



## PHOTONICS WORKSHOP

### ASSEMBLE A LIGHT BOARD (10-14)

*Proposed by the partners : UJM – IOGS – OpenFactory*

Making a 'light board' is a workshop that can be executed in Fab Labs.

**Properties of this workshop:**



**Target audience: 10 - 14**



**Time planning:** Total: 3h

1. Understanding theoretical points such as 'total internal reflection', 'colour mixing' and the process of 'fluorescence'.
2. Assemble the light board
3. Drawing on the light board.



**Estimation cost:**

40 euros by participants, the cost being essentially the LED ribbon and driver.

## Summary & Educational content

The aim of the workshop is essentially to assemble a light board, and to understand the basic principle of operation of this device.

An extended version of this workshop is proposed for the 15 – 18 years (see the corresponding document), which includes the mounting and programming of the LED driver, and also a dedicated creative session to exploit the phenomenon of coloration by light absorption and fluorescence.

Regarding the LED ribbon driver, there are two options: the first one consists in using a commercial LED driver, the second one consists in preparing in advance the home made LED driver based on Arduino that we have designed for the second workshop (15 – 18 years).

Note that in both cases, as these workshops are likely to take place during the day, it is recommended to prepare a "dark room" in the fablab, in order to visualise the LED backlighting in the best conditions. You can also fold a black paper behind the Plexiglas.

Each participant will get to take home his complete light board.

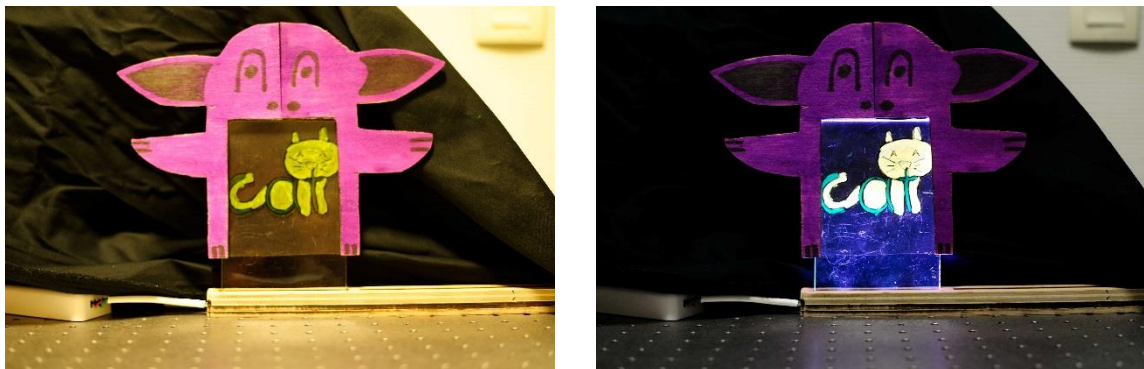


Fig. 1 : Overall aspect of the light board including the support, the plexiglass sheet, the LED ribbon and commercial driver, and a funny housing. Image on the left : LEDs are off, image on the right : all LEDs are on (white light).

During the workshop, the participants will have performed the following tasks :

1. Analyze the operation of light board : total internal reflexion, role of rough edge, notion of optical contact.
2. Assemble the light board in two step : assemble the Light guide support and the device.
3. Examine the colour content of various objects by illuminating with different bands of the visible spectrum (a special colour chart can be printed and examined using this experiment)

## Workshop Outline :

The workshop contains three main steps :

Step 1: Workshop introduction (45 minutes)

Step 2: Cutting of the Light guide and the Plexiglas (30 minutes)

Step 3: Assembling the light guide and drawing (60 minutes)

Step 4 : Playing with light guide (45 minutes)

### Scientific background of the workshop:

The workshop has essentially two main photonic contents to introduce to young mind:

- The first one is the principle of light guidance within a Plexiglas sheet
- The second one is the science of color and the role of lighting on color perception.

The physical background is the same in the 10 – 14 and 15 – 18 years old students, but of course, the technical level of explanation will have to be adjusted for each audience.

#### • LIGHT GUIDANCE IN A PLEXIGLAS PLATE

A light board is essentially a planar light guide coupled with LEDs, based on the same principle than edge-lit backlight of LCD flat panel display or than LED planar lighting. We recommend to demount a LED ceiling light for instance and show to the young student the different elements of the device : LED ribbons, light guide and patterning for light extraction.



Fig. 2 : Example of a LED ceiling light

Guidance in Plexiglas plate is based on the principle of total internal reflection by refraction. Refraction is phenomenon that often occurs in nature (see an example on the turtle image).



Fig 3 : Picture of a turtle inside water. The light refraction at the air/sea interface explains the double image of the turtle.

Total internal reflection is a particular case of reflection where light gets reflected inside a material over and over again. The phenomenon occurs when the angle of incidence is larger than a critical angle with respect to the normal to the surface. The expression of the critical angle can be found thanks to the Snell's law :

$$n_1 \sin(i_1) = n_2 \sin(i_2)$$

The critical angle is the angle  $i_1$  for which  $i_2 = \frac{\pi}{2}$ . Hence,  $i_1 = \arcsin\left(\frac{n_2}{n_1}\right)$ . It depends on the optical index, and internal reflection is possible only when  $n_2 < n_1$ .

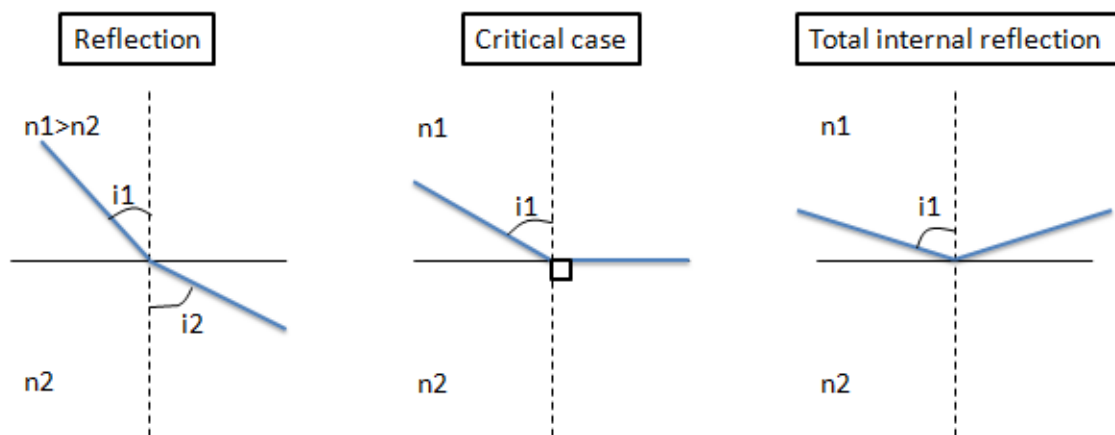


Fig. 4 : Refraction of light and total internal reflection

In this workshop a plexiglas plate will be used, and the light will be trapped into the plate, as shown in the figure below.

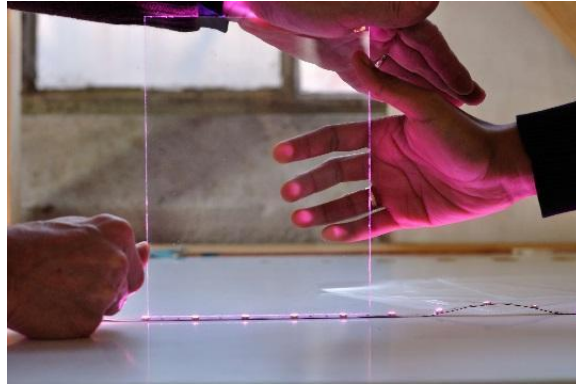
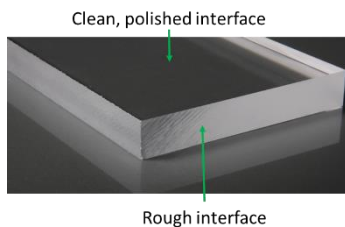


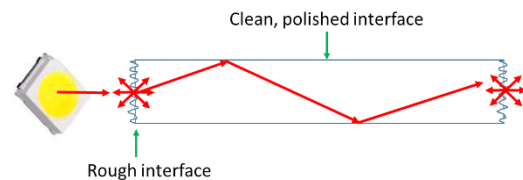
Fig. 5 : interesting experiment to understand the light guidance within the plexiglas plate

Let us comment the experiment of figure 5. We do not see any light coming from the plate, but there is in fact light trapped inside. The light that can be seen is the light emitted by the LED in the observer direction, the light emerging at each rough edge of plate, and the light that escape from the light due to defect at its surface (such as the one induced by the fingers). This later phenomena is called the "Frustrated total internal reflection", and it is also what happens when we draw or write on the light guide surface.

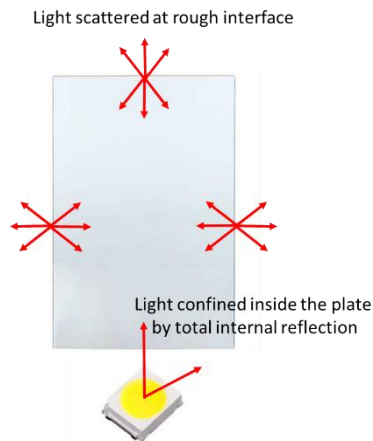
It is important to introduce to concept of clean, polished interface (fundamental for optical devices) where the law of refraction applies, compared to rough interface, where the light is essentially scattered, as illustrated in Fig. 6.



*Difference in term of interface quality in plexiglas light guide*



*Light guidance induced by total reflection*



*Why light can be seen at the edge of the light guide: impact of rough interfaces.*

Fig. 6 : Illustration of the role of rough and polished interfaces in light guidance

In other words, as the edge of the light guide are not polished, the following popular experiment using laser (Fig. 7) cannot be reproduced.



Fig. 7 : Light guidance using laser in a plexiglas sheet where the lateral side have been polished.

The rough edge of the Plexiglas can be improved:

- By polishing (however the equipment required for polishing is not common in fablab)
- By pasting an aluminum foil (even if the obtained improvement in term of light trapped in the light guide can hardly be seen at eye, and would require more accurate illuminance measurements)

Interestingly, a white painting of the light guide edge would not change anything (at eye). Indeed, white painting is also a source of light scattering, as rough interfaces.

Similarly, the light coupling between LED and light guide can be improved:

- By introducing an optical paste (not recommended in the workshop because of the potential degradation of the paste induced by LED heating);
- By adding prism to the light guide, to capture a larger fraction of the light emitted by the LED and guide it into the plexiglas sheet;
- By inserting the LED directly into the plexiglas.

We recommend to illustrate all these conclusions by a proper set of experiments, helping student to analyze the operation of light guide.

- **OPTICAL CONTACT BETWEEN THE LIGHT GUIDE AND A TRANSPARENT SURFACE**

It is also possible to draw on a transparent slide and place it on the plexiglas surface (as seen in Fig. 8). However, in this later case, we need to put the two elements in optical contact, i.e. to avoid a prejudicial air gap between the plexiglas and the slide. This can be done by introducing a liquid with a similar optical index between the plexiglas and the slide. Water works.



Fig. 8 : Drawing directly on the plexiglas surface (left) versus drawing on a transparent slide placed on the plexiglas surface (right). We use water in the right case to get an optical contact between the plexiglas and the slide.

There is a second interesting experiment that can be done with a simple adhesive tape. If we put an adhesive tape directly on the plexiglas surface, it does not change its aspect, as there is almost not optical contact between the two elements. However, it is possible to let the light escape by applying a local pressure. This procedure allow to write with light on the adhesive tape, as shown on Fig. 9.

Interestingly, if the adhesive tape is removed, the optical contact of course disappears, and the written message is erased.





1/ Two slices of adhesive tape on the Plexiglas light guide surface



2/ Writing on the tape by applying a pressure



3/ Result of writing



4/ Erasing the writing by removing the tape



5/ Putting back the second tape ribbon



6/ Writing again

Fig. 9 : Optical contact experiment using an adhesive tape.

## • COLOR PHYSICS

Daylight contains the full visible spectrum, and thus can reveal all colors. However, the combination of only red, blue and green light, called primaries colors, can also produce white light. White light (or white color) is thus not unique, and can be obtained by an infinite combination of light, providing that the full spectrum is covered.

The color of a surface (induced by inks and pigments coloration for instance) is not a fundamental properties of the surface itself, but also depends on the lighting. Each colored surface is in fact absorbing a fraction of the light depending on its spectrum. As illustrated on

Fig. 10, a red surface appears red because it is absorbing all the spectrum, except red. However, a red surface illuminated by blue or green light will appear black (absence of light), as blue or green light are absorbed by red surfaces. A white surface essentially absorb no visible light.

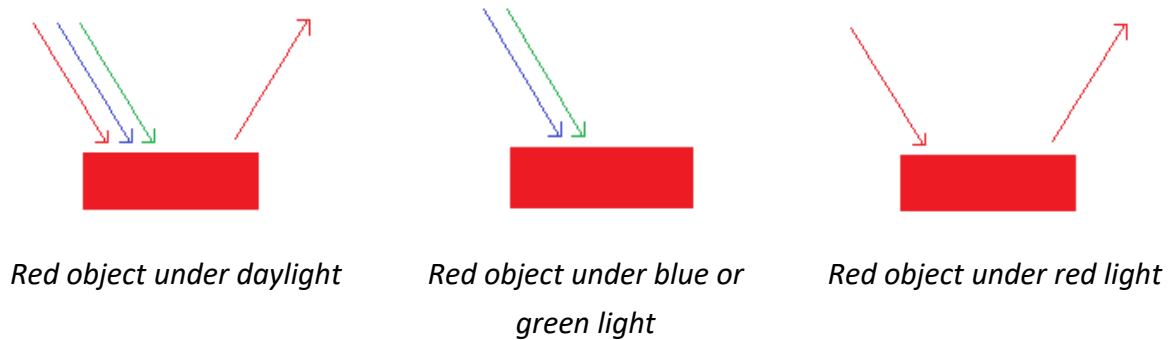


Fig. 10 : impact of white, cyan and red light on a red colored surface

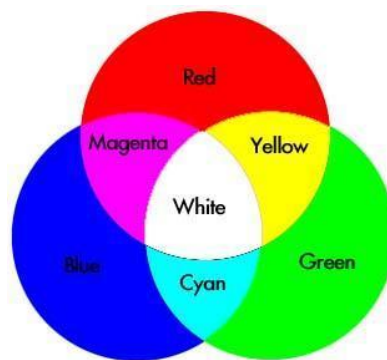


Fig. 11: Primaries and complementary colors

Two colors are said to be complementary colors if their mixing is white (see Fig. 11). Complementary colors of primaries color are respectively cyan (blue + green), magenta (red + blue) and yellow (green + red). Interestingly, complementary colors appears black when illuminated by only one primary color. For instance, as cyan is made of blue and green inks, it turns black only under red light.

These concepts can be nicely illustrated by drawing on the light board (see Fig. 12). We recommend to use acrylic painting, as it can be easily washed used soap and water.

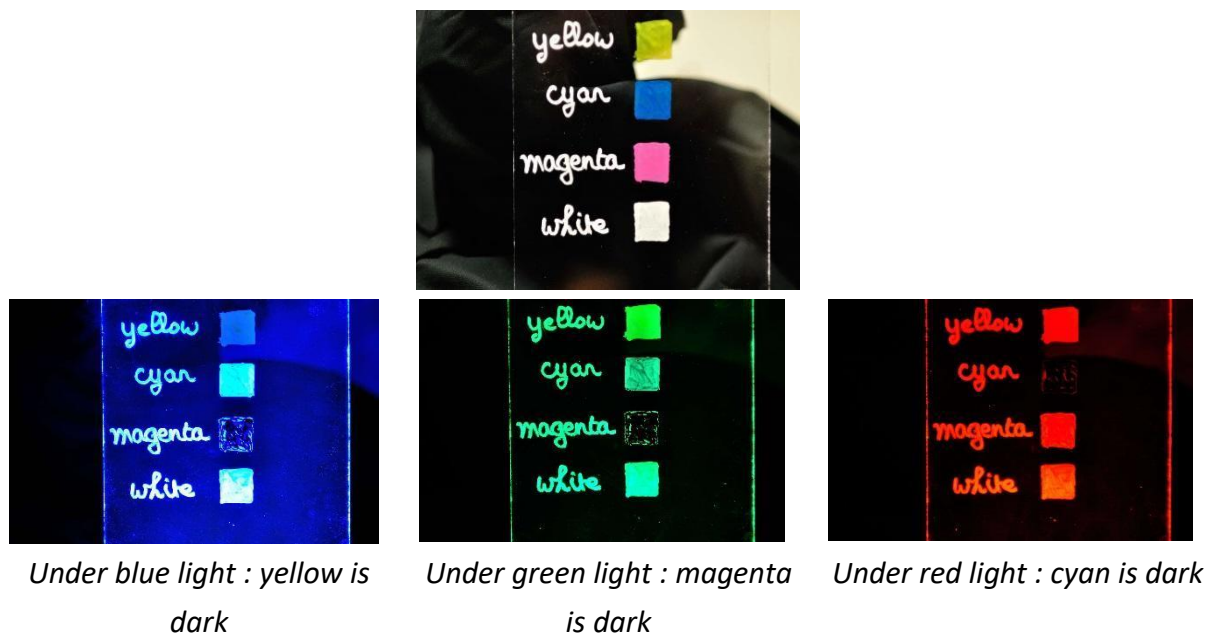


Fig. 12: Illustration of complementary colors cyan, magenta, yellow under red, green and blue light. Note that the theory is not perfectly respected as magenta is also partially dark under blue light, and yellow not completely green under green light. This is probably due to the use of fluorescent elements in magenta and yellow inks.

- **FLUORESCENCE**

Contrary to most material that only absorb part of the incident light spectrum, fluorescent material not only absorb light, but also re-emit light with a different spectrum, usually at a short wavelength (lower photon energy). Under excitation, fluorescent material appears glowy, because the light emitted by the fluorescent material is not expected by the human visual system and is interpreted as an excess of light.

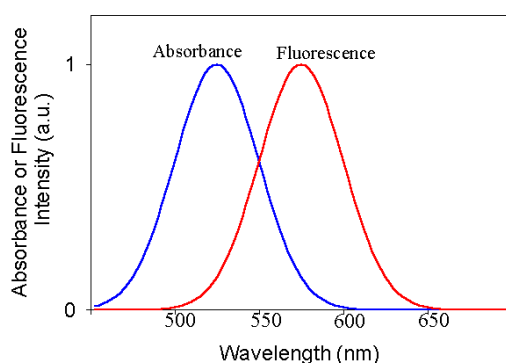


Fig. 13: Typical spectrum of absorbance and fluorescence of a fluorescent material.

Each fluorescent material needs a specific light excitation spectrum. It is the UV light in many case, which is quite spectacular, as UV light is not visible. However, we avoid to use any UV light during our workshop, as UV light might damage human retina.

As shown in Fig. 14, all fluorescent inks used in classical pencils are fluorescent under blue light, and some of them (pink and orange) are also partially fluorescent under green light. It is typically difficult to discriminate the absorption and fluorescent contribution of inks and painting from an experimental point of view, this issue is addressed in our third workshop (for young professional). Fluorescent inks are attractive for drawing on the light board as they appears colored under blue light (and sometimes green light), contrary to classical absorbing inks (which are dark or blue only).

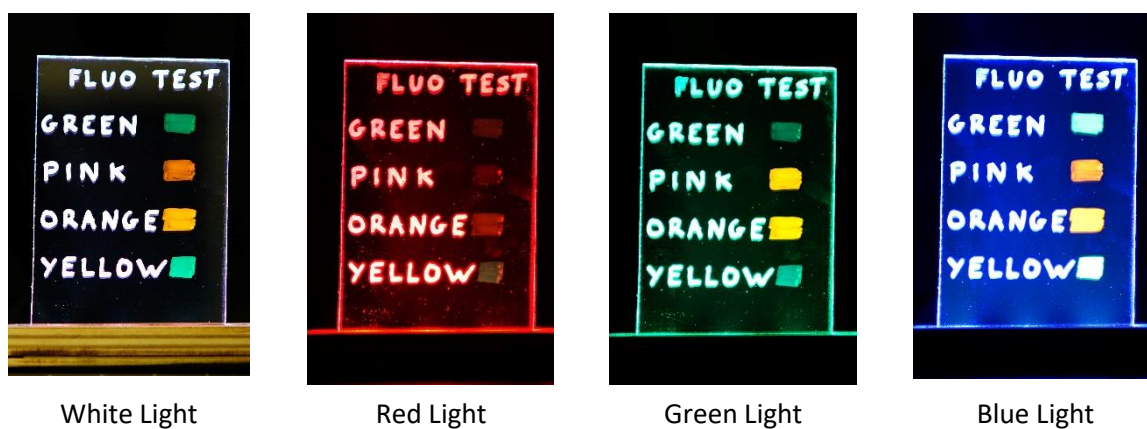


Fig. 14 : Fluorescent inks under white, red, green and blue light

## Workshop instruction

### Part and equipment list

- Wood, A4 size (21cm x 29.7cm) 3mm thickness
- Laser cutting machine
- 12v Led ribbon with RGB lights
- Led ribbon RGB driver and 12v power supply,
- Fluorescent stabilos
- Acrylic pencils
- Plexiglass plate, 5 mm thickness, 100cm x 50cm

- White paper and pen
- Ruller
- Circular saw (if your Laser cutting machine can't cut more than 3mm)
- Sandpaper
- Wood glue or hot glue gun
- Painter's tape
- Soldering iron
- Soldering tin
- Heat-shrinkable sheat
- Screwdriver

The LED ribbon contains circular spots composed of 3 LEDs that we can separately controlled (one red, one green and one blue).



Fig. 15 : Typical LED ribbons

Thanks to the control unit we can obtains 7 different lighting: red, green, blue, magenta (red+blue), cyan (blue+green), yellow (red+green), white (red+green+blue).

## Step 1: Workshop introduction

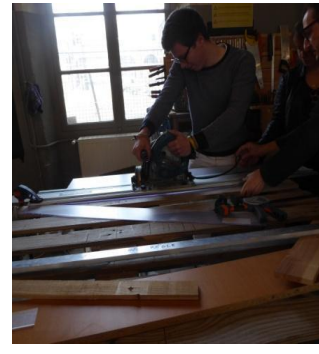
In the beginning, we suggest to show the final result of the workshop, the light board, and explain through the experiments described in the section "Scientific background of the workshop", the operation principle of the light board.

## Step 2: Cutting of the plexiglas plate

First, trace the cutting lines on the plate with a pen and don't remove the protective film that is on the plate. Cut the plate of into 10 x 15cm rectangles.



Use the circular saw in order to cut all the rectangles without removing the protection film of the plate, and don't forget to hold the plate tightly.



Use the sandpaper on each side of the plate to remove all of the smudge.

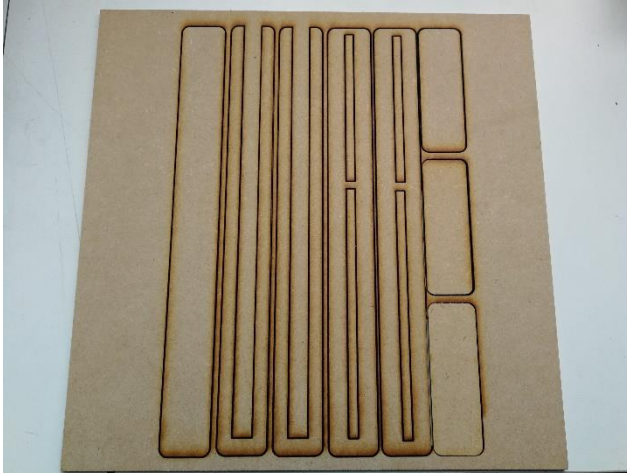
You can also use a laser cutting machine.

The final plexiglas plate looks like this :



### Step 3: Laser cutting of the Light guide support and background

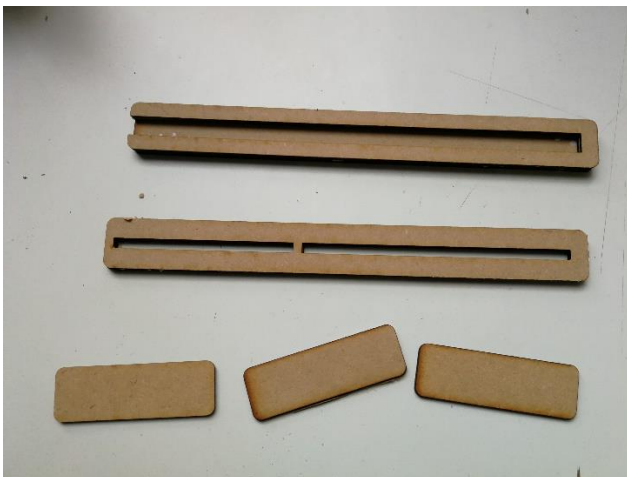
1. Use the files you can find on the google doc to cut the wood  
cut the wood

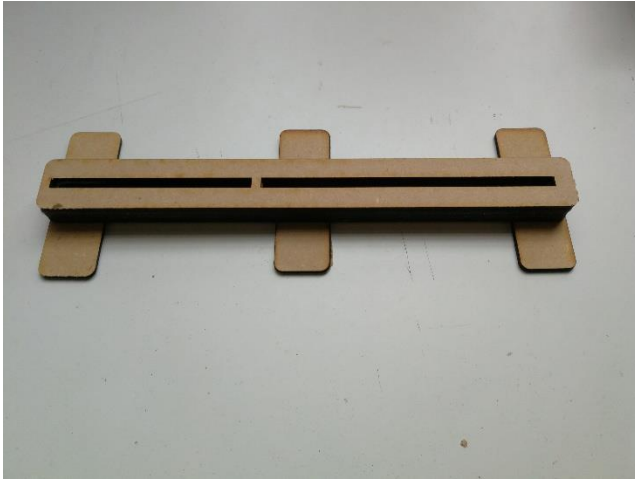


2. Remove carefully all of the parts



3. With the wood glue, stick the different part together, as show on the picture





4. Weld the led ribbons with the electric wire, then use the heat-shrinkable sheat to protect the welding
5. Connect the RGB Led ribbons to the driver and to the power supply



(Commercial LED driver and power supply, allowing to switch on and off all Red or Green or blue LED)

We recommend to use black or white material for realizing the background. You can find all ot the files for the 3D print [in this folder](#). Support "Gizmo" refers to the background. After the print, you have to use glue to assemble the background. If you don't want to print the background you can cut a black paper and insert behind the Plexiglas plate.



## Step 4 : Playing with light guide

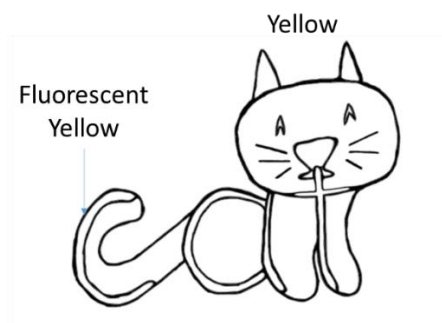
For the first level workshop, we suggest to use our examples, respecting the proposed coloration. Before you draw on the plexiglass, make a try on a paper, then transfer the model on the plexiglass.

[You can find our example here](#)

We show in the following two examples quite easy to explain.



Example 1 : The dragon : the red part of the dragon appears on red light and disappear on blue light.



Example 2 : Application of the principles of fluorescence : a hidden word, "cat" is written using a fluorescent ink. It is best revealed in this case using magenta lighting.

An another sympathetic method for the drawing for the kids is to use google to find pictures.  
Then dispose the Plexiglas plate on a screen and calk the picture.



# PHABLABS 4.0

**PHABLABS 4.0** is a European project where **two major trends** are combined into one powerful and ambitious innovation pathway for digitization of European industry: On the one hand the growing awareness of **photonics** as an important innovation driver and a **key enabling technology towards a better society**, and on the other hand the **exploding network of vibrant Fab Labs** where next-generation **practical skills-based learning** using KETs is core but where photonics is currently lacking.

[www.PHABLABS.eu](http://www.PHABLABS.eu)

This workshop was set up by the *Institut d'Optique Graduate School and University Jean Monnet de Saint-Etienne* in close collaboration with *OpenFactory*.



PHOTONICS PUBLIC PRIVATE PARTNERSHIP