# T1 Tutorial description

This tutorial, entitled :

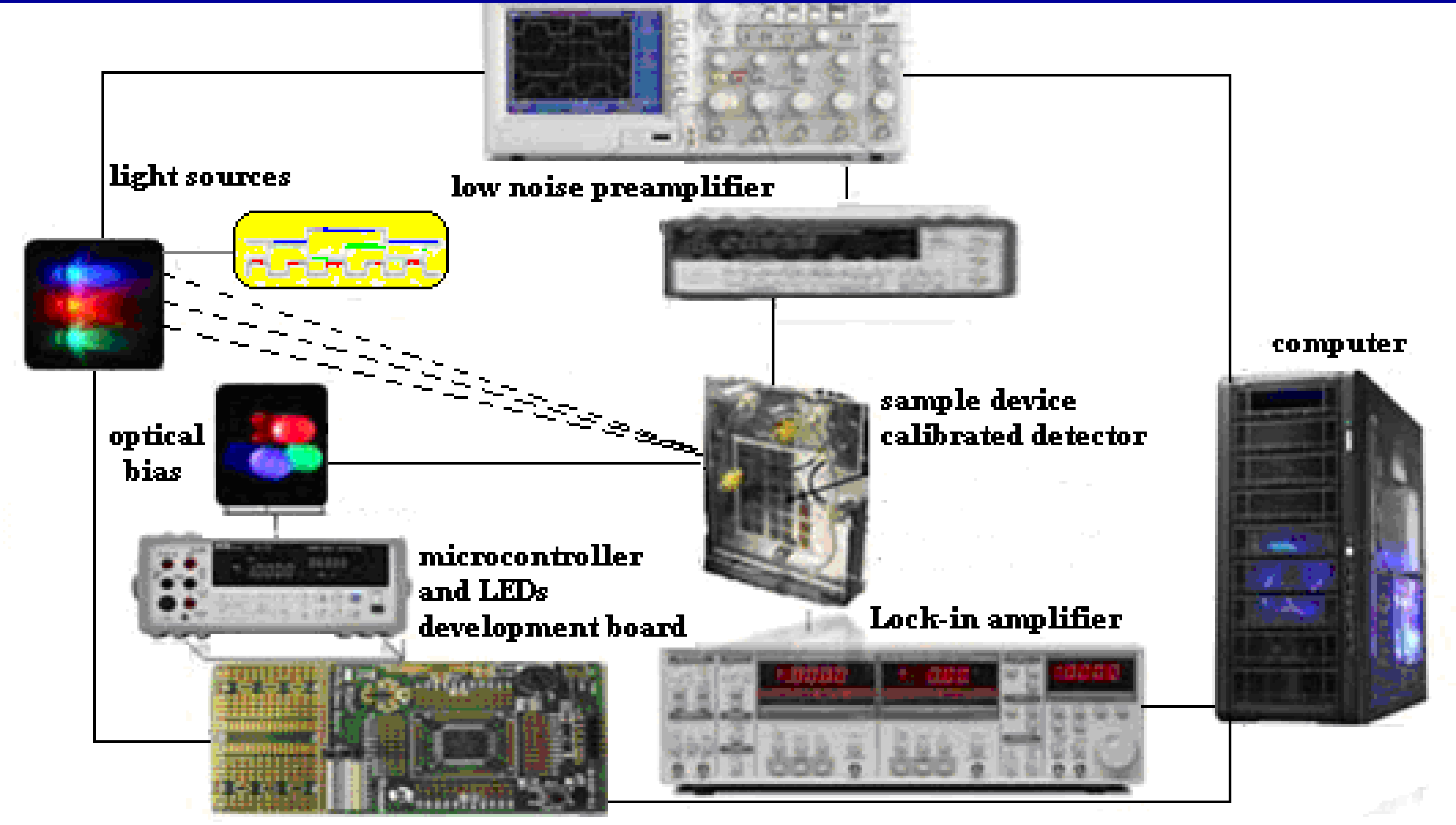
**”Visible light communications in smart road infrastructures”,**

reports four work areas:

- **Admission Regulation of Traffic to Improve Public Transport in Urban Areas**
- **Essays for optical communications**
- **Indoor positioning using a-SiCH technology**
- **Connected cars: road to vehicle communication through visible light**

# *II Work Area:*

# Essays for optical communications



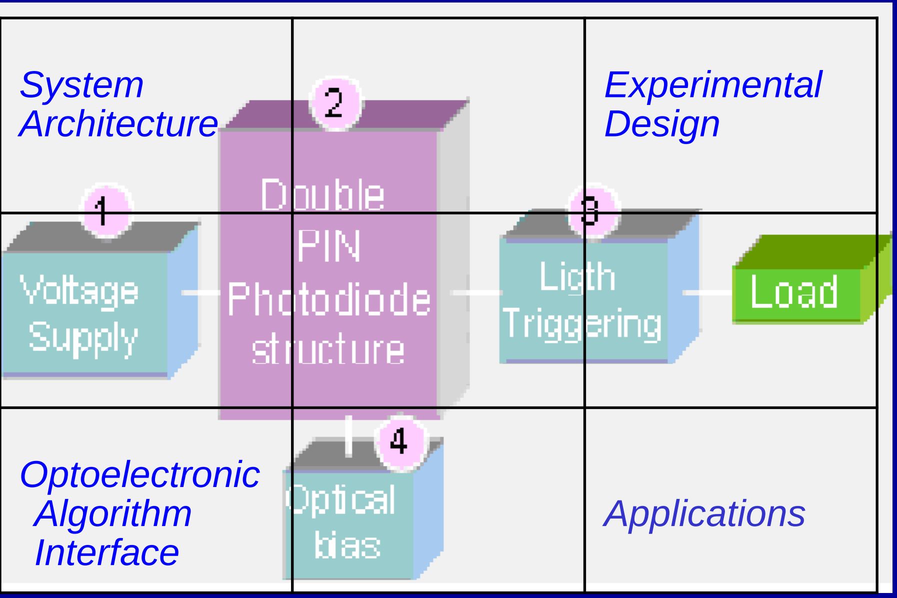

*Schematic diagram of the transducers essays.*
*An indoor, line-of-sight visible light communication link.*

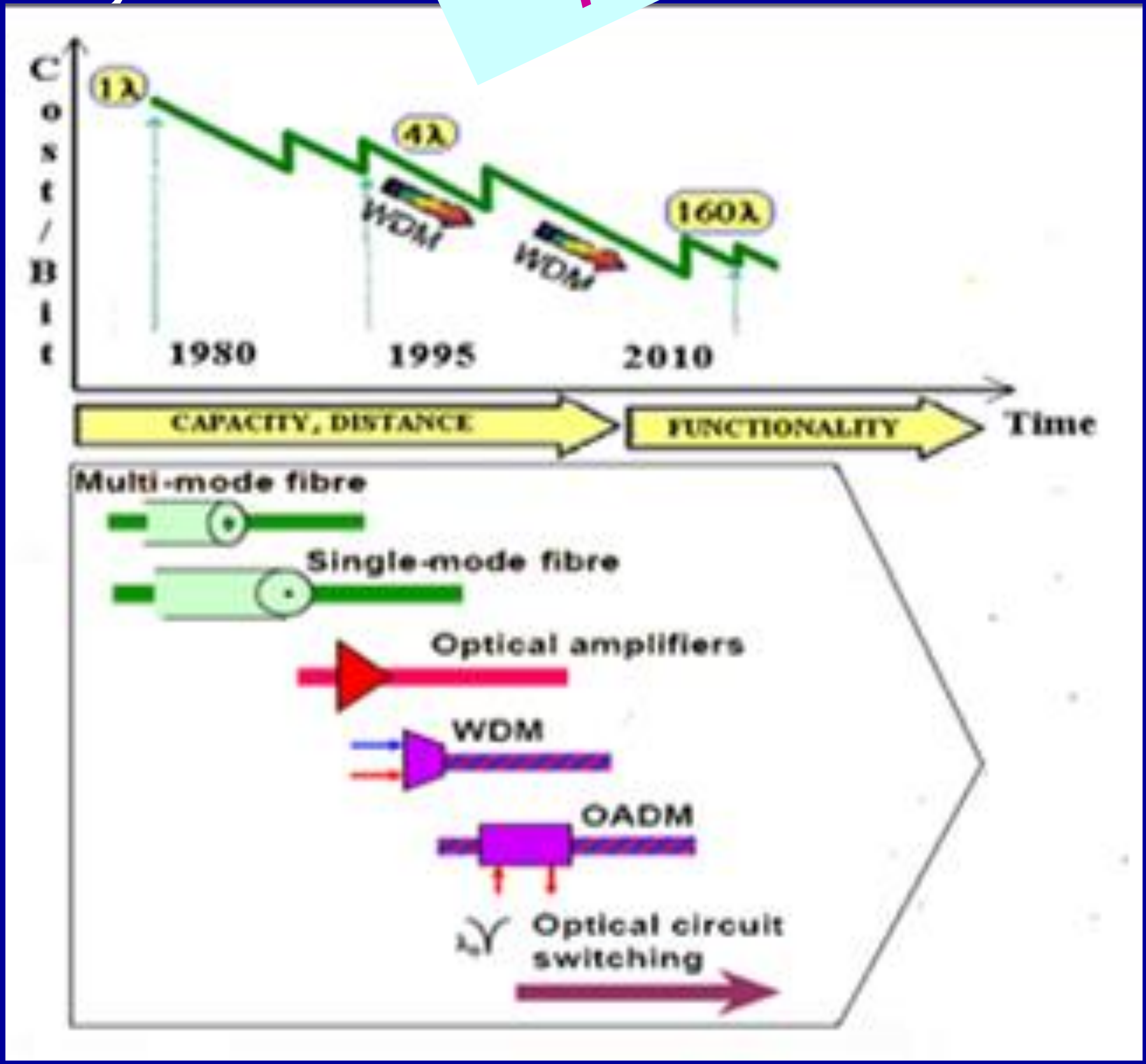
# Motivation and Objectives

Innovative concept
Paradigm shift

Optoelectronic WDM system:

**MAIN WORK AREAS:**



# Outline

- **State of art:**

  **Experimental Design Work Area. The original idea.**

- **Bias controlled device:**

  **Voltage and Optical bias. Self amplification. Photonic filters.**

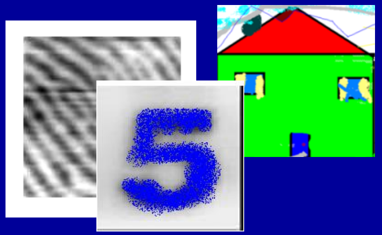
- **Dynamical effects:**

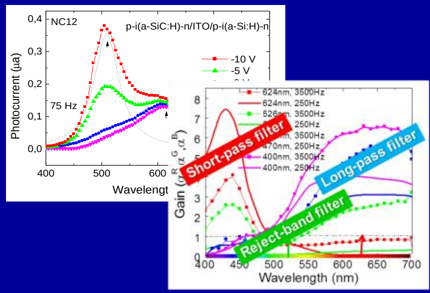
  **A two stage active circuit. Optoelectronic simulator.**

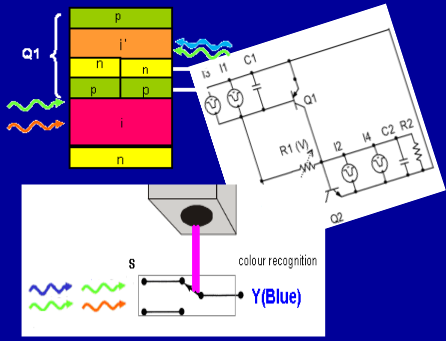
- **Reconfigurable active filters:**

  **Opto-electronic conversion. Optoelectronic logic functions.**

- **Conclusions and future trends.**

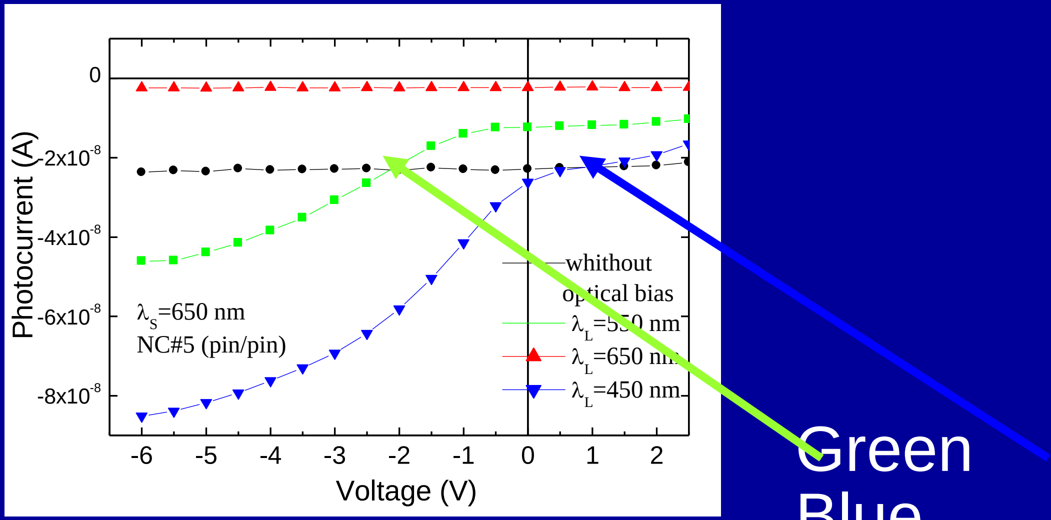




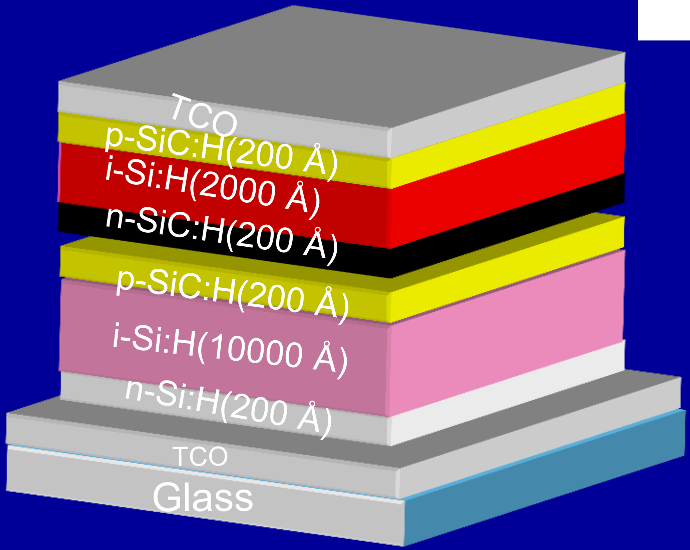




# State of art of a-Si/SiC Photodiodes

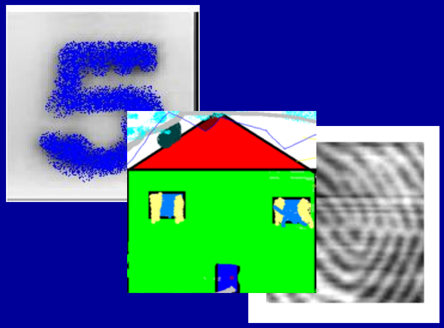
- Produced by PECVD
  - The thickness of the front photodiode was optimized for blue collection and red transmittance
  - The thickness of the back photodiode was adjusted to achieve high collection in the red spectral range




Color rejections function on the applied bias



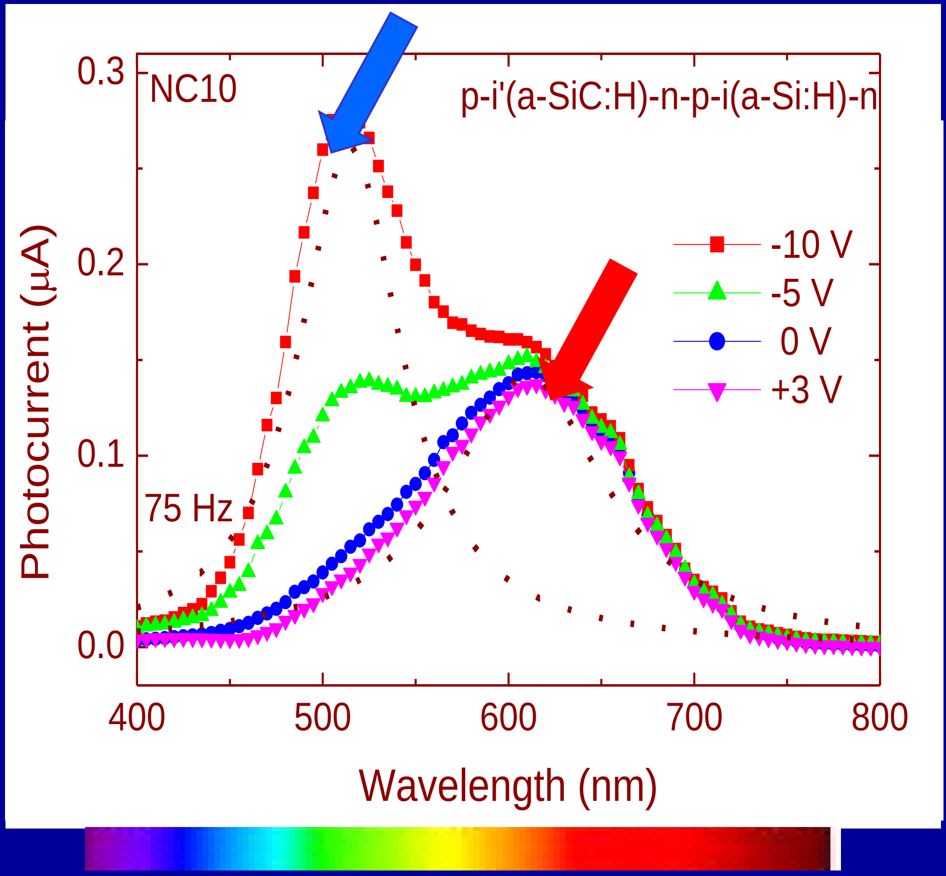

p-i-n p-i-n



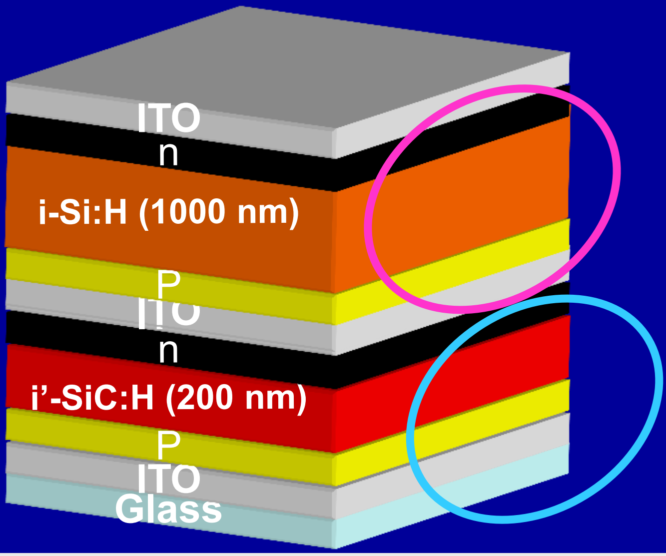
Light-to-dark Sensitivity depends strongly on the carbon concentration

*P. Louro, M. Fernandes, A. Fantoni, G. Lavareda, C. Nunes de Carvalho, R. Schwarz and M. Vieira "An amorphous SiC/Si image photodetector with voltage-selectable spectral response"Thin Solid Films, 511-512, 2006, pp.167-171*

# Voltage controlled optical filter

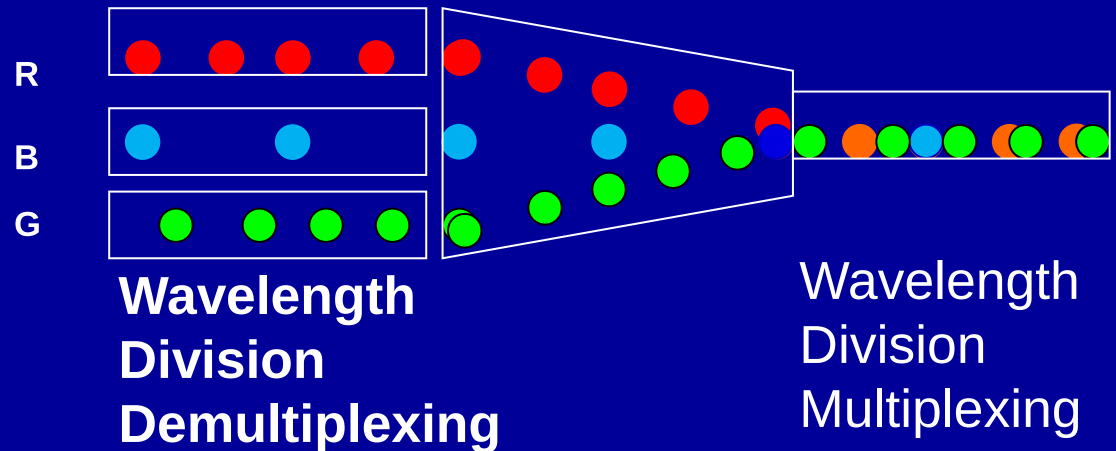



Back diode –Cuts the blue

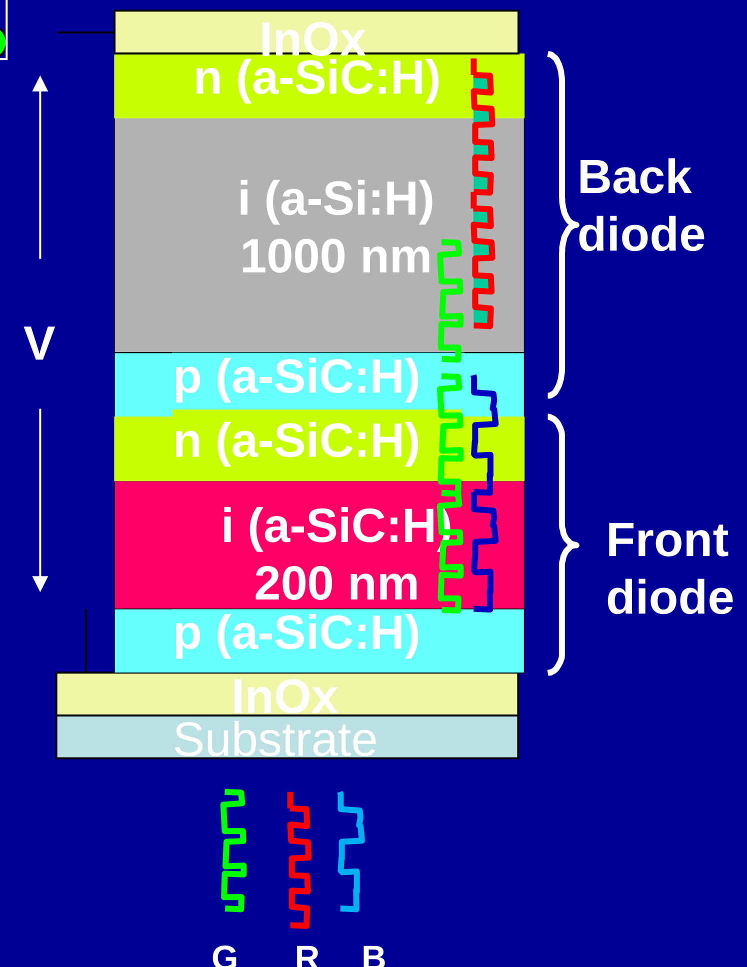


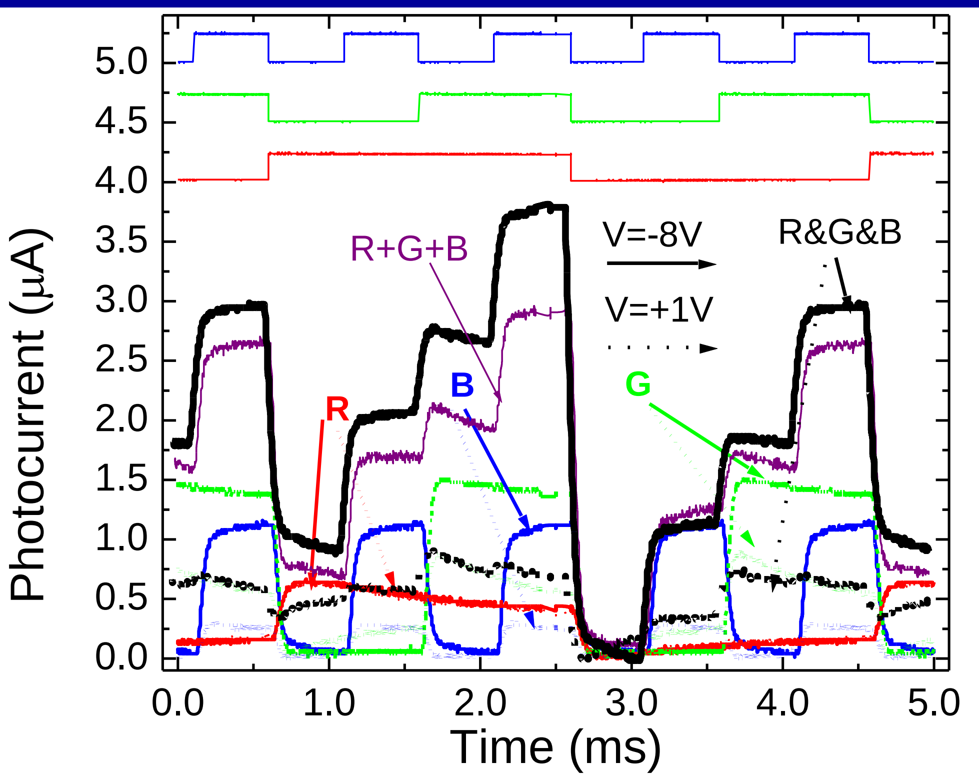

- Both front and back diodes act as optical filters confining, respectively, the blue and the red optical carriers, while the green ones are absorbed across both.

# Operation Principle



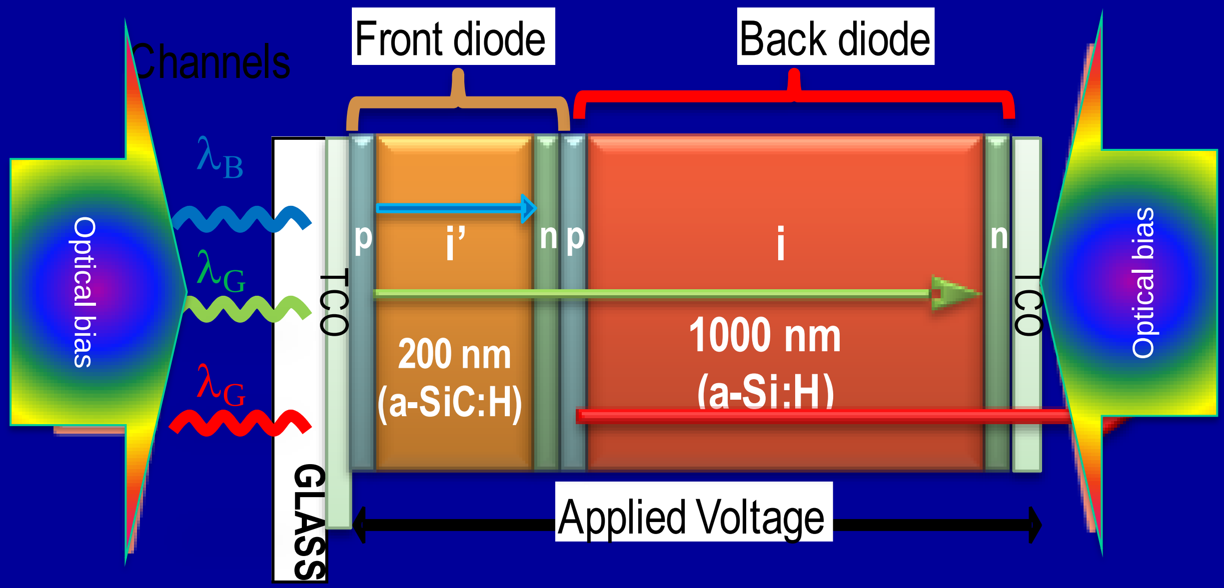

## Experimental Design Work Area

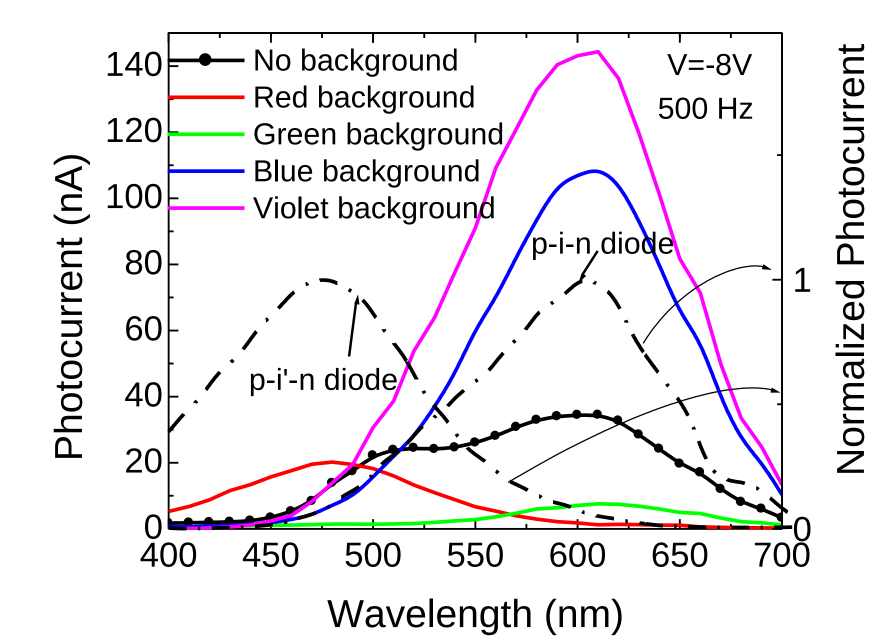


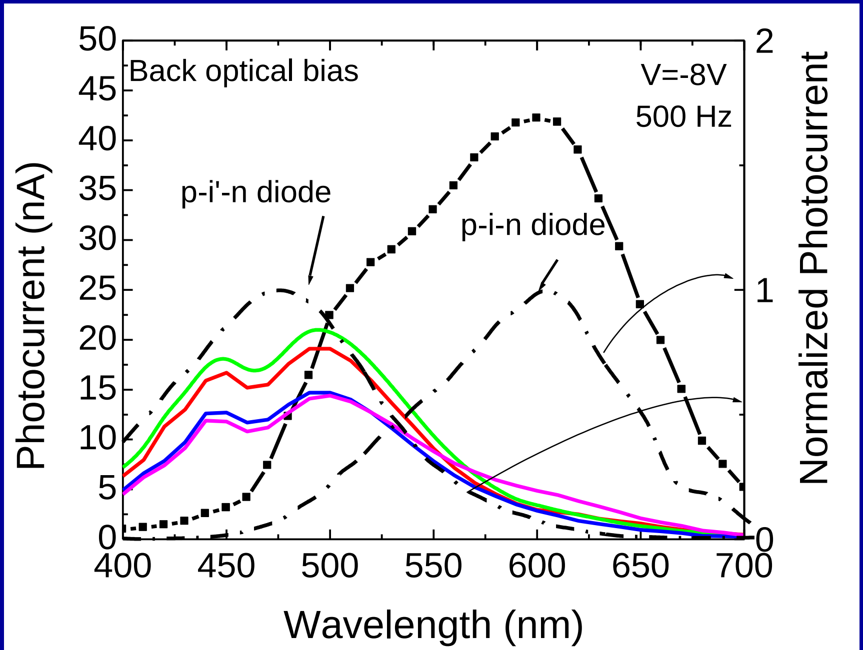




*M. Vieira, M. Fernandes, P. Louro, A. Fantoni, M. Barata, M A Vieira, "Multilayered a-SiC:H device for Wavelength-Division (de)Multiplexing applications in the visible spectrum" Mater. Res. Soc. Symp. Proc. Volume 1066 (2008), pp.225-230 DOI:10.1557/PROC-1066-A08-01*

# Optical bias controlled optical filter



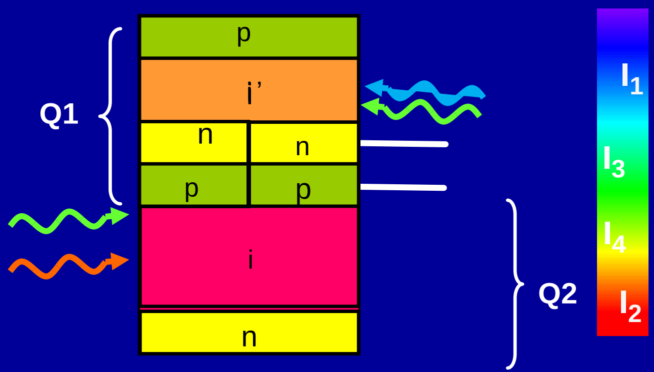



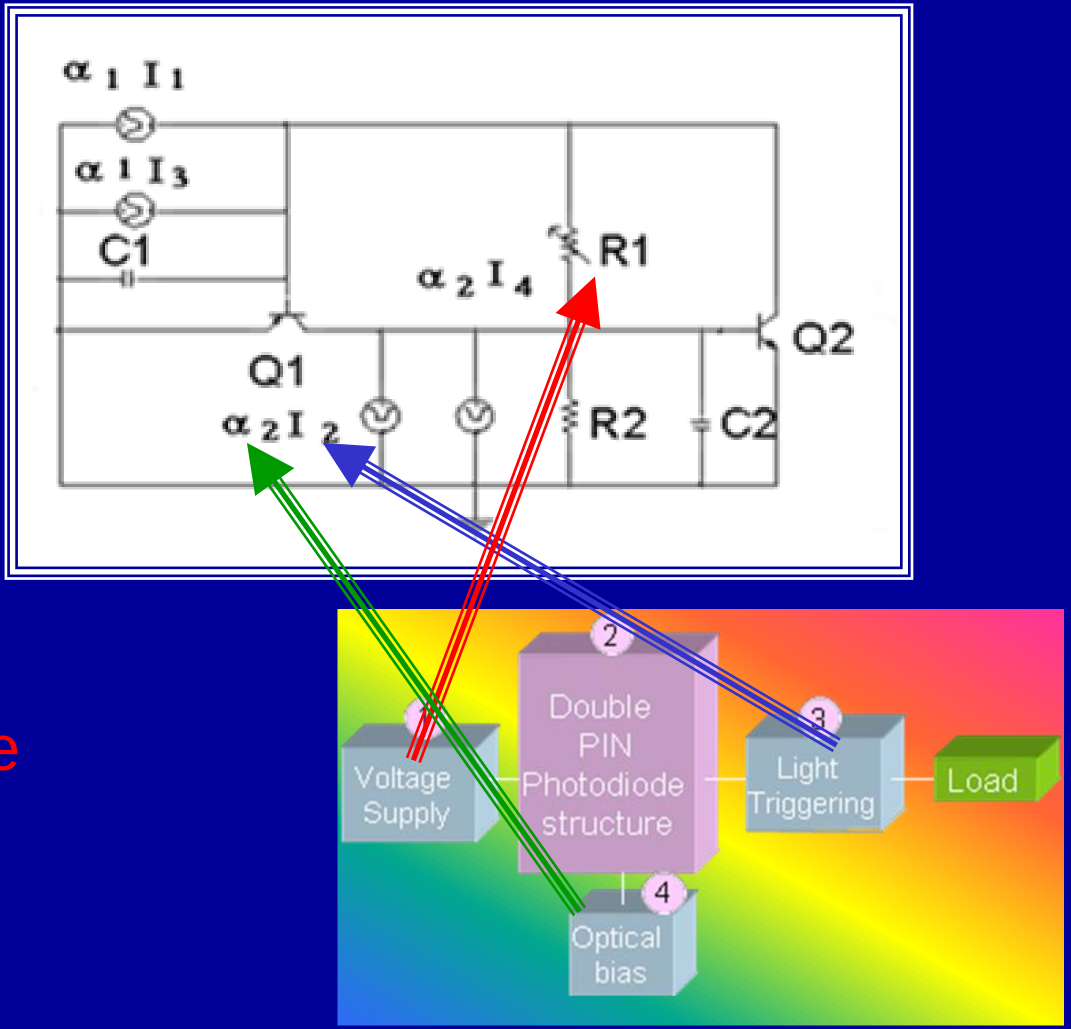
# Dynamics of electrical model with light biasing control

**Two stage active circuit**

**Two amplifying elements**
**Two capacitive filter sections**




*ac equivalent circuit*




**Two optical gate connections**

Light triggering

Electrically programmable

Light Biasing Control

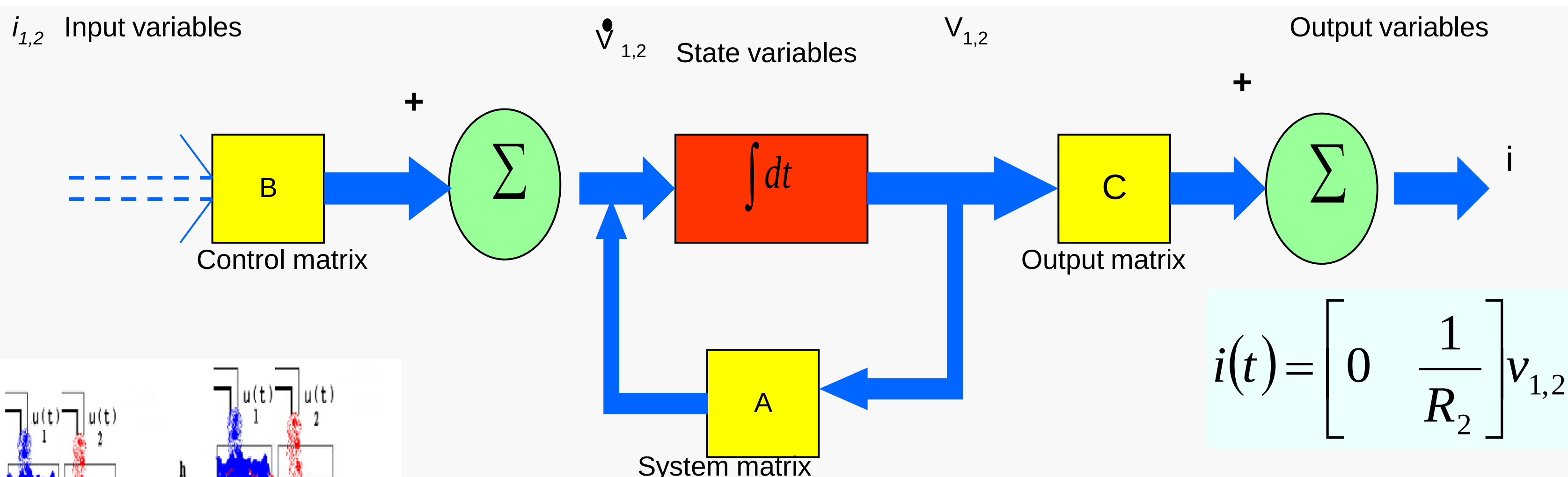
*Charge storage modelled by space-charge layer*


*M A Vieira, M. Vieira, M. Fernandes, A. Fantoni, P. Louro, M. Barata, Amorphous and Polycrystalline Thin-Film Silicon Science and Technology — 2009, MRS Proceedings Volume 1153, A08-03*

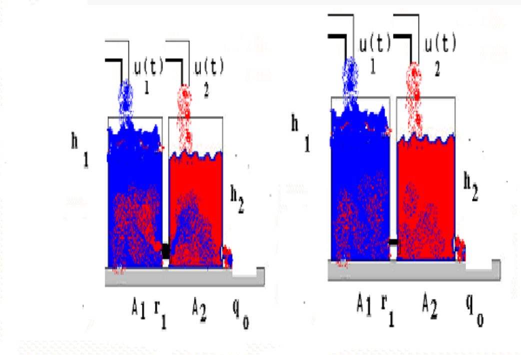
# State-space realization of the photonics active filters

Dynamics of a parallel bucket connection

How does the system input affect the state change??




$$i(t)=\begin{bmatrix}0 & \frac{1}{R_2}\end{bmatrix}v_{1,2}(t)$$




How does the current state affect the state change??

$$\frac{dv_{1,2}}{dt}=\begin{bmatrix}-\frac{1}{R_1C_1} & \frac{1}{R_1C_1}\\ \frac{1}{R_1C_2} & -\frac{1}{R_1C_2}-\frac{1}{R_2C_2}\end{bmatrix}v_{1,2}(t)+\begin{bmatrix}\frac{\alpha_1}{C_1}\\ \frac{\alpha_2}{C_2}\end{bmatrix}i_{1,2}(t)$$

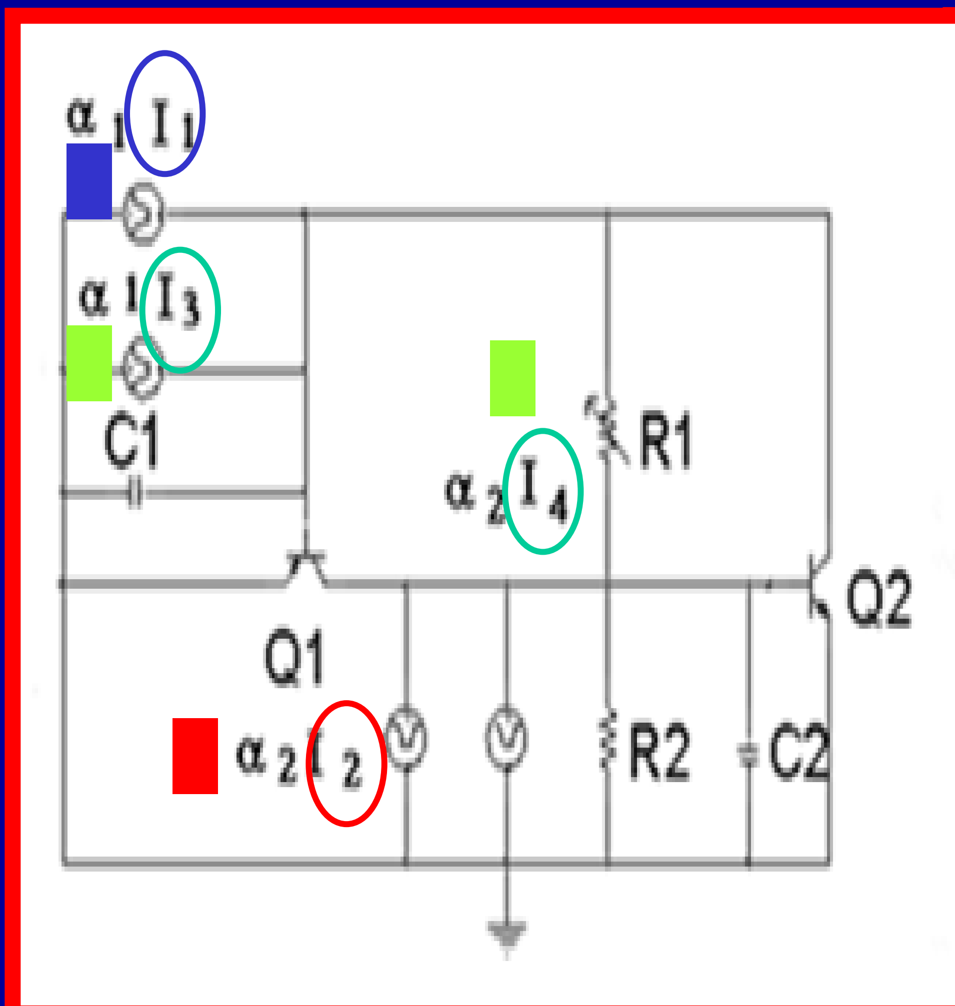

*M. A. Vieira, M. Vieira, J. Costa, P. Louro, M. Fernandes, A. Fantoni, "Double pin Photodiodes with two Optical Gate Connections for Light Triggering: A capacitive two-phototransistor model" in Sensors & Transducers Journal Vol. 10, Special Issue, February 2011, pp.96-120.*

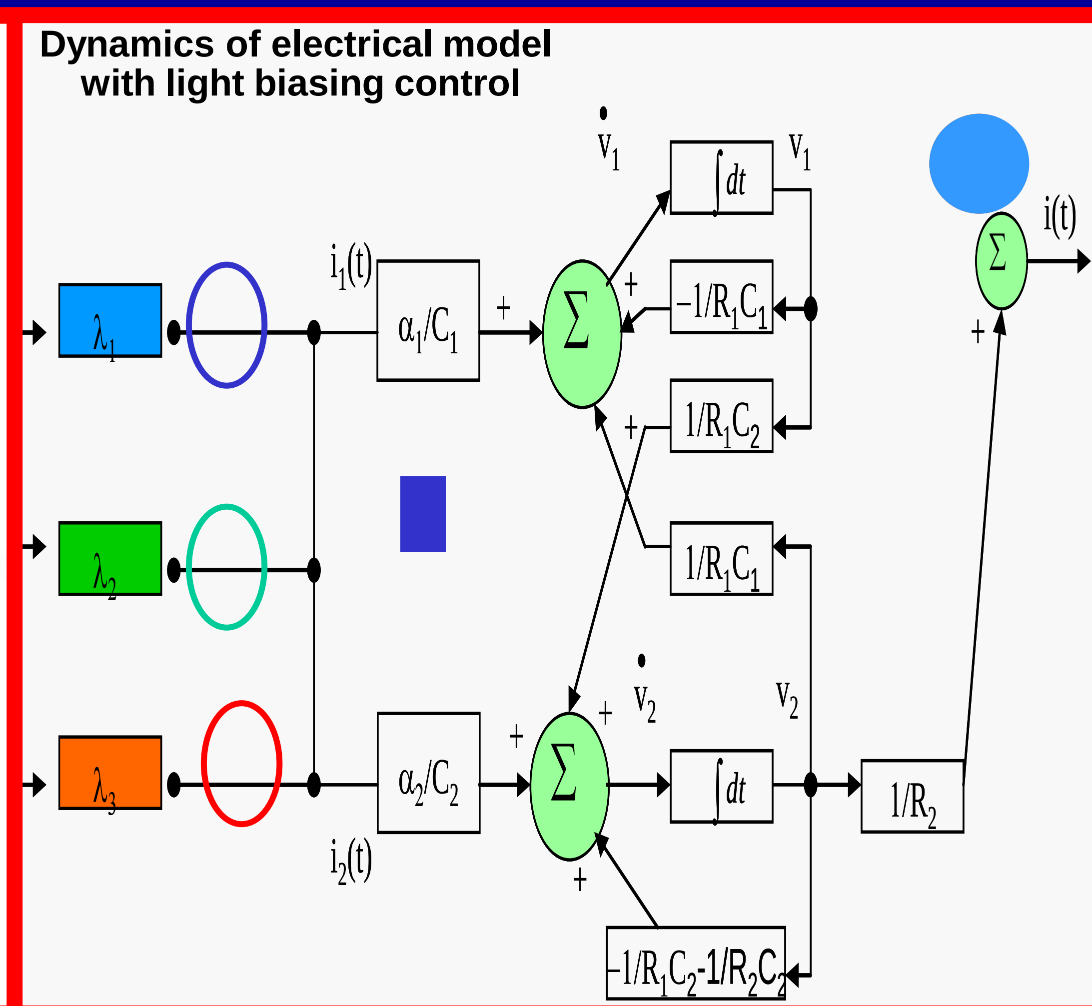
# Optoelecronic simulator

Input channels (RGB)

*Vieira, M.A., Louro, P., Vieira, M., Fantoni, A., Steiger-Garção, A. "Light-activated amplification in Si-C tandem devices: A capacitive active filter model " IEEE SENSORS JOURNAL, VOL. 12, NO. 6, JUNE 2012 pp. 1755-1762* ***DOI:*** *10.1109/JSEN.2011.21765372012*

## Electrical model ⟷ Simulator



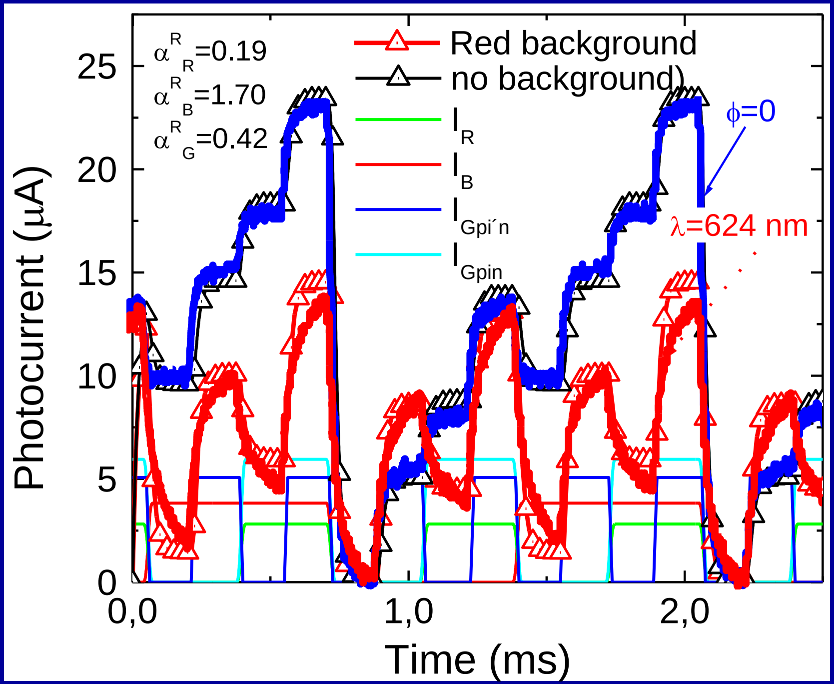
# Validation of the model

MATLAB as a programming environment and the four order Runge-Kutta method to solve the state equations

Under negative dc

Without background
Encoding: 8-levels

Front Red background
Encoding: 4-levels




experimental (solid lines)

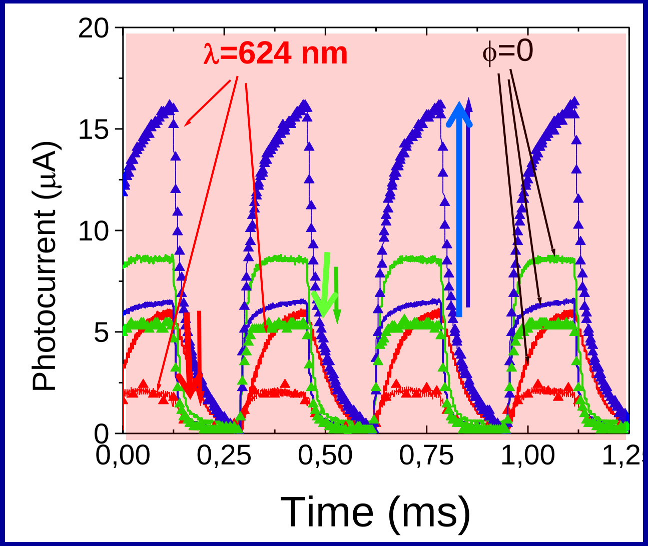
simulated (symbols)

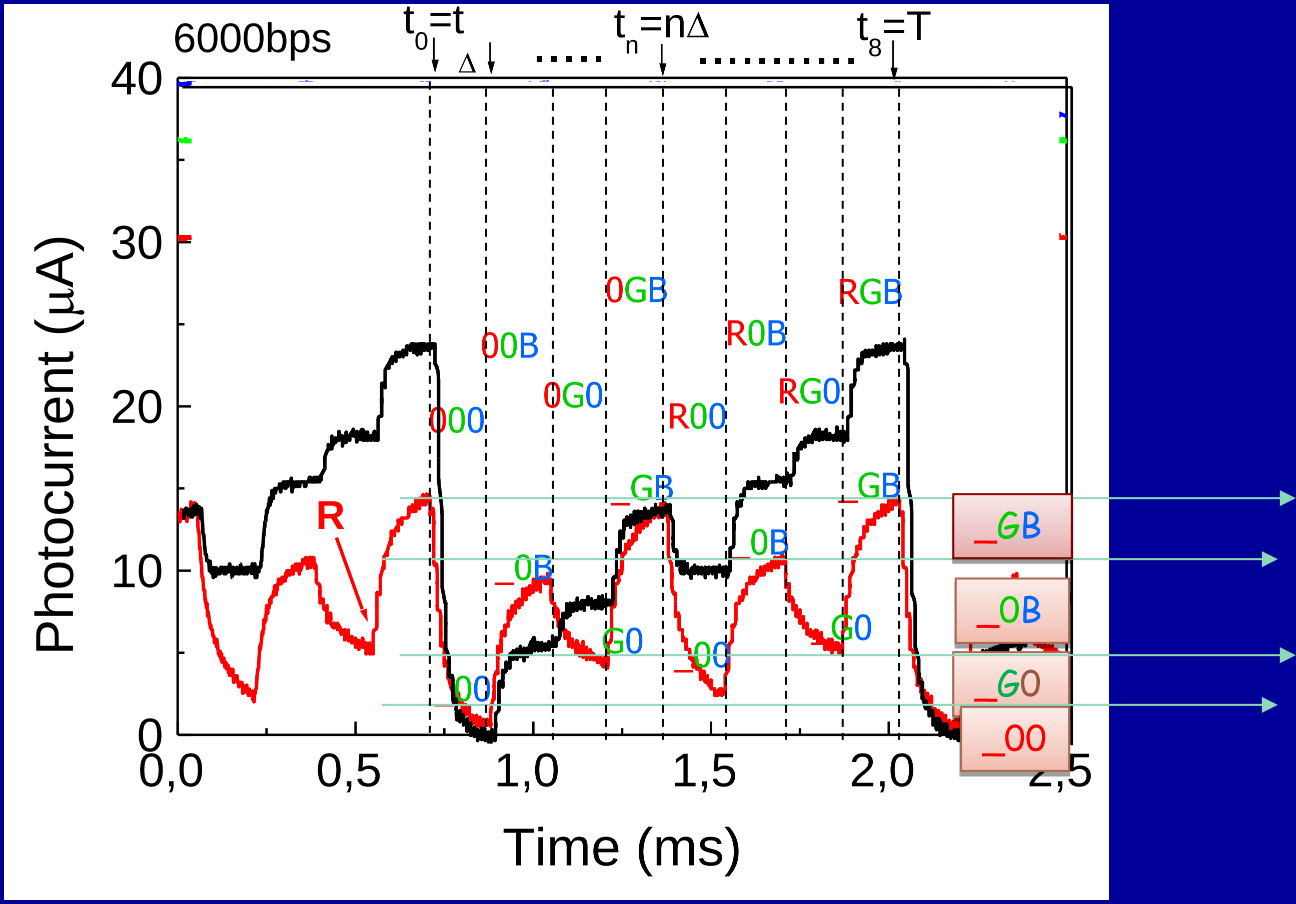
Good agreement between experimental and simulated data

*M A Vieira, M. Vieira, M. Fernandes, A. Fantoni, P. Louro, M. Barata, Amorphous and Polycrystalline Thin-Film Silicon Science and Technology — 2009, MRS Proceedings Volume 1153, A08-03*

# Optical encoded data stream front red/without irradiation

SiC tuneable background nonlinearity-based RGB logic gates




($\alpha^R_B >> 1$)

($\alpha^R_G < 1$)

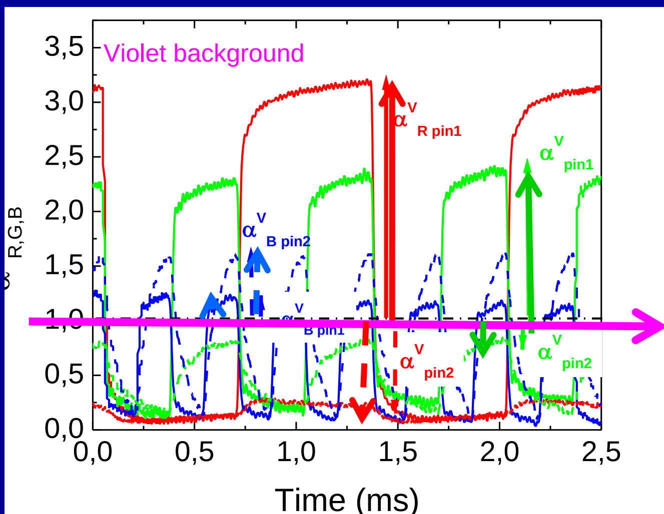
($\alpha^R_R << 1$)

Red Background :
The output waveform becomes a main 4-level encoding ($2^2$).

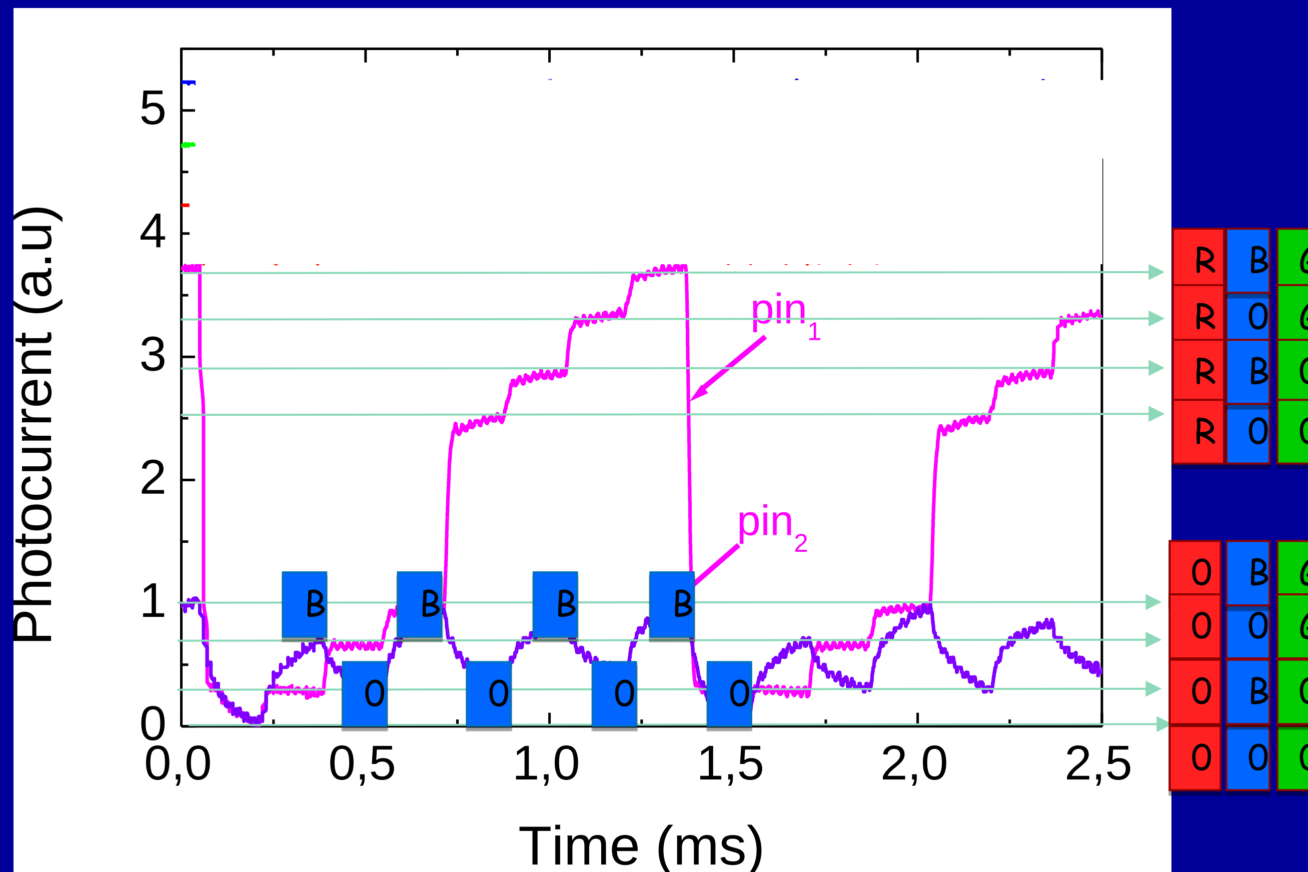
Without optical bias is an 8-level encoding ($2^3$) to which it corresponds 8 different photocurrent thresholds.

# Optical encoded data stream front/back violet irradiation

SiC tuneable background nonlinearity-based RGB logic gates




**Front violet optical bias**
8-level encoding ($2^3$) to which it corresponds 8 different photocurrent thresholds.




($\alpha^V_R$>>1)

($\alpha^V_G$>1)

($\alpha^V_B$~1)

**Back violet optical bias :**
The output waveform becomes a main 4-level encoding ($2^2$).

($\alpha^V_B$>>1)

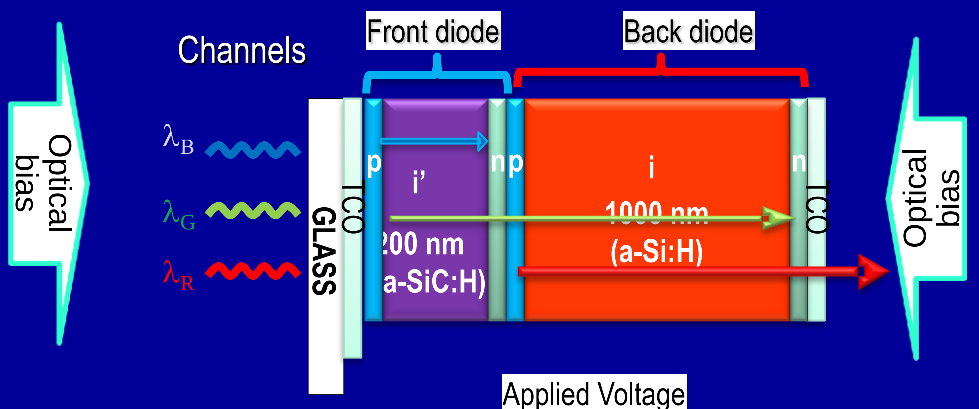
($\alpha^V_G$~1)

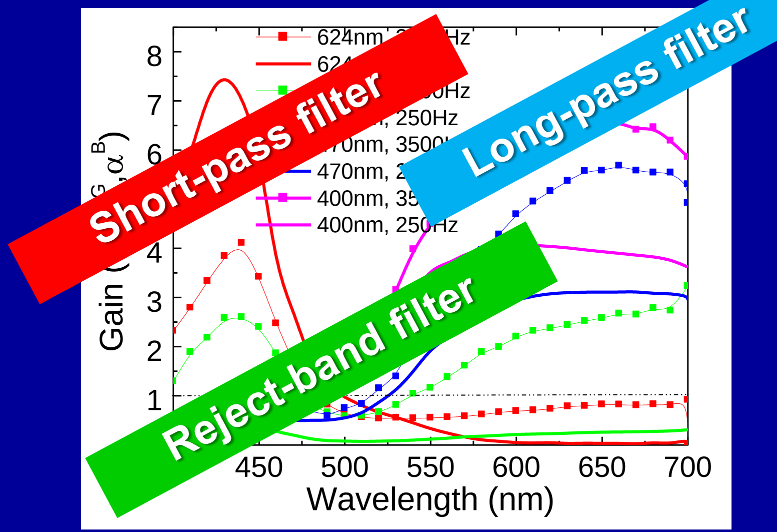
($\alpha^V_R$<<1)

# Conclusions

- Light-activated pi'n/pin a-SiC:H devices that combines the **demultiplexing** operation with the simultaneous **photodetection** and self **amplification** of an optical signal were designed, analyzed, validated and evaluated.

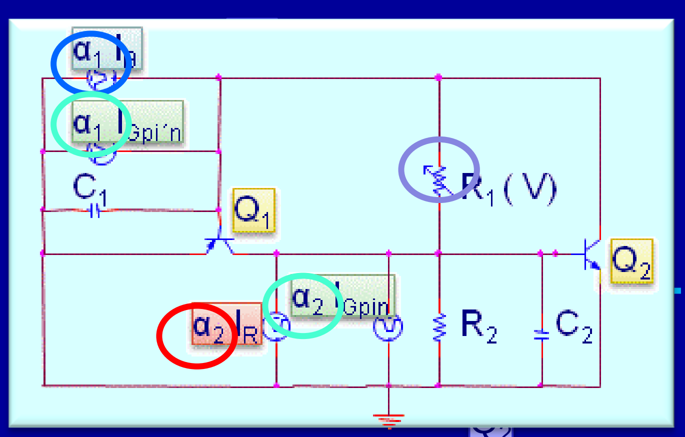
Experimental Design




- Depending on the applied **voltage** and wavelength of the external **background** it acts either as a short- or a long- pass band filter or as a band-stop filter.

Optoelectronic model

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$$i(t)=\begin{bmatrix}0 & \frac{1}{R_2}\end{bmatrix}v_{1,2}(t)$$