PHABLABS 4.0

PHOTONICS WORKSHOP

ART WITH POLARISATION

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PROPERTIES OF THIS WORKSHOP

Summary:

In this project we will create beautiful pieces of art that can change their colour when you move them. We dot this by using the phenomoenon called polarisation - this is a property that light waves exhibit. So, in the end, you will not only use your creativity but also learn something about the physics of light! Besides, you will use a laser cutter, a 3D printer and many of the other handy tools provided in a Fab Lab. Let's get started!

TARGET AUDIENCE:

Young students (10-14 years old)

SUGGESTED TIME PLANNING: (Total: 2h10)

Timing in minutes	**activity**
15 min	Understanding the concept of polarisation
60 min	Making the wooden box
10 min	Creating an individual Mosaic with adhesive tape
30 min	Cutting an individual sentence from UHP sheets
15 min	Finding out if others can decipher your encrypted sentence

TOOLS:

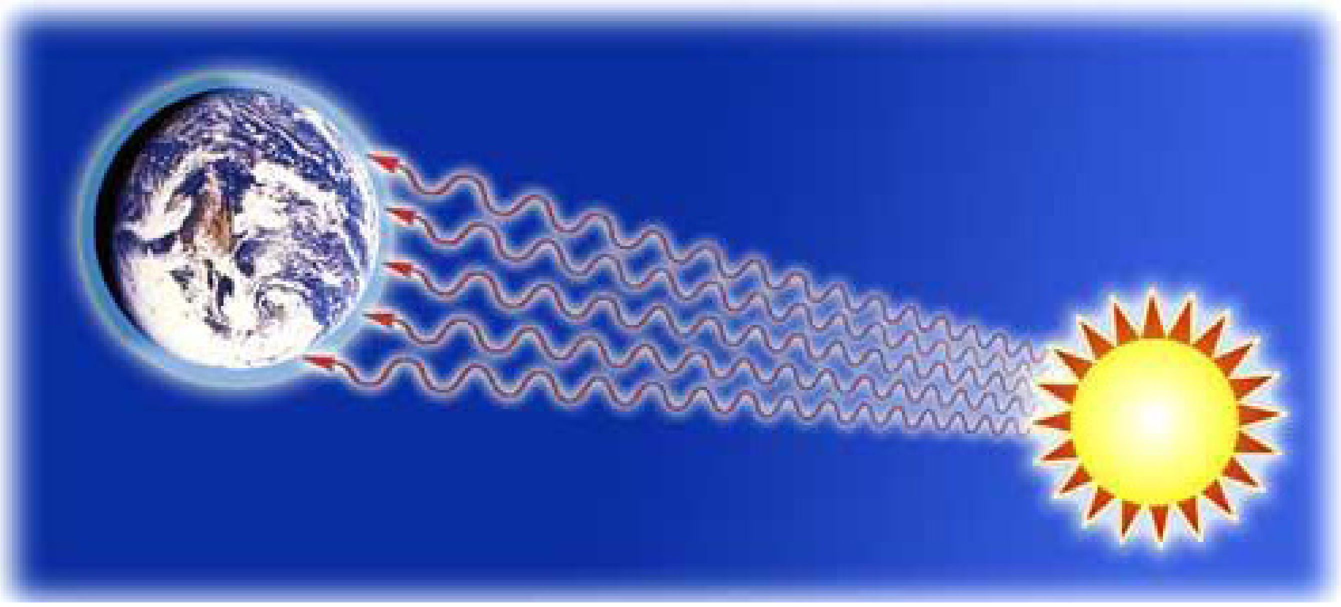
3D printer, laser cutter, scissors, screwdriver, permanent marker, super-glue

WEBLINK:

All needed files for lasercutting andWemos can be found on:
http://www.phablabs.eu/workshop/art-polarization
or via the QR code.

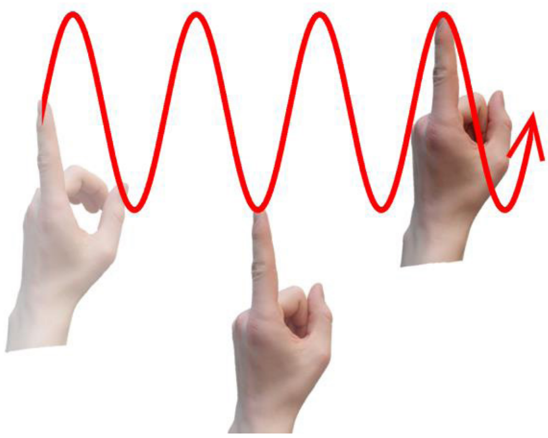
Step 1: What is polarisation?

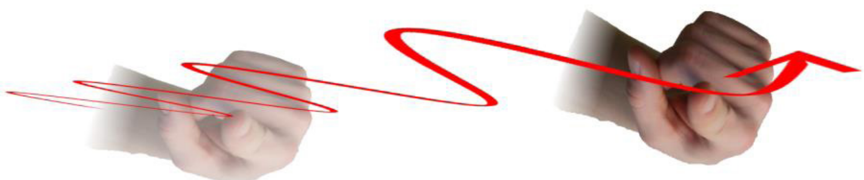
We all know the sun is the ultimate source of existence for nearly all living species- no sun, no life! As the sun will continue to shine for about five billion years, you don't have to worry for now. Instead, let's see what we can learn in the meantime.



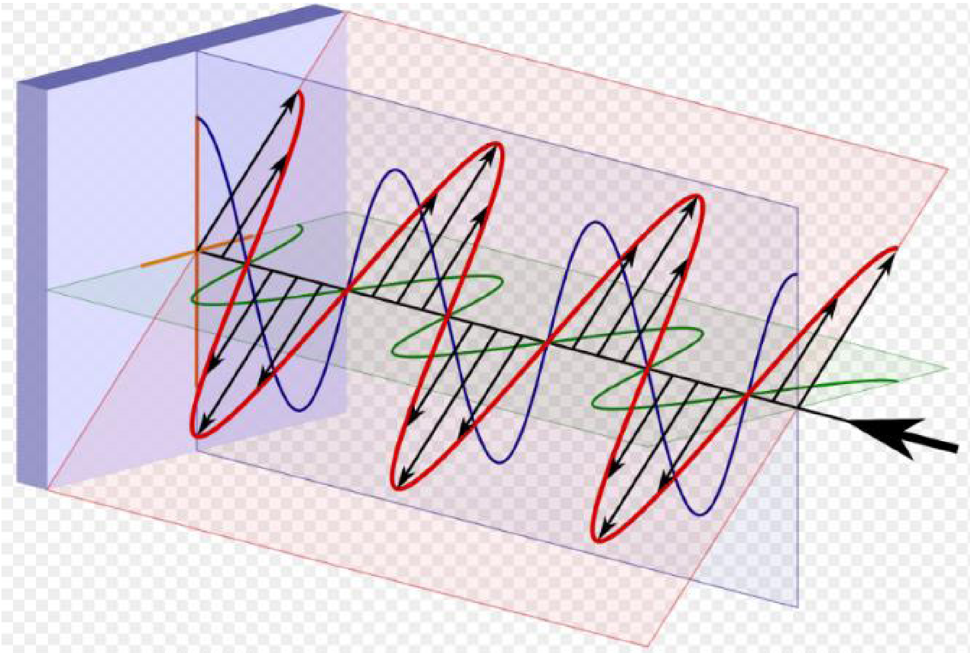
The sun emits a huge amount of light waves to the earth.

Light is made up of waves that travel in space. Try to trace the path of a single light wave with your hand. You will find that there are different directions in which the wave can oscillate. It might go up and down or it might go back and forth - or maybe something in between:





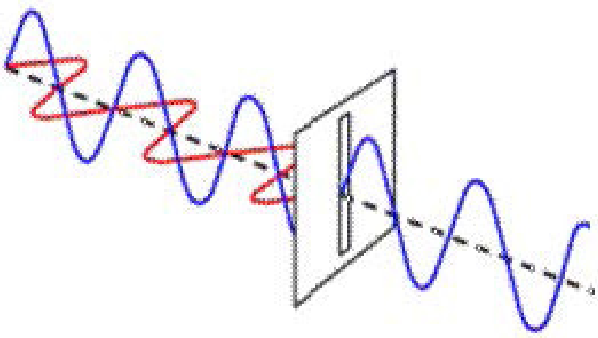
So while different light waves might share a common direction in which they travel, they might still have a different direction in which they oscillate. For example, in the following figure you see three different waves (red, green, blue). The green waves oscillates back and forth, the blue wave oscillates up and down an d the red wave has chosen to oscillate somewhere in the middle:



This phenomenon is called **polarisation**. The plane in which a wave oscillates is called a plane of polarisation.
If all waves coming from a light source share the same plane of polarisation (that is, all oscillate in the same direction) the light is said to be **linearly polarised.**
Typical gadgets which emit linearly polarised light are, for example, lasers and LCD displays. But most light we deal with in our daily life is not linearly polarised – instead, all the individual light waves have a different plane of polarisation. In this case we call the light **unpolarised**.

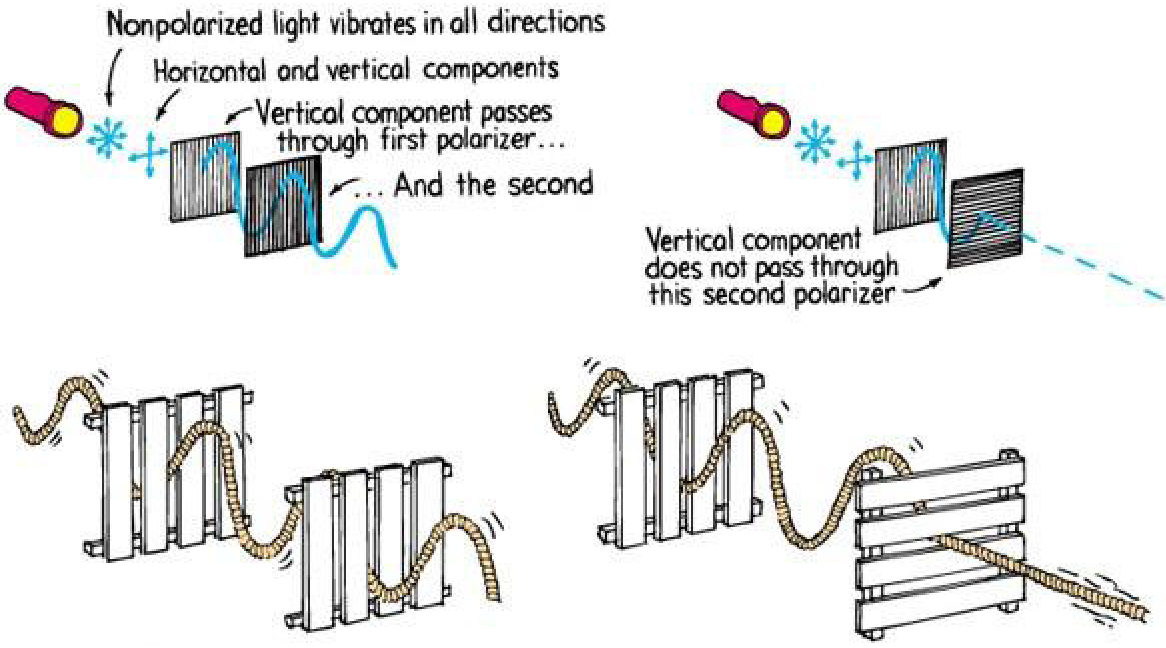
You already know the biggest source of unpolarised light. Exactly: It's the sun!

It is possible to filter light according to its polarisation using polarisers. A polariser is an object that only lets through light waves with a certain plane of polarisation. When you send an unpolarised light beam through a polariser you will end up with a linearly polarised light beam at the other side. This way, you can compare it with a fence or gap, which would only let through items oscillating in the direction of the opening. The next picture is an example where only the light waves moving up and down are let through:



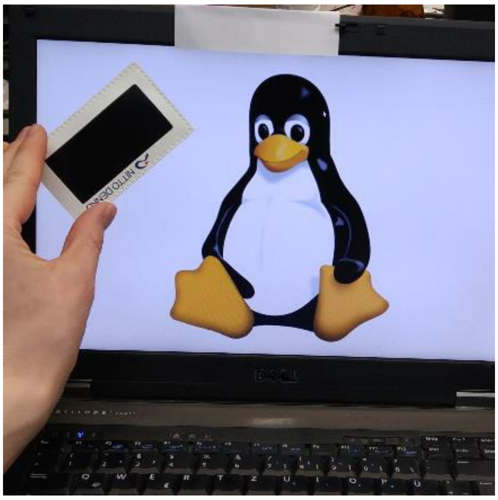
A beam of unpolarised light is filtered by an oscillator resulting in a beam of linearly polarised light.

Now imagine the following: A second polariser (called analyzer) is placed behind the first one. When the orientations of the two polarisers match, the linearly polarised light coming from the first polariser is let through the second one. However, if you turn the analyzer by 90° the light is blocked entirely as the light does not match with the orientation of the first polariser:

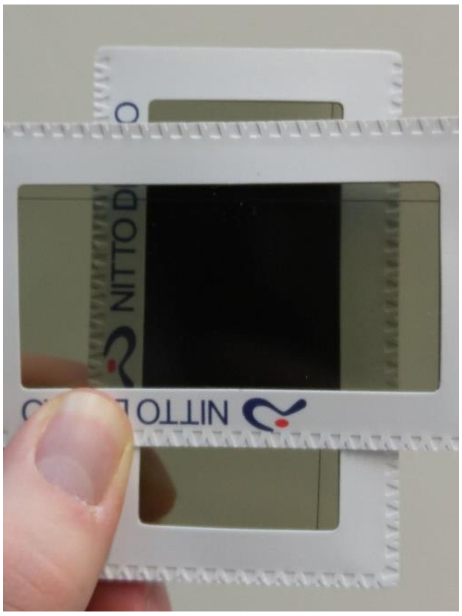


In this scheme the light wave is represented by a wave moving on an oscillating rope. The role of the polarisers is played by picket fences.

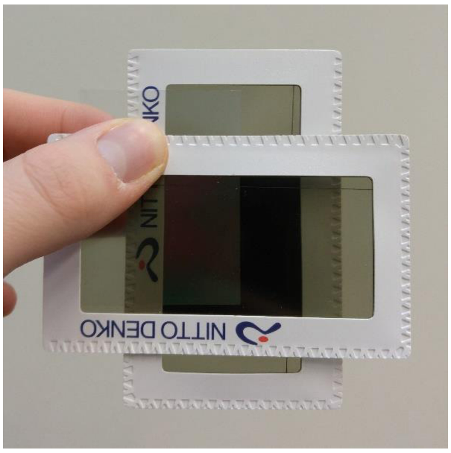
Example 1:
You can try this out with a polariser sheet and an LCD display (i.e. a laptop, TV, smartphone). Just hold the polariser in front of the display and rotate it. As the LCD emits linearly polarised light, the light is only let through when the orientation of the analyzer and the plane of polarisation match. If you turn the analyzer by 90°, you will notice that nearly all the light is blocked:



Example 2:
You can easily try this out with two polarisers. Just place them behind each other and rotate one of them:



Now we get to the interesting part: There are materials which rotate the plane of polarisation of the light that goes through them. These materials are called optically active.
Now, if you place an optically active object between the two polarisers, the linearly polarised light will be rotated. So, when it reaches the analyzer, it will again (at least partly) match with the orientation of the analyzer – the light is not blocked anymore!

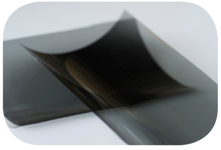


Cellophane, a substance often used for transparent films, shows optical activity. So you can take a cellophane film, cut an artful pattern into it, and place it between two polarisers. Voilà – you've made your own artwork based on polarisation optics! You can also see different colours. The colours change with the number of sheets which are piled up. This is what we're going to do in this project.

Step 2: Parts list

Collect all materials for each participant.

Photonics Parts:

Linear polarising sheet (10 x 10cm)
roll

Overhead projector transparancy sheet

Other Parts:

Plastic filament

Plywood

Wood glue
Transparant adhesive tape

The photonics parts can be bought by [EYESTvzw](#).
The electronic parts can be bought by [Fablabfactory.](#)

Step 3: Printing two polariser mounts

We'll print two polariser mounts – one will be called "attachment" and the other one "lid". The attachment will be glued to the wooden box later on, so that the lid can be clicked in. As the printing process takes about 40 minutes for each part, we'll initiate the print job first.

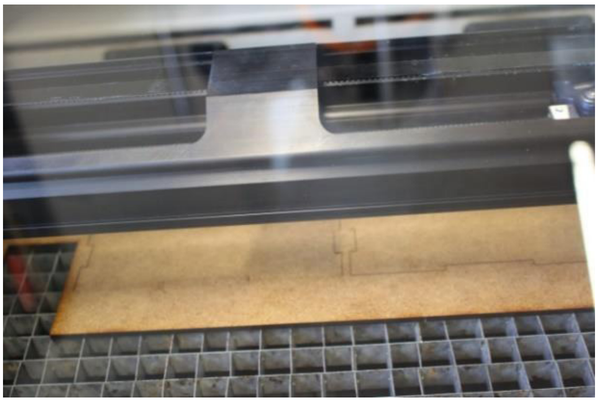
Make sure the 3D printer is switched on and there is enough plastic filament.
Now, load the model of the two parts into the 3D printer and let the process start.

Step 4: Making a wooden box

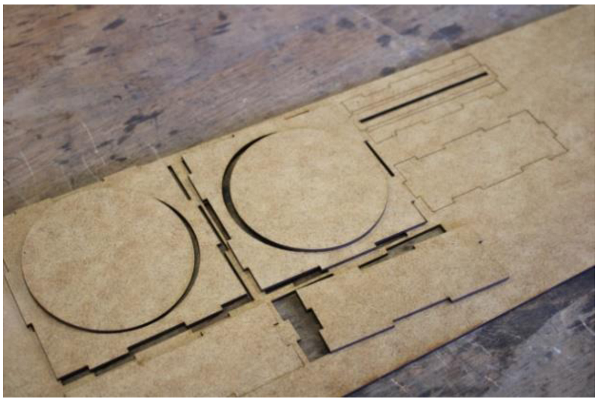
In this step we'll be using a laser. Make sure you've understood all necessary security regulations. Especially, it's important to keep the laser casing shut during operation!

Choose the position of plywood sheet (3 mm thick) and put it into the laser cutting machine. The cutting pattern can be found in Polarisation_Art_Casing.pdf. Make sure you have the appropriate laser parameters set! For plywood with a thickness of 3 mm processed by a 40 W CO_2 laser we determined the following parameters to be optimal:

- Speed: 65%
- Power: 90%
- Pulse frequency: 500 Hz



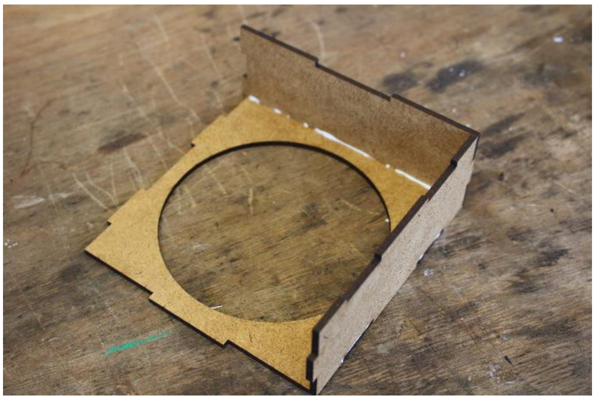
Put the plywood into the lasercutter.



Separate the sliced parts from the plywood.

Step 5:Assembling the parts

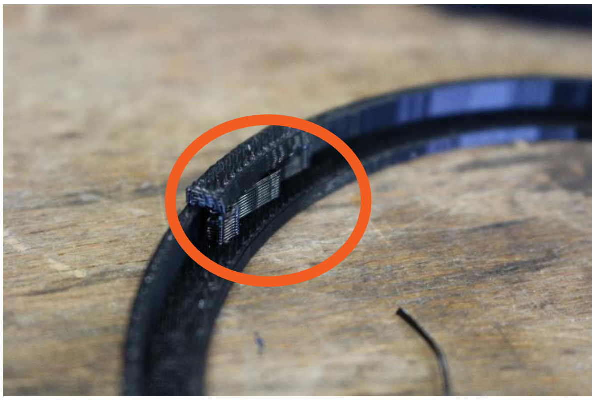
Take the remaining plywood parts from Step 4 and glue them together with wood glue. You will get a rectangular box with two big round openings. Don't be afraid – you can't do anything wrong. It is constructed as simple as possible, so glue together what fits in – that's all!



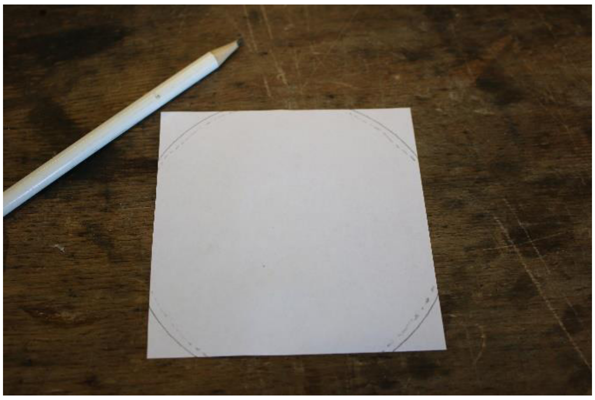
In the meantime, the 3D parts from Step 3 should be completed.

Step 6: Attaching the polariser

Now you should remove the supporting parts from the lid with a screwdriver - be careful not to remove the clamps themselves.

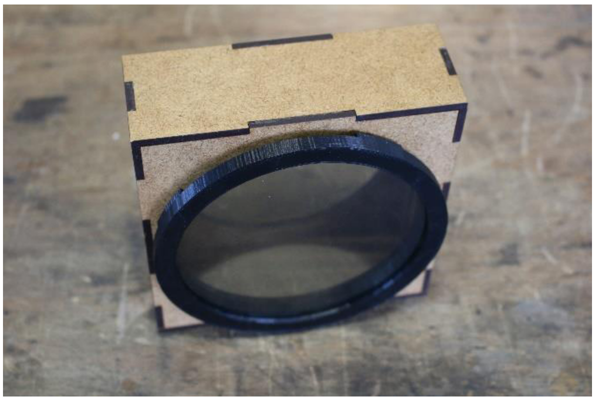


Take the polariser sheet and cut a round circle (diameter 10 cm). It is helpful if you put the 3D part on the 10x10 cm polariser sheet. Use a permanent pencil so you can draw on the sheet. Draw a line on the outer edge of the lid. Next, draw an inner circle with a diameter that is approximately 3 mm smaller. If you cut the edges of the rectangle you should try if it fits properly in the lid. Try – draw – cut and do the same again and again until it's perfect. As polariser sheets are rather expensive, be careful not to waste too much material.



Now, it is time to glue the attachment part on the wooden box. Clamp the polariser circles in the lid and click-in to the attachment.



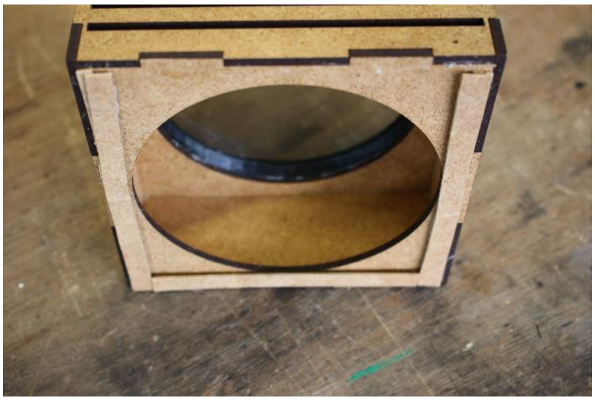
Step 7: Cutting the frames

Now we will use the laser cutter to make frames to hold the other polariser sheet and the pictures we will design. We provide the file Polarisation_Art_Frames.pdf for the cutting patterns. Take a thinner plywood sheet (thickness 1 mm) and put it into the laser cutting machine. For a 40 W CO2 laser you may use the following parameters:

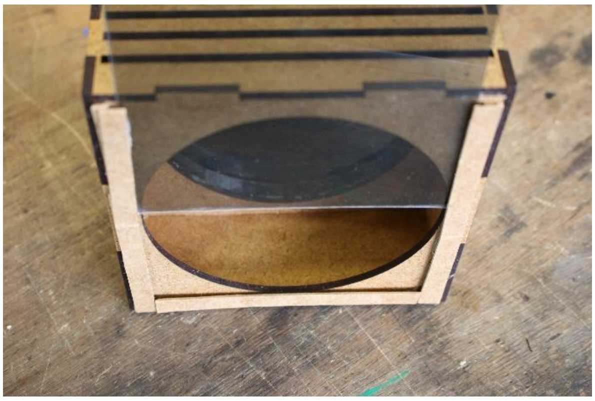
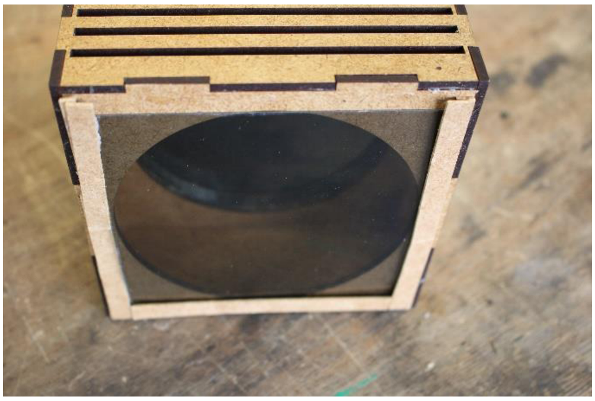
- •Speed: 90%
- •Power: 45%
- •Pulse frequency: 500 Hz

You get two frames: One that is rather broad and one that is thinner. First, glue the thinner of the two frames onto the backside of the box using wood glue:


Next, glue the remaining frame on top of the thin frame like this:




Now, insert the polariser sheet:

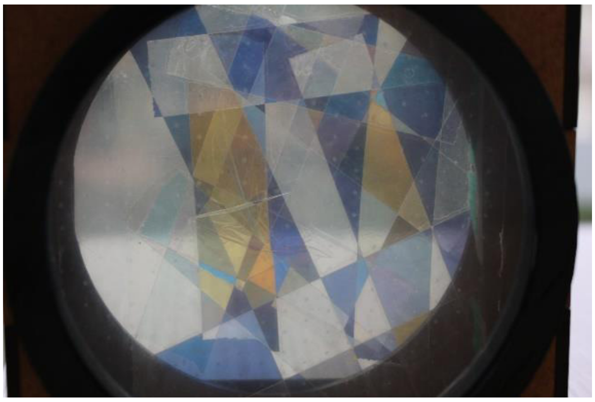
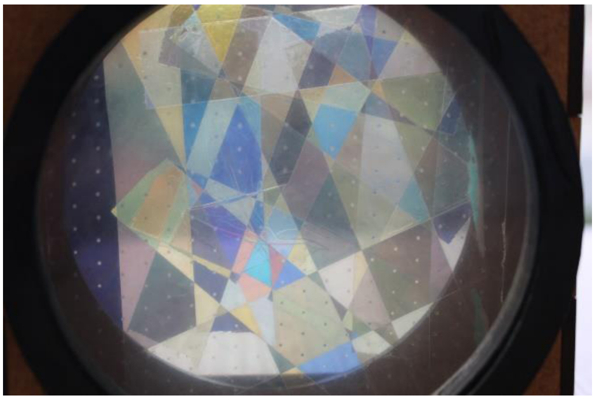
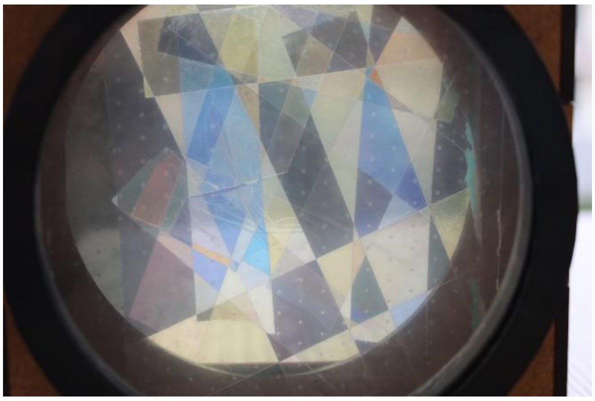
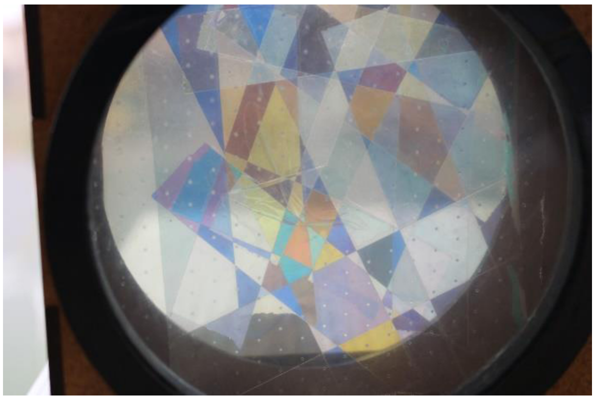
You also got two frames to hold the pictures you are going to design. Take an overhead projector transparency sheet and cut two squares of 10cm x 10cm. Glue the squares onto their corresponding frames. They should easily fit into the slits on the top side of the wooden box.

Step 8:Creating an image with adhesive tape

Now it's time to use your creativity! Take one of the two frames with the OHP transparency sheet. Take adhesive tape and stick it onto the sheet. Don't be afraid to make anything wrong. The untidier your pattern is the more interesting the resulting image will look.
You can pile several layers of tape on top of each other to render different colours:

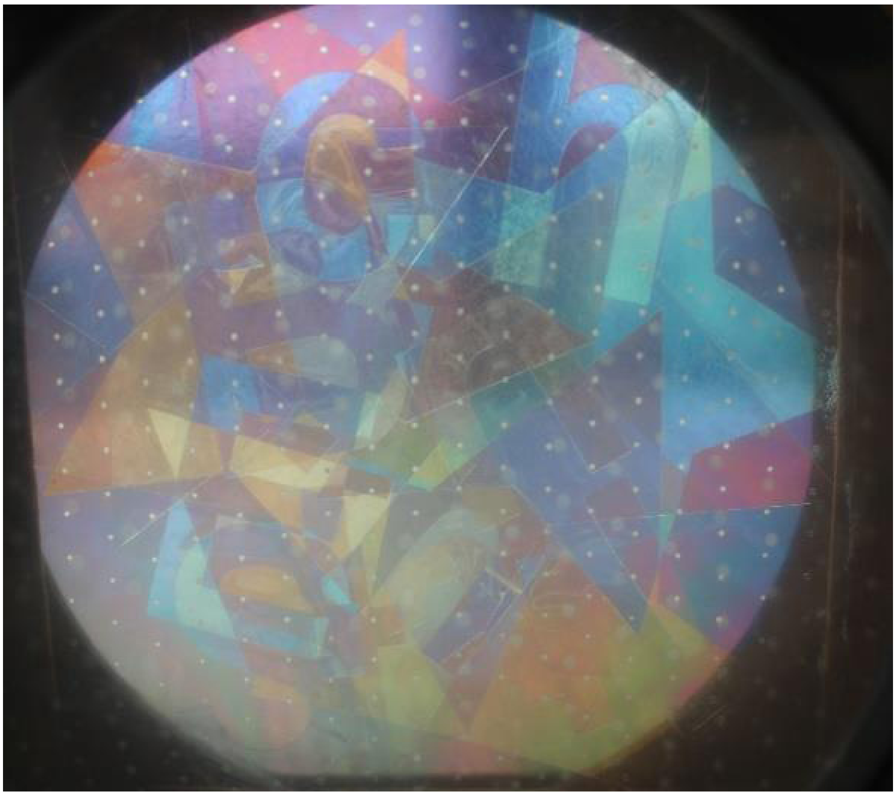
Number of layers	Colours
1	Dark blue, transparant
2	blue, yellow
3	turquoise, rose
4	green, violet
5, 6, 7, 8, 9 ...	green, violet stays - no other colour appears

Put your image into the box and explore the colour effects that are generated by the phenomenon of polarisation. Rotate the polariser to see how the colours change:

Step 9: Writing an individual phrase

Use a PC and start a vector graphics editor (like, for example, Inkscape). Write a short sentence – we used Arial bold and a font size of 72. It is advisable not to write more than 15 letters as things might get to messy otherwise. Keep in mind that the sentence should fit into a circle of 10 cm diameter. If you are ready to plot – put the OVP transparency sheet into a plotter and plot your sentence. Once done, arrange the letters on your second image sheet and fix them using adhesive tape. Using adhesive ape will add additional layers, so your piece of art will become even more colourful – and your phrase will be harder to decipher.



Step 10: Let others decipher your phrase

Put the image from the last step into the box through one of the three slits. Hand it over to someone else (who hasn't seen your phrase inside the vector graphics program) and let her or him decipher it for you.

Step : End result & conclusions

What we learned?

The participants
•learn about the wave nature of light, especially about the phenomenon of polarisation
•get into contact with the modern field of laser material processing
•use their manual skills by assembling the different parts for the polarisation box
•use their creativitity by designing an image for the cellophane sheet
•learn how to use a laser cutter

Concluding thoughts

•Which other patterns would you like to make with the technique presented here?
•Which exact role does the adhesive tape or the OHP transparency sheet play?
•We used cellophane (a material found in adhesive tape and OHP transparency sheets) to generate the desired. Could we have used any other transparent film?
•Why do we see different colours?

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

This workshop was set up by the *Institute of Photonics Sciences, ICFO* in close collaboration with *Fablab Barcelona and Tinkerers Lab.*

PHOTONICS PUBLIC PRIVATE PARTNERSHIP