<u>LASER KALEIDOSCOPE</u>

Title of the workshop: LASER KALEIDOSCOPE
Target audience: students (15-18 years old)
Time planning: Total *2h*
Estimated cost: < 32€

<u>**Step 1. Diffraction, Interference and Kaleidoscopes**</u>

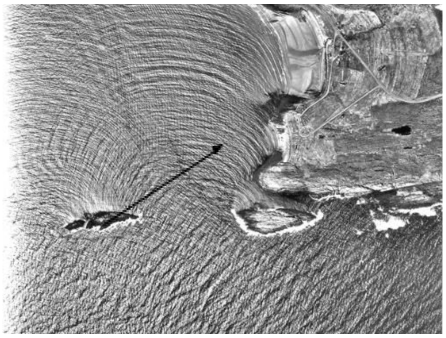
Picture A. Every day beauty

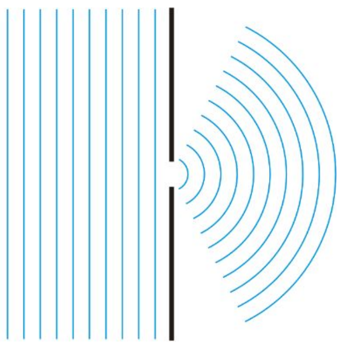
Have you ever wondered why soap bubble shine in various colors? Why oil on the road has all the colors even though oil itself is colorless? Or why butterflies have all these beautiful shining colors that changes when you look at butterfly at different angle? Well, now you can find out.

Picture B. Light as wave

First of all you have to know that white light consist of main seven colors: red, orange, yellow, green, blue, indigo and violet. We can beak light by using triangular prism (see Picture B) – since every color is a different length electromagnetics wave it breaks in different angles and that's why we can distinguish colors.

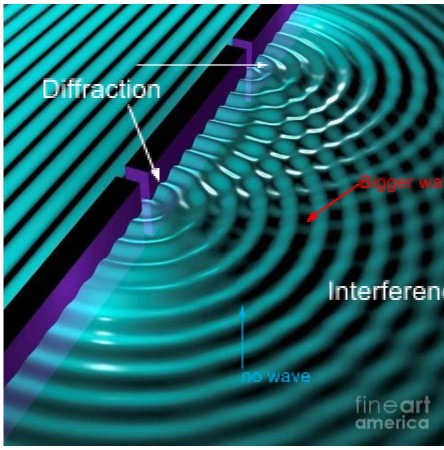
So if we want to found out why soap bubbles are changing colors, we have to find out some properties of waves. Since every wave (light, sound, or simple at sea and etc.) behaves the same, in order to be clearer, let see how waves behave at sea.



Picture C. Diffraction in sea – obstacle. *Picture D. Diffraction in sea – opening.* *Picture E. Diffraction scheme.*

Diffraction is a process that takes place when any wave on its way meets any obstacle. For example, in Picture C you can see a diffraction process that occurs in sea – even though there is an obstacle (rocs) in the sea but waves manages to reach the shore. This happens because waves can bend around obstacles. This can occur when the wave encounters a small object in its path (like in Picture C). The same thing happens when the wave is forced through a small opening (see in Picture D, Picture E).

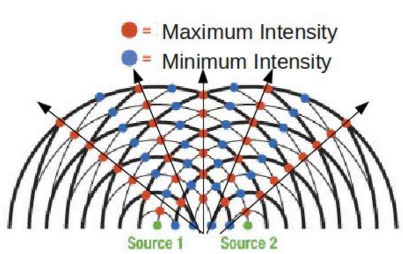


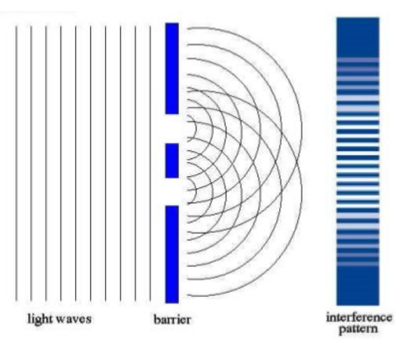
Picture F. Example of wave interference.

How from two waves greater amplitude wave forms

How from two waves no wave forms

When we have several small openings near each other, we can notice **interference**. Interference happens when one wave comes into contact with another wave and they interact. Interference is a phenomenon in which two waves superpose to form a resultant wave of greater (constructive interference), lower (destructive interference), or the same amplitude. Interference usually refers to the interaction of waves that are correlated or coherent with each other, either because they come from the same source or because they have the same or nearly the same frequency (see Picture F, Picture G).





Picture G. Intensities of interference. *Picture H. Scheme of interference.*

If in interface area we put a screen we would see so called interference pattern (see Picture H). Where intensity of wave is maximum, the line will appear on screen. The same thing can happen with light.

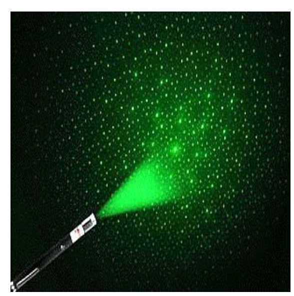
Picture I. Interference in soap bubble.

So how about the soap bubble – you ask? The colors seen in a soap bubble arise from interference of light reflecting off the front and back surfaces of the thin soap film. Reflected light is coherent so the interference phenomenon occurs. Depending on the thickness of the film, different colors interfere constructively and destructively in different places. That's way we see all these different colors by viewing in different angles. The same explanation can by applied for oil spill and etc.

Knowing that light can diffract, interfere and interact we can make more beautiful thing by ourselves. One of them is kaleidoscope (see Picture J). A kaleidoscope works by reflecting light that bumps into a reflective surface such as a mirror. It has two or more mirrors placed at an angle to each other. The reflectors (or mirrors) are usually enclosed in a tube, often containing on one end a cell with loose, colored pieces of glass or other transparent (and/or opaque) materials to be reflected into the viewed pattern. Rotation of the cell causes motion of the materials, resulting in an ever-changing viewed pattern.

Picture J. Toy kaleidoscope.

Picture K. kaleidoscope view.



Picture L. Laser kaleidoscope.

During this workshop you will find out more about laser kaleidoscopes.

Step 2: Part list

Photonics parts:

- Green, red and blue laser pointer
- Two diffraction gratings
- Three mirrors

Electronic parts:

- Two wires (blue and red)
- Li-ion cell
- Charger
- Arduino Micro
- Motor driver
- Motor with reductor
- On/off switch
- Potenciometer
- Button

Other parts:

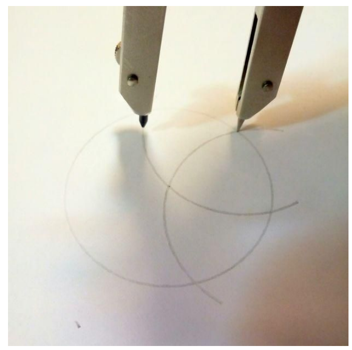
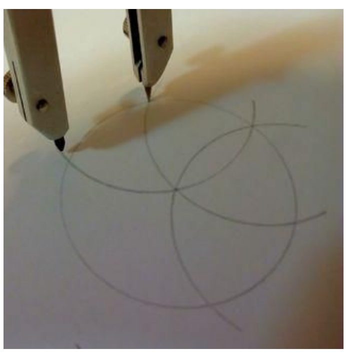
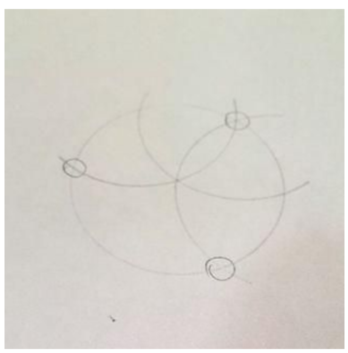
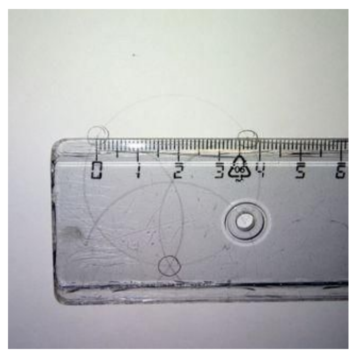
- Screws
- Isolation tape
- Glue

The photonics parts can be bought by EYESTvzw.
The electronic parts can be bought by Fablabfactory.

Step 3 Making and assembling a kaleidoscope

Kaleidoscopes are usually made from elongated pieces of glass. The simplest kaleidoscope contains only two pieces of glass, where the angle between two pieces is either 18^0 or 20^0 degrees. However those are high to align without additional casing and holders. Therefore we try here a three-mirror equilateral triangle type kaleidoscope first. It yields an infinite pattern that fills the entire visual field and is easier to implement.
We start with three equally shaped mirrors. Take an isolation tape and form a triangular tube. In order to make everything easier, you can either draw a triangle on a piece of paper or use it to align mirrors or you can make a tube for an easier alignment. Keep in mind that the radius of a circle (or of a tube) is the width of the mirror multiplied by squared root of 3 (circa 1,7). In our case we have used a frame made from cardboard

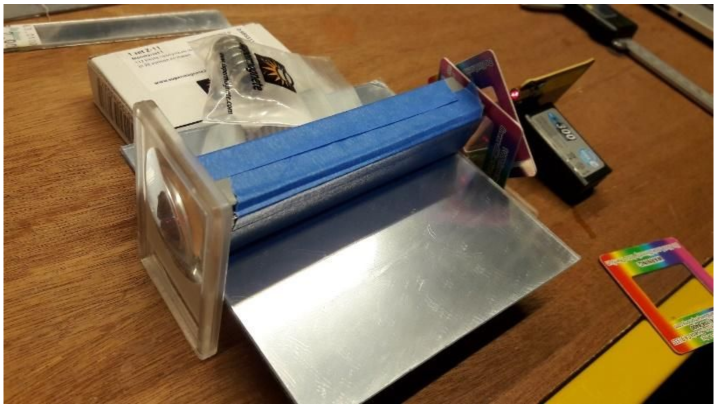


Now, use a triangular frame made from a cardboard to assemble a kaleidoscope from mirrors. Carefully place two mirrors on top of the cardboard frame. Use a tape to secure them. Carefully

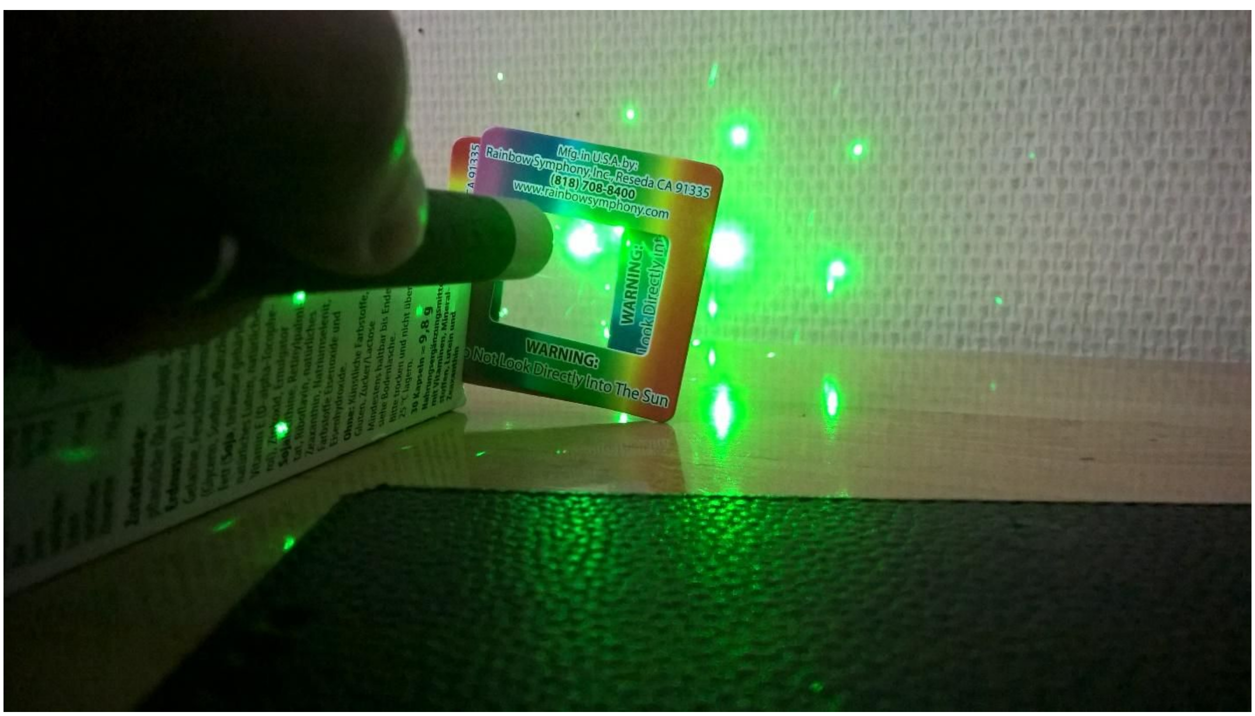
rotate the cardboard frame and mirrors. Place the third mirror on top of the cardboard. Use some tape to secure everything. Now remove the cardboard frame from the inside of the kaleidoscope.
Alternative you can make from cardboard a housing for mirrors and assemble everything inside the that frame.


EXTENSION
An alternative way to produce a kaleidoscope is to make it from four mirror pieces.



Step 4 – Lighting up lasers and diffraction gratings

Now it is time to play around with lasers and diffraction gratings. Light up a laser or laserpointer, and shine it onto a single diffraction grating. You will instantly see a line of equidistanced laser spots behind the grating.
Now, take a second one and rotate it by 90 degrees. Combine two diffraction gratings together. Shine with a laser onto it. You will notice now that there is squared mesh of laser spots behind two gratings. Now try to rotate one grating while shining onto gratings with laser.
Now, keep the second grating rotated by 30 degrees in comparison to the first on. Take now the third grating and counter-rotate it in comparison to the first one also by 30 degrees. Put gratings in a holder (or clothespin). Shine with laser on the gratings. You will instantly note, that there is a hexagonal structure of hotspots behind three gratings.
To get better idea what grating does to differently colored laser beams, take second laser with different color and shine it onto the gratings while the first is laser is still on.
Now we got basic idea, what happens when we change number of gratings, change their angles and change colours of laser beams.



Video
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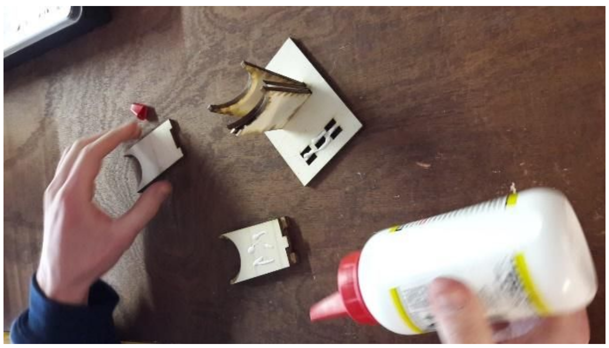
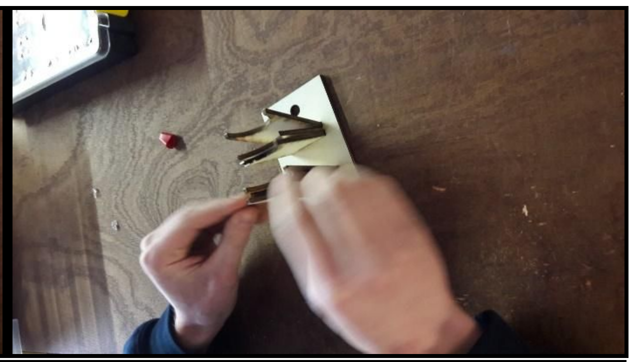
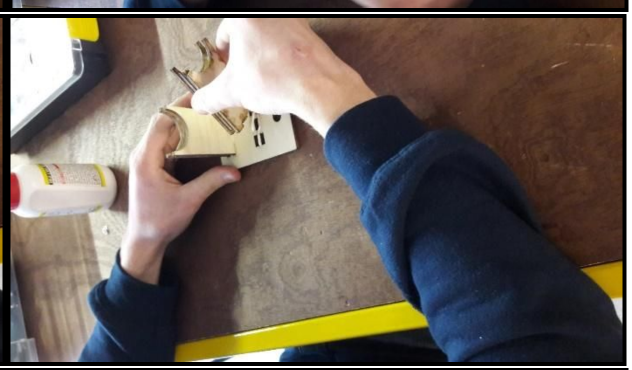
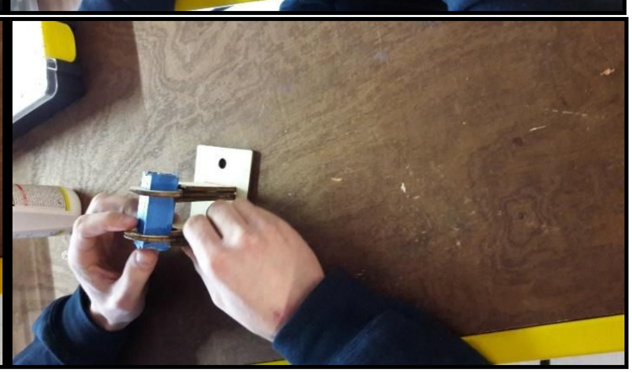
Step 5 – Holders and case

Now it is time to make an encasing and holders for our kaleidoscope. Use a laser cutter and cutter from plywood all parts.
First of all check whether parts fit the holes in the base plate. After doing so, put glue on individual parts and onto the base plate. Assemble holders together.
Now put the kaleidoscope into the casing you made with laser cutter. Check whether the casing fits into holders.



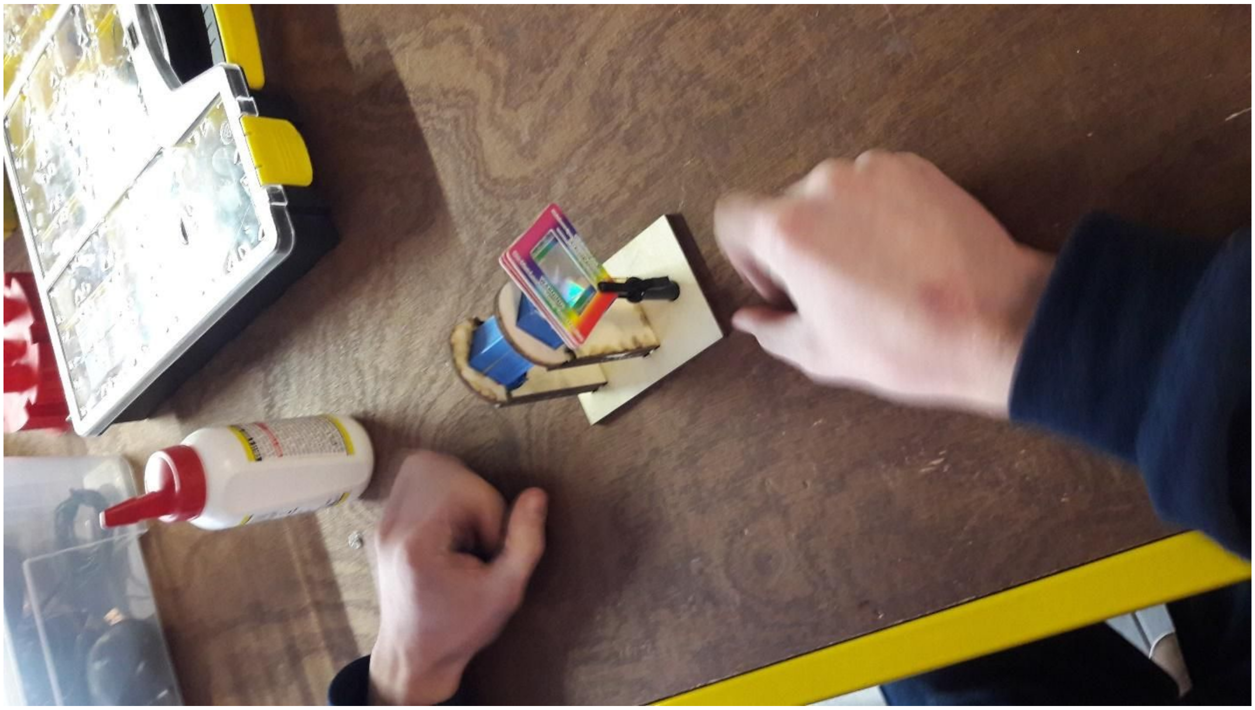



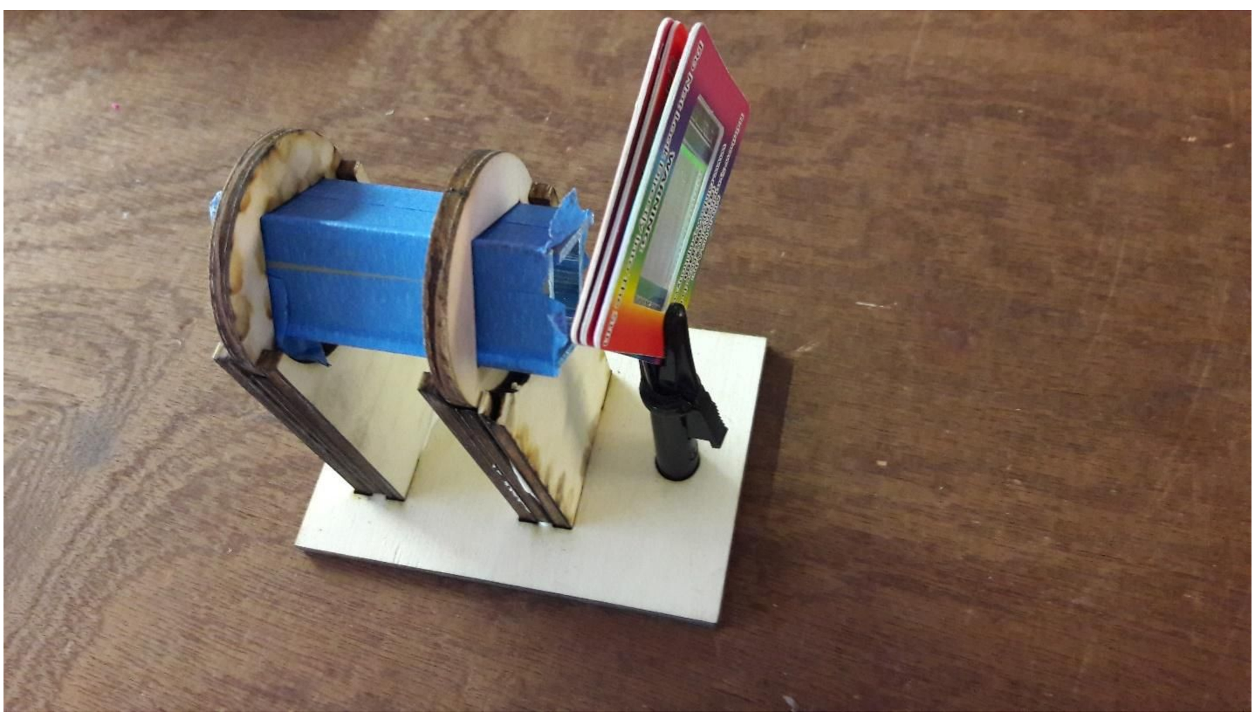




Last step: Observing laser kaleidoscope

Now it’s time to play around with the kaleidoscope. Place diffraction gratings before the kaleidoscope. Direct the laser beam onto the grating and observe what happens after beams exit the kaleidoscope.





What we learned?

• Day light consist of main seven colors: red, orange, yellow, green, blue, indigo and violet. Every color is a different length electromagnetic wave.
• Diffraction refers to various phenomena that occur when a wave encounters an obstacle or a slit. It is defined as the bending of light around the corners of an obstacle or aperture.
• Interference is a phenomenon in which two waves superpose to form a resultant wave of greater, lower, or the same amplitude. Interference usually refers to the interaction of waves that are correlated or coherent with each other, either because they come from the same source or because they have the same or nearly the same frequency. Interference effects can be observed with all types of waves, for example, light, radio, acoustic, surface water waves or matter waves.
• Kaleidoscope - an optical instrument with two or more reflecting surfaces inclined to each other in an angle, so that one or more (parts of) objects on one end of the mirrors are seen as a regular symmetrical pattern when viewed from the other end, due to repeated reflection.
• Diffraction grating can make light interfere.

Concluding thoughts

Photonics is an amazing science which lets us find out more about light generation, detection and manipulation. Some of the most beautiful and (some say) magical things in nature can be explained by this science. Today you have learned that light can diffract and interfere. It happens in our daily life everyday (remember soap bobble example) but, also, you can use these light properties for making amazing experiments – like creating your own laser kaleidoscope. This experiment not only lets you to know more about light but also you can create amazing patterns and amaze your friends and family. Just remember – be cautious – do not aim the laser beam at eyes!

The following part will always conclude a workshop of PHABLABS 4.0. Please add the names of your institution and that of your pilot fab lab and the logo's.

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.

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This workshop was set up by the Center for Physical sciences and technology (Sergejus.Orlovas@ftmc.lt)

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