



# An on-line experiment: Solar Cell I-V Characterization

A. Neveu<sup>1</sup>, A. Legendre<sup>1</sup>, O. Martinez<sup>2</sup>, J. Adiego<sup>3</sup>, M. A. Gonzalez<sup>1</sup>, V. Parra<sup>4</sup>  
<sup>1</sup>École D'ingénieurs, Université de Nantes, Nantes, France  
<sup>2</sup>Department of Physics Condensed Matter, <sup>3</sup>Department of Informatics  
<sup>4</sup>Instalaciones Pevafersa S. L. Energías Renovables, Parque Tecnológico de Boecillo, Valladolid



University of Valladolid, Spain

## Remote Laboratories

- The development of WWW has made possible to work without being present, using the appropriate devices (sensors, motors, webcam, etc).
- Remote laboratories can be beneficial for students and teachers. Teachers can easily incorporate inexpensive laboratory demonstrations in traditional lecture courses, and students find a new exciting communication channel, allowing them to be independent of location and timetable.
- Some studies have been carried out comparing remote, simulated and classical laboratories, and have proved that remote laboratories provide similar learning outcomes to their class analogues

## Experiment

### Objectives:

The objectives of this experiment are to determine the I-V characteristics of a typical multicrystalline Silicon Solar Cell (SC) under different conditions suchs different light fluxes and various wavelenghts. Testing the SC and acquiring the characteristic curves require an illumination source, a variable load resistance and a data acquisition system.

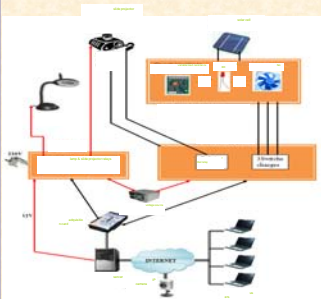


### Experimental set-up: Description

- The device used for lighting is an old slide projector equipped with several density filters to regulate de luminous flux, modified to facilitate its remote control.
- To obtain the I-V characteristics it has been designed a circuit to remotely modify the load resistance.
- A programmable data acquisition USB module is used for control and capture data.

◀ Solar Cell Experiment

## System Structure

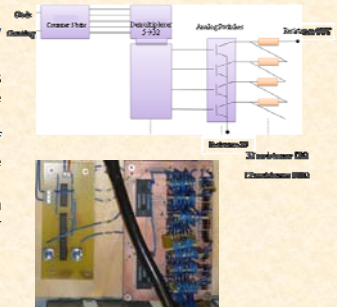


### Software & Architecture

- Server/client architecture: Students (clients) talk with the server (Laboratory) by means of web browsers
- The control program software was developed with Labview
- The web site has been implemented with PHP, MySQL and JAVA

### Hardware

- A circuit has been designed to obtain the I-V characteristics.
- The circuit is composed by logical components (counter/shift register, 4 de-multiplexers and 16 Analogue Switches) and standards resistors (10 and 100 Ω).
- With this system one can get up to 31 pairs of different values of I-V characteristics of the illuminated solar cell.
- A programmable data acquisition USB module with analogical and digital input-output channels, is used for control and data capture

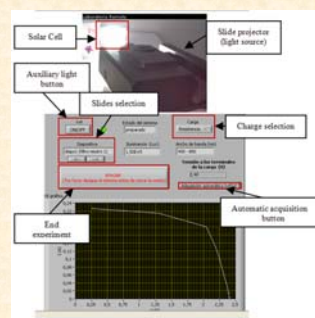


### Welcome page

- Welcome page with username and password
- User page for controlling the instruments in laboratory with a real time image of the experiment
- There are two types of users, the user with restricted account and the administrator with account privileges
- The administrator can create new users and change some physical parameters.
- The system log the last users acces and finally put on line the experimental results files



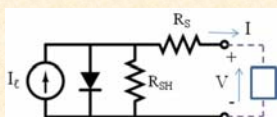
<http://labrem3.eis.uva.es>



### Control Interface

- The user chooses the primary light filter and stars up the experiment.
- A video IP-camera is used to visualize the experience
- Students feel that they have the real control of the experiment
- The results are sent in text format

## Results



PV cells can be modelled as a current source in parallel with a diode.

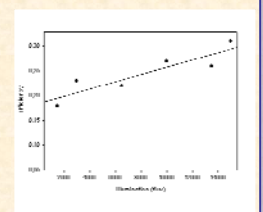
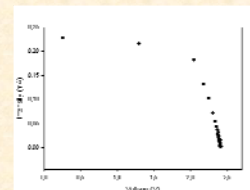
- The total current I depends on the current I<sub>l</sub> generated by the saturation current of the diode I<sub>0</sub>, according to equation
- n is the diode ideality factor (typically between 1 and 2), R<sub>S</sub> and R<sub>SH</sub> represents the series and shunt resistences

$$I = I_l - I_0 \left( e^{\frac{q(V+IR_S)}{nkT}} - 1 \right) - \frac{V + IR_S}{R_{SH}}$$

### Equivalent Circuit

### Experimental results

- Left: I-V characteristics.
- Right: Efficiency versus illumination



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## Conclusions

- The New Technologies in teaching allow access to resources that improve the quality of education
- Teachers and students have a tool that focuses their work in a creative way, more related to the technological environment

\*Corresponding author: [mrebollo@eis.uva.es](mailto:mrebollo@eis.uva.es)