Animated drawing using RGB lighting of an image combining classical and fluorescent inks.

PHOTONICS WORKSHOP

CREATIVE DRAWING USING LIGHT BOARD
(15-18 years old)

Proposed by the partners : UJM – IOGS – OpenFactory

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CREATIVE DRAWING USING LIGHT BOARD is a workshop that can be executed in Fab Labs.

Properties of this workshop:

Target audience:

High school teenagers (15 – 18 years old)

Time planning: Total: 3,5 h

1. Understanding theoretical points such as 'total internal reflection', 'colour mixing' and the process of 'fluorescence'.
2. Assemble the light board
3. Assemble and programming of the LED drivers
4. Propose amusing drawing on the light board exploiting absorption, florescence versus LED lighting.

Estimation cost:

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

Summary & Educational content

The aim of the workshop is to assemble a light board including the Arduino LED driver, to learn how to program the RGB LED ribbon and to propose innovative drawing exploiting the properties of absorption and fluorescent inks.

Note that 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.

Each participant will get to take home his complete light board.
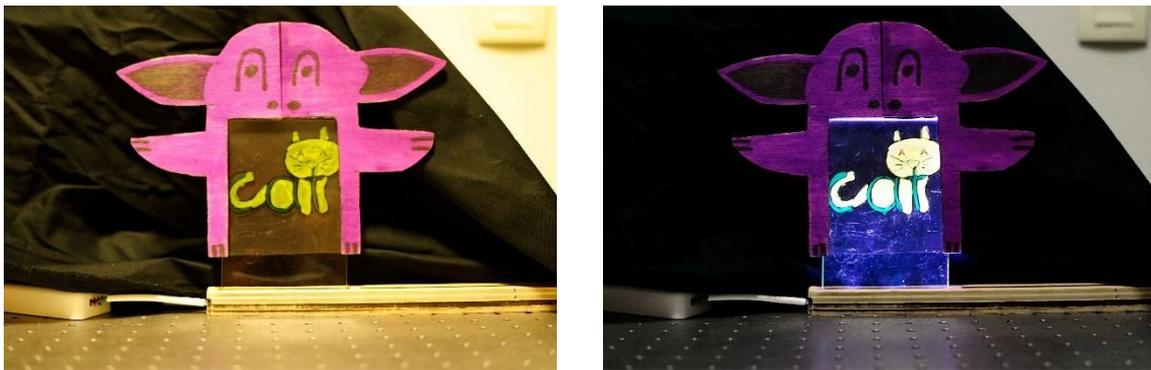
Fig. 1 : Overall aspect of the light board including the support, the plexiglass sheet, the LED rubbon and commercial driver, and a funny housing. Image on the left : LEDs are off, image on the right : all LEDs are on (white light).

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

1. Mount an electronic circuit and an arduino cardboard to control an RGB LEDs on a support made with carving machine, in a box which will hold the electronics in place and through which the participant can look

2. 3D print a half box to block ambient light, sits on top of the support and the sample plexiglas plate are placed in.

3. Examine the color content of various objects by illuminating with different bands of the visible spectrum (a special color chart can be printed and examined using this experiment)

4. Get creative by painting some artworks using regular and fluorescent paints in order to produce amusing images, changing depending on lighting conditions.

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Workshop Outline :

Step 1: Workshop introduction (15 minutes)
Step 2: Cutting of the plexiglas plate (30 minutes)
Step 3: Light guide support and background (45 minutes)
Step 4 : Assembling the LED driver (30 minutes)
Step 5 : Programming the LED driver (30 minutes)
Step 6 : Creative drawing using the light guide (60 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, $i_1 = arcsin(\frac{n_2}{n_1})$. It depends on the optical index, and internal refraction is possible only when n2 < n1.
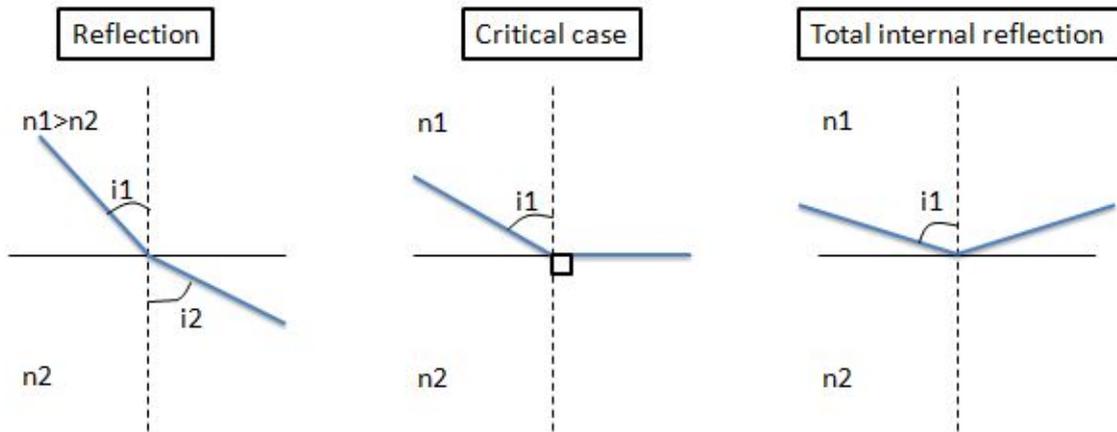
Fig. 4 : Refraction of light and total internal reflection

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

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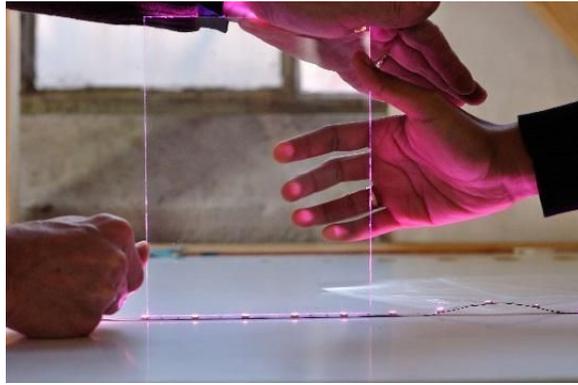
Fig. 5 : interesting experiment to understand the light guidance within the plexiglas plate

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.
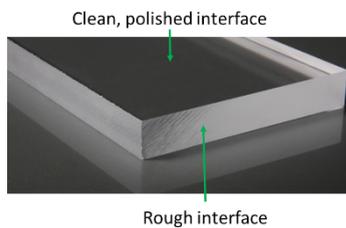
Difference in term of interface quality in plexiglas light guide
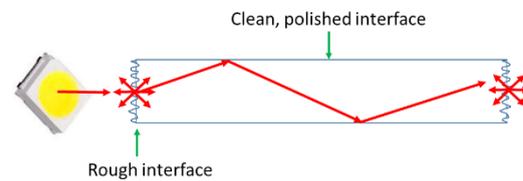
Light guidance induced by total reflection

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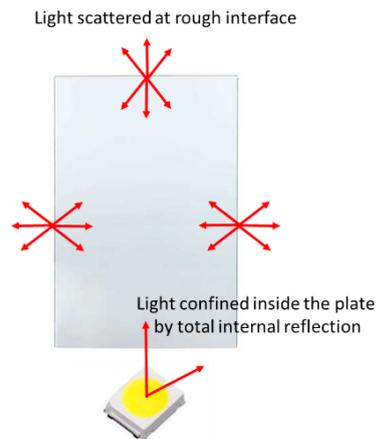
Why light can be seen at the edge of the light guide: impact of rough interfaces.

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.

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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.


Red object under daylight   *Red object under blue or green light*   *Red object under red light*
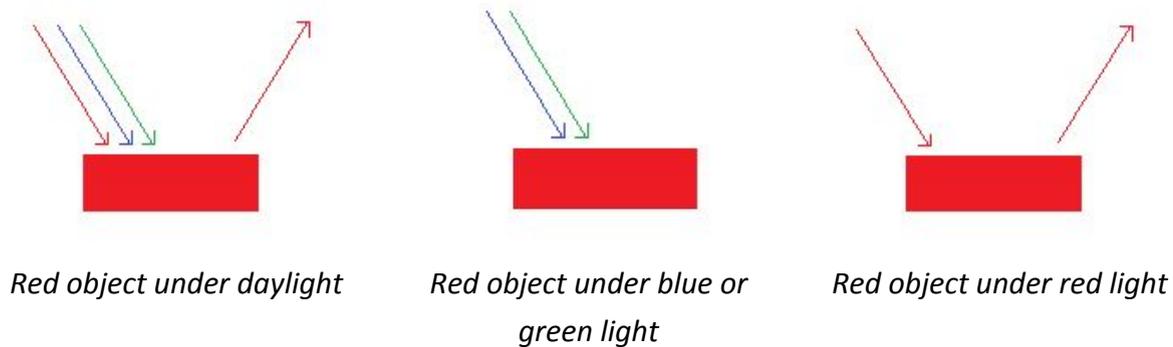
Fig. 10 : impact of white, cyan and red light on a red colored surface
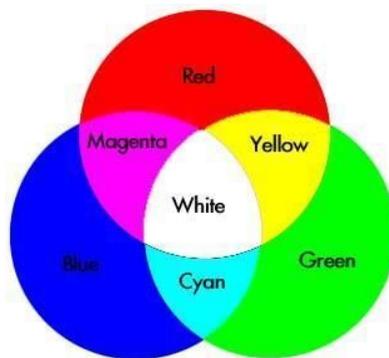
Fig. 11: Primaries and complementary colors

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.

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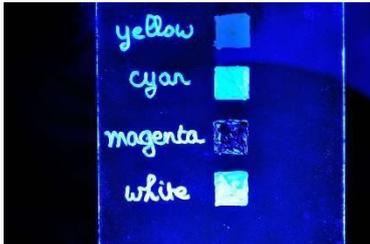
Under blue light : yellow is dark
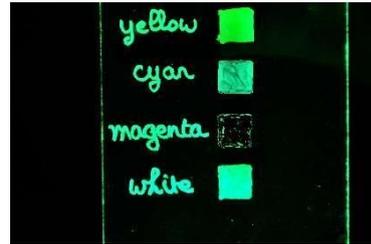
Under green light : magenta is dark
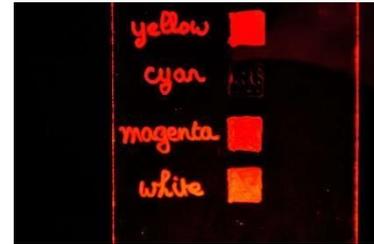
Under red light : cyan is dark

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 glowly, because the light emitted by the fluorescent material is not expected by the human visual system and is interpreted as an excess of light.
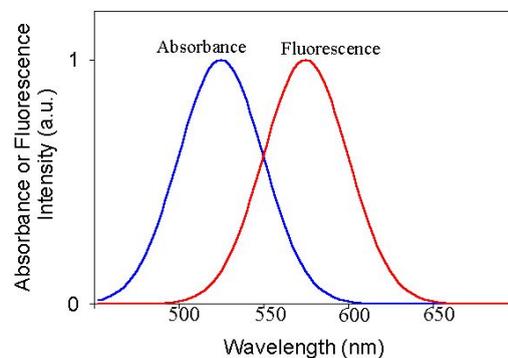
Fig. 13: Typical spectrum of absorbance and fluorescence of a fluorescent material.

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).

| White Light | Red Light | Green Light | Blue Light |
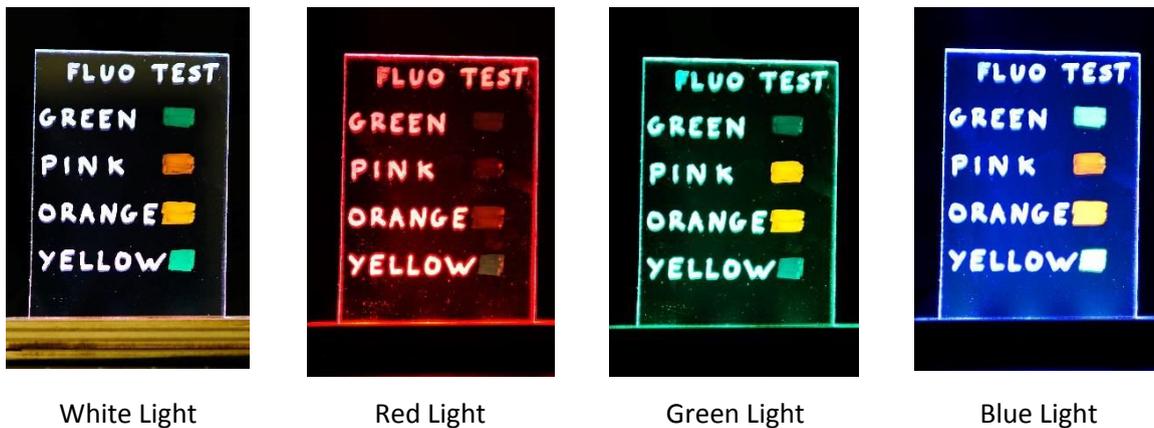
Fig. 14 : Fluorescent inks under white, red, green and blue light

Workshop instruction

Part and equipment list

- PLA plastic wire
- 3D printer
- Arduino nano
- Circuit - file can be find here
- Resistance 220 ohms

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- 2 x Resistance 80 ohms
- 3 x Loader LCC 100 nf
- Axial loader 100 nf
- Rotary encoder EC12PLRVFD24
- Led ribbon with RGB lights
- USB cable compatible with the Arduino nano
- USB outlet
- Soldering iron with wire
- Fluorescent stabilos
- Acrylic pencils
- Plexiglass plate, 5 mm thickness, 100cm x 50cm
- White paper and pen
- Ruller
- Circular saw
- Sandpaper
- Superglue
- Painter's tape

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 Plexiglas of size 100x50 cm 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.
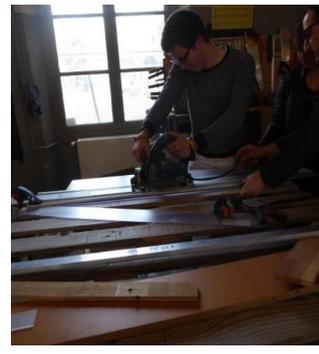
Use the sandpaper on each side of the plate to remove all of the smudge.

The final plexiglas plate looks like this :

Step 3: Light guide support and background

In this workshop, the students will 3D print the light guide support that contain both the Arduino drive, the plexiglass plate, the led ribbon.

3D printing can be used also for processing the background. 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.


Different realization of the "Gizmo" background for the light plate in wood (left) or back plastic (right)

Step 4 : Assembling the LED driver
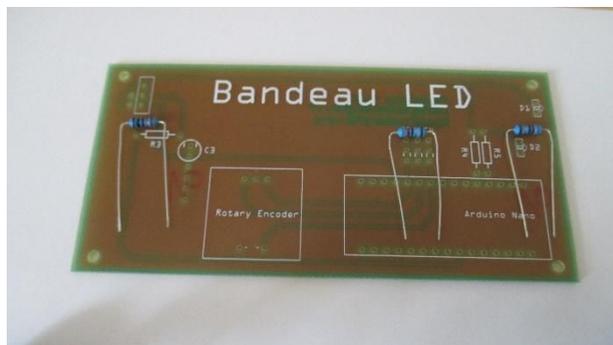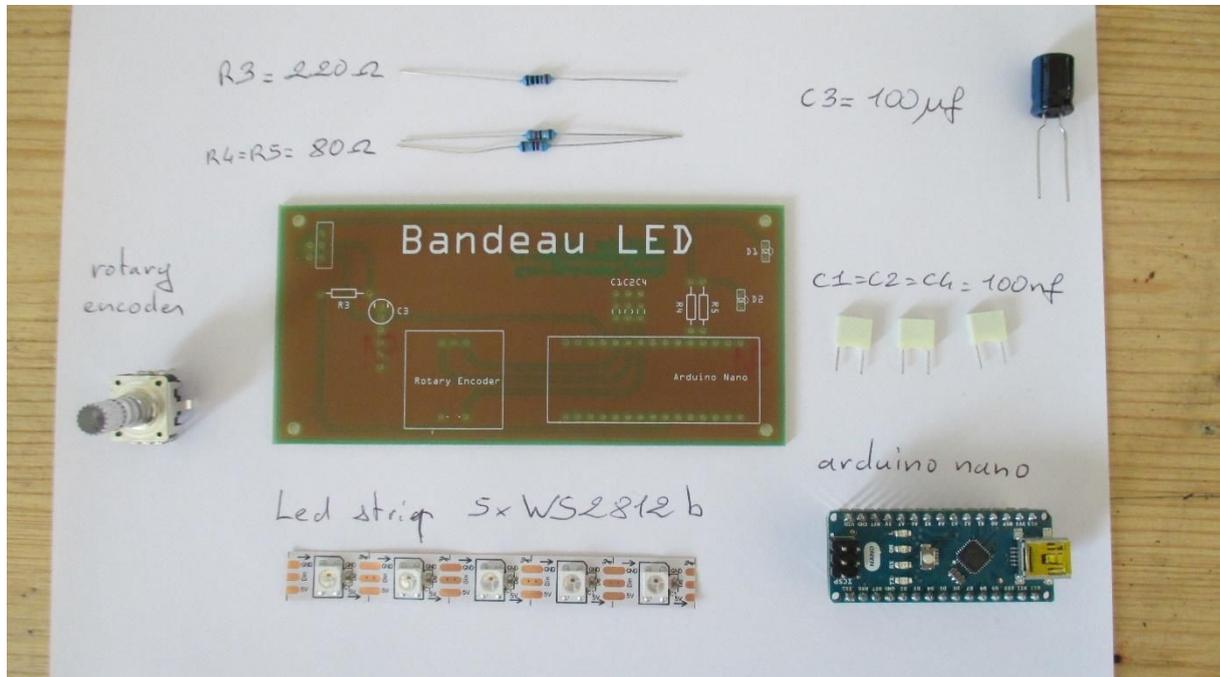
	1 – Place the resistance as describe on the PCB board

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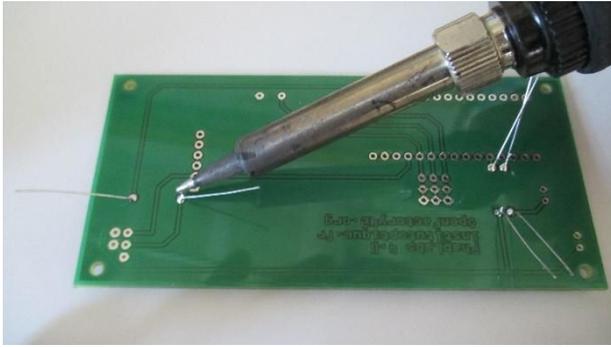
|	2 – Weld the resistance
	3 – Cut the leg and keep them. We are going to re-use them latter.
	4 – Place the loader and the axial loader as write on the circuit
	5 – Fold the axial loader. It is going to make the device flatter.
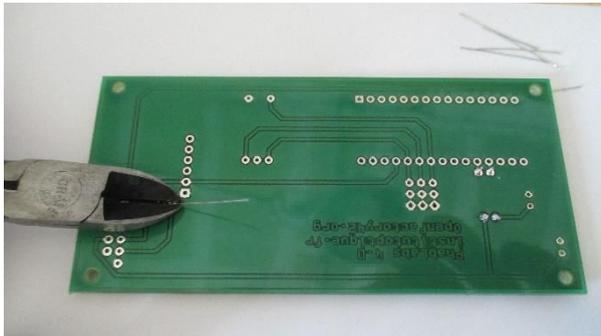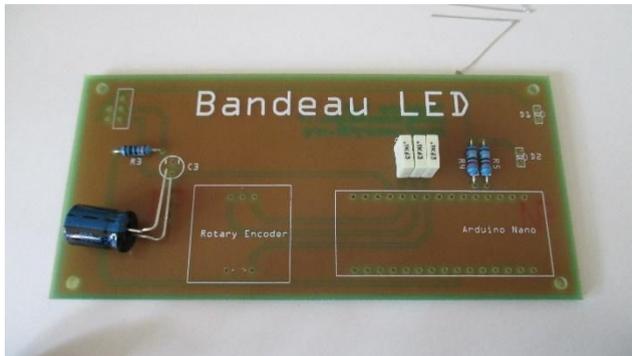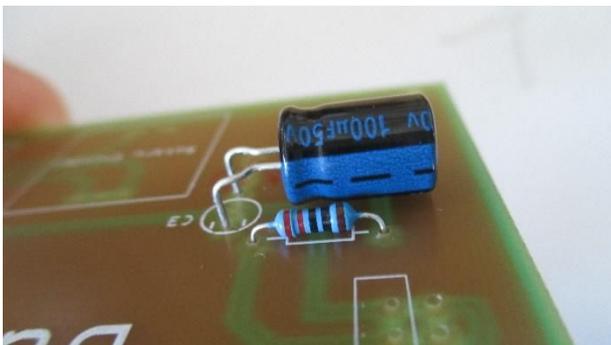
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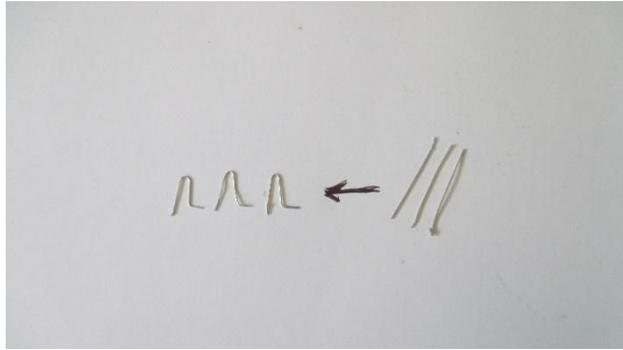
	6 – Take the leg you keep in step 3 and fold them like in the picture.
	7 – Cut a piece of you Led ribbons, as long as your device, and weld it to your circuit with your folded legs.
	8 – Then, weld the rotary controller and the Arduino nano. Don't forget to place the USB output to outside of the circuit.
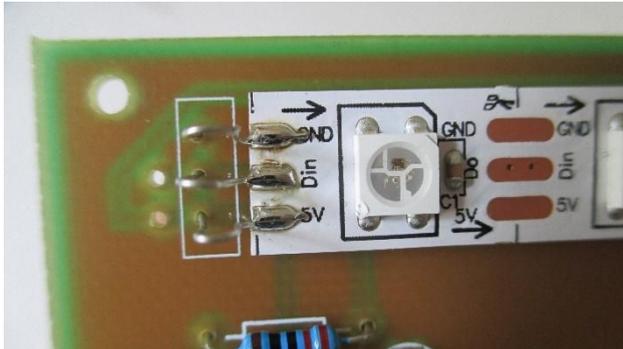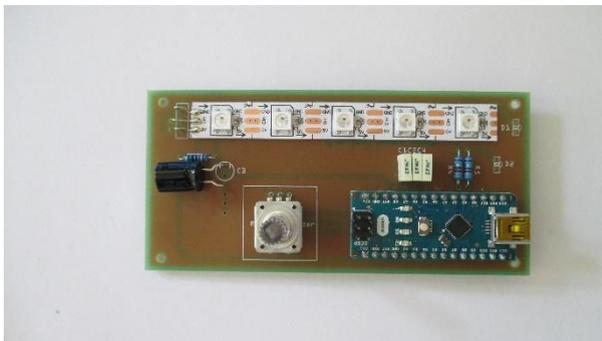
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The final LED driver, based on Arduino, using an USB plug. In this image, we can see that each LED can be controlled independently.

Step 5 : Programming the arduino

Download the Arduino IDE program (C language) on your computer. You can download the lastest version here

Then, connect the Arduino to your computer, launch the Arduino IDE and copy this code in your IDE (FluoBoard.ino). Save and quit.

Now you can connect your device, turn it on by pressing on the rotary device and try all the built in modes. You can design your own mode by modifying the C program that drive the LEDs. This point is interesting for the next step, as each new images will require a specific modification of the LED driver.

Step 6 : Creative drawing using the light guide

Light guides can be used in several different ways to get creative, funny and amazing images. In the following, we show 4 different ways to use light guide :
- Reveal part of the drawing playing with lighting (example 1 : the dragon)
- Create animated images (example 2 : the bike & example 3 : the flower)
- Hide message within the drawing (example 4 : the hidden cats)

There is surely other ideas in the air (other suggestions: exploiting both side of the light guide, 3D images with anaglyphs …). Please let us know all the new ideas that will come out of your works !

We suggest to start with samples showing the appearance of each inks available in the fablab under different lighting (primaries and complementary colors). Then, we can present our examples, and asks students to create other drawing ! You can find our example here

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

White

2 3 4

2 Yellow, 3 Cyan, 4 Magenta
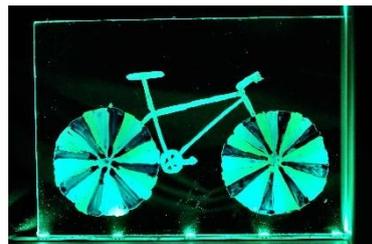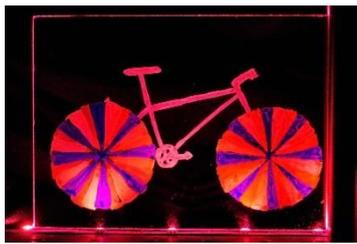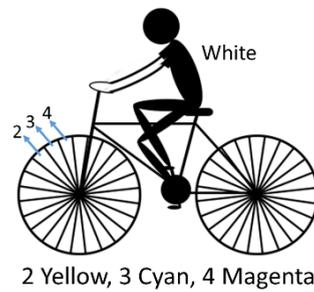
Example 2 : Application of the concept of complementary colors : Bike in motion. The radius of the bike's wheels are made of complementary colors cyan, magenta, yellow. Using alternative red, green and blue lighting, radius turns black one after the others, giving a feeling of motion.

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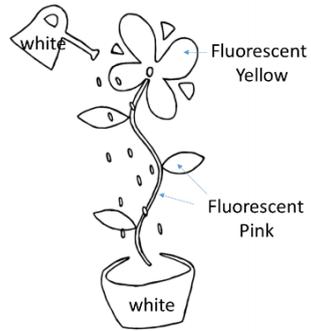
Example 3 : Application of the principles of fluorescence : The flower stalk is made of fluorescent pink that appears both on green and blue light, while the flower petal appears only with the blue light.
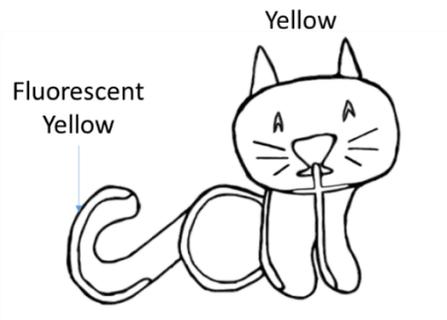
Example 4 : Application of the principles of fluorescence : a hidden word, "cat" is written using a fluorescent ink. It is best revealed in this case using magenta lighting.

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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.

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