

*Emilie BIALIC, Advanced R&D Division*

**Optical  
Communication  
&  
Passive optical Sensor**



# PROGRAM

- **SunPartner Technologies**
- **LiFi Technology**
- **Video demonstration**

# SUNPARTNER TECHNOLOGIES PRESENTATION

# SUNPARTNER Technologies's Vision

SMART SURFACES EVERYWHERE TO PRODUCE OFFGRID ENERGY  
& ENHANCE USER EXPERIENCE, USING SOLAR ENERGY



**Innovative solutions** for mobile devices,  
displays, transportation, smart buildings & cities



# SUNPARTNER Technologies' s Company

## KEY FIGURES

2008

COMPANY  
CREATED

85

EMPLOYEES

5

FIELDS OF  
ADVANCED  
EXPERTISE

*(optics, photovoltaics,  
semiconductors,  
manufacturing processes,  
electronics)*

>130

PATENTS

3

BUSINESS  
MODELS  
*(licensing, JV, fabless)*

70

€ MILLIONS  
RAISED

**wysips**<sup>®</sup>GLASS

BUILDING & TRANSPORTATION  
smart glazing

**wysips**<sup>®</sup>CRYSTAL

CONSUMER  
emissive screens

**wysips**<sup>®</sup>GRAPHICS

CONSUMER  
aesthetic surfaces

**wysips**<sup>®</sup>REFLECT

CONSUMER  
any surfaces and reflective screens

# CONSUMER PRODUCTS





## PERFORMANCES

- > Available for sizes up to 6"
- > Up to 85% transparency
- > From 1mW/cm<sup>2</sup> to 3mW/cm<sup>2</sup>  
*depending on display and transparency requirement @ 1 SUN*

## APPLICATIONS

### WATCHES

(DIAL, DISPLAY OR COVER LENS)

## ADDED VALUE

- > Extended autonomy of 30% to 50%
- > Standard quartz watches: no more battery change
- > Analog watch « slightly » connected :  
adding value & features with enhanced connectivity
- > Smartwatches: moving to higher autonomy  
and get closer to traditional watches with Wysips<sup>®</sup>





## PERFORMANCES

- > Available for sizes up to 6"
- > Up to 85% transparency
- > From 2.5mWp/cm<sup>2</sup> to 4mWp/cm<sup>2</sup>  
*depending on transparency requirement*  
@1 SUN

## APPLICATIONS

EVERY DEVICE WITH EMISSIVE DISPLAY  
(SMARTPHONE, WEARABLE)

## ADDED VALUE

- > Emergency power reserve:  
Last call, last picture, last alert
- > IoT connectivity: Geo-localization , tracking,  
access control, mobile paiement
- > Invisible & embedded light sensor:  
ALS, Li-Fi/VLC reception
- > Bring autonomy to low power consumption displays



# BUILDING



# Products dedicated to the building sector

**wysips**<sup>®</sup>  
VISION-GLASS



Transparent  
photovoltaic glass

**wysips**<sup>®</sup>  
DESIGN-GLASS



Semi-transparent  
photovoltaic glass  
+  
power management

**wysips**<sup>®</sup>  
CAMELEON



Aesthetic  
photovoltaic glass



# Consumer & Glass Production Lines



## Consumer production line

*Rousset*

Pilot line: pre-series

*Shanwei, China*

Production under license with Truly

Semiconductors Ltd.



## Glass production line

*Rousset*

Photovoltaic glass products

Capacity: 150 000 m<sup>2</sup>/year



# TRANSPORTATION



# Transportation Applications

## APPLICATIONS

CARS



AIRCRAFTS



TRAINS



MARINE



## ADDED VALUE

- > Improve autonomy of electrical vehicles
- > CO<sub>2</sub> regulation
- > Solar protection system: user comfort
- > Power electronic devices or functions: off-the-grid dimmable windows, power pre-ventilation / pre-start operations

Under development  
with key players  
of the market

# VISIBLE LIGHT COMMUNICATION

## LIFI

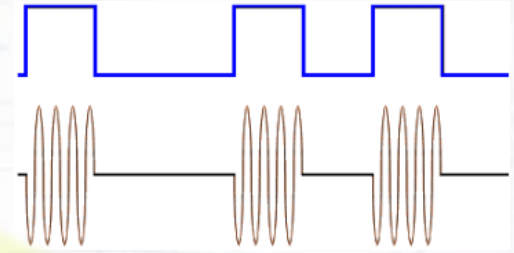


# VLC & LiFi

Network



Modulated Light



# The Best LiFi Receiver

## Only few papers :

[1] H. Haas et al., *Towards Self-powered Solar Panel Receiver for Optical Wireless Communication*, Optical Networks and Systems (2014), p.3348 – 3353. **(Multicrystalline silicon module)**

[2] E. Bialic et al., *Specific innovative semi-transparent solar cell for indoor and outdoor LiFi application*, Applied optics vol.54 No.27 (2015), p.8062 – 8069. **(Semi-transparent amorphous Si module)**

[3] H. Haas et al., *Organic solar cells as high-speed data detectors for visible light communication*, Optica vol.2 No.7 (2015), p.607 – 610. **(OPV PTB7:PC<sub>71</sub>BM & PEDOT:PSS module)**

[4] W. Shin et al., *Self-reverse-biased solar panel optical receiver for simultaneous visible light communication and energy harvesting*, Optics Express vol.24 No.22 (2016), p.1300 – 1305. **(Monocrystalline silicone module)**

Thin &  
Integrable

Omni-  
Directional

Energy  
Sufficient

No outdoor  
solution

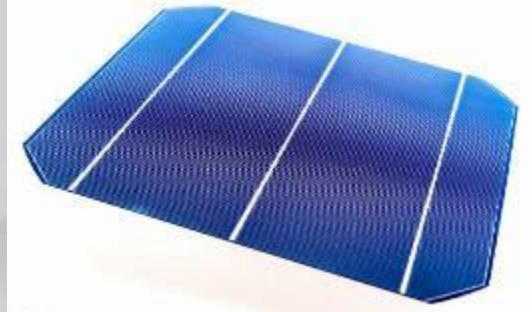
Universal  
Receiver

High  
Data Rate

Self  
Adaptive



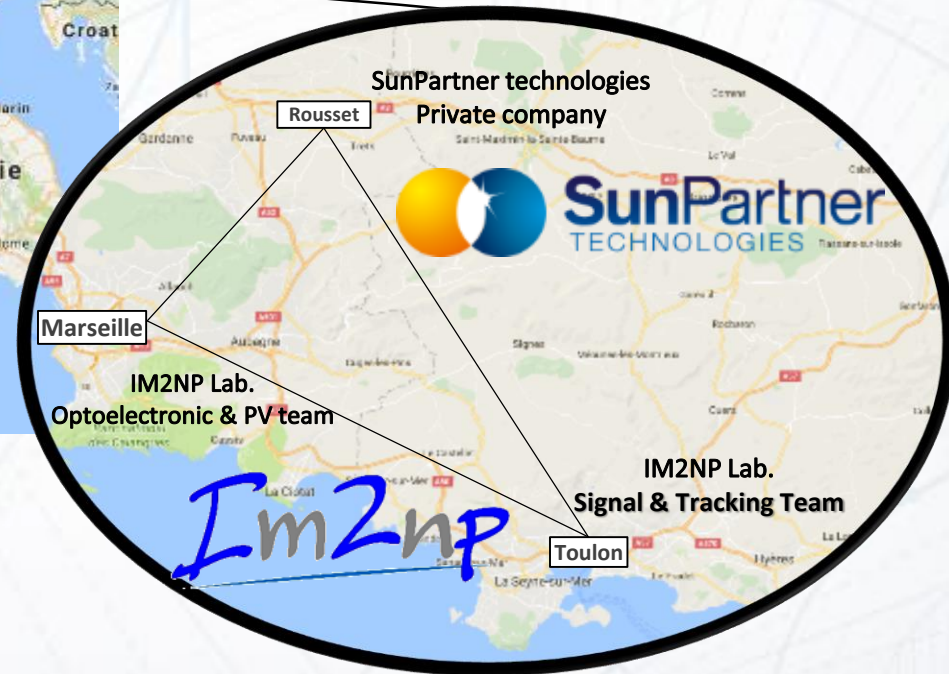
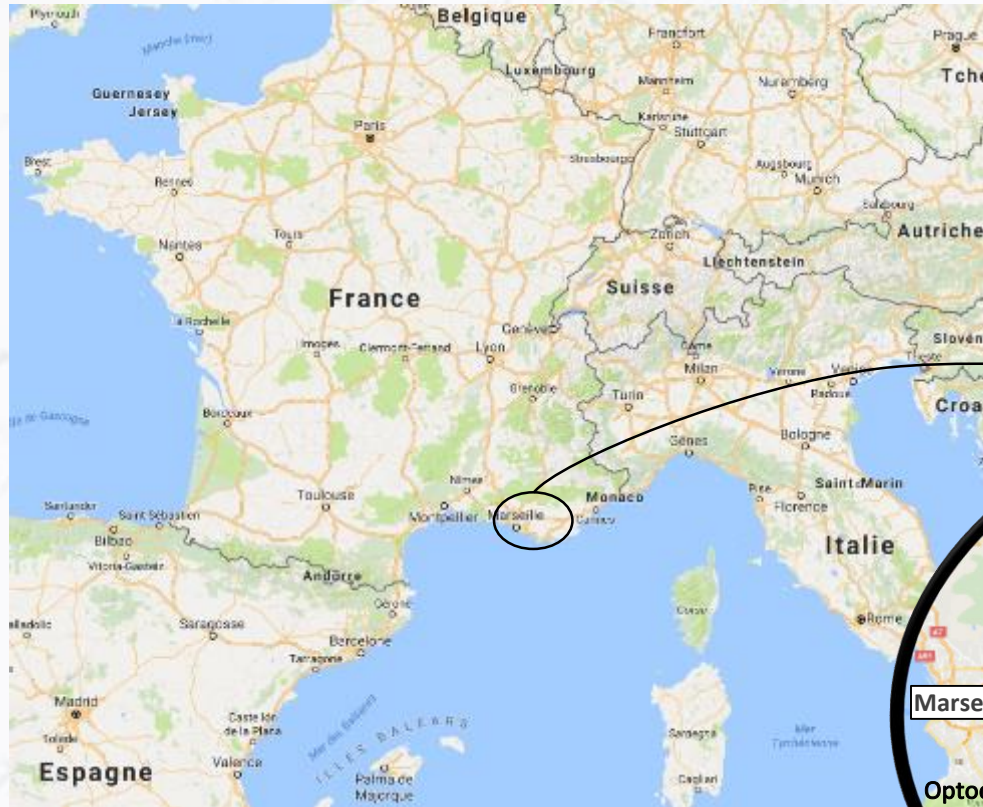
## Why not ?



# COLLABORATION

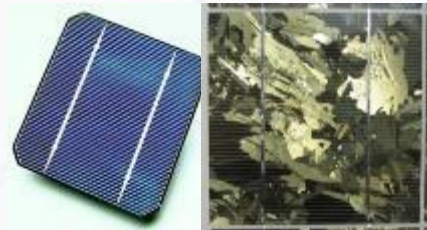


# Collaboration Team



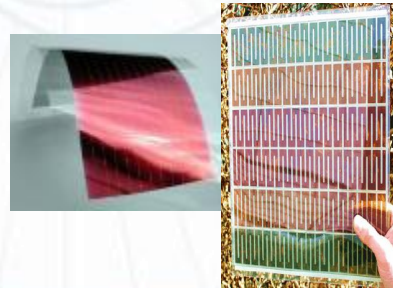
*Im2np*

## Optoelectronic and Photovoltaic Team (OPTO-PV)

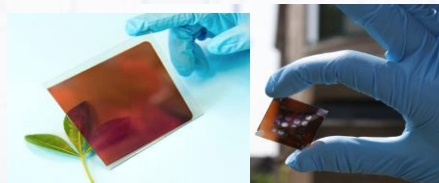


OPV / DSSC

Silicon



Nanostructure  
pérovskite



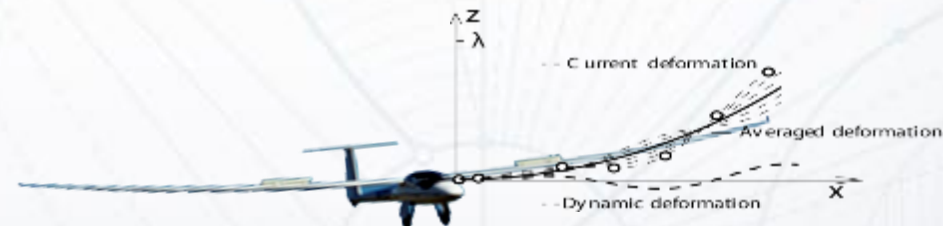
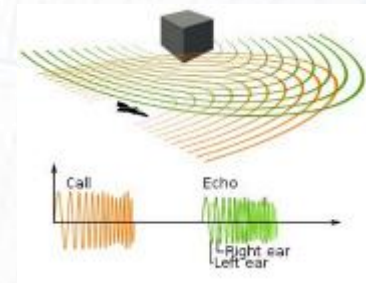
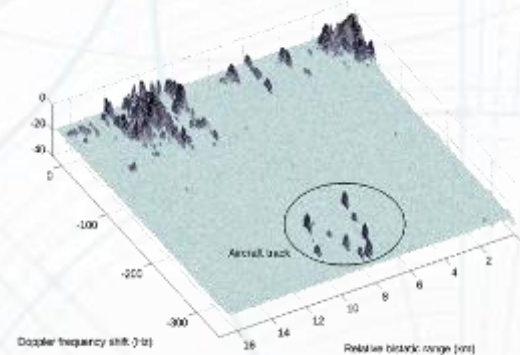
Inorganic thin  
film solar cells

Im2np

## Signal & Tracking Team

Signals from  
Environment : Biological ...  
Acoustic : Sonar ...  
Telecom : **OFDM** ...  
Domestic : consumption ...  
2D : Images

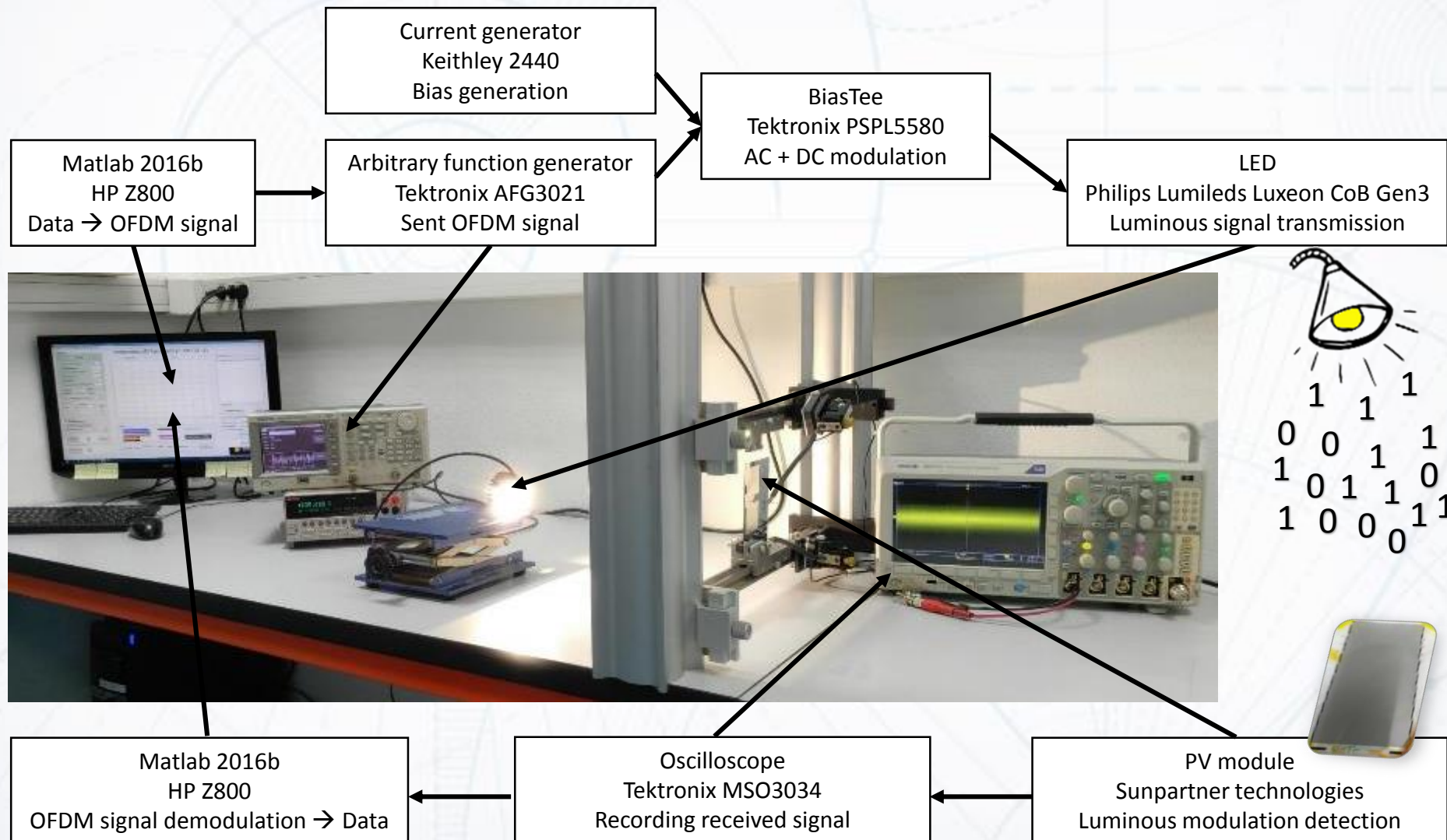
Signal Analysis  
Signal Modeling  
(Maths - Proba Stat)



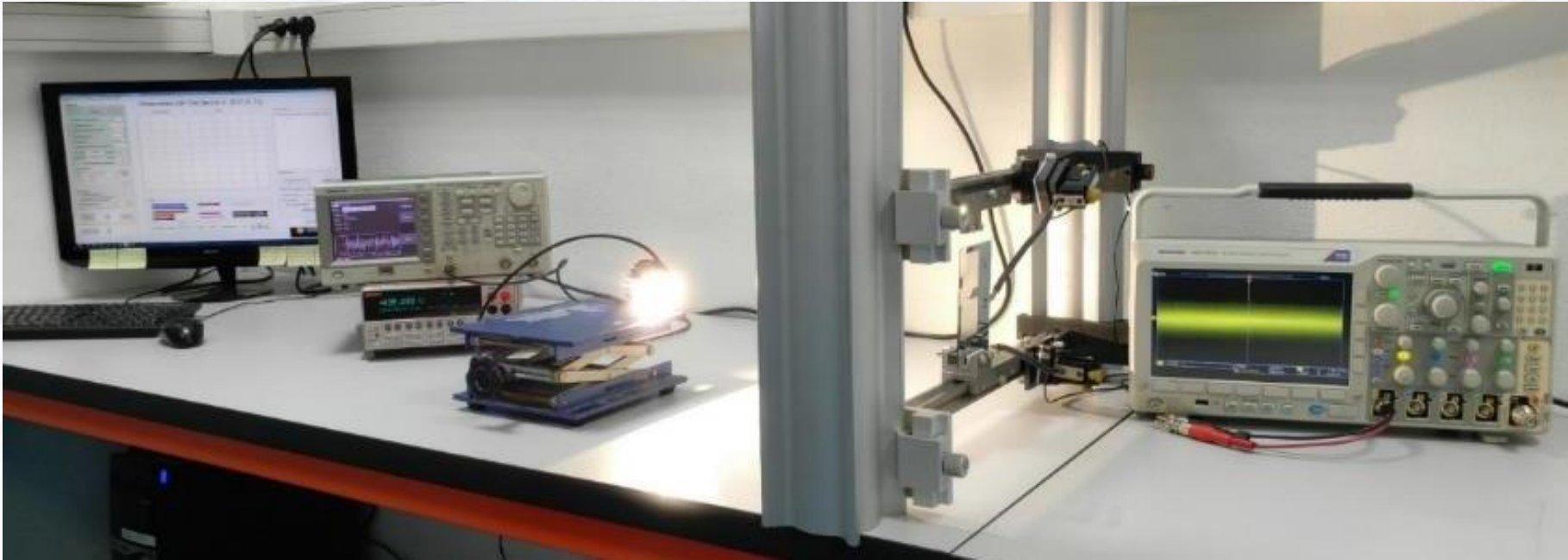
# LIFI CHARACTERIZATION TOOL



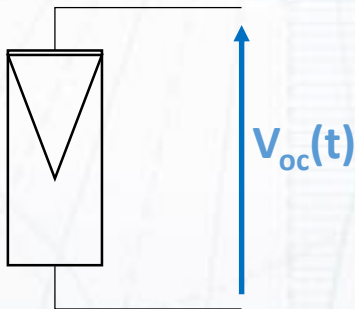
# LiFi Test Bench



# LiFi Test Bench



PV module



## Working range:

- **E/R distance:** 1cm  $\rightarrow$  2m
- **Luminous intensity AC+DC:** 100lx  $\rightarrow$  400000lx
- **Frequency modulation:** 50 KHz (Bias Tee)  $\rightarrow$  25 MHz (LED)
- **Calibration:** Hamamatsu APD photodiode
- **Modulation type :** DCO-OFDM  
(IM2NP internal software development)

# LiFi Modulation : DCO-OFDM

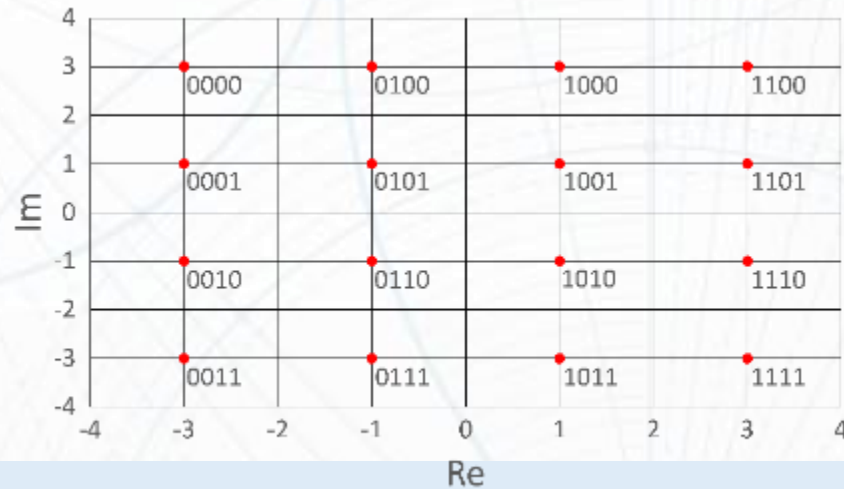
## DCO- OFDM :

- DC biased Optical – Orthogonal Frequency-Division Multiplexing

## Principle :

- Send multiple frequency at same time without interferences
- Send set of bits on each frequency (by using some amplitude level on signal)

Constellation map example  
for 4 bits on each frequency



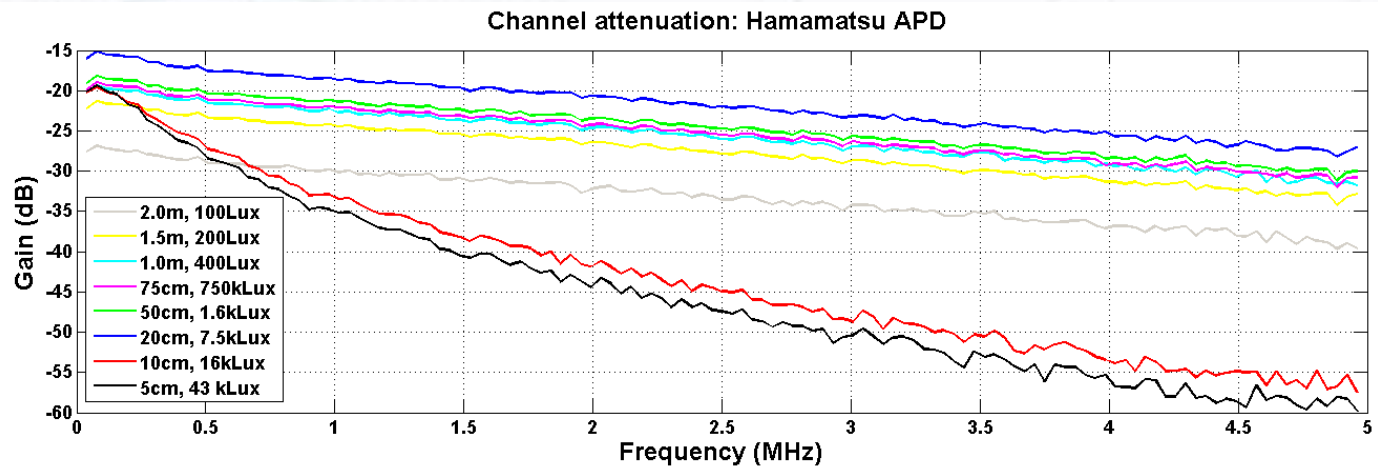
## Interest of OFDM modulation :

- Increase data rate
- Measure channel on all selected frequency at same time

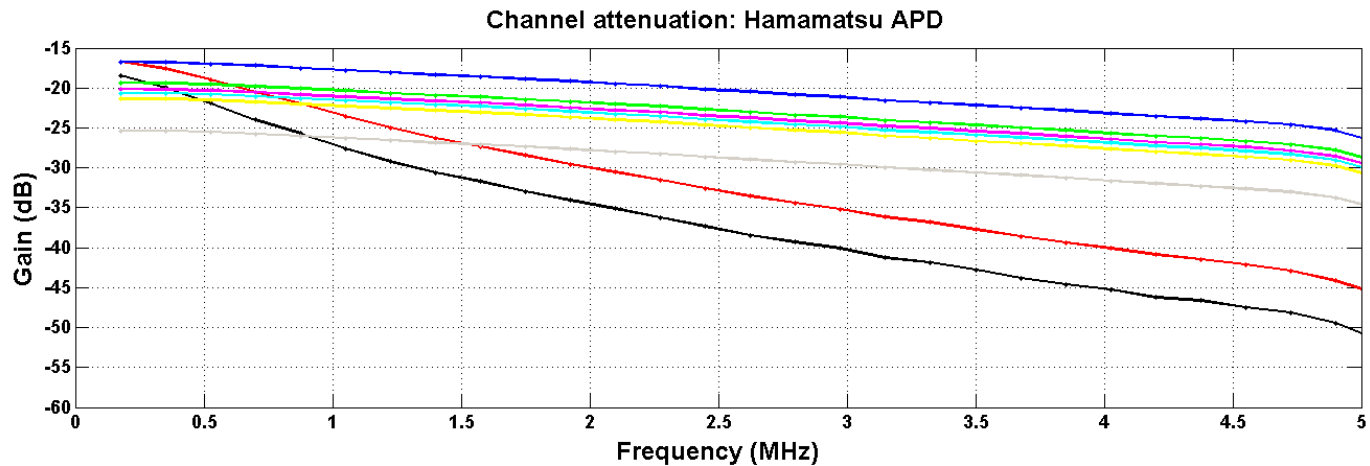


# LiFi Bench validation

## IM2NP



## CEA



Bench calibration have been made compared to SunPartner / CEA-Leti publication

**SPECIFIC LIFI APPLICATION**

**SPECIFIC LIFI RECEIVER**

# Specific indoor LiFi Applications

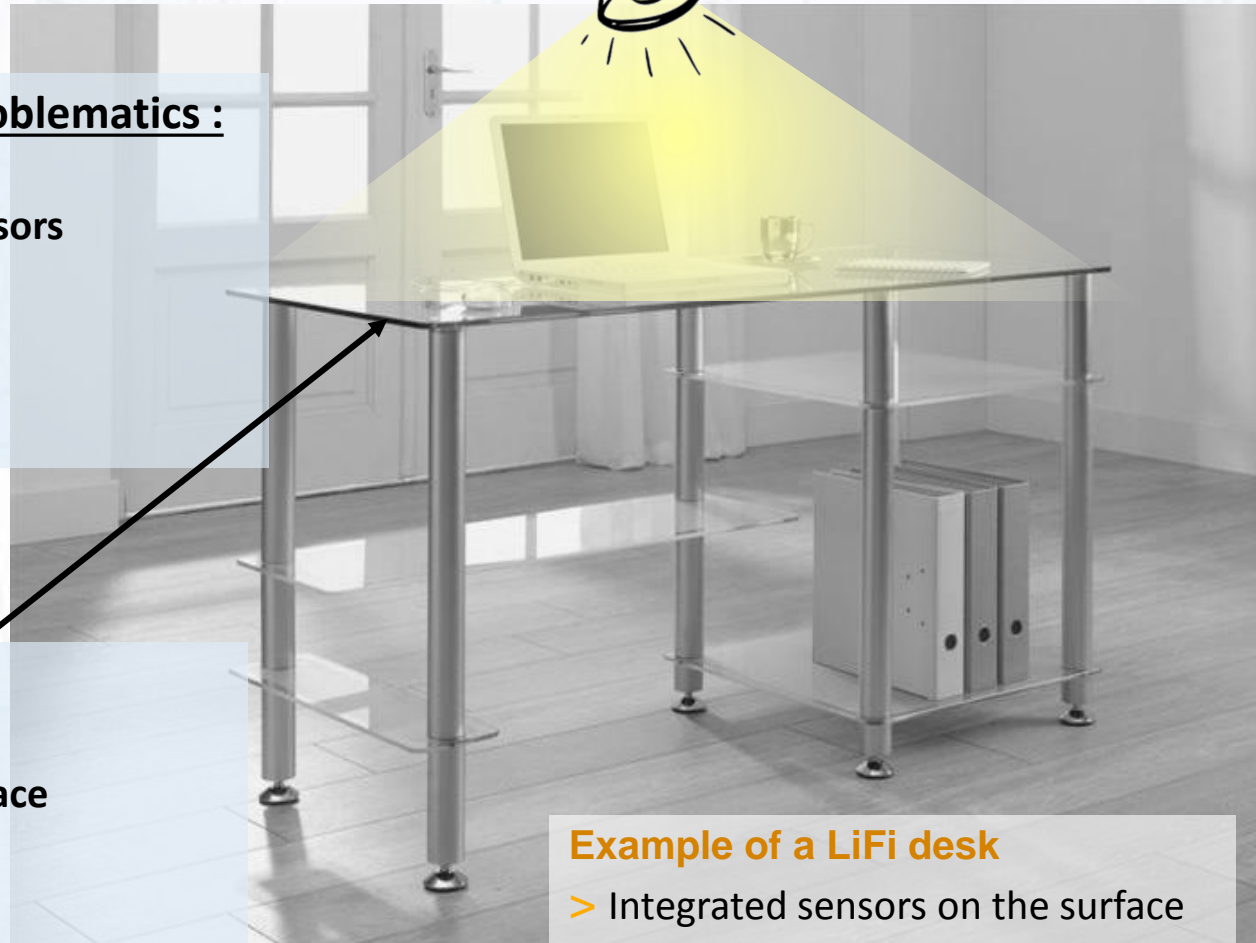


## Conventional reception problematics :

- **Small sensors, opaque sensors**
  - Not well integrated
- **Need to be powered**
- **Strong shading effect**
- **Directional reception**

## Photovoltaic solution :

- **Large semi transparent surface**
  - Well integrated
- **Optical passive sensor**
- **Weak shading effect**
- **Omni-directional receiver**
- **Could be used as energy harvester**

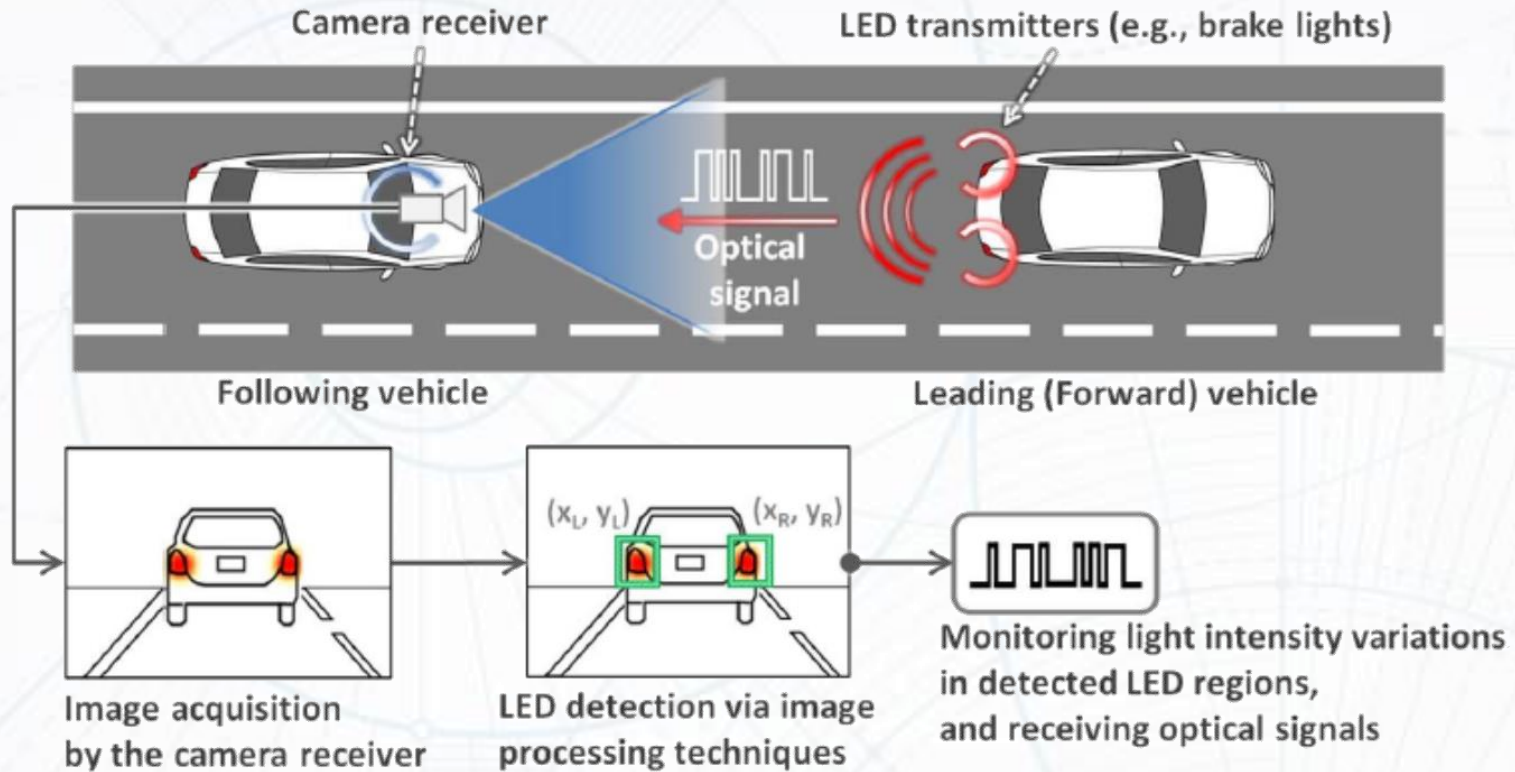


### **Example of a LiFi desk**

- > Integrated sensors on the surface
- > USB connection to smart object



# Specific outdoor LiFi Applications

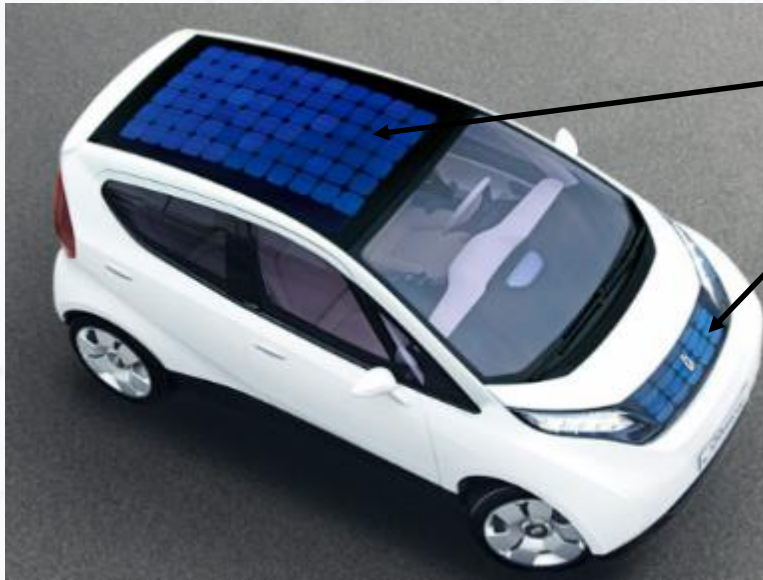


Source : Isamu Takai *et al*, « optical Vehicle-to-Vehicle Communication System Using LED Transmitter and Camera receiver », IEEE Photonics Journal, 2014

## Conventional reception problems:

- Ambient Lighting saturation effects
- Sensor location
  - Not well integrated
- Need to be powered
- Directional reception

# Specific outdoor LiFi Applications



## Photovoltaic solution :

- Large surface
  - Well integrated
- **Optical passive sensor**
- Weak shading effect
- Omni-directional receiver
- Could be used as energy harvester

Source : <http://www.voiture-electrique-populaire.fr/tag/panneaux-solaires-photovoltaiques>



LED Transmitter



**Bi-directional link**

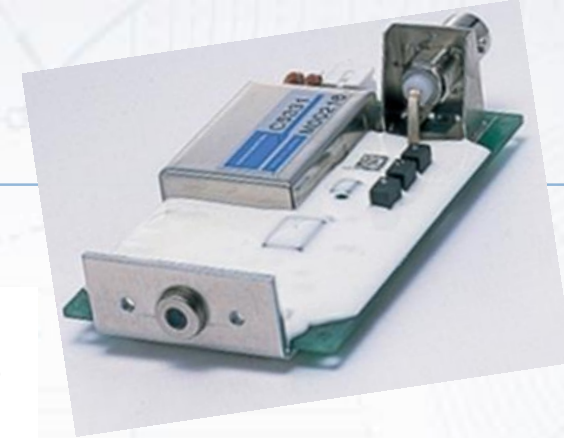
PV module receiver



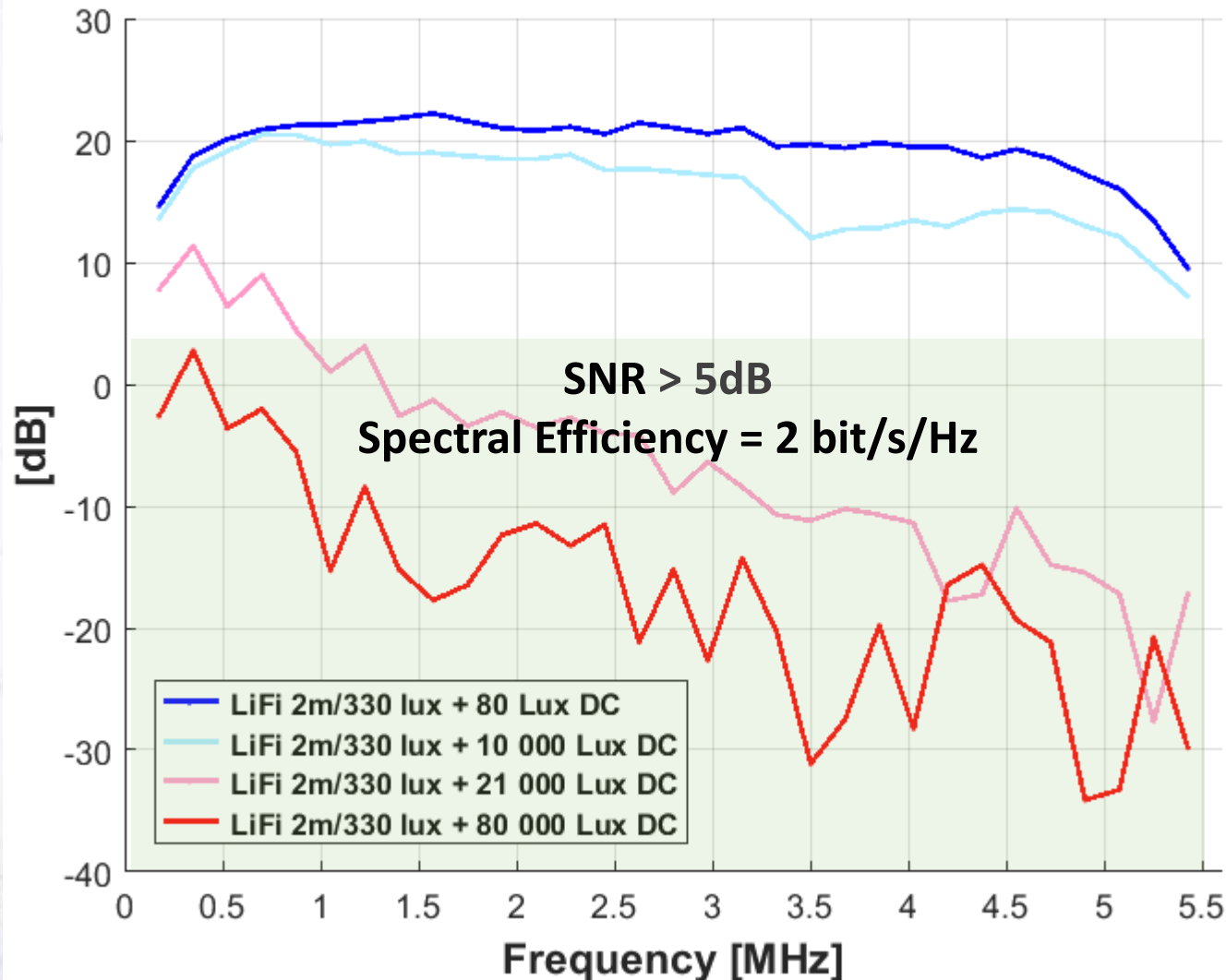
# AMBIENT LIGHTING EFFECT



# Conventional LiFi effects



**SNR : APD Hamamatsu C5331-5**



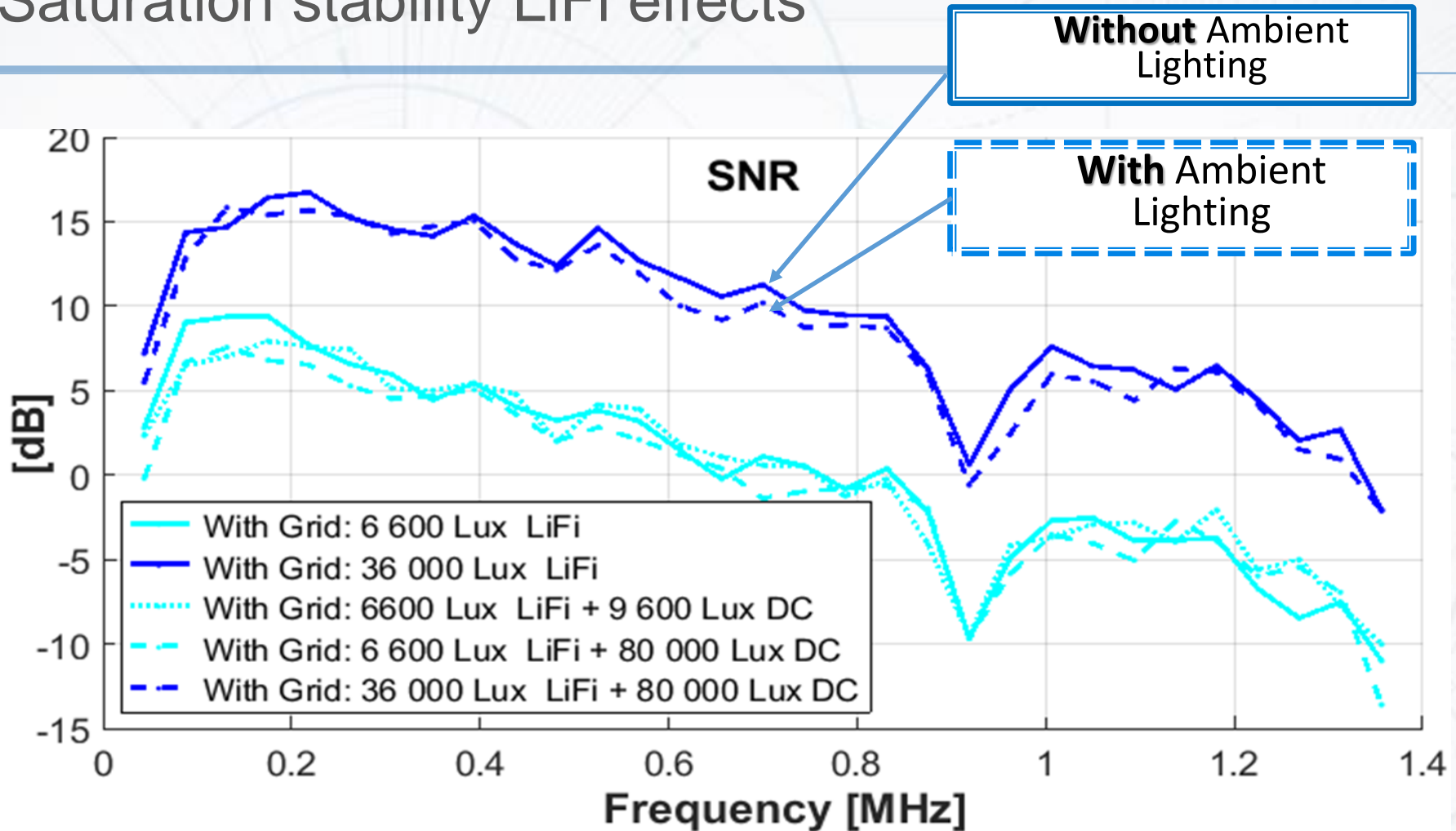
**Indoor Ambient  
Lighting Conditions**

**> 11 Mbit/s**

**Outdoor Ambient  
Lighting Conditions**

**0 Mbit/s**

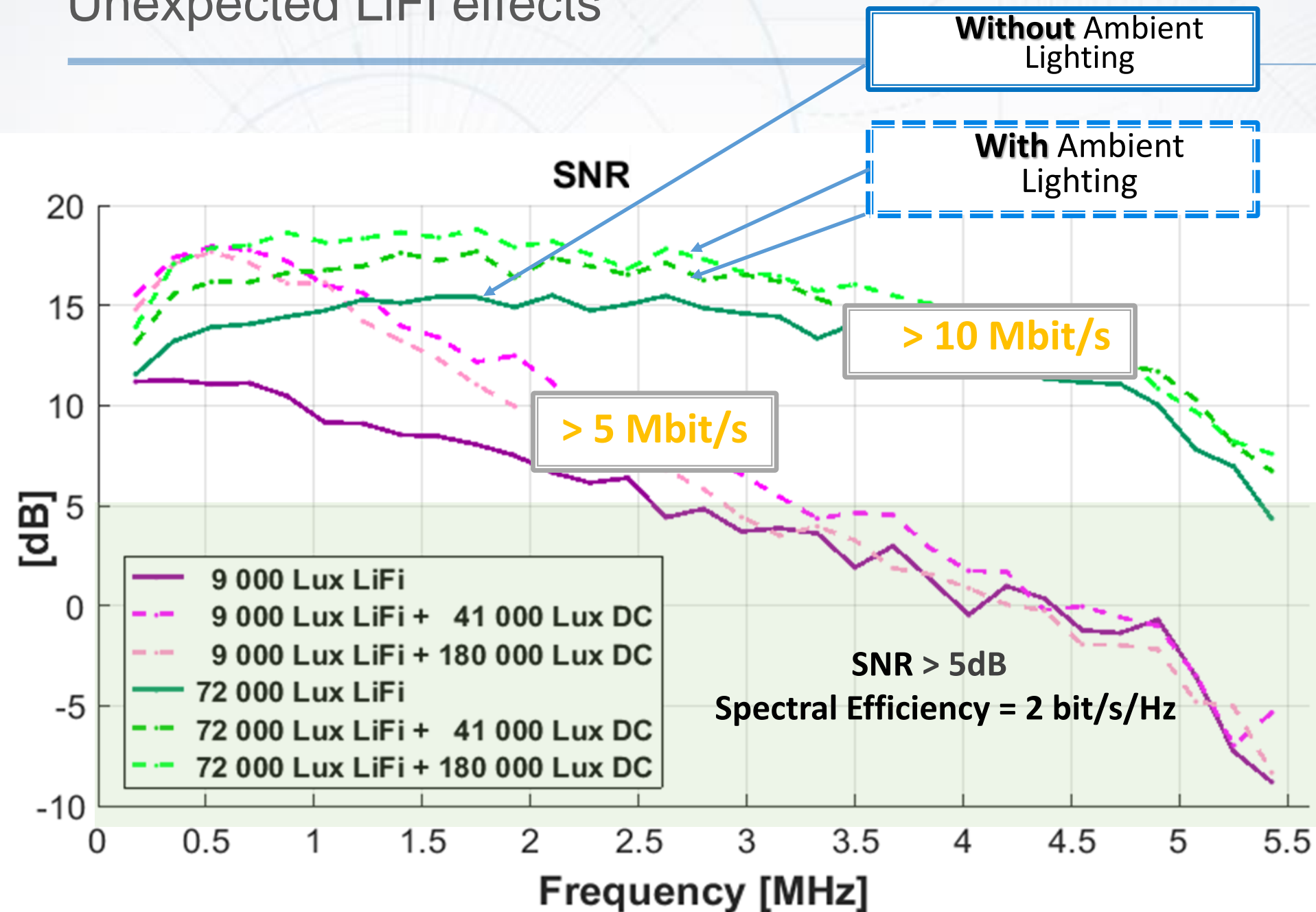
# Saturation stability LiFi effects



Indoor Ambient Lighting Conditions & Outdoor Ambient Lighting Conditions

Same performances

# Unexpected LiFi effects





# 3 different ambient lighting effects

## ➤ Conventional LiFi effects :

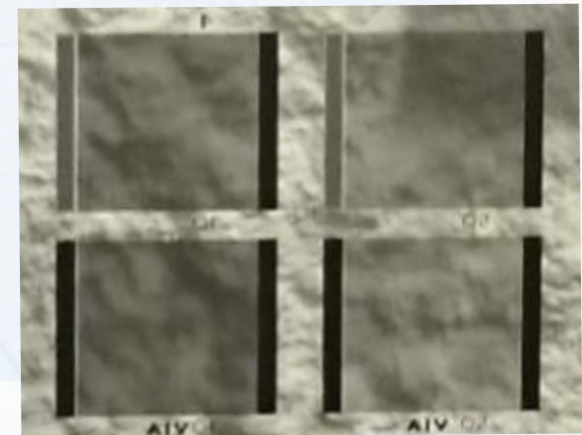
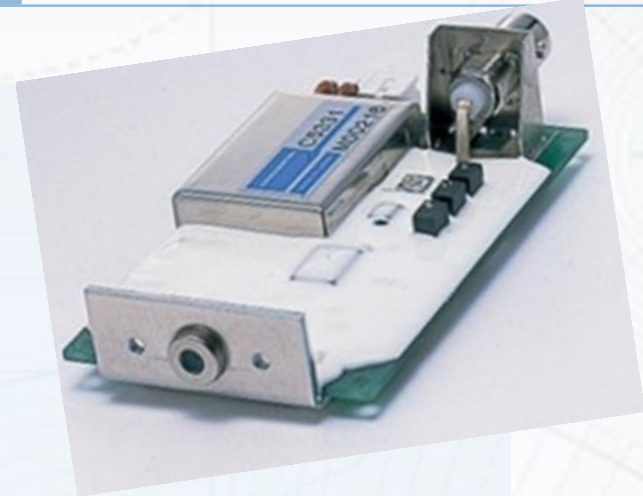
- If the ambient lighting  Then the SNR 

## ➤ Saturation stability effects :

- If the ambient lighting  Then the SNR 

## ➤ Unexpected LiFi effects :

- If the ambient lighting  Then the SNR 



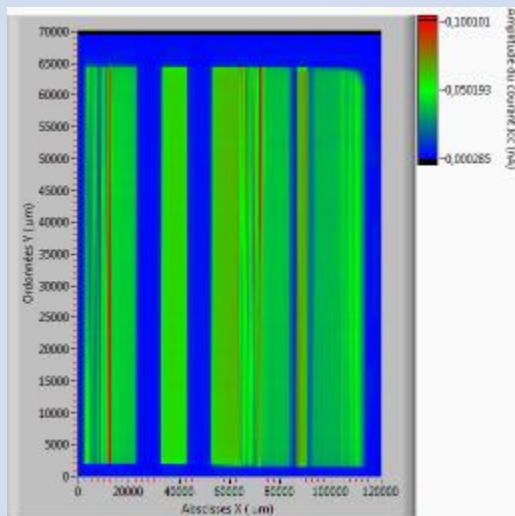
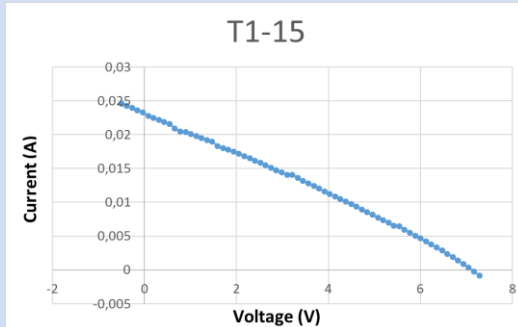
## Sources

1. E. Bialic, L. Maret, D. Ktnéas, « Specific innovative semi-transparent solar cell for indoor and outdoor LiFi Application »
2. E. Bialic, presentation at WISEE 2016

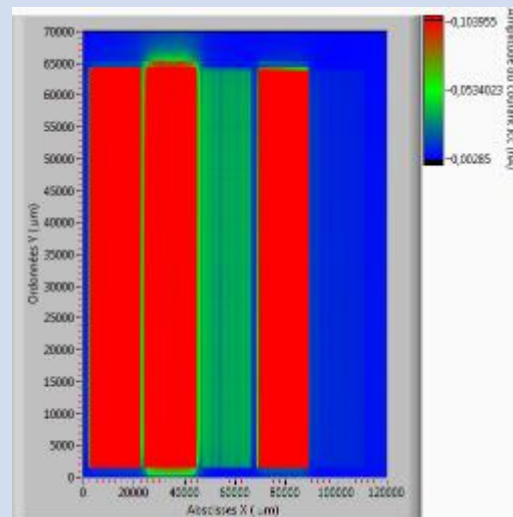
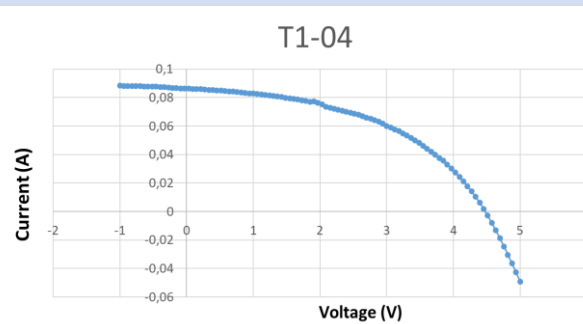
# SHADING EFFECTS

# T1-15 & T1-04 : I(V), LBIC (Light Beam Induced Current)

T1-15 : 11 cells, 33% PV

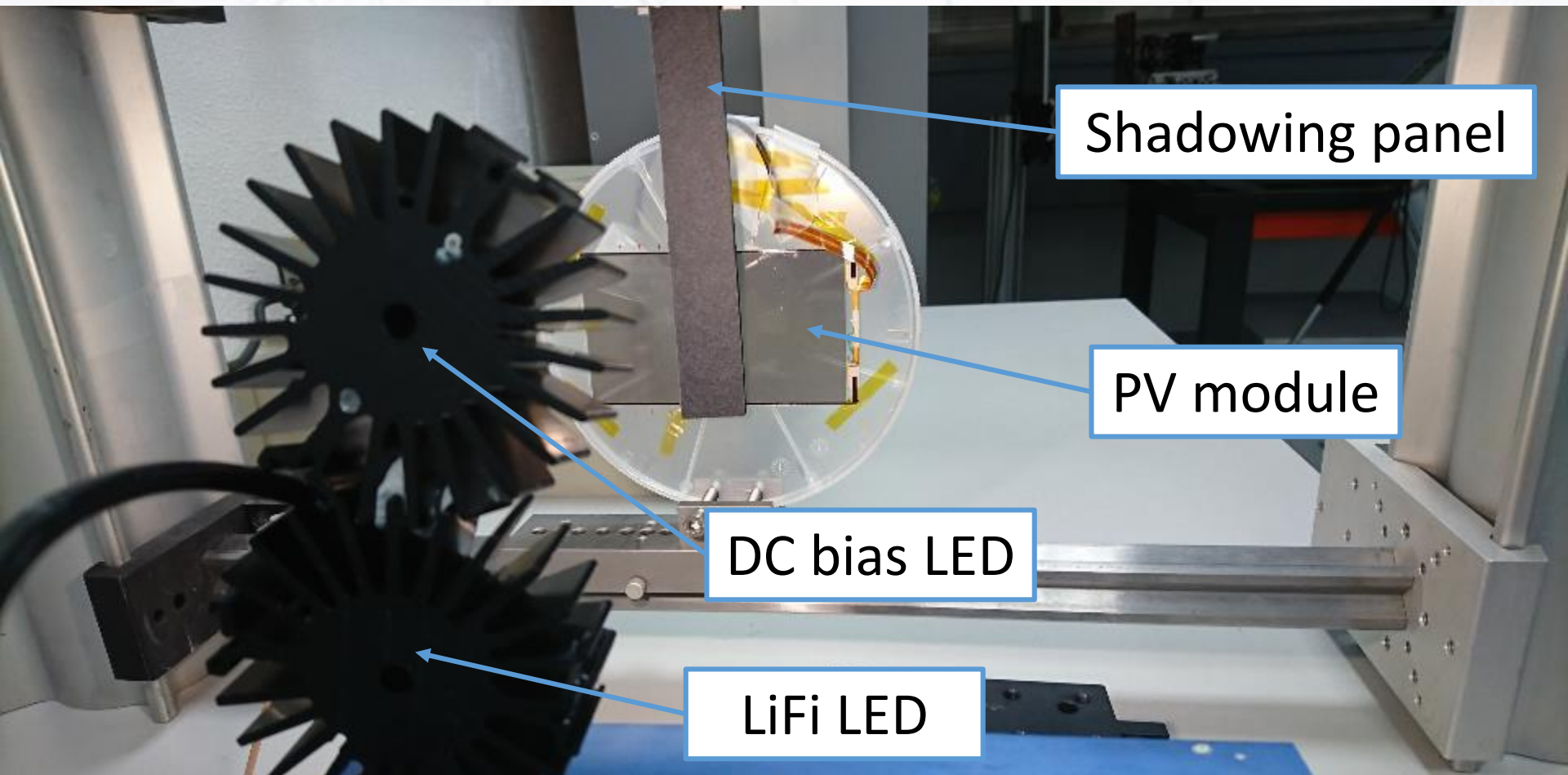


T1-04 : 5 cells, 33% PV

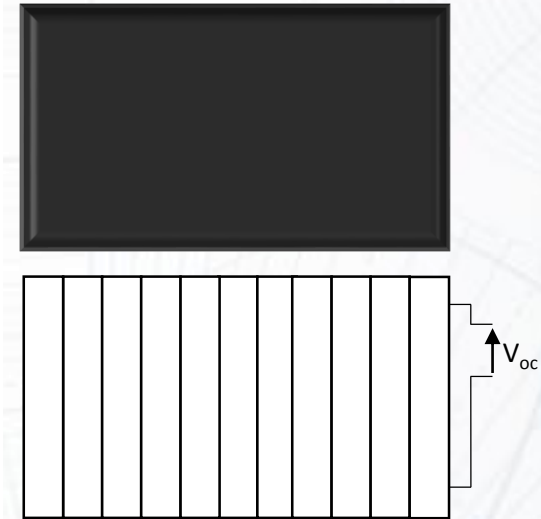
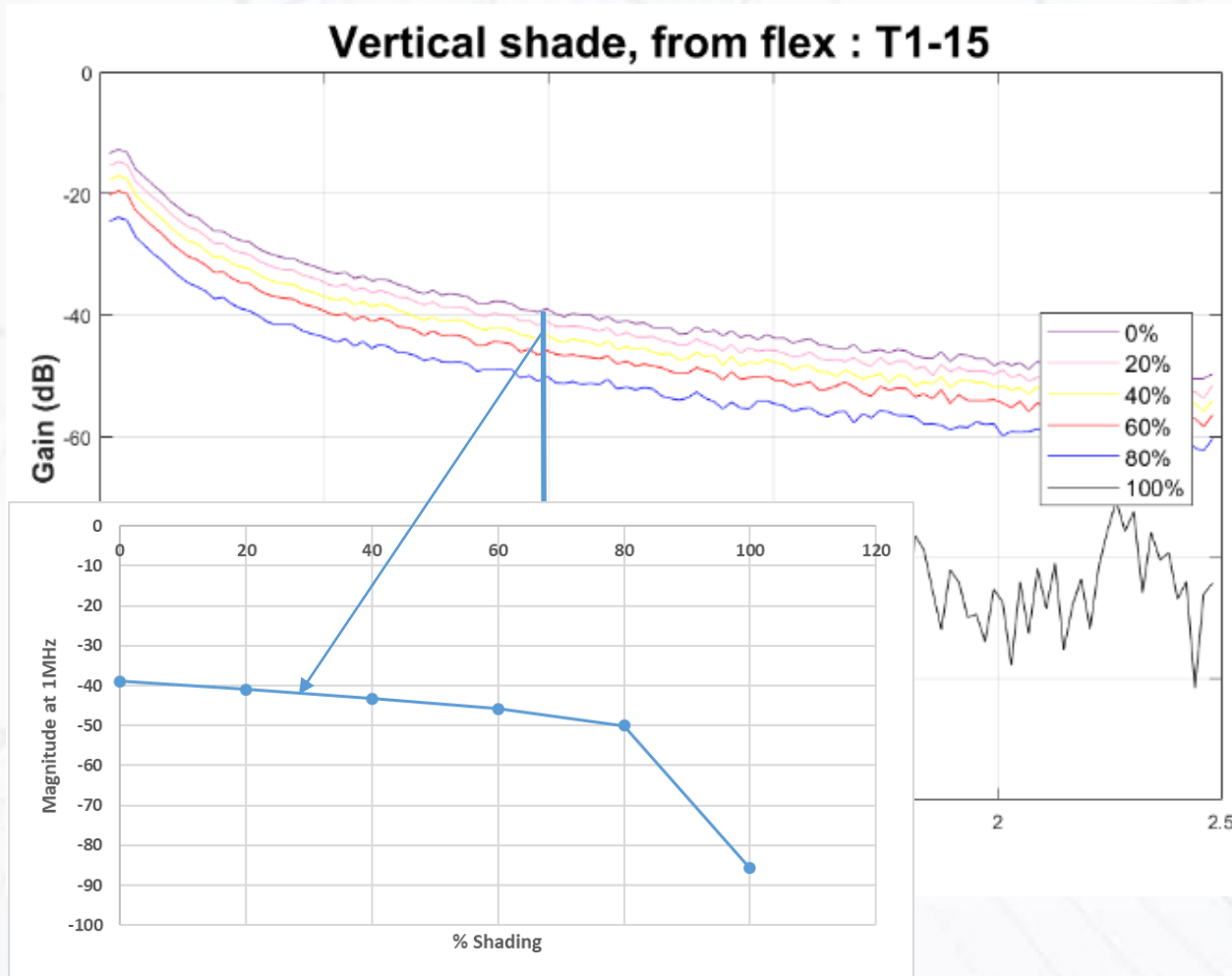




# Shading Effect Test Bench

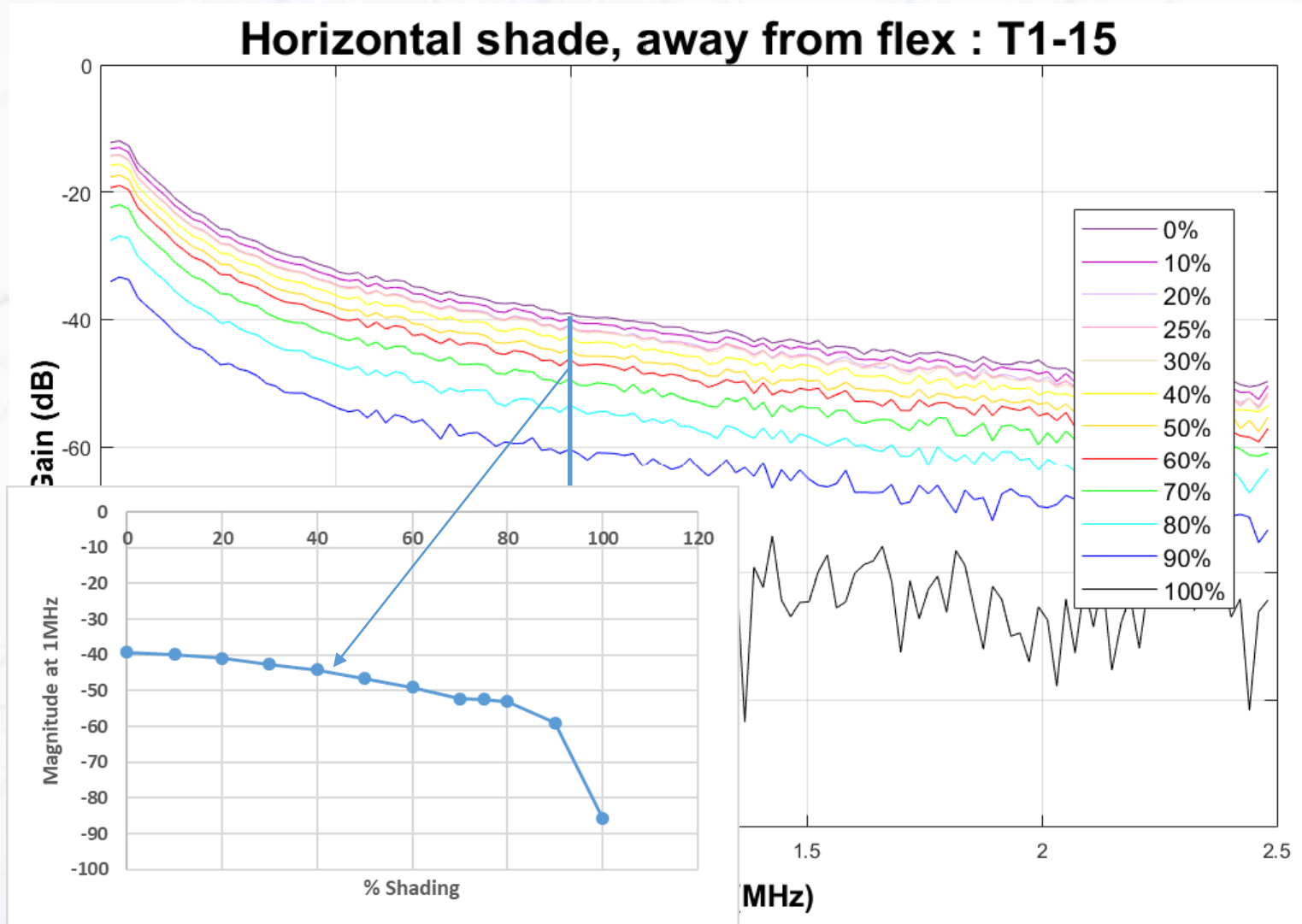


# Vertical shade



**LiFi detection operational up to 80% shading**

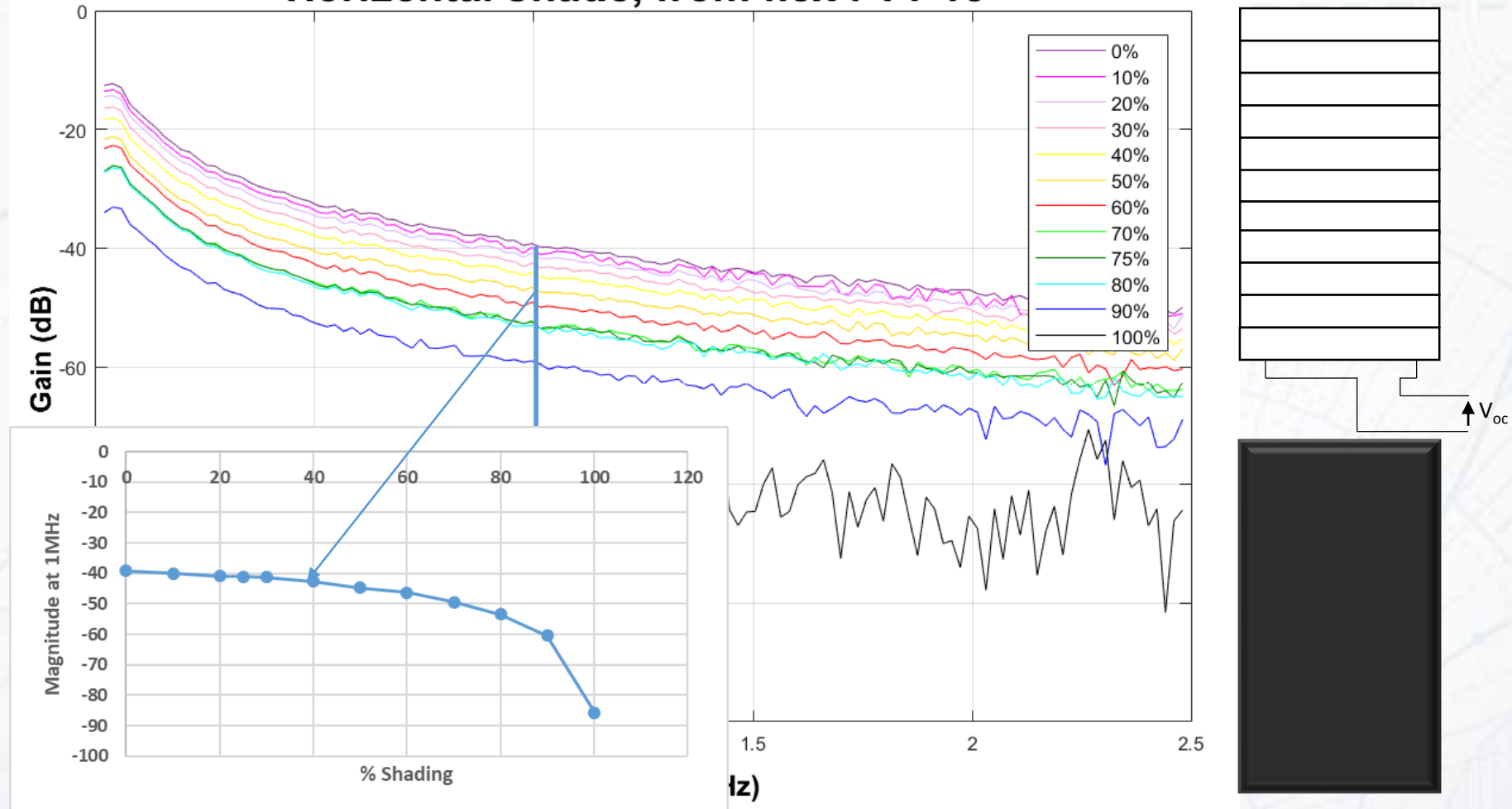
# Horizontal shade





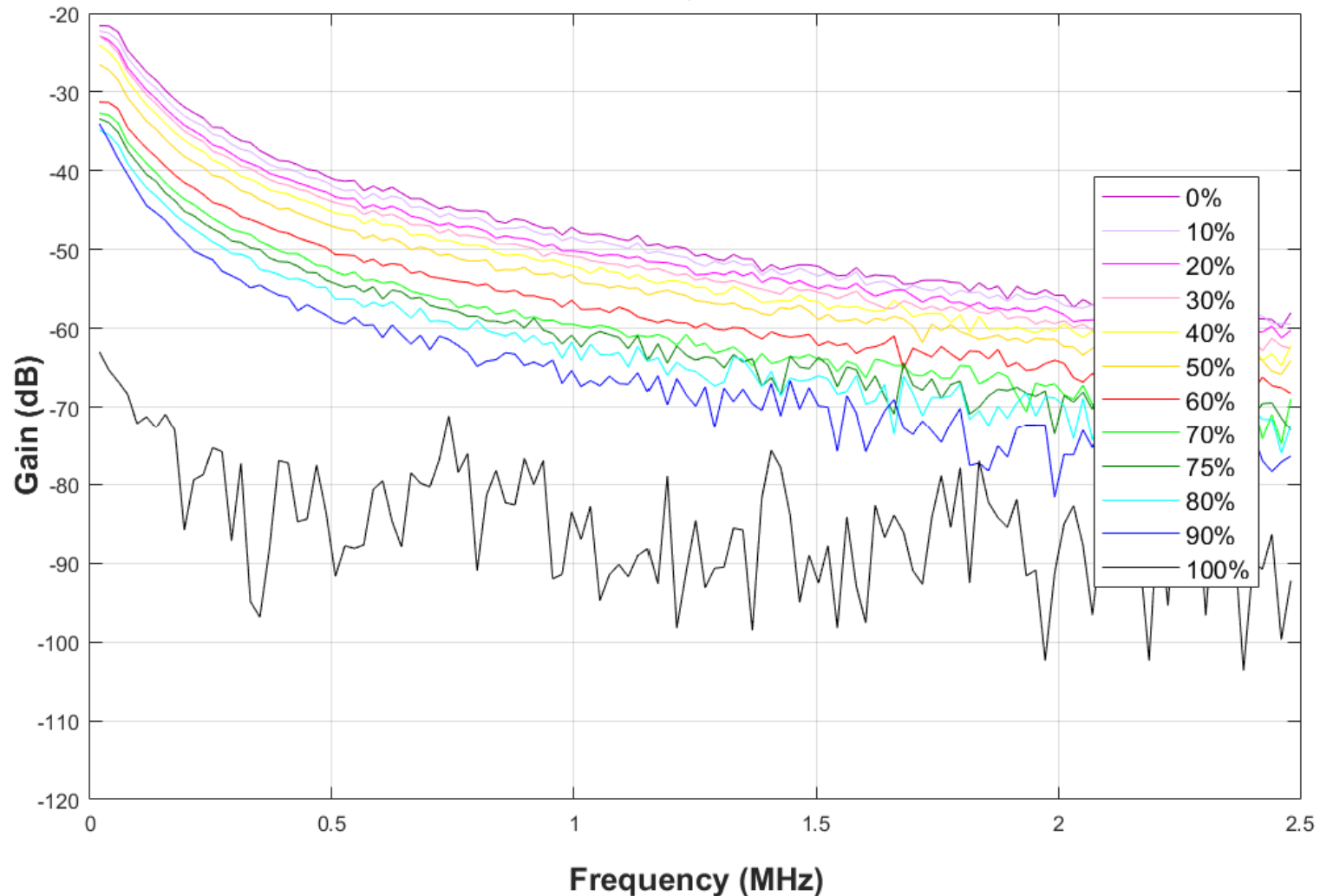
# Horizontal shade

Horizontal shade, from flex : T1-15



# Horizontal shade

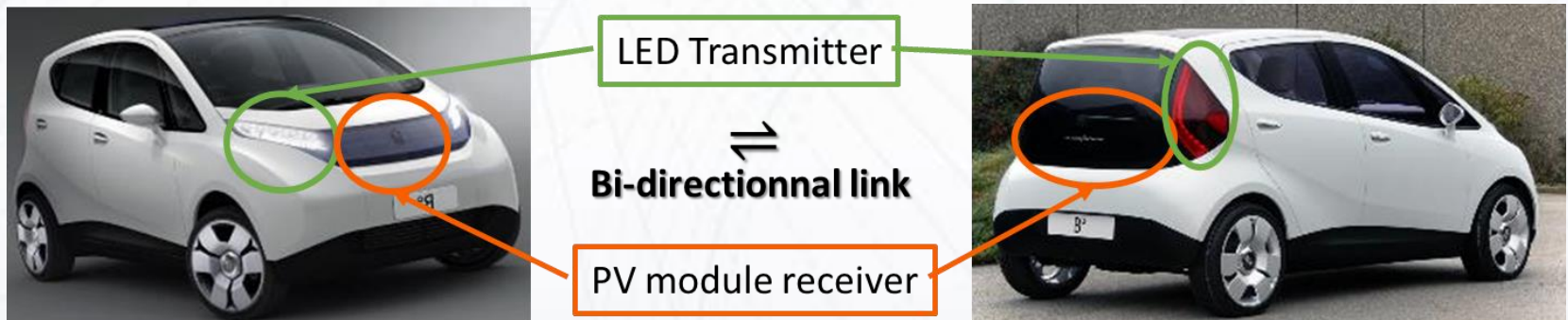
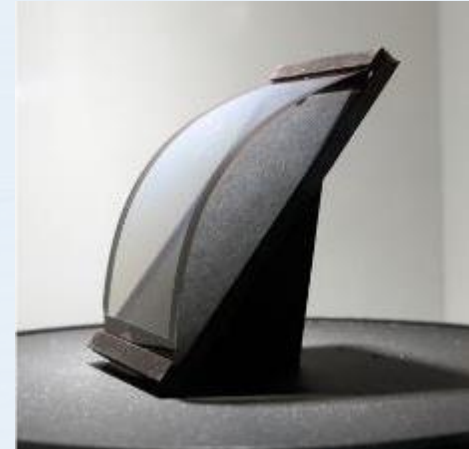
## Horizontal shade, from flex : T1-04



# Conclusion

## Photovoltaic receiver: a good solution for specific LiFi applications

- **Large surface**
  - Well integrated
  - Semi-transparent or design solution
  - Glass or flexible solution
- **Passive optical sensor**
- **Compatible with outdoor environment**
- **Weak shading effect**
- **Omni-directional receiver**
- **Could be used as energy harvester**





# Thanks for your attention – Let's Go to the demonstration

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240 Avenue Olivier Perroy - 13790 Rousset - France  
+33 (0) 4 42 39 86 44



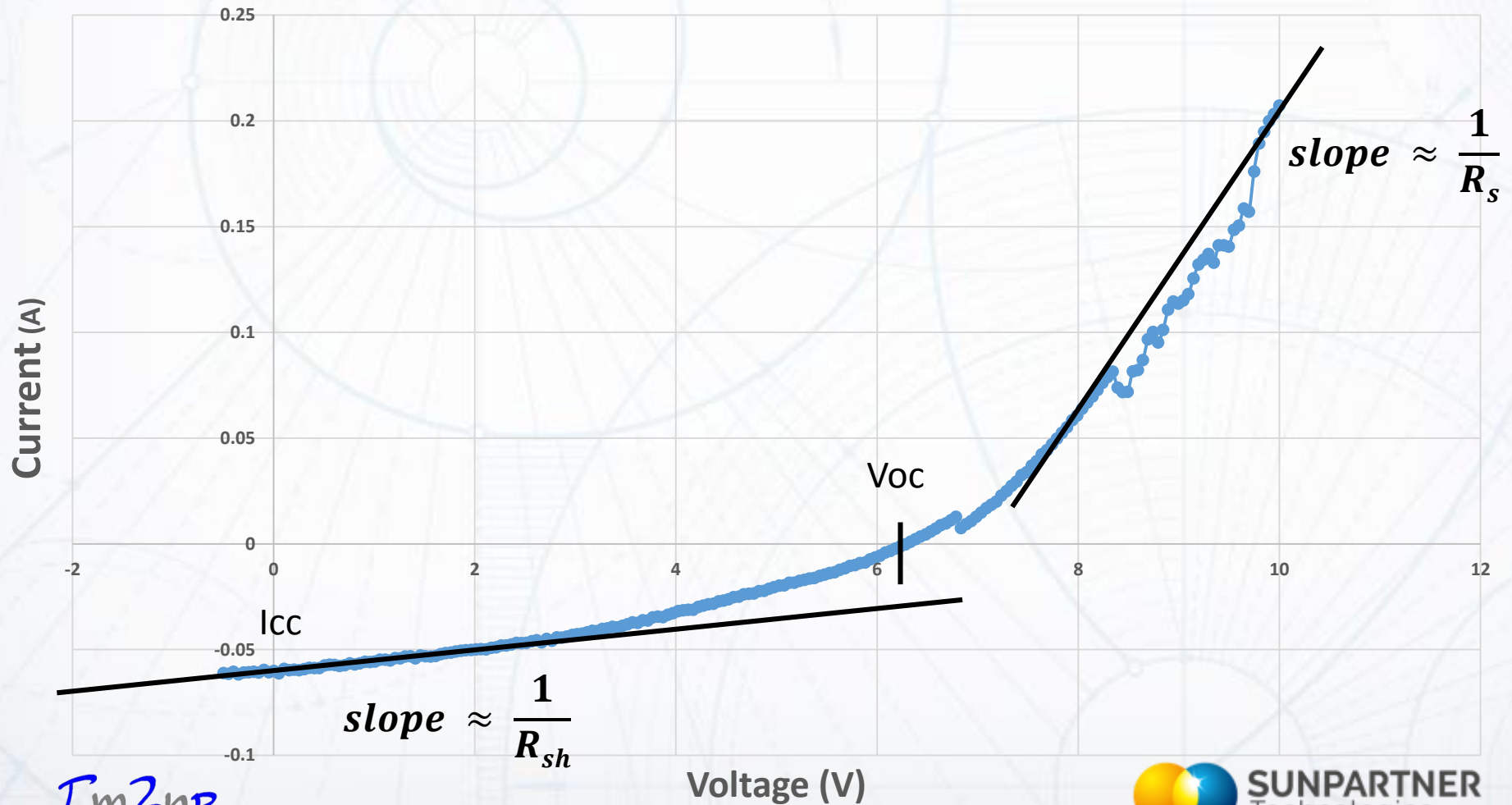
[www.sunpartnertechologies.com](http://www.sunpartnertechologies.com)

# ANNEXES

# STATIC CHARACTERIZATION TOOLS

I(V)

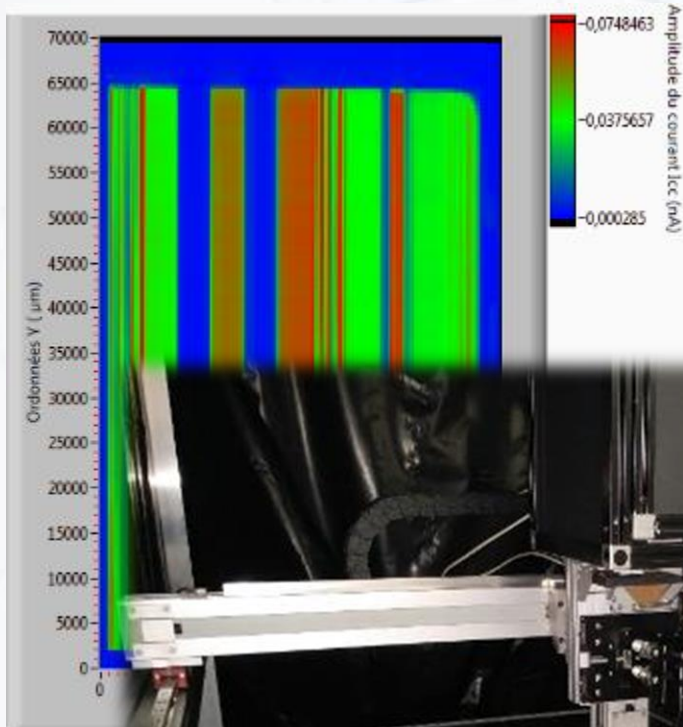
## CIGS Disasolar



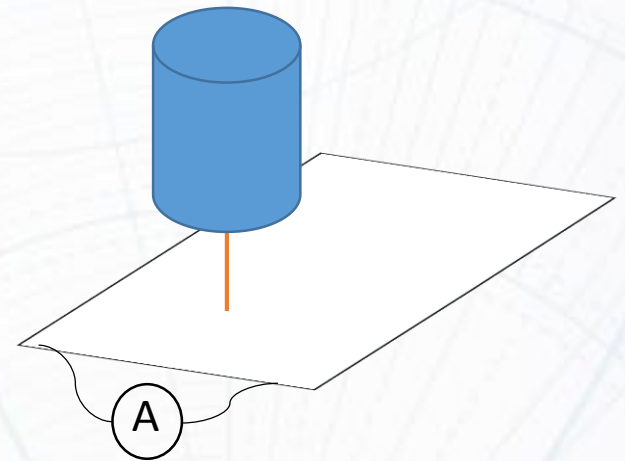
$I_{m2np}$



# LBIC : Light Beam Induces Current



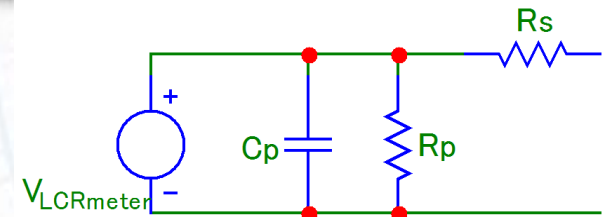
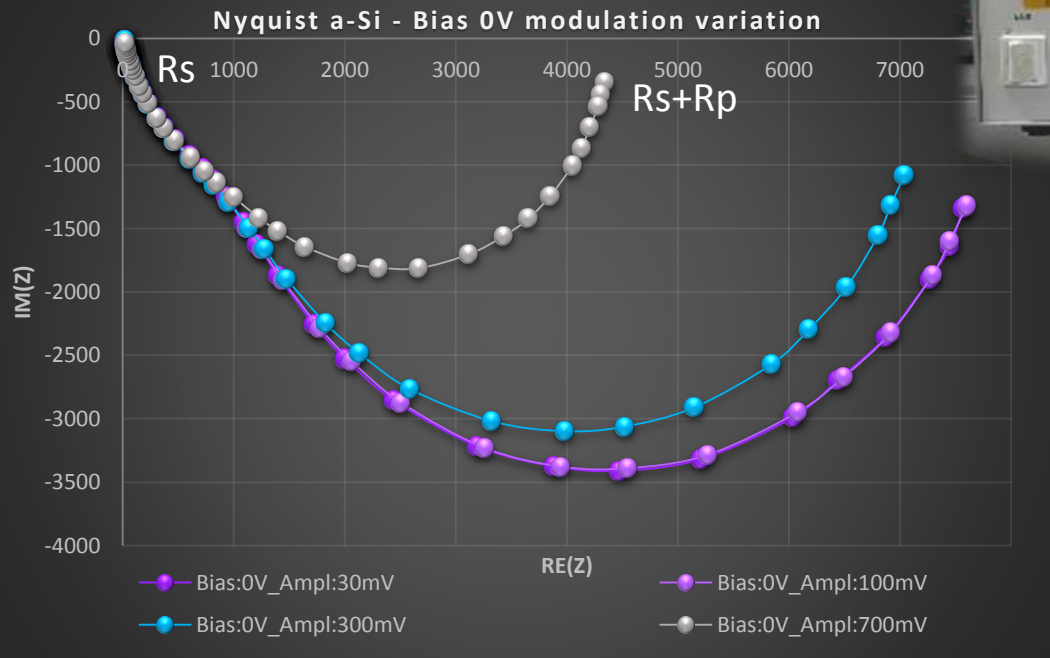
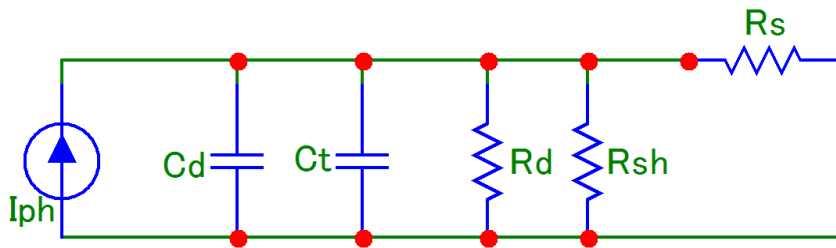
A beam light illuminate the module point by point and current module is measured.



**Resolution:** 50µm x 50µm (light spot)  
**Wavelength:** 400 to 1100nm or white light  
**Largest module acceptable:** 1.5m x 1m

# DYNAMICAL CHARACTERIZATION TOOLS

# Impedance spectroscopy



AC+DC voltage is sent to the DUT and current fluctuation is measured.

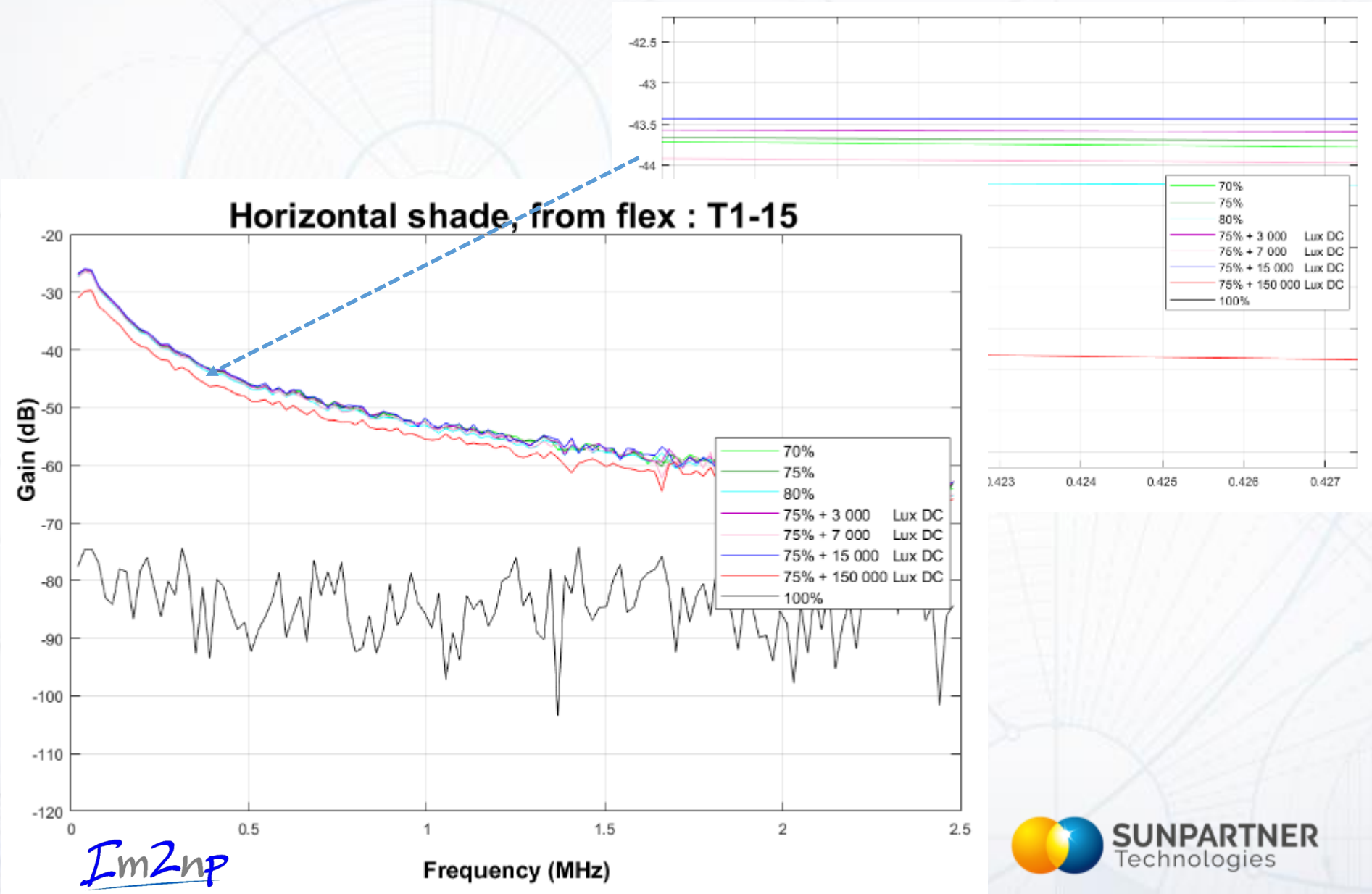
$$U = Z \cdot I$$

Reverse bias:  $R_p \sim R_{sh} \mid C_p \sim C_t$   
 Forward bias:  $R_p \sim R_d \mid C_p \sim C_d$

$$C_p = \frac{1}{\omega R_p} \sqrt{\frac{|Z|^2 - (R_s + R_p)}{-|Z|^2 + R_s^2}}$$

*ImZnp*

# Horizontal shade & bad cell : no lighting effects



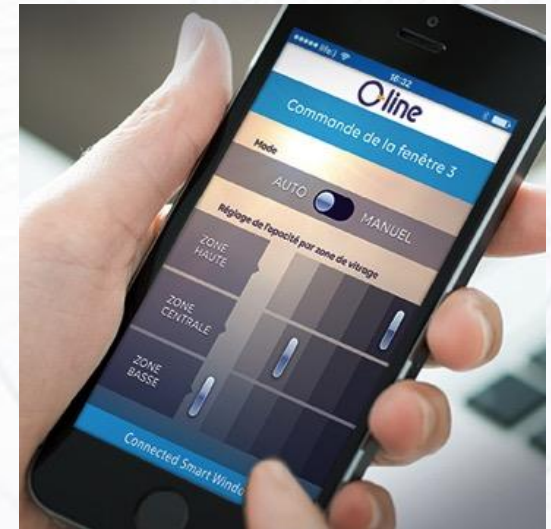


## Smart window

- > Tintable glass control
- > Integrated sensors\*
- > Wireless communication (Bluetooth & LoRa)
- > Battery management

## Real time control

- > Automatic or manual mode
- > Precise control



\* presence, temperature, outdoor luminosity, Intrusion detection, Open window detection system