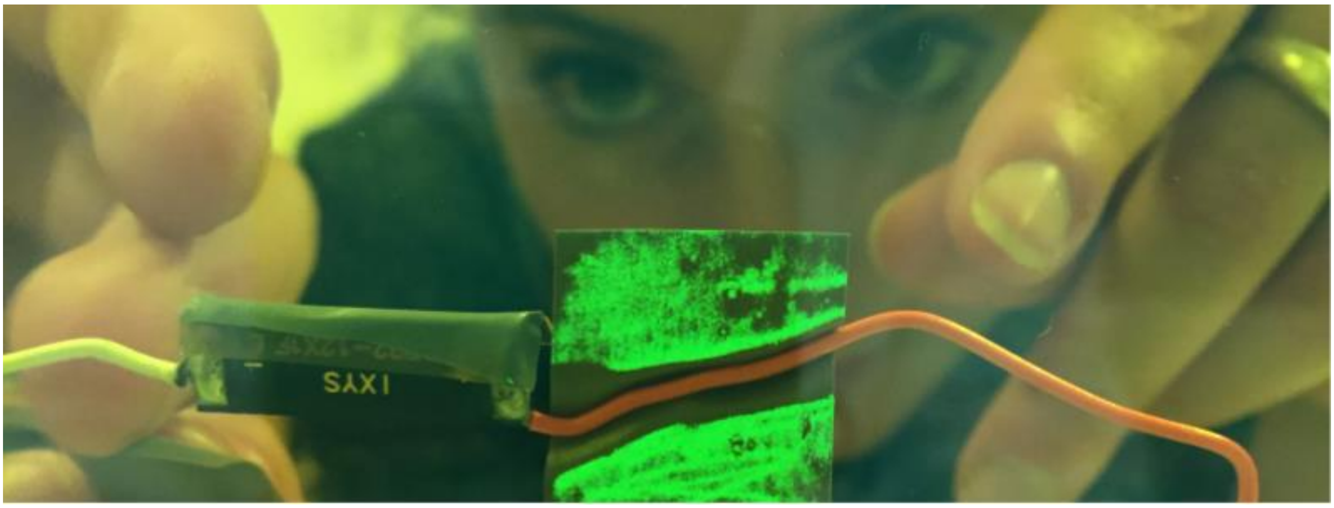
Studying photo-luminescent samples emissions

Part #2

Fluorescent Materials



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Characterizing Fluorescent Acrylic-Sheets as Luminescent Solar Concentrator (LSC)

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Short description of the topic

Experimental investigation of the efficiency in producing electrical energy by Fluorescent Acrylic-Sheets used as Luminescent Solar Concentrator (LSC)coupled with Photovoltaic-Cells

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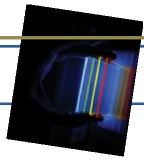

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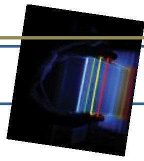

[Short] Theoretical Introduction

→ *This introduction is intended only as a quick background of the theoretical concepts needed to understand the experiments described in the following. Therefore it is quite schematic and not very in depth.*

→ *For further and more detailed discussion on the theoretical description of the physical processes involved see the corresponding background readings.*

Luminescent materials

By luminescence we mean the physical event occurring when some kind of materials emit light (i.e. electromagnetic radiation in the visible or near-visible spectrum) due to an external stimulation. There are many kinds of luminescence depending on the type of the external stimulation (e.g.: triboluminescence, chemiluminescence, etc.)

With regard to photo-luminescence the external stimulation is light: the atoms or molecules of the material absorb the incident light (trough an interaction between the electromagnetic radiation and the external electrons) and then re-emits light again. Some general characteristic of the photoluminescence are:

- each material responds only to certain spectral bandwidths of the incident radiation (into the visible bandwidth or in some cases also in the UV or Near-Infra-Red), usually those with a shorter wave-length (greater energy);
- the emitted radiation has always longer wave-length than the incident one (lower energy);
- the emitted radiation is usually concentrated in a relatively narrow spectral bandwidth, thus producing a characteristic material coloration.

Depending on the time-length of the phenomenon, photoluminescence is divided in ***fluorescence***, where the emitted radiation stops practically at the same time of the external stimulation (typical times are shorter than 10^{-8} sec), and in ***phosphorescence***, where the material still emits long after the incident radiation has stopped, although the intensity of the emitted radiation decreases quite quickly.

Fluorescent Acrylic-Sheets

They are sheets, with different thickness and dimensions, composed of a matrix made of plastic acrylic materials (e.g. Plexiglas) with good optical properties: transparent to (visible) light and with high refractive index. They also have good structural properties: they are lightweight and robust, and they can be easily cut and shaped as needed; for all these reasons they are suitable to be used in buildings.

During the production, fluorescent pigments are diffused into the acrylic matrix. The incident light penetrates into the sheet and goes through until absorbed by the fluorescent pigments and re-emitted back due to fluorescence.

The incident radiation is only partially absorbed and only in specific wave-lengths (usually those corresponding to greater energy), the remaining part is transmitted through the sheet. This is why sheets and rods look semi-transparent and you can easily see trough them. The wavelength of the light that is directly transmitted through the sheet (without having been absorbed) corresponds to a colour which is complementary to the absorbed wave-lengths: this effect is more evident with

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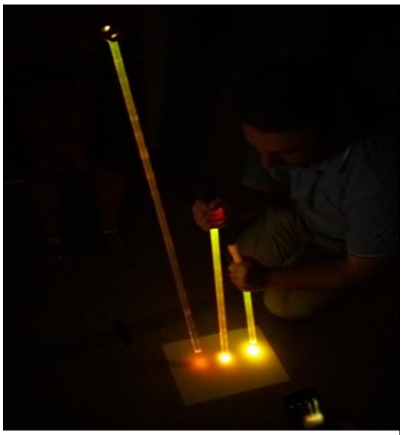
thicker sheets or, better, whit rods (see below).

The emission by fluorescence occurs only at specific wave-lengths (always corresponding to lower energy with respect to the absorbed wave-lengths) depending on the fluorescent pigment used.

This material is commercialized also in rods (***acrylic-rods***). We experimentally observed that if you point white light at one of the extremities of the rod, its colour changes along the whole length (see Picture 1). This effect seems to come from the combination of the different percentages of transmitted, absorbed and re-emitted radiation with the corresponding changes in wave-length (and therefore in visible colour); surely these percentages are somehow connected to the path length travelled by the radiation inside the rod.



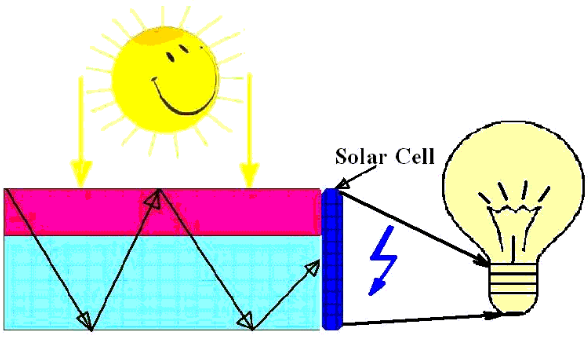
Picture 1

Luminescent Solar Concentrator - LSC

A Solar Concentrator is a device designed to harvest incoming light radiation (typically solar radiation) from relatively large surfaces and concentrate it on smaller areas. Usually they are coupled with devices - such as PV-cells - able to transform radiant energy into electrical one with a gain in efficiency. Moreover the reduced dimension allow also for lower costs of production and installation.

In recent years, beside traditional optical devices (working on reflection and refraction like mirrors and lenses) innovative devices have been invented where the concentration exploit photo-luminescence effect: the ***Luminescent Solar Concentrator*** (***LSC***).

To this purpose the Fluorescent Acrylic-Sheets described above seem particularly suitable. Actually in this case the radiation emitted by the fluorescence within the sheet, thanks to the high refractive index of the acrylic matrix, is mainly trapped inside the sheet through ***total internal reflection*** (see the diagram below) even if a part is transmitted through the sheet (and this is why it looks clear to us).



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Total internal reflection is the same effect by which fiber optic works (both those made in glass and in acrylic). This is why Acrylic-Sheets/rods are also known as “light guides”. However in this case there is an important difference. In fiber optics the radiation trapped and then transmitted inside is only that part of the radiation entering one end of the fiber at a specific and limited incidence angle (within the so called “acceptance angle”). Radiation coming in transversal

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direction onto the fiber would simply go through the fibre itself, as the material in itself is transparent.

With regard to the Acrylic-Sheets instead, the trapped radiation actually is the light emitted by the fluorescent pigments inside the bulk of the acrylic material. Most of it propagates in a direction which is not too near to the normal to the surface. Thanks to this, the sheet absorbs most of the radiation incident on the wide lateral surface (with only a slight portion of such a light being transmitted through the sheet) therefore emitting at the edges after repeated total internal reflections-most of the radiation produced. As edges have a very limited area, the required concentration effect is produced. This is well demonstrated by the much more intense and bright colour shown the edge of the sheet with respect to the lateral face, even in low and diffuse light condition. (see Picture 2).

Picture 2

Characterization of Photovoltaic Cells

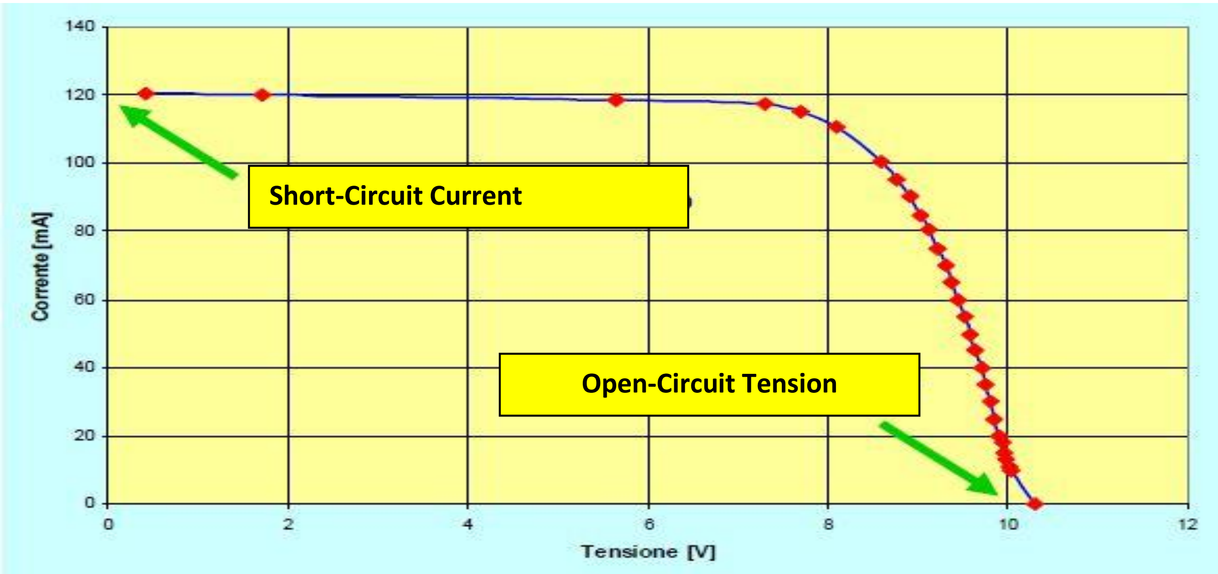
As we said above, an LSC device is often used coupled with photovoltaic cells (PV-cell) to produce electrical energy; this is why we need to introduce some basic concepts on characteristics of the PV-cell.

The characterization of a PV-cell is quite a complicated thing: the electrical energy produced, described in terms of ***e.m.f.*** (or ***tension***) **V** and ***current*** **i** generated and the connected ***Power***

$$P = V \times i$$

produced by the PV-cell, are not only dependant on the lighting condition (which is quite obvious), but also depends on the electrical load connected to the PV-cell itself. Such electrical load may be represented by the total ***resistance*** **R** of the device connected to it.

Typically the PV-cell ***characteristic curve tension-current*** (**V-i**) is given by the following graph:



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A parameter quite often used to summarise the behaviour of the PV-cells is the so called ***Maximum Theoretical Power*** $\mathbf{P_{Max}}$ given by the product of the ***tension generated by the cell measured in a open circuit*** situation (corresponding to an infinite load **R** so that no current is circulating) , $\mathbf{V_{OC}}$, multiply by the ***current measured in a short-circuit*** situation, that means directly connecting the two poles of the cell trough a ideally null resistance, $\mathbf{i_{SC}}$, (and in this case is the tension generated by the cell being null).

The value of $\mathbf{P_{Max}}$ can be used to classify the efficiency of the PV-cell, but in any case it can never be obtained in practical applications, when the cell is connected to some kind of real utilizer. For these purposes another parameter can be introduced, the so called ***fill-factor***, that represents the ratio between the area under the characteristic curve of the PV-cell and the area of the rectangle with sides given by $\mathbf{V_{OC}}$ and $\mathbf{i_{SC}}$, which means the $\mathbf{P_{Max}}$ itself. Values of the fill-factor near 1 means that the efficiency of the PV-cell in practical applications is quite near to the maximum theoretical value that is possible to get.

Practical Application

At present the efficiency of a LSC coupled with PV-cells- in terms of electrical energy produced with respect to the total incident light energy entering the system- is very low, in the order of magnitude of some percents; surely is much lower than the efficiency of a traditional PV panel made by silicon.

However, due to their peculiar characteristics, the use of these innovative materials can be advantageous in some situation. Actually, besides the basic advantage given by the capacity to work also in diffused and low light condition-differently from traditional PV systems with highest efficiency under direct and strong solar light- the Acrylic-Sheet used as LSC has also the following advantages:

- They are semi-transparent, therefore suitable to be used in wide structures, as shelters on passengers platforms in airports or railway terminals, where you want some external light to come in
- They are more lightweight than PV-panels of the same size and they do not need big supports below them being self-supporting (until certain limits), therefore they can be used directly as building elements, producing great economic savings in construction; furthermore they can also be positioned vertically to build glazing and facades;
- They are coloured and so they can be inserted with a pleasant effect in urban structures, as decorative elements, while performing also different functions, such as sound-adsorbent panels;
- last, but not least, the fluorescence effect is by itself quite nice from an aesthetical point of view, so they can be used to produce design objects.

With a simple Google research it's quite easy to find out many examples of practical application of all these characteristic of the Luminescent Solar Concentrator. [See also the References at the end of this paper]

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The Basic Experiment

Experimental Goal

The aim of this experiment is to verify whether and under which conditions different kinds of Fluorescent acrylic-sheets actually work as LSC and to give a quantitative evaluation of this effect of light concentration through measures which can easily be performed in a high school physic lab.

Due to the complicated physical mechanism on which the acrylic-sheets work, it isn't possible to operate direct measurements of the intensity of light radiation (both incident and concentrated at the edge of the sheet). This would in fact be too complicated for the following reasons:

- the response of the light sensor is strongly connected to the angle of the incident light and such angles are not easy to evaluate;
- in LSC mechanism are involved various wave-lengths (incident, transmitted, absorbed and emitted radiation) which can't easily be measured beyond qualitative aspects (mainly the corresponding colours).

As the typical use of an LSC is to concentrate light on PV-cells system fixed at the edges of the sheets, we turned on the light and measured both the power (**P**) produced by a PV-cell placed <u>on the edge</u> of the sheet and the power produced by an <u>identical</u> PV-cell, used as reference, placed <u>at the centre</u> of the front face of the sheet itself

To facilitate comparison we introduced the adimensional parameter:

$$\eta = \mathbf{P}_{\mathbf{Edge}}/\mathbf{P}_{\mathbf{Face}}$$

where $\mathbf{P}_{\mathbf{Edge}}$ e $\mathbf{P}_{\mathbf{Face}}$ are the ***power produced*** by the PV-cell ***on the edge*** of the sheet and ***in the centre of the (front) face*** respectively. [The power we refer to can be both the maximum theoretical ones, $\mathbf{P}_{\mathbf{Max}}$, introduced above, and/or the power actually produced by the PV-cell with connected to some specific loads, which- obviously-should be the same for both cells]

The η parameters gives a quantitative measure of the efficiency of the acrylic-sheet used as a LSC, in particular when $\eta > 1$ this means that the sheet DID concentrate on the edge the incoming radiation.

Moreover also the efficiency of energy transformation from lighting to electrical operated by the PV-cell depends on the wave-length of the incident radiation. Therefore the efficiency that we measure with the above described method really is those of the system composed by the acrylic-sheet plus the specific PV-cell used.

Nevertheless this approach is suitable for an experimental study intended for subsequent practical application (evaluating which is the system with the best performance with respect to the working conditions which are determinate - in terms of lighting condition and electrical load - during the project phase).

The experimental data allow also to draw through experimental points the characteristic curves tension-current of both PV-cells making comparison easier.

The Experimental Setup

The complete experimental setup is shown in the following Picture 3:

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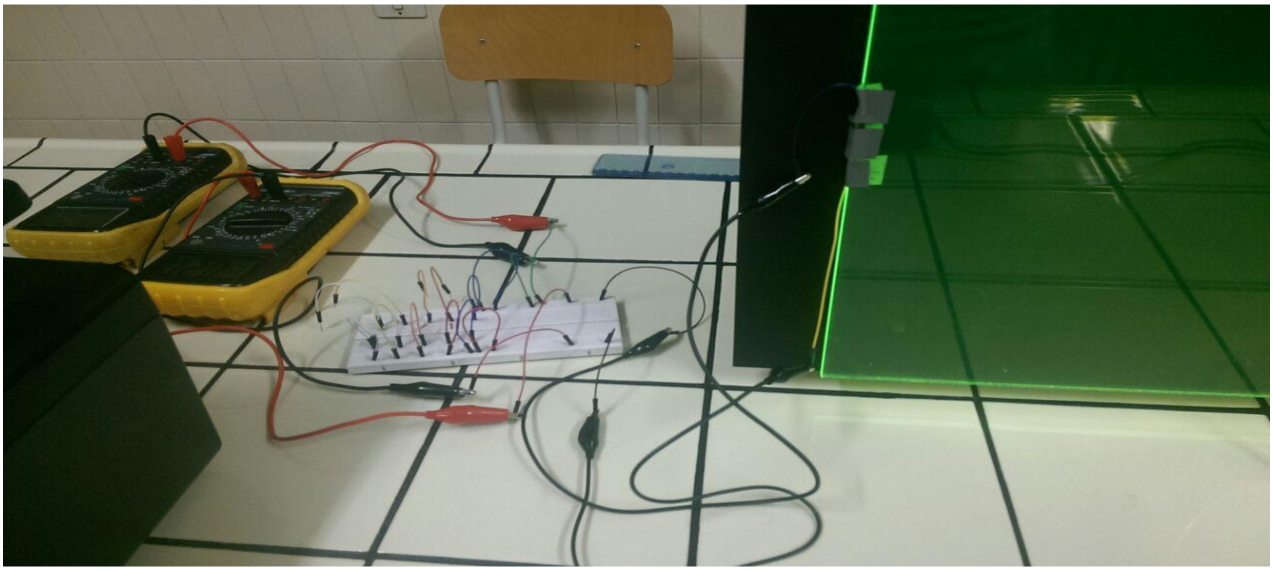
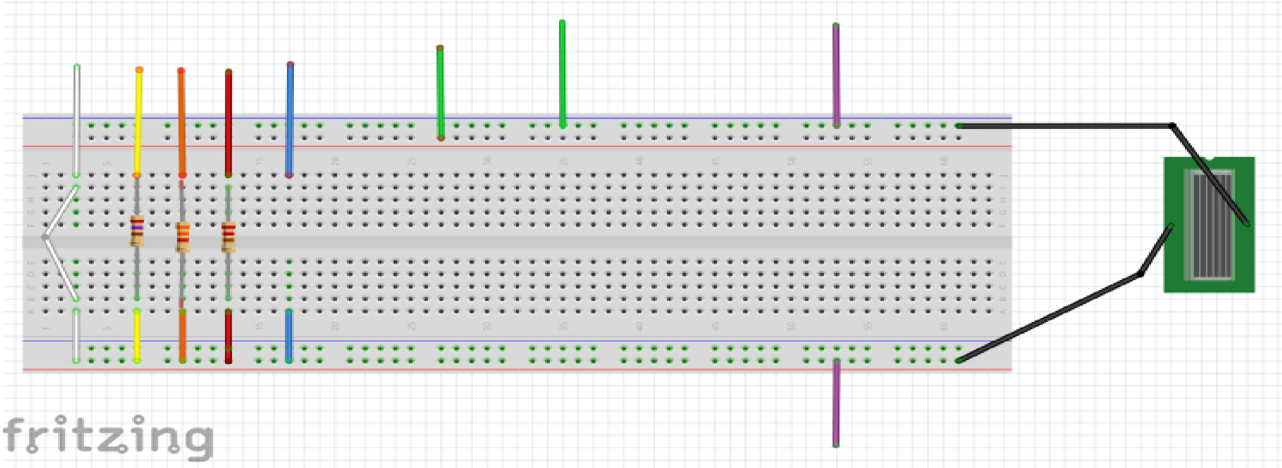


Picture 3

Two identical PV-cells are fixed with tape to the ***Acrylic-Sheet*** (in this case of green colour), one on the edge of the sheet (collecting light from the inside of the sheet) and the other (not visible in the picture) in the centre of the lateral surface of the sheet (collecting light from the exterior t). Connection cables should be previously soldered to the PV-cells; the cable should be long enough to permit quick connection of the PV-cells, once at a time, to the electrical circuit used to take the measures.

The ***electric circuit diagram*** is as following:



Between the two violet (purple) connectors, in parallel with the PV-cell, insert the first multimeter, used as voltmeter, to measure the ***tension*** (potential difference) **V** generated by the PV-cell.

Between the two green connectors, in series to the PV-cell, insert the second multimeter, used as ammeter, to measure the ***intensity of current*** **i** produced by the PV-cell.

We choose to use two multimeters to be able to take measures more quickly; it's possible however to use just one multimeter, first as voltmeter and then as ammeter, inserting it at the corresponding points of the circuit (remember to join together the two green connectors when you are not using the ammeter).

The five coloured connectors left have to be connected, in succession and ***once at a time*** during the measurement, with the second horizontal connection line of the ***bread-board***, closing the

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circuit through the green connectors inserting a ***variable load resistance***; in particular:

- the white connector inserts an ***ideal null resistance*** **R=0** (white connecting cable), so allowing to measure the ***short-circuit current*** i_{SC};
- the blue connectors inserts an ***infinite resistance*** (corresponding to an open circuit: the two bleu connectors are NOT connected together) so allowing to measure the ***open-circuit tension*** V_{OC};
- the other three connectors (yellow, orange and red) inserts into the circuit ***different resistances***: their exact value doesn't matter a lot, but they should be chosen within the first of the order of hundreds of Ohm, the second of the thousands of Ohm and the third of the tens of thousands of Ohm, so to be able to study the PV-cell characteristic curve in experimental points well distinct between them [In our case the values of the three resistances was in particular 270 Ohm, 3.300 Ohm and 22.000 Ohm respectively].

The circuit was so planned as to be able to do in a quick way many measures of current and tension generated by the PV-cells (once at a time); in particular it is possible to recover the PV-cell characteristic curve by 5 different experimental point (counting the extreme point corresponding to the short-circuit and open-circuit situation).

It is also possible to improve the experimental setup [although this is not necessary for what will follow] by adding more different resistances, connected in a similar way as the others. If you have an online data logger system you may substitute ALL the resistances with a potentiometer, whose resistance varies from zero to infinity, this will allow you to draw the full characteristic curve in real time.

Data Collection and Analysis

Data collection and subsequent data analysis are performed according to the following steps:

1. we fix a ***well specified lighting condition***; WARNING! you must take care that the lighting condition does NOT change throughout the whole the experiment;
2. using the two multimeters we ***measure the tension* V *and the current* i** produced by the PV-cell on the face of the sheet varying the resistance inserted into the circuit;
3. we ***repeat the measurements*** in step 2 with the PV-cell on the edge of the sheet connected into the circuit; WARNING! when you shift connections from one PV cell to the other, you should take extreme care not to project shadows with your body over the acrylic sheet as they may affect and invalidate measurements; [this actually applies to the whole experiment: to avoid such eventuality we suggest working with connecting cables of proper length];
4. we fill a ***data table*** with all the measures (see below for an example of data-table suitable for this experiment);
5. with the previously collected data and a spread-sheet program (e.g. Excel) we calculate, for both PV-cells, the ***power* P** generated VS the varying load resistance inserted into the circuit, (multiplying the correspondent values of **V** and **i**); we also calculate the value of:
$$P_{Max} = I_{SC} \times V_{OC};$$
6. by calculating the ratio between P_{Max} produced by the PV-cell on the edge of the sheet and P_{Max} produced by the PV-cell on the face of the sheet we obtain the **η *parameters*** which offer a rough estimation of the LSC system efficiency.

As previously pointed out, the **η *parameters*** may also be calculated as a function of the ***varying load resistance***. However for simplicity sake and for a quicker comparison of different lighting

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condition and different LSC systems, we usually limited ourselves to considering only the ratio between the maximum theoretical powers.

Plotting the measured values of tension **V** and current **i** on a graph, it is finally possible to obtain the **characteristic curve** for both PV-cells.

Last but not least, it is also possible to give an ***estimation of the fill-factor***, for both cells, by calculating the ratio between $\mathbf{P_{Max}}$ (maximum theoretical power) and the highest value of the power actually produced.

Typical Results

We report here typical results for this specific lighting condition:

- internal room, day light (but NO Solar Radiation shining directly onto the window); artificial light ON (4 Neon lamps).

Values either measured or calculated with the above described procedure are all shown in the following table:

Lightening Condiction	Internal room; day light (but NO Solar Radiation directly onto the window; artificial light ON (4 Neon lamps)						
Resistence	PV-cell on the **FACE** of Acrilic Sheet			PV-cell on the **EDGE** of Acrilic Sheet			**Efficency - η**
	Tension	Current	**Power**	Tension	Current	**Power**	
R	**V**	**i**	**P = V x i**	**V**	**i**	**P = V x i**	$\mathbf{P_{EDGE} / P_{FACE}}$
[Ohm]	[Volt]	[mA]	**[mW]**	[Volt]	[mA]	**[mW]**	
0 [Short-Circuit: $\mathbf{i_{SC}}$]	0	0,274	**#**	0	0,423	**#**	#
260	0,100	0,270	**0,027**	0,154	0,413	**0,064**	**2,36**
3.300	0,344	0,102	**0,035**	0,374	0,111	**0,042**	**1,18**
22.000	0,372	0,017	**0,006**	0,393	0,180	**0,071**	**11,19**
∞ [Open Circuit: $\mathbf{V_{OC}}$]	0,377	0	**#**	0,396	0	**#**	#
		$\mathbf{P_{Max} = i_{SC} \times V_{OC}}$ =	**0,103**		$\mathbf{P_{Max} = i_{SC} \times V_{OC}}$ =	**0,168**	
Efficency of LSC : $\boldsymbol{\eta = P_{Max\text{-}EDGE}/P_{Max\text{-}FACE}}$ **= 1,62**							

As shown in the table, the η ***parameter*** is greater than 1, this means that we succeeded in verifying that our system actually works as an LSC, which was exactly one of the experiment goals.

It is also possible to observe that the efficiency of the system changes a lot depending on the resistance inserted into the circuit, reaching higher values, greater than 10 (corresponding to 1000%), with the higher loads.

However the power produced is very little (hundredths of milliWatt) although it has to be considered that also the area of the PV cell is very little (about 2 cm^2). Please notice that the system experimental analysis is made only for didactical and research purpose.

Further experimental inquiring

The basic experiment described above can be easily and quickly repeated changing the experimental conditions: intensity and type of incident radiation, way in which the incident radiation is directed onto the sheet, colour and shape of the acrylic-sheet itself.

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One of the aims of this inquiry is to determinate, in a purely experimental way, which would be the best combination of all the above factors producing the highest efficiency for the LSC device, according to the subsequent practical condition in which the device will be used in real applications.

Through a systematic analysis of the efficiency values of different kinds of acrylic-sheet - obtained varying all the external parameter indicated above - it is also possible to get, at least partially, a more deeper understanding of the physical principles that are at the basis of the mechanism of an acrylic-sheet based LSC.

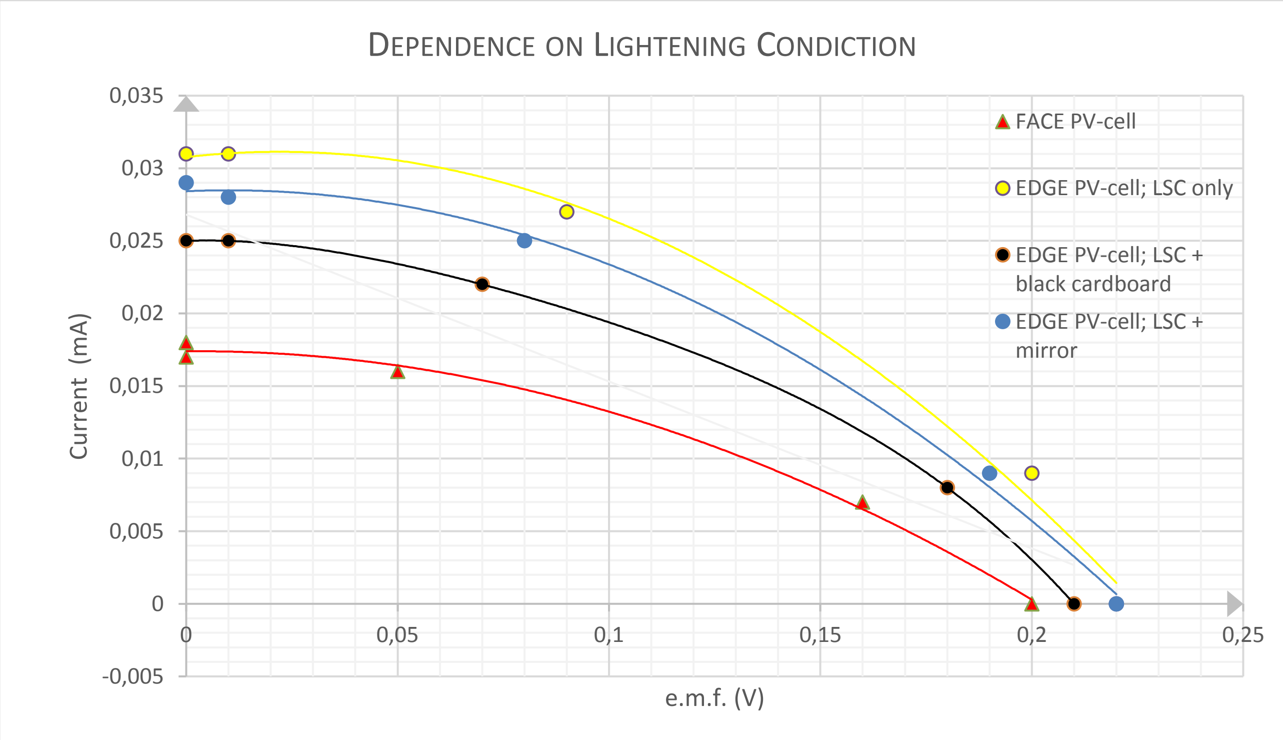
We report here the results of some experiments we made.

Dependence on the lighting condition

Working indoor with only diffused artificial light [in a standard classroom illuminated by 4 neon lamps] we compared the efficiency of our LSC system [using a yellow acrylic-sheet]in the three different conditions of lighting:

- both lateral surfaces of the acrylic-sheet ***free to receive*** light;
- one of the lateral surfaces [the one where NO PV-cell is fixed !!!] covered by a ***black cardboard***, ideally considered as a totally absorbing surface;
- one of the lateral surfaces covered by a ***mirror****[as above]*, ideally considered as a totally reflecting surface.

Measured data are reported in the graph below:



As we can see from the graph, in all observed cases the experimental plot is quite similar to the theoretical shape of the PV-cell characteristic curve. Obviously measurements from the PV-cell on the front face do not change in the three cases since it directly receives the environmental light and is not affected by the absence/presence of back reflection obtained applying the black

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cardboard and/or mirror on the other side of the sheet.

The efficiency calculated in the three cases is reported in the following table (the efficiency is referred only to the P_{Max} produced by the cells):

Condition	Efficiency
LSC only	1,89
LSC + black cardboard	1,46
LSC + mirror	1,77

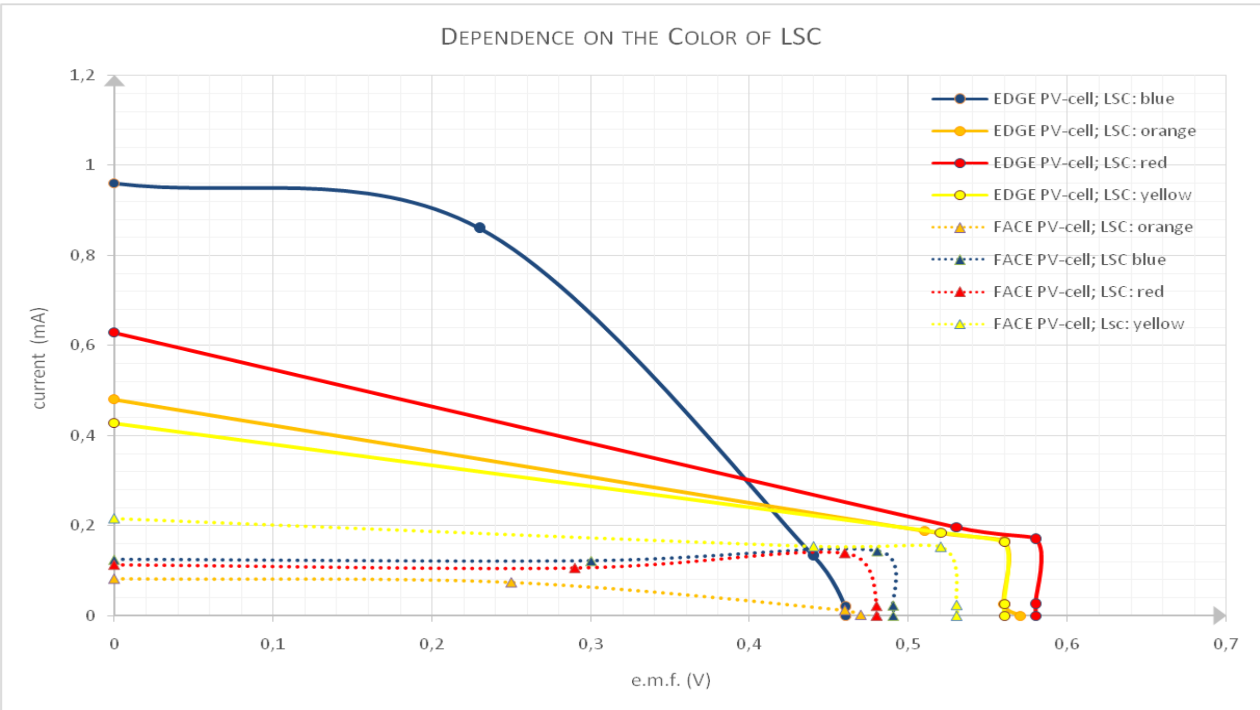
In all the three cases the efficiency is greater than one, meaning that the LSC is working well, however with both the cardboard and the mirror the efficiency is lower, the decrease being much more remarkable in the case of the cardboard.

We think we can explain these facts in the following way: the sheets absorbs radiation from both lateral surfaces and when one of these is obscured by the cardboard, the flux of incident radiation decreases and, as a consequence, also the radiation concentrated to the edge undergoes a decrement. Notice also that due to black there's no light back scattering.

However not all the radiation re-emitted by fluorescence remains trapped within the sheet and finally concentrated at the edge, a (minor) fraction of this escapes through the lateral surface, as it also proved by the (less bright) colour shining at the edges. By adding the mirror the potentially lost radiation is reflected back into the sheet and then concentrated at the edges. So this effect compensates, at least partially, the loss of the incoming radiation from the second face of the sheet precluded by the mirror itself.

Dependence on the kind of acrylic-sheet

Working outdoor, in full direct sunlight, we repeated the experiment using acrylic-sheets of different colours. Measured data are reported in the following graph:



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Also in this case we observe a distribution of the experimental points quite similar to the shape of the PV-cell characteristic curve, however much less regular than in the previous cases. This may be due to the fact that working with natural light makes it much more difficult to ensure constant intensity of incident radiation throughout the whole experiment.

Efficiency calculated for sheets of different colour is shown in the following table (again notice that the efficiency is calculated only with respect to the measured P_{Max}):

Colour of Acrylic-Sheet	Efficiency
Blue	7,21
Orange	6,95
Red	6,66
Yellow	2,09

We can note that the efficiency, however greater than 1, can vary in a remarkable way from one kind of sheet to the other. We get the highest value, corresponding to a gain greater than 700%, with the blue acrylic-sheet.

Dependence from the intensity and kind of incident radiation

We repeated the experiment varying the intensity of incident radiation by changing the number and/or kind of lamps, or by varying their distance from the sheet: in almost all the cases we got an efficiency higher than 1, although with remarkable variations from one case to the others.

Generally, as was expected, the efficiency of the LSC device seems to be greater in condition of ***diffused and not too much intense light***, while with direct and very intense light efficiency tends to decrease. This is due to the fact that in such conditions the PV-cells already reach the maximum power they can produce , therefore the effect of light concentration brings no additional gain.

We recorded efficiency lower than 1 just in one case, when we used only one quite weak halogen lamp shining directly onto the sheet. We don't know whether this is due to the fact that we used too weak a lamp or rather connected to the kind of radiation. The specific wave-length emitted by this lamp may in fact not be suitable for the acrylic-sheet pigments excitation.

In general we would needed of a more detailed and deeper study on how our device responds to changing in the wave length of the incident light, repeating the basic experiment but operating now with coloured filters and also with UV and NIR radiation.

We did only one experiment of this kind, so we can't have concluding answers to this question; however in this experiment we found an interesting effect.

We used as a filter for the halogen lamp light an acrylic sheet of the same kind (i.e. colour: in this case blue; see Picture 4) of the one used as LSC. With the filter we observed that the power produced by both cells remarkably decrease: this shows that actually the acrylic sheet absorbs radiation (concentrating it at the


Picture 4

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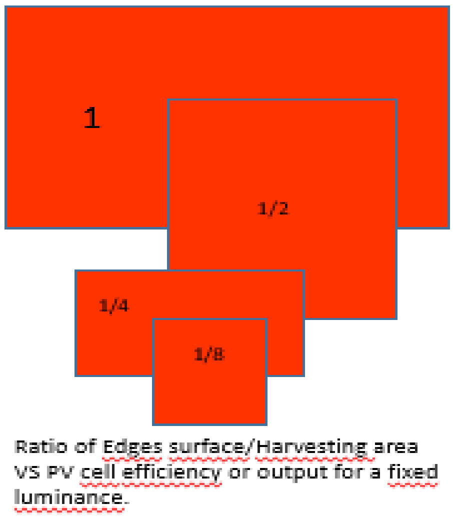
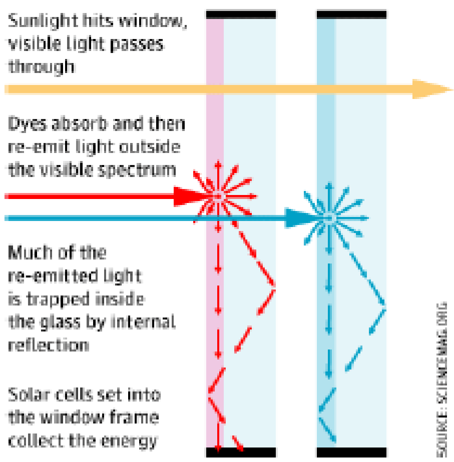
edge). But the efficiency of the system, although remaining less than 1, remarkably grows with respect to the situation without the filter. We think that this could indicate that the radiation transmitted by the sheet used as a filter could be more suitable to interact with the second sheet of the same kind (that means same colour = same wave-length of the radiation emitted by fluorescence) respected to the light directly emitted by the halogen lamp.

Worth Further Researching Issues in a IBSE, PBL framework

- **Shape of the sheet**: what happen to the efficiency if we change the area of the sheet, so changing the ratio between edges surfaces/harvesting area (see Picture 6)? And what if we change the shape of the sheet?
- **Light Incidence Angle dependence**- What if we embed the sheets in building facades? How much do we lose in reflections? Do they work early in the morning and late in the evening when the sun is low at the horizon? ENI boasts minimum to no angle dependence…
- **How large should a sheet be** to reach the best and most cost effective configuration?
- **Which frequencies work best?** To delve deeper into the issue we may use a spectrophotometer for transmission and reflection measurements. But this is quite far advanced and most schools don't own the equipment.
- What about having **stacks of different colours** harvesting at different frequencies wave-length (see Picture 5)?
- What about night harvesting with full moon light or near street lamps as boasted in the picture at http://www.technologyvista.in/pin/noise-barriers-on-highway-a-new-way-of-generating-energy/
- Could they harvest efficiently even indoor?
- … and more to come …



Picture 6



Picture 5

Funded by EU under the Erasmus+ KA2 grant N° 2014-1-IT02-KA201-003604_1.

Prototyping: from Research to Innovation

Students designed a self powered PV lamp based on fluorescent acrylic sheet. It's an example of indoor photovoltaic and matches engineering with design .

The first version of the lamp (On the right in the Picture 7) harvested energy during the day concentrating radiant energy on the PV cells and storing it in a battery, while at dusk the cylinder on which the cells were mounted rotated and substituted cells with LEDs.

Picture 7

Picture 8

The LEDs shone light at the edge of the sheet creating a stylish visual effect thanks to the light diffusion through the sheet and the concentration effect at the edges (see Picture 8).

The LDR sensor and the servo motor rotating the cylinder were both driven with an ArduinoUno microcontroller.

Further prototypes went in the direction of eliminating the moving parts. Students are still working on the design of aesthetically beautiful battery chargers.

SAVE lamp prototype made it to the 2016 edition of International Makers Faire Rome 2017.

Funded by EU under the Erasmus+ KA2 grant N° 2014-1-IT02-KA201-003604_1.

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Where to get the materials

Shops selling plastic and polymeric materials. Google fluorescent acrylic sheets/rods and you will find plenty of on-line resellers.

We bought at https://www.plexishop.it/ in the category ***Plexiglass→ plexiglass fluorescente***.

The cost (without cutting and shipping) goes by the meter. Standard costs - depending on thickness - are shown from the screen-capture aside.

Same goes with rods: a 1 mt long rod with a 15mm diameter costs around 20 euros. You can have them laser cut but rods can be easily cut on

your own with any manual saw.

Credits

We want to thank the students Alice Pasini, Luca Poletti, Sara Orsini, Denian Errigo, and Matteo Tagliazucchi which actually prepared the experimental setup, made all the measurements and worked on the PV concentration lamp prototypes.

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