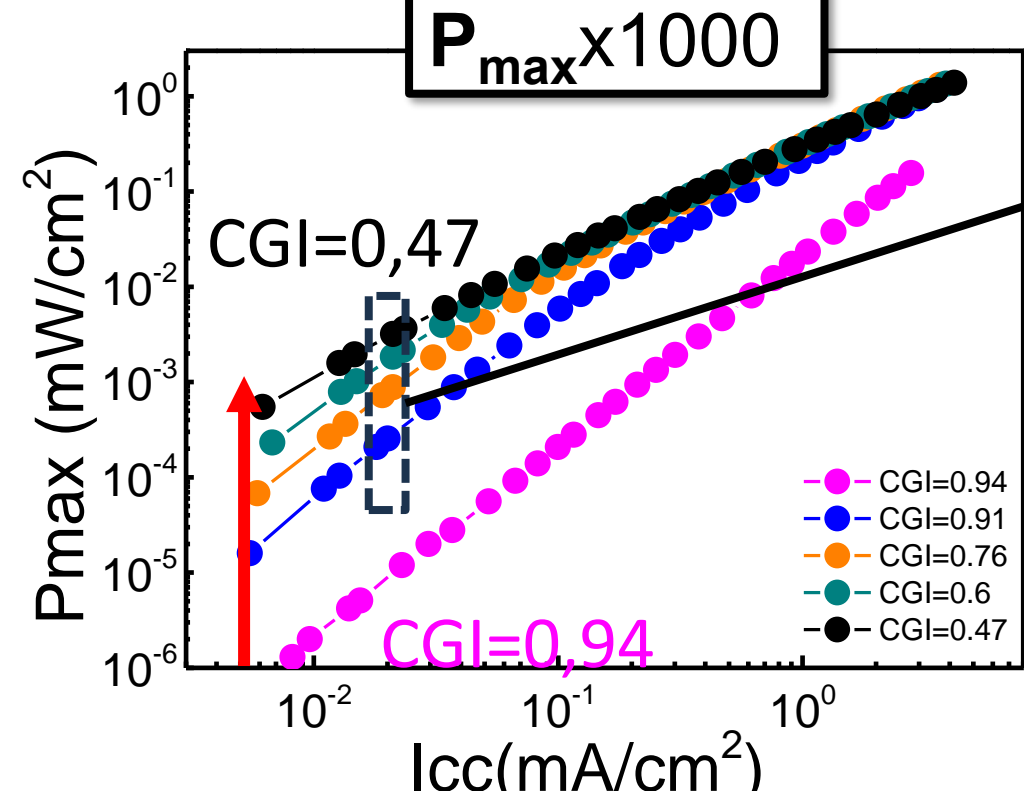
The increase of the bandgap keeps a constant I_{cc} in the case of the LED while a reduction is observed with the sun.

Effect of the copper content on the shunt resistance and the performance of CIGS cells

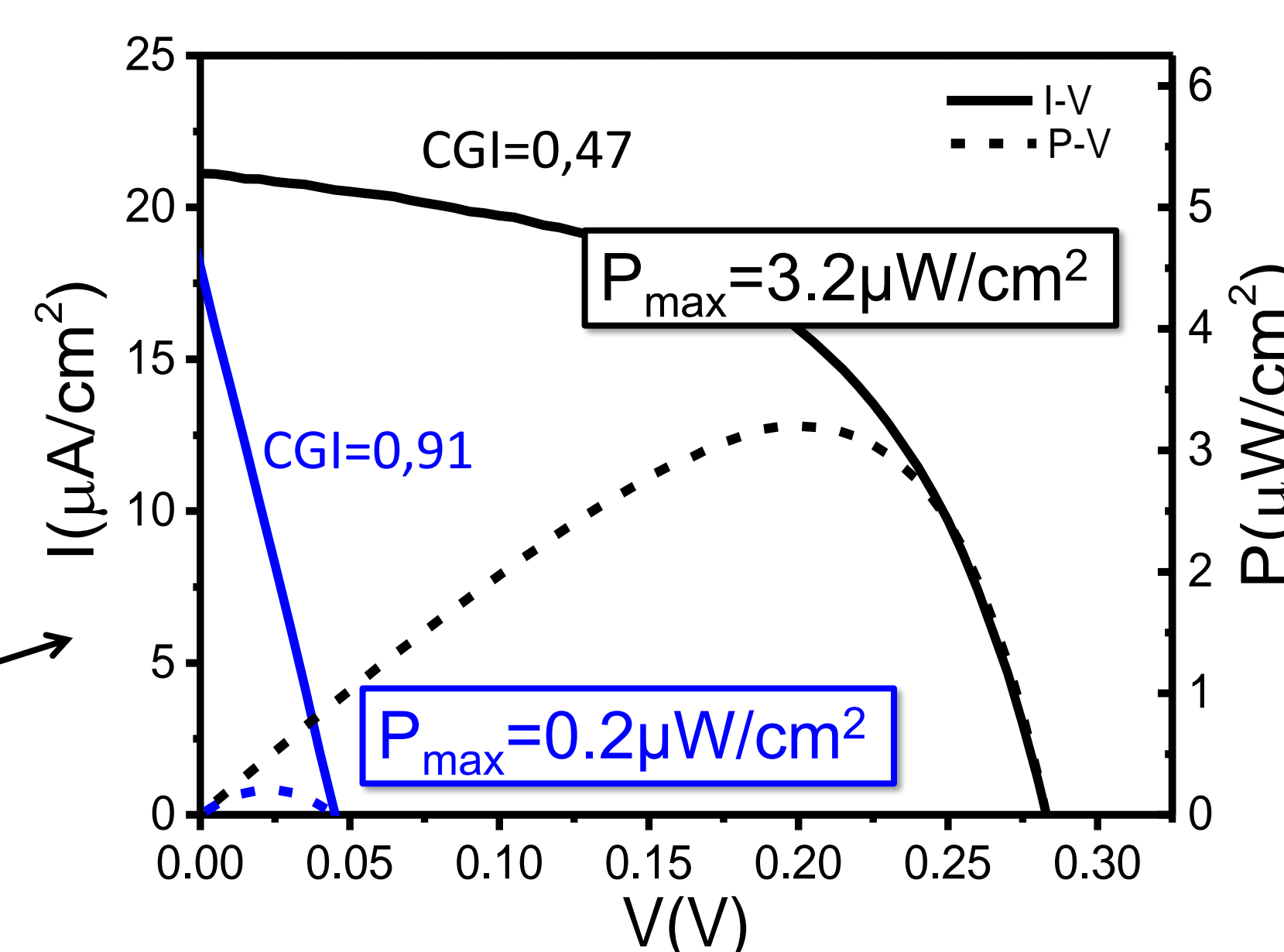
The Current-voltage characteristics are measured with a white LED over 3 orders of illuminance.



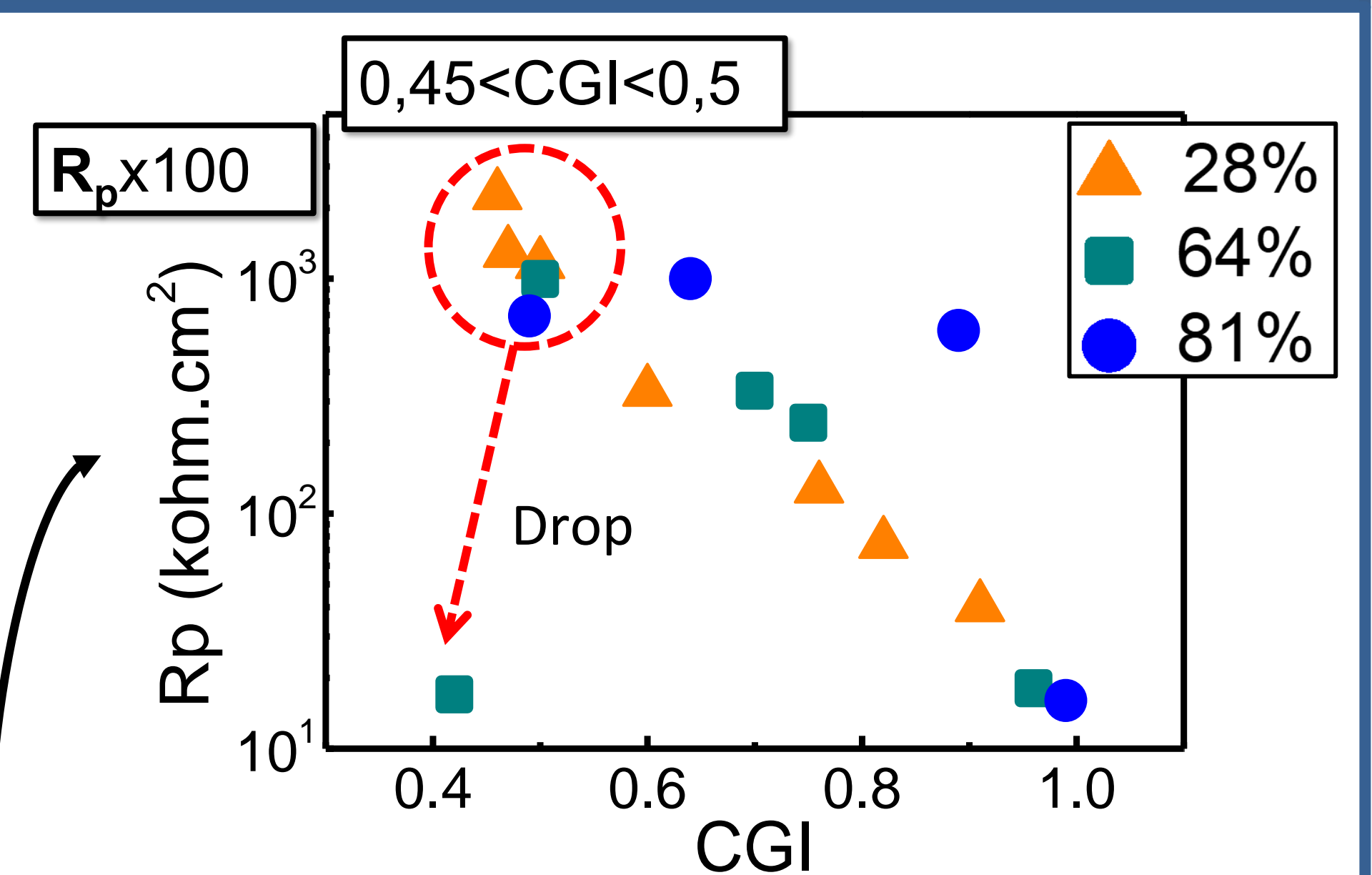
An improvement of the electrical parameter has resulted in enhancing the P_{max} by a factor 1000 in indoor conditions.



Comparing the I-V curve at **200 lux**, the copper-deficient cell exhibits diode-like behavior, leading to improved performance.



Effectively, the copper poor cells that showed the best performances at low light are those with the **highest shunt resistance**.



We optimized the CIGS absorber layer composition for indoor applications. The optimal range for **copper to Gallium/Indium ratio** is between **0.45 and 0.5** with the highest parallel resistance. However, if the CGI ratio drops below 0.4, there is a possible reversal of the doping, making the cell non-working.[3]

Contact

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References

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Acknowledgments

This PhD is funded by **Region Occitanie** and **Programme d'investissement d'avenir PIA3 - Campus des Métiers et des Qualifications "Habitat, énergies renouvelables et éco-construction"** – IUT de Nîmes