PHOTONICS WORKSHOP

LIGHT BRUSH

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PROPERTIES OF THIS WORKSHOP

SUMMARY:

Light sheets are the core of many scanning and microscopic devices, but in this case, the light sheet that the students will create will be used for artistic purposes, more specifically light painting

TARGET AUDIENCE:

Students (15-18 years old)

SUGGESTED TIME PLANNING: (Total: 3h)

Timing in minutes	**Activity**

TOOLS:

ESTIMATED COST:

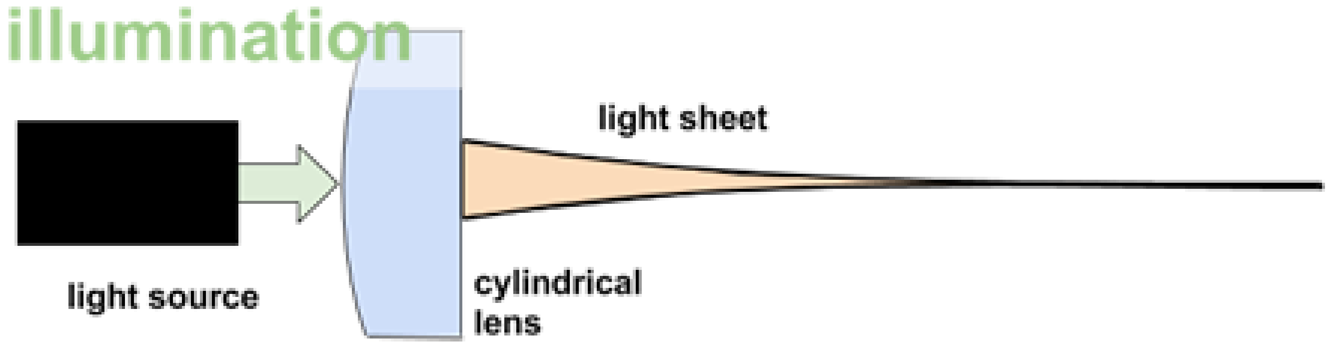
€ 30

Step 1: The main photonics principle in the light brush is the creation of a light sheet.

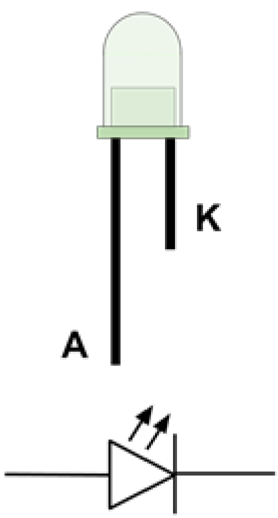
Light sheets have multiple uses, especially in the field of scanners and microscopes.

Light sheet
Light sheets are, as its name suggests, simply a way to call a small thin, light layer.
Participants will learn 2 main topics:
1) **Photonics**: use, types and printing of lenses and what a LED is
2) **Core tools in a makerspace**: 3D printing and milling machines

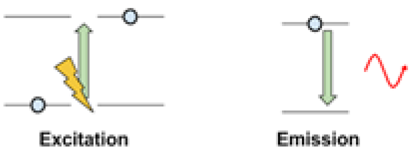
Setup
The main properties of a light sheet could be summarised to be the **thickness**, the **uniformity** and the **ability to penetrate the scattering tissue.** Therefore, we can use any setup that fulfils those requirements to try to make the illumination. For instance, a basic one would be that shown in the figure, which was proposed by Huisken et al: a laser beam falls over a cylindrical lens that concentrates it.
As it can be seen in the drawing below, if one wants to observe a certain sample, it should be left in the focus point of the lens, that is where the light sheet is going to be the thinnest possible and, therefore, where it will fulfil the best the properties detailed above.



That basic setup is enough to get a light sheet and, as it will be explained later on, is the one we will use. Anyway, there are a few other techniques that could also have been used such as taking advantage of the Gaussian laser beams (the most common output of a laser or, at least, the most commonly desired).



Light source: the LEDs
In the experience, we are going to use an array of LEDs.
LEDs –light emitting diodes- as their name indicates, are semiconductor diodes.
You can simplify the typical role of a diode in a circuit as a switch. Therefore, the role of a LED is more or less the same. If the voltage is higher in the anode lead than in the cathode, they act as a resistor: there is a voltage drop in them (usually around 0.7V) that is used to excite electrons so that when they get back to their ground level a photon is emitted.



In the other hand, if the voltage is higher in cathode than in the anode, it is as if there was nothing to close the circuit: it acts if we had an opened switch.

(Choose one of the activities bellow.)
Activity 1: Ohm's law

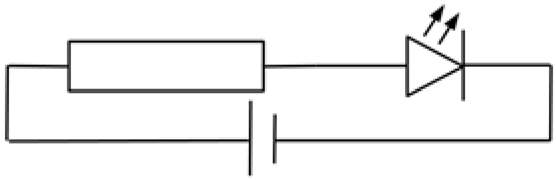
Ohm's law, as you may already know, states that

$$V=R\cdot I$$

, where V is the voltage, R the resistance and I the intensity.

Try to design a circuit with one or more resistors (represented as a rectangular block in the figure below), a LED and a 5V voltage source (represented as two parallel lines in the circuit, one shorter than the other).

Take into account that most LEDs need an intensity about $I\approx 20mA$ to work and the voltage drop in the LED is about $V_{LED}=0.7V$ in order to do the calculations.



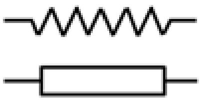
Tell the instructor what resistor have you chosen before trying the circuit and show it to him.

a. Does the LED turn ON?
b. Try to change the anode and the cathode of the LED. What does it happen?
c. Take a resistor a little bigger and a little smaller than the one you got before and

repeat the experience. What does it happen now?

! Note that resistors are usually designed to be able to dissipate up to $W_{max}=0.25W$ where W stands for the power: $W=V\cdot I$. If the intensity is wrongly computed, W_{max} could be exceeded and the resistor could burn.

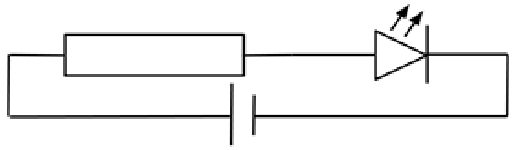
! Note that resistors symbols are different if different parts of the world. You may be more familiar to either the first or the second of those two:



Solution: Let's focus on the resistor: $V = 5-0.7 = R\cdot I = 20mA\cdot R \Rightarrow R = 215\ \Omega$ (a)$\pm 50\Omega$ (c).

Activity 2: Get familiar with LEDs

Take a 200Ω resistor (the rectangular block in the figure below), a 5V voltage source (represented as two parallel lines in the circuit, one shorter than the other) and a LED and build up the circuit drawn in the figure bellow, connecting each of the elements using wires:



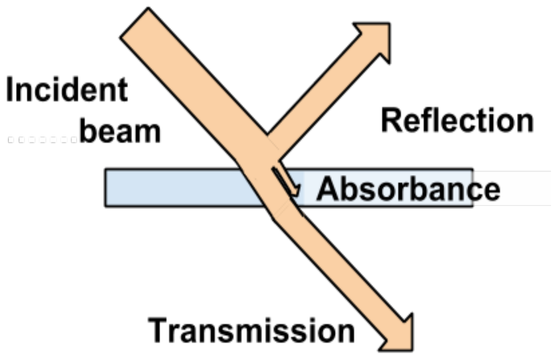
Tell the instructor what resistor have you chosen before trying the circuit and show it to him.

a. Does the LED turn ON?
b. Try to change the anode and the cathode of the LED. What does it happen?
c. Take one 250Ω and a 150Ω resistor and repeat the experience. What does it happen now?

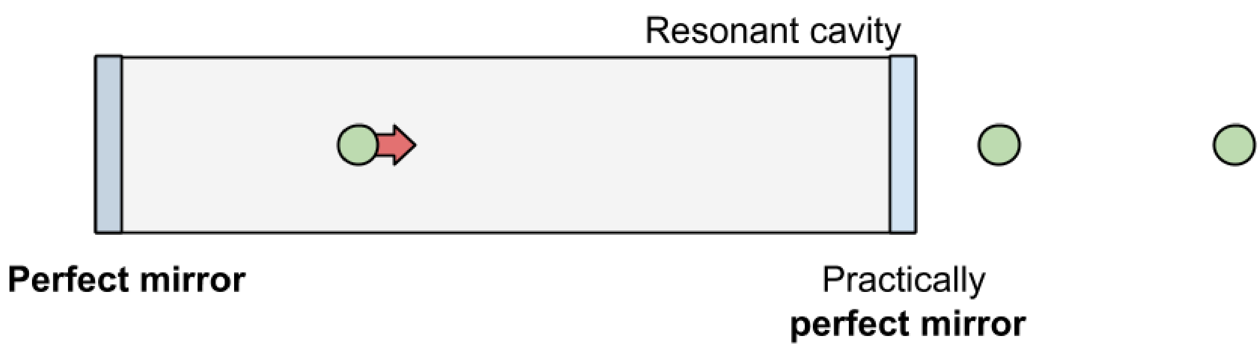
In our setup we will use an array of LEDs' light that will be concentrated through the lens.

A laser beam

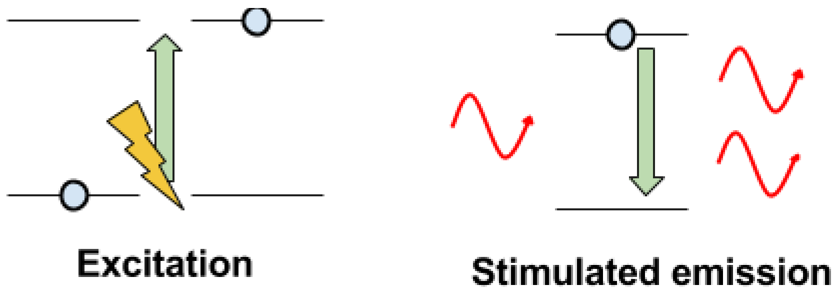
When an incident beam reaches an object, part of it is reflected and, therefore, gets back to the medium it came from; and part of it gets transmitted or absorbed.
That object could be, for instance, a mirror. We consider a mirror is "perfect" if there is neither transmission nor absorbance. Therefore, a photon reaching a perfect mirror will be completely reflected while in case it is practically perfect there will be a possibility that it gets transmitted.



The resonant cavity of a laser such as the one that can be seen in the figure consists just of two mirrors: one perfect and the other one practically so. Between the mirrors, inside the resonant cavity, there is what is called to be a gain medium.



The gain medium consists of a series of atoms that have been excited using either a light source or an electrical field. In other words, thanks to the use of either the electric power or another source or energy, the atoms have got electrons that are not any longer in their ground level: the energy has been used to make them increase one of them.
In that way, when a photon reaches one of that atoms, there exists the possibility that the electron that was excited falls into its ground level again and photon gets emitted[1] . This phenomenon is what is called **stimulated emission**.

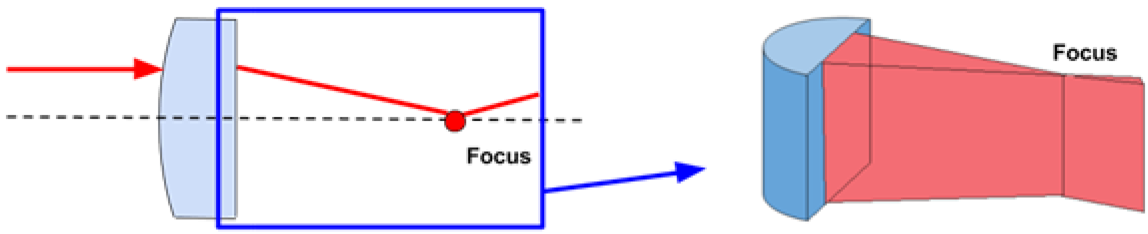


It is well-known that through stimulated emission the photons released have the same wavelength than the ones that reach the atom. Therefore, in that way, we get:

- •A number of emitted photons that each time increases faster and faster (if there are more photons, more atoms can get reached).
- •Photons that have the same wavelength than the first one emitted (that is a property we call coherence. Lasers are really coherent while LEDs are not so at all.)

A cylindrical lens

The cylindrical lenses are well-known for concentrating light towards a focus line, as it can be seen in the diagram below. The basic idea is the same we would get for the spherical lenses but, instead of a point, their focus is a line.



Applications

This kind of light sheets can be used for scanning. Therefore, they are the key part, for instance, of light sheet microscopy –a method to obtain 3D images of objects– or bar-code readers that are usually found in the supermarket cashiers[2].

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[1] Following the energy conservation theorem, if the energy of the atom decreases because the electron loses his excited level, the difference in the energy quantity has to be released somehow. It is well known it is done through to a photon. The wavelength of the photon, and therefore, of the laser, will depend of that energy as the Planck-Einstein relation states: $E=h\cdot c\lambda$.

[2] The setup in the cashiers is a bit different as they do not use the cylinder concentrator but a Bessel beam. Anyway, the idea is the same

Activity of Light Painting to use the light brush built during the workshop:

Light Painting is an activity that can be performed in different places; all what is needed is:

- •a webcam and a computer and software program, a camera for long exposure photography, or a smartphone that uses an app to convert it into photo camera for long exposure
- •darkness and
- •at least a light source (e.g. the light brush)
- •Anything that makes or modifies light (e.g. cellophane paper to turn white light into color light, diffraction slides,...)

With these items it's possible to write, paint or draw with light and to have pictures with the results.

To use the webcam and the computer, or the smartphone, there are several apps that allow for real time light painting (you can see in the screen, real time, what you are drawing), being an example: http://lightpaintlive.com/.

And there are several apps for mobile (to convert the mobiles into long exposure cameras) such as "Dr. Light" https://play.google.com/store/apps/details?id=anzalichi.light.

When using a photo camera, you can start by using the following setting (and modified them to accomplish different effects or to adapt to the darkness of the room):

· Photo camera for long exposure:
- Film speed/ sensitivity: ISO 1000
- Aperture: f/5.6
- Select manual focus (MF)

Important note: Before starting the activity it is very important to explain that in case you are using lasers as light source, lasers should not point directly into the eyes. For the same reason, it is very important to be careful while using mirrors and other tools while combined with lasers.
If you paint with lasers you should paint facing the wall, never towards the camera or people.
Other less intensive light sources, can directly point to the camera.

Step 2: Parts list

Collect all materials for each participant.

Photonics Parts:


LED SMD Red
200 pieces

Additional components:

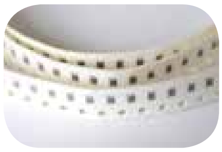
9V battery
20 pieces

Electronic Parts:

PCB FR-4 Single Sided
20 pieces


Battery snap
20 pieces


Toggle switch
20 pieces

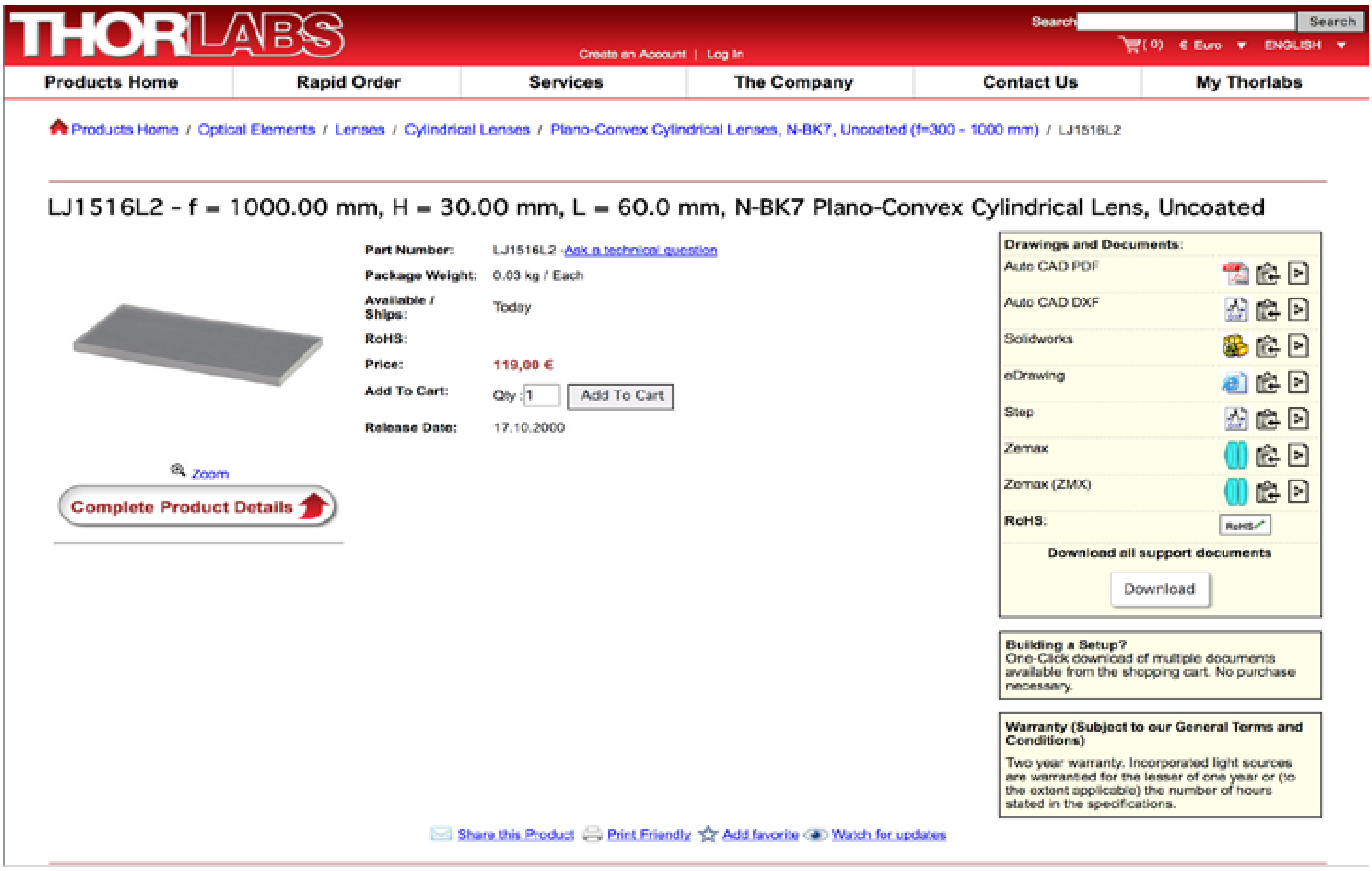
Resitor (311-1.00KRFCT-ND)
20 pieces

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

Download all the software, parts and find information here. An index list of suppliers and components:
-Thor Labs
-Form Labs 2
-Preform
-Onshape
-Rep Rap BCN
-Cura
-Fab Modules
-Roland MonoFab SRM - 20
-V panel
-Weller WES51

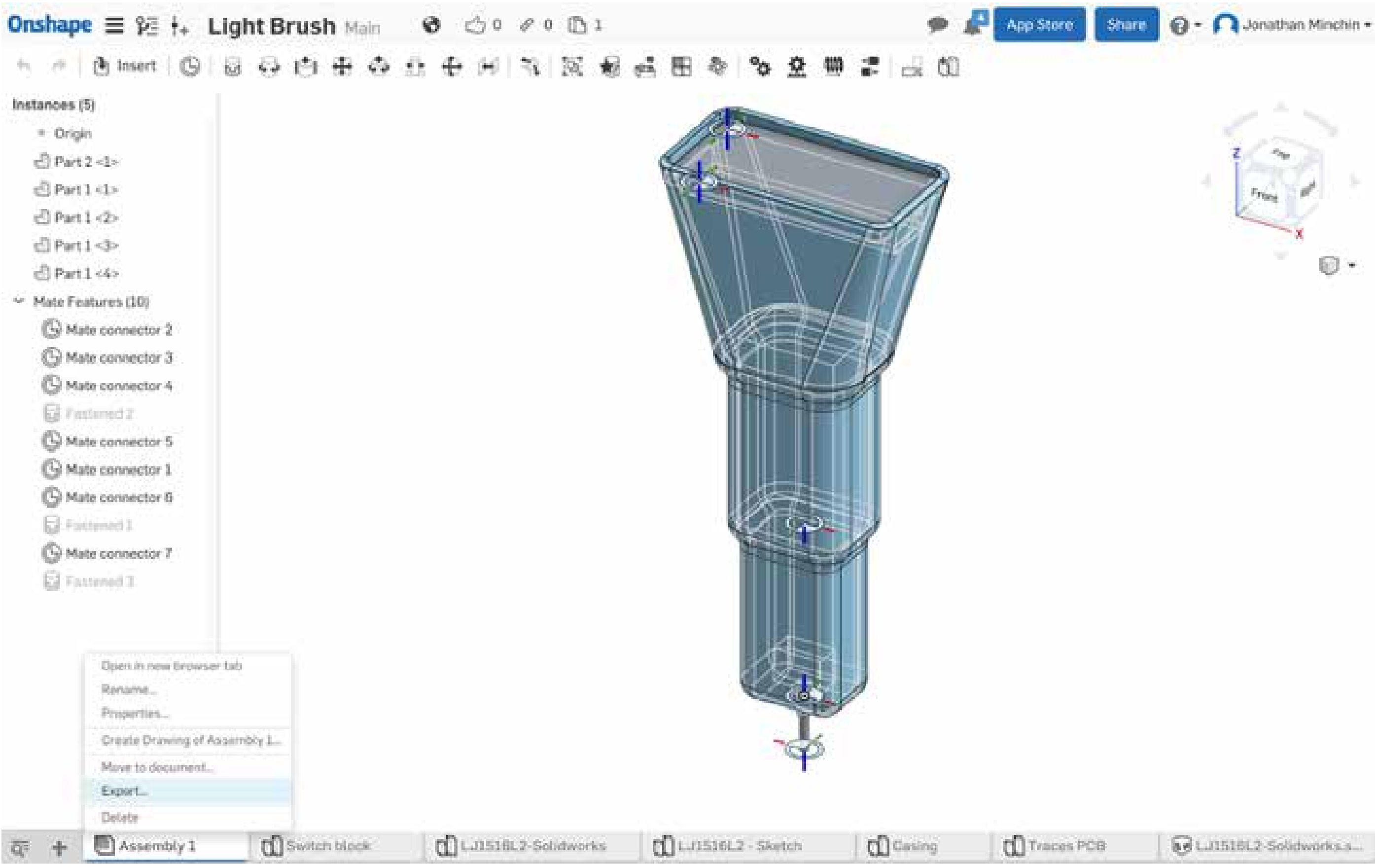
STEP 3: DOWNLOAD THE LENS

The lense of the light sheet is the main active component. We are using a Form Labs 2 resin based printer to do the prints with clear resin but first we need a file.to print. Luckily the Thor Labs website offers lenses in a variety of downloadable 3d formats for free. For the Light torch we will be using a convex lense with the number LJ1516L2. You can search the website for preview to find the downloads pages.



You will find lots of different 3D file types for the lense which you download, these load into 'CAD software' but are not yet ready for a 3D printer 'CAM software'. We have used some free software to help convert those files into a format ready for a 3D printer. Onshape is a platform that lets you design and share things in the browser online. We have already uploaded the lense to the model page here: Onshape - Light Brush.

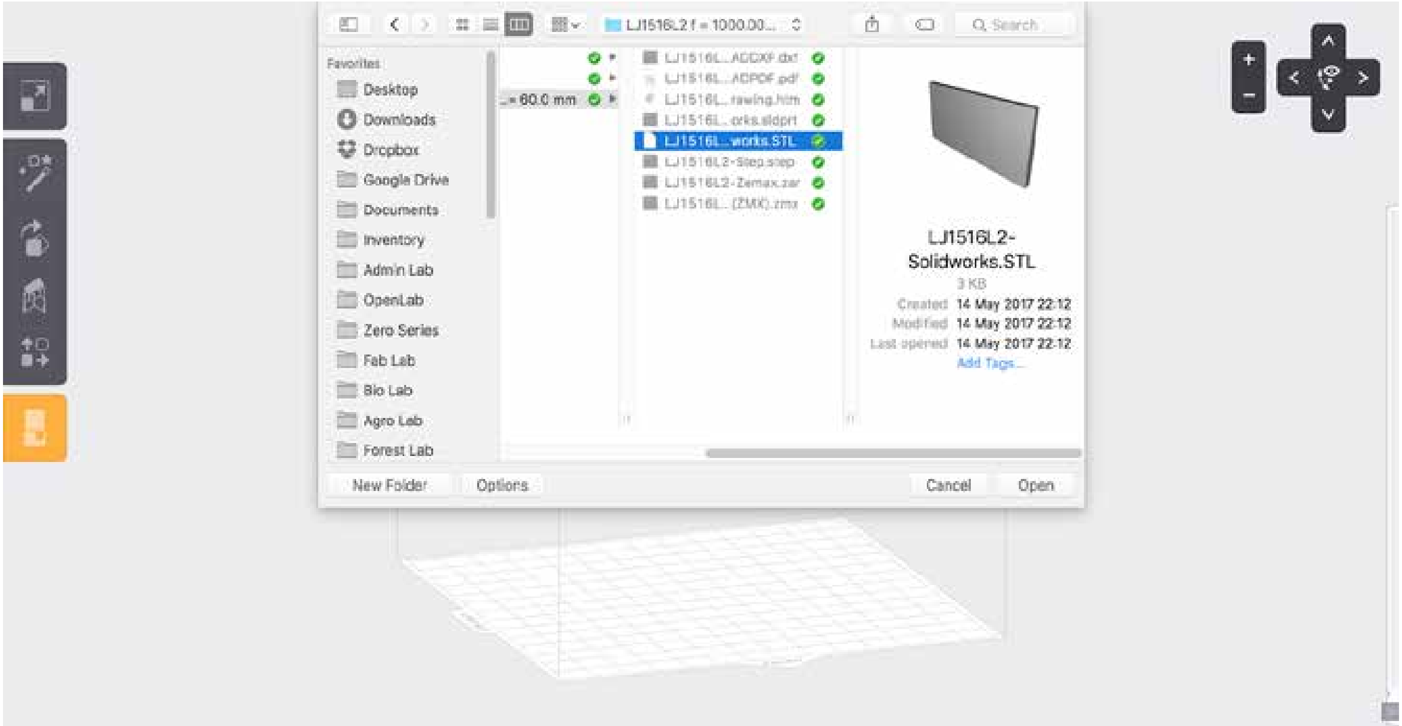
You can right click on any component in the model to export it. You will need an STL (Stereolithography) file to load into the CAM software.



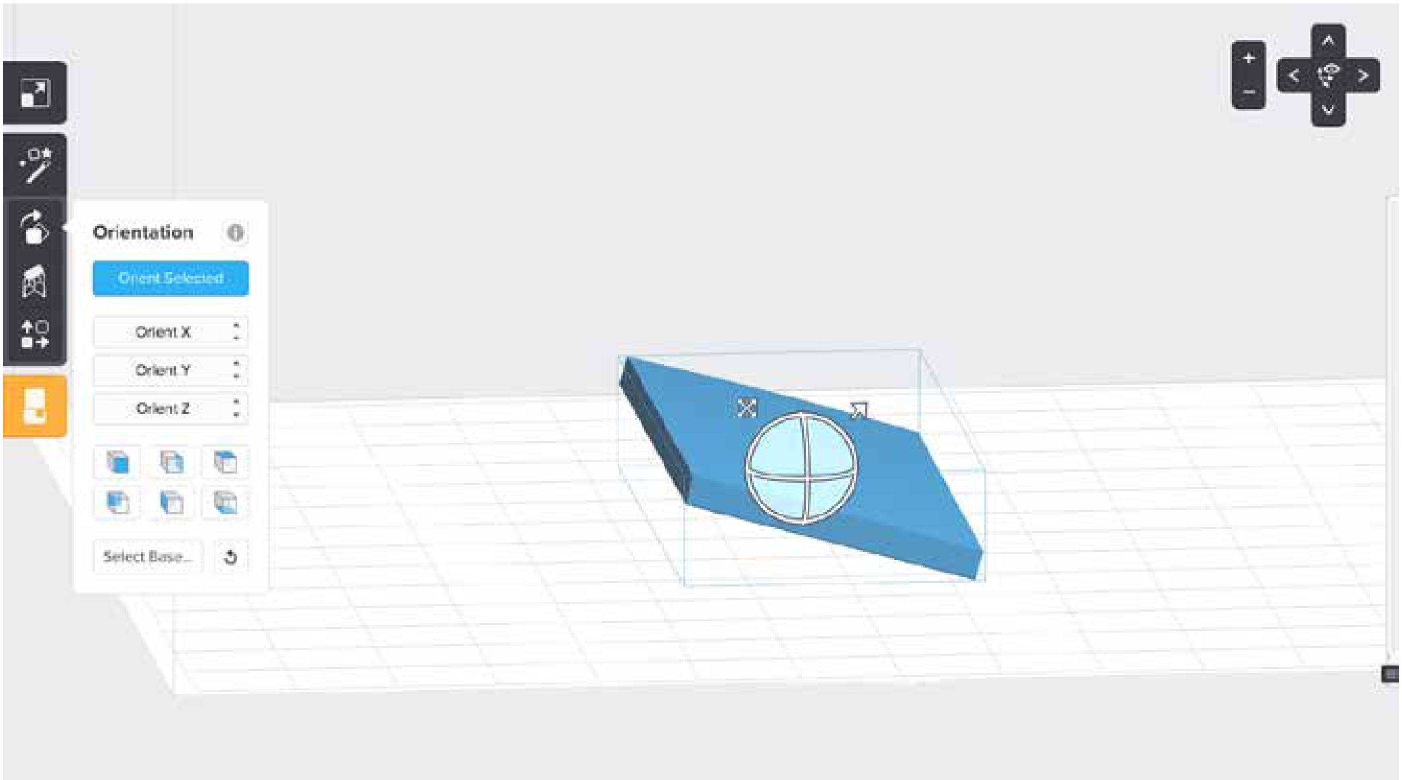
STEP 4: PREPARE THE STL PRINT FILE

Next is to setup the 3d model of the lense in the 'slicer' software for the form labs printer. The software is called '[Preform]' and works by slicing a model into layers that the printer can use to recreate the digital model in resin step by step. Preform is free and works on most operating systems.

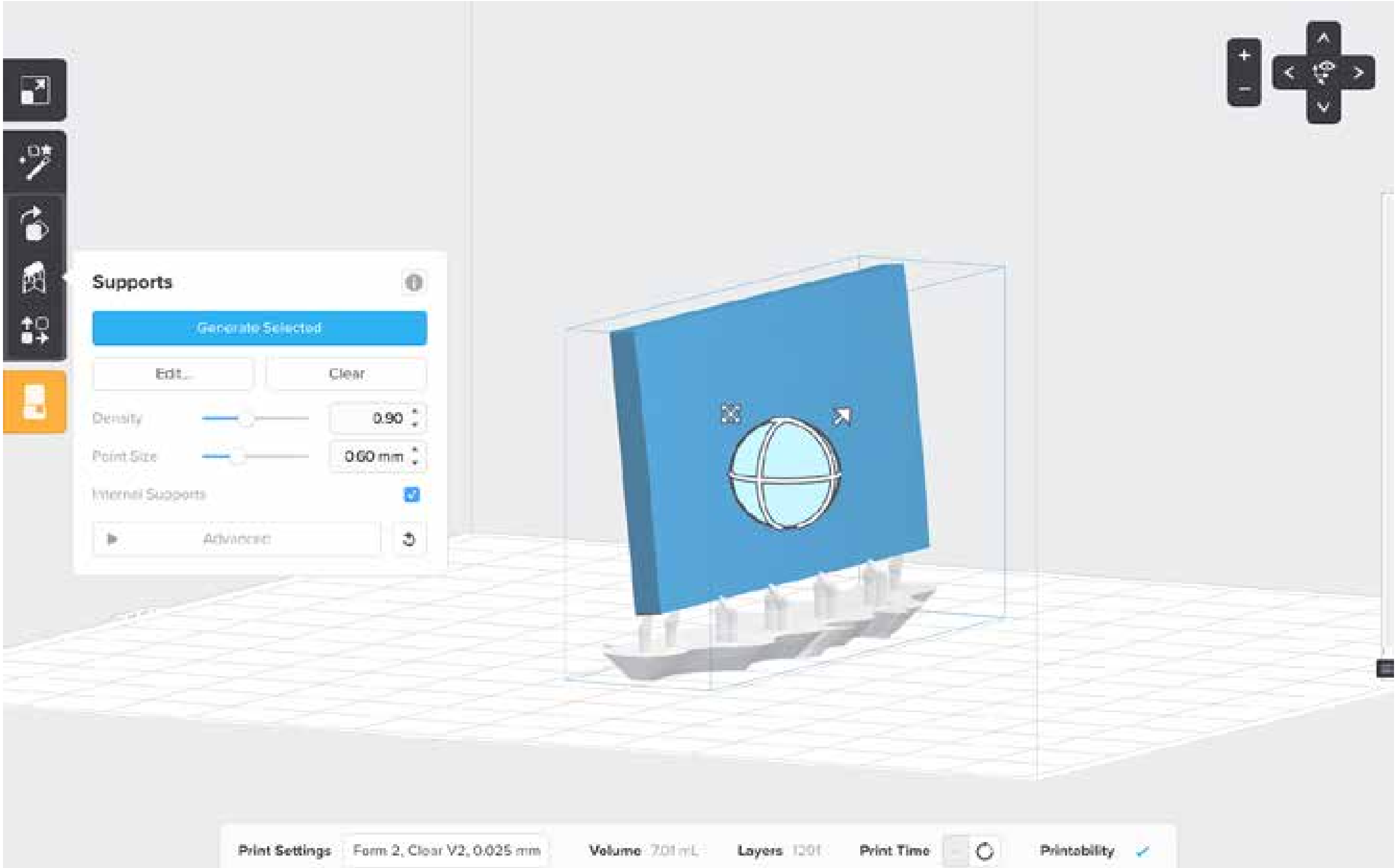
After Installing Preform and connecting your computer to the printer we must load in the model and design a build platform to hold the object whilst it is being printed.



Once the model is loaded into the software you have varied options for adjust its orientation and prepare it to print with supports. Use the rotate, move and magic prepare buttons to help you.



Each object is different so this process is both art and a science. We have tried to build as much support for the lense as possible, but avoiding support points touching the faces of the lense. Also positioning the lenses longest side parallel to the build platform will reduce the number of layers needed to print and will speed up the print.



STEP 5: PRINTING THE LENS

The Form Labs 2 printer is a [STL (Stereolithography)] Resin based printer that works by projecting a laser onto a photoreactive layer of resin. The Resin solidifies on contact with laser, the model can then be built up in steps of layers. All of the instructions for setting up the printer and connecting it to your computer are found in the [online instructions.]

TIP: *The Form Labs 2 printer is extremely simple to use and setup. But once you have installed everything and ready to receive the print make sure that you have left the cap of the resin open, remember also to close it after the print is finished. The print will take some hours, this is obviously faster than the months Galileo spent cutting and polishing glass to achieve a similar effect.*

Once the print has finished you should extract it from the build plate in the cleanest and safest way, there are very thorough instructions on the Formlabs website. You will need to dip the print in [isopropyl alcohol] to clean it before being able to touch or polish it. Remember to use the protection gloves provided.

[Video of Form Labs printing.]

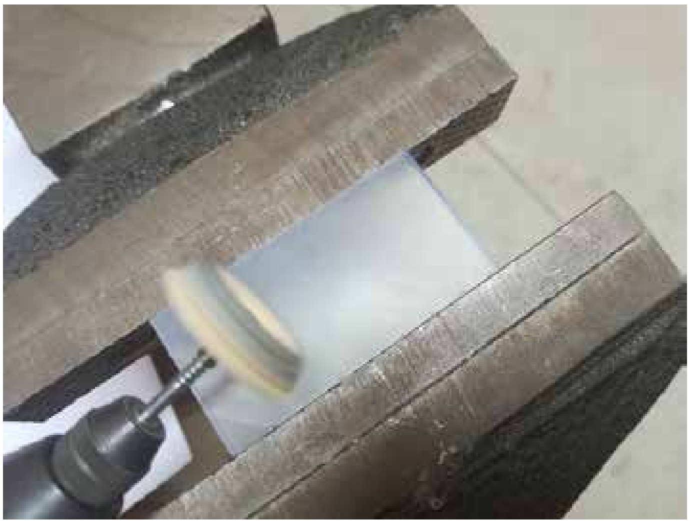
STEP 6: POLISH THE LENS

When the lense is dried and cured from the Resin Printer, it is important to polish the surface to a fine degree. Always it is good to go form a coarse grained abrasive to a finer grained abrasive. There are several methods and ways to do this. Here is what worked for us:

Method 1 : Use a Micro drill with a leather head and buffer agent.

We used a Proxon drill with a buffing head and bugger agent as an abrasive to remove most of the tarnish on the lense. Remembering to use gloves and safety glasses. The lense can be safely positioned in a vice. Move the drill in circular motions around the lens face until it is of a uniform polish.

VIDEO : A Buffing Agent



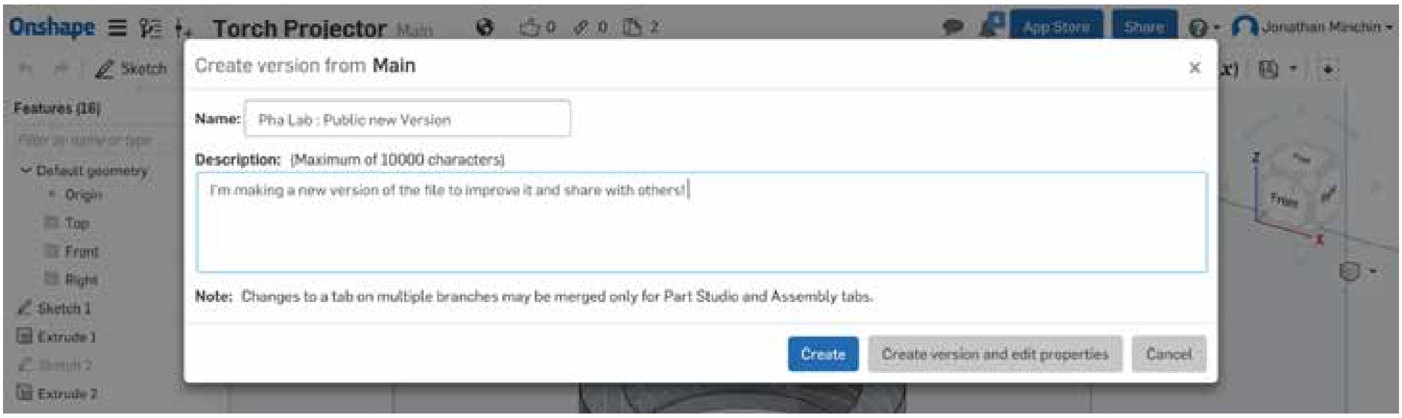
Method 2 : Use a chemical liquid buffing agent with cotton buds.

VIDEO 1: Polish the lens.

This agent should reduce the surface to an even finer finish. Use a similar circular motion around the faces of the lense with the chemical agent until they achieve a uniform polish. For comparison we have use two types of buffing agent; Titanlux and Novus. The Novus seemed to take a lot longer and never reached the same shine produced by the Titanlux.

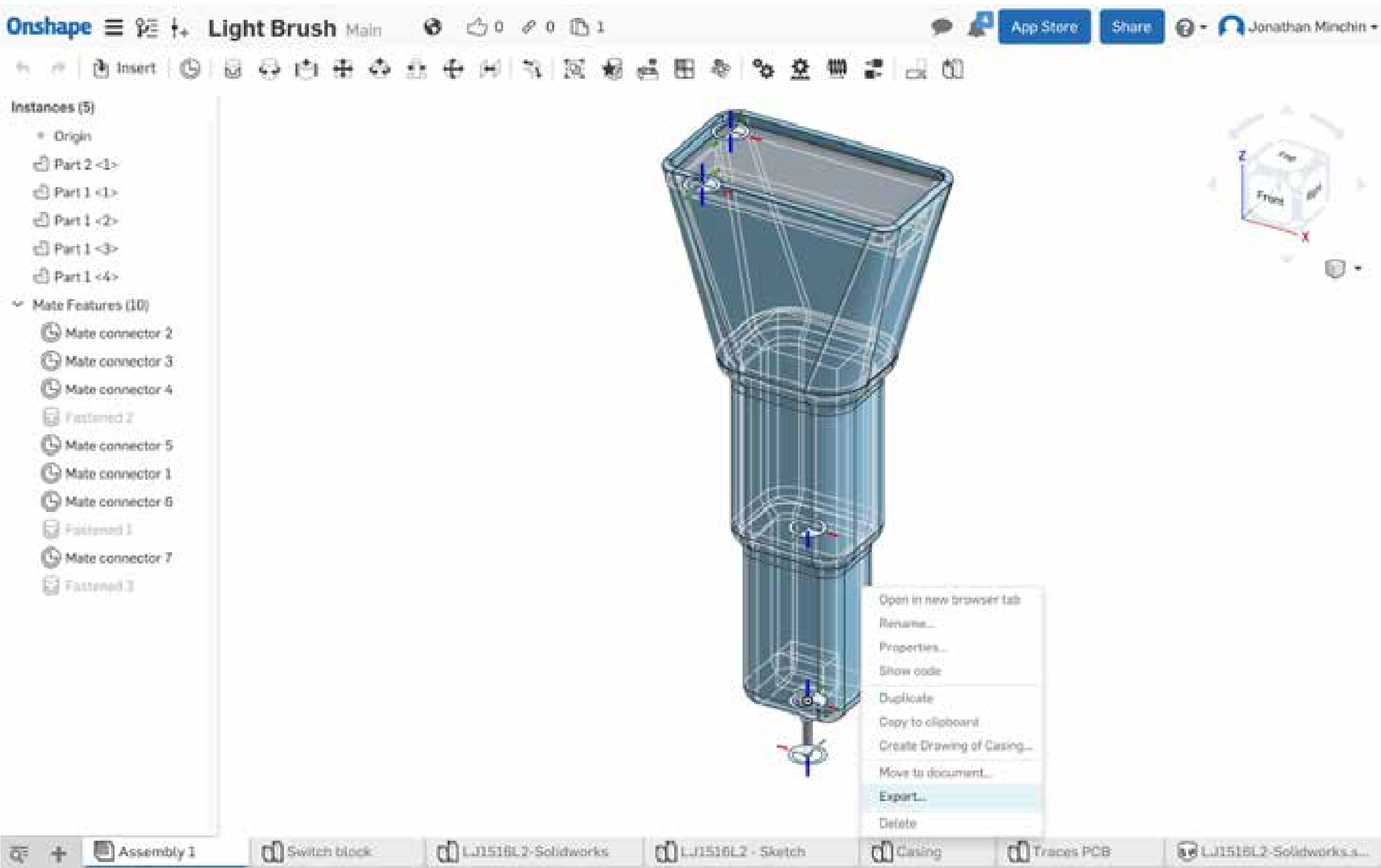
STEP 7: DOWNLOAD THE CASING

NOTE : *We have designed the case components using the Free online platform called Onshape. This is a very powerful software that allows users to edit designs. If you want to make your own version of the case, or modify it you can! If you make your own account you will be able to simply 'Fork' a new version from our own files. Forking is a way of creating a new version that allows everyone us track changes and collaborate to improve the design.*



You can download any of the components using the same process as that for the Lens from this repository : [Onshape - Light Brush](). There is only one component to be printed:

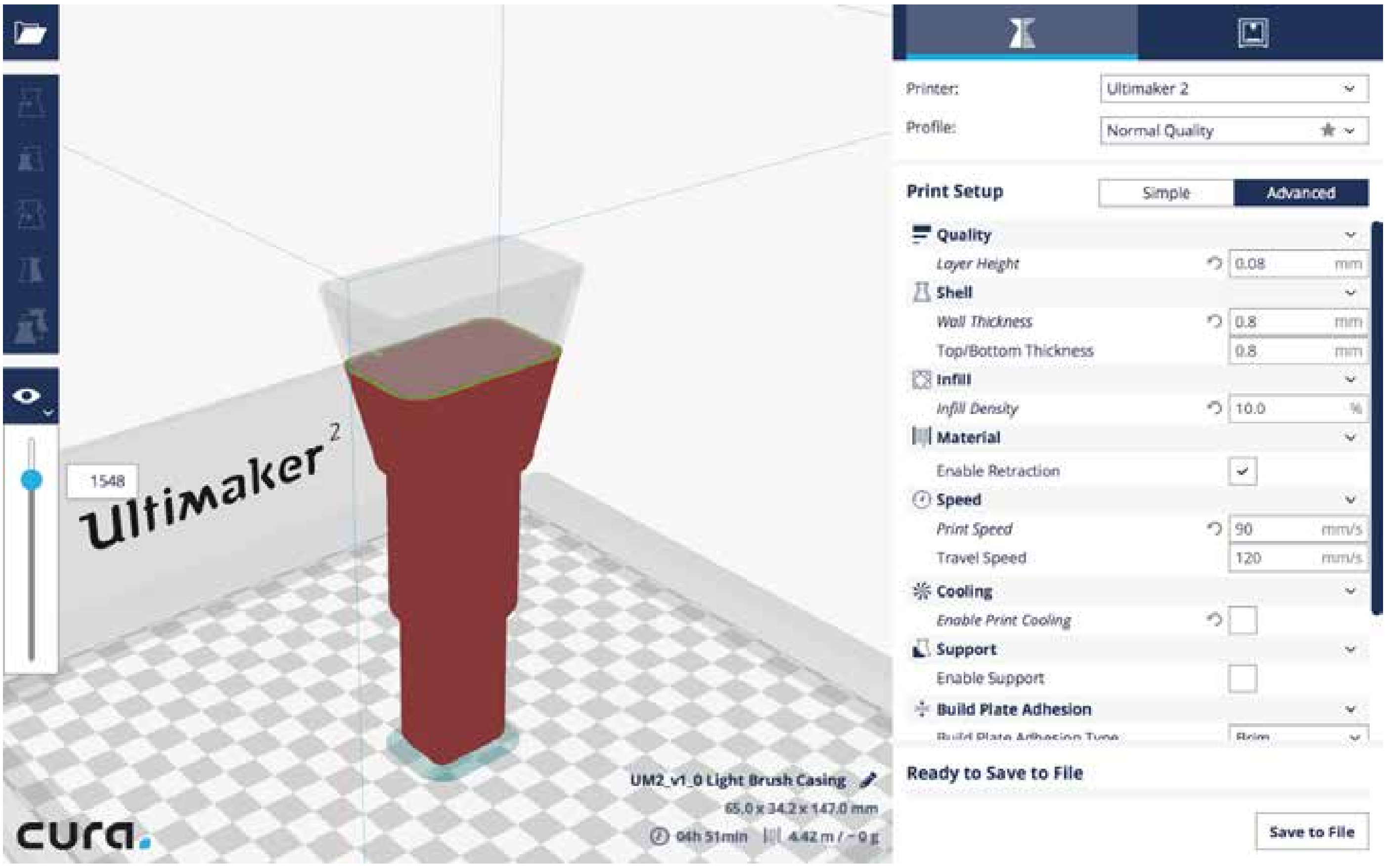
Print : Casing



STEP 8: PREPARE THE FDM PRINT FILE

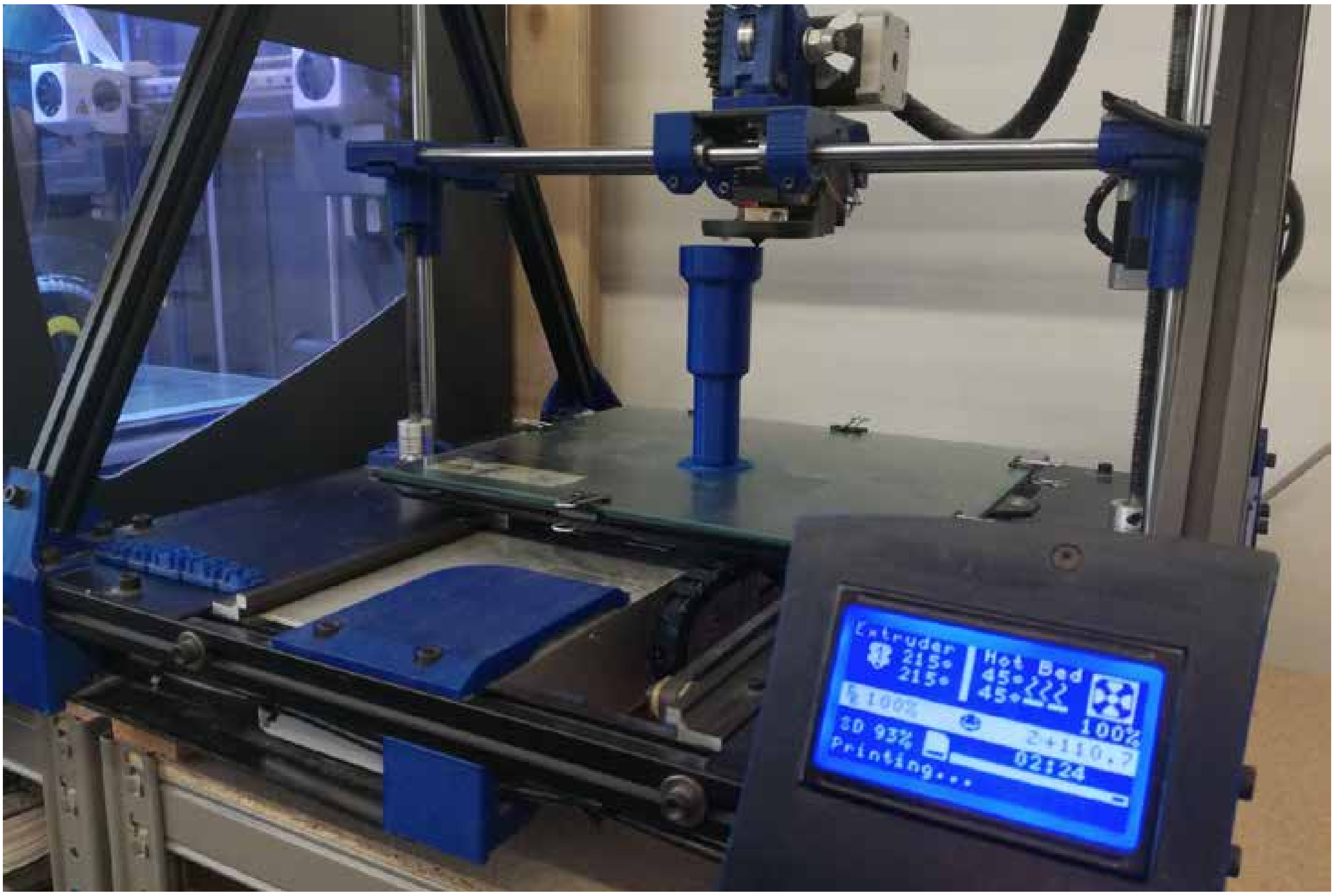
These case files can be printed using any 3D printer, we are using the Form Labs 2 to print the lenses and this will also work for the case also, however the Resin is expensive and we are using a clear resin to print the lenses. For this reason we choose to use an FDM (Fused Deposition Modeling' printer like the Rep Rap or Ultimaker for the case.

There are different types of Slicer software or CAM software for the Rep Rap and Ultimaker 2. We use Cura for use with the FDM machines. There is a lot of instructions online for Cura and it is suggested to read that as there are are a lot of options. Again this is just as much an art as it is a science.



TIP : You can print the casing in a vertical position with the widest part at the top, this seems counter intuitive but actually helps with delivering some of the interior parts. We find it best to use PLA filament because it is more ecologically friendly! Also using the Brim setting is sufficient to hold the object to the build plate, it also speeds up the process.

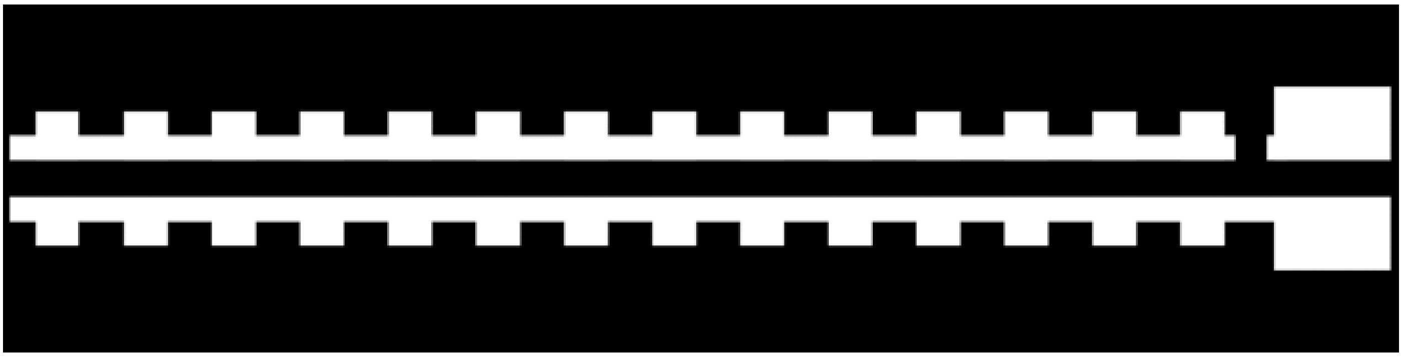
VIDEO : Printing Torch Holder



STEP 9: MAKE PCB cutting files with FAB MODULES

We want to cut co small round pieces of circuits called PCBs (Printed Circuit Boards). These will help position and hold the LEDs in place. The two PNG files below will be used to generate the machining strategies using Fab Modules. These can be downloaded from the file system.

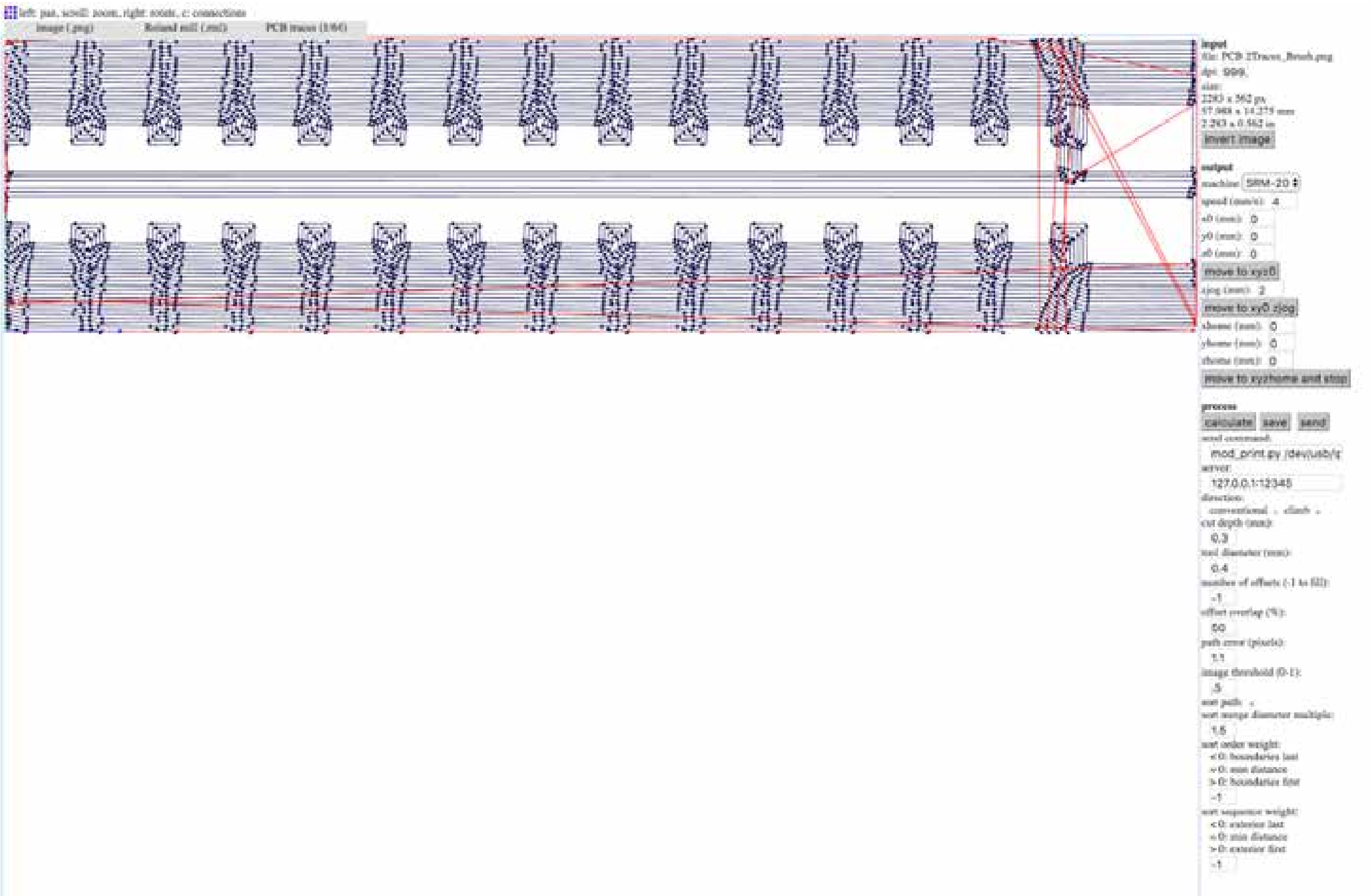
1 - PCB Traces



2 - PCB Profiles

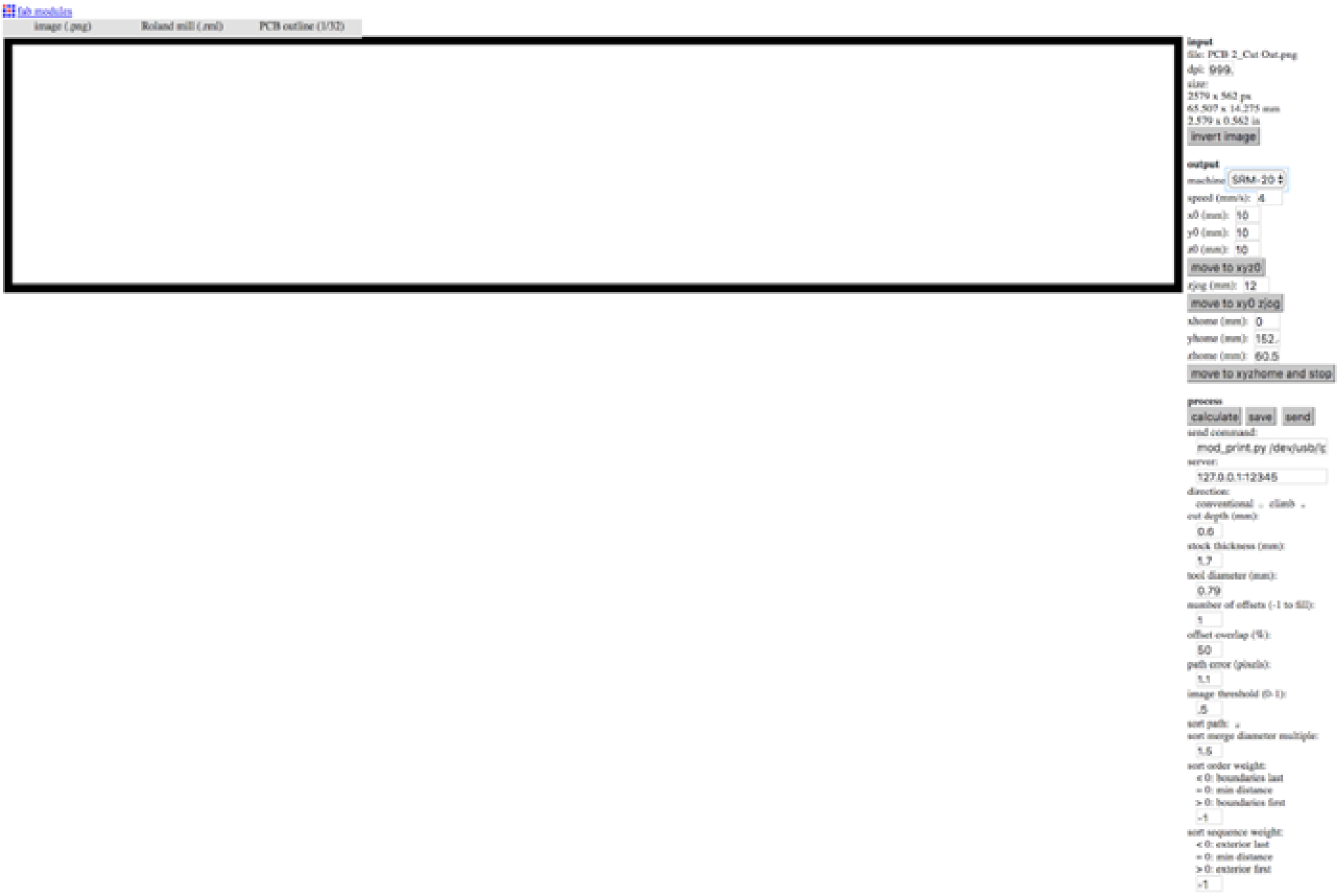
The PNG files have a page size that will allow the machine to accurately return to the same position between the two processes of first cutting the Traces and then cutting the Profiles and holes. [Fab Modules] is open Source CAM software designed for the [Fab Academy.] It allows users to generate machining strategies for lots of different processes and machines, it runs in the browser so there is no need to download it. We will be using the [Roland MonoFab SRM - 20] milling machine.

You can load the files from your computer into the software and select the process in a guided steps. The image below shows the settings and tool paths of the Tracing file. We are using a tiny milling bit here and it will only need to remove 0.5 mm of material from the top of the copper PCB blank.

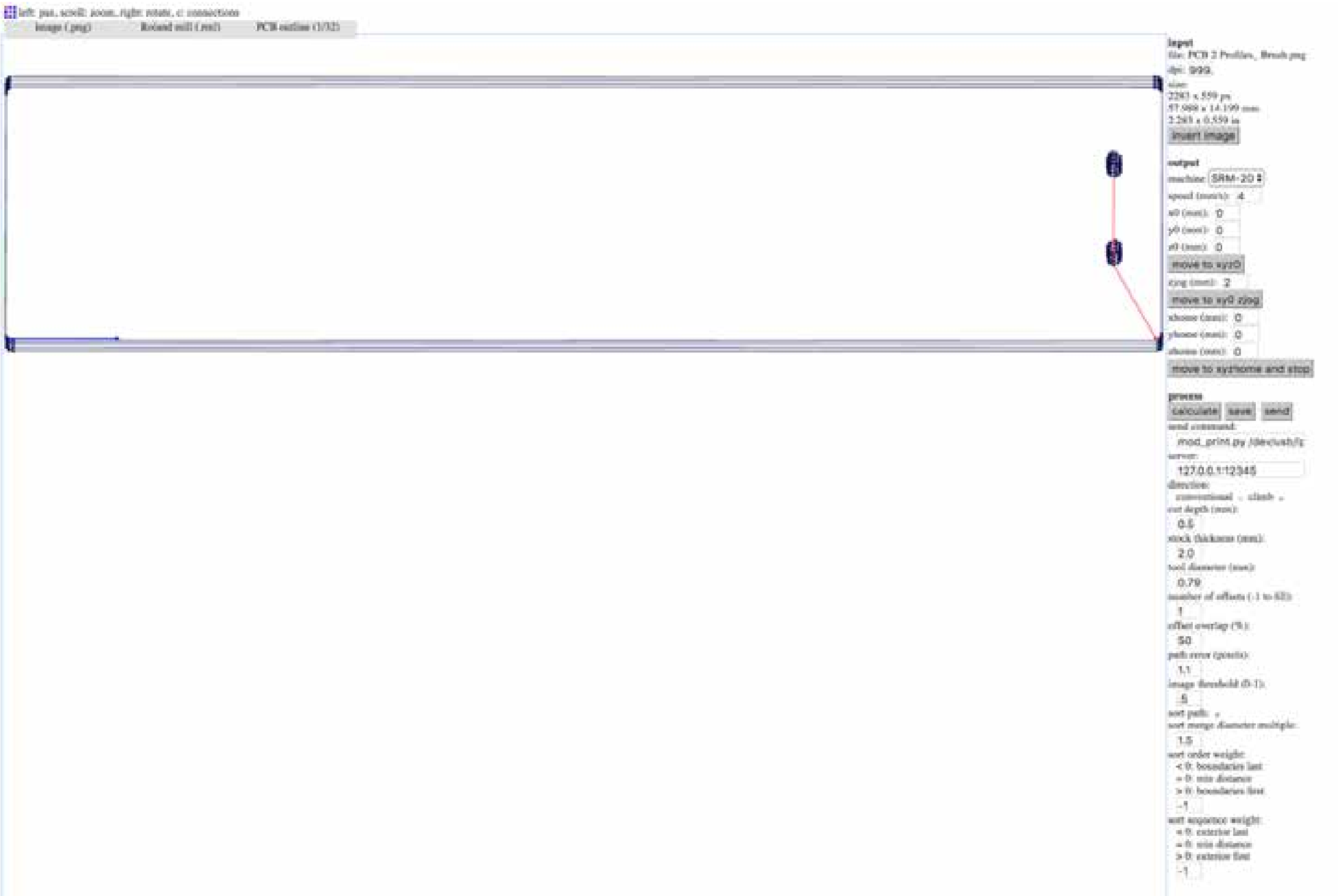


Once you have finished setting up the cutting strategy and are happy that the speeds and depths are correct you should save the file. This will download it to your computer as a .rml file.

The next file to be prepared are the Profile or Outlines of the PCBs. We will use a bigger milling bit and this time will cut all the way through the blank. Select the PCB outline option.

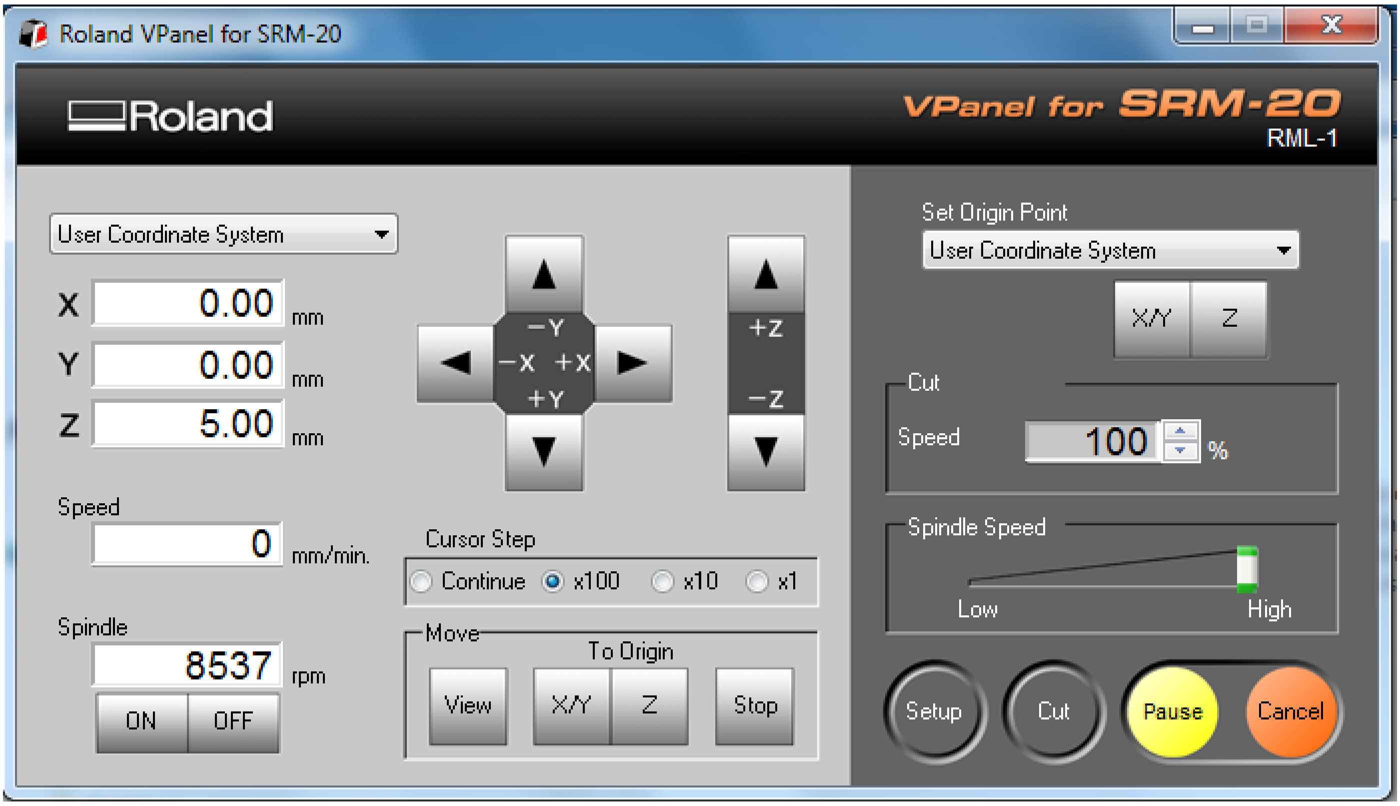


The image below shows how that the tool paths have multiple levels. The settings show a thickness of 1.8 mm

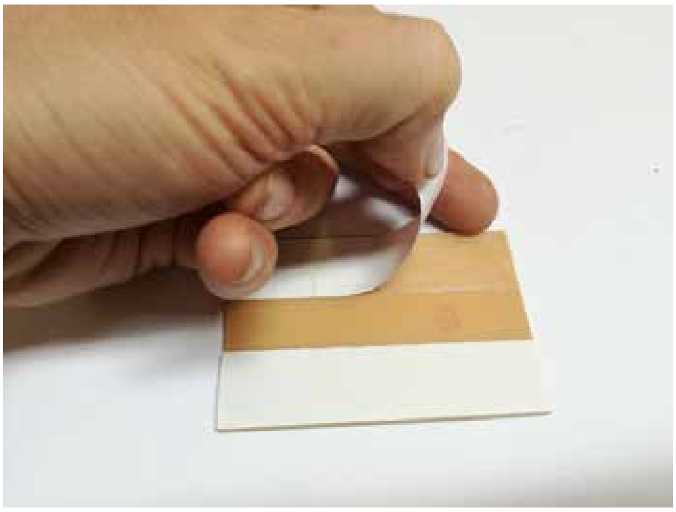


STEP 10: MILL PCBs using ROLAND MONOFAB

The Roland Monofab is a desktop milling machine that cuts material. It moves in much the same way as a 3D printer, but instead of adding material it subtracts it. The CAM software that controls the machine is called V panel, which will use to run the .rml files that we created in the previous step from Fab Modules.



First is we will need to secure the Blank PCB to the bed of the monofab with double sided tape. Then by moving the Milling bit at the bottom left corner of the blank we can Zero the X and Y axis using the User coordinate system.

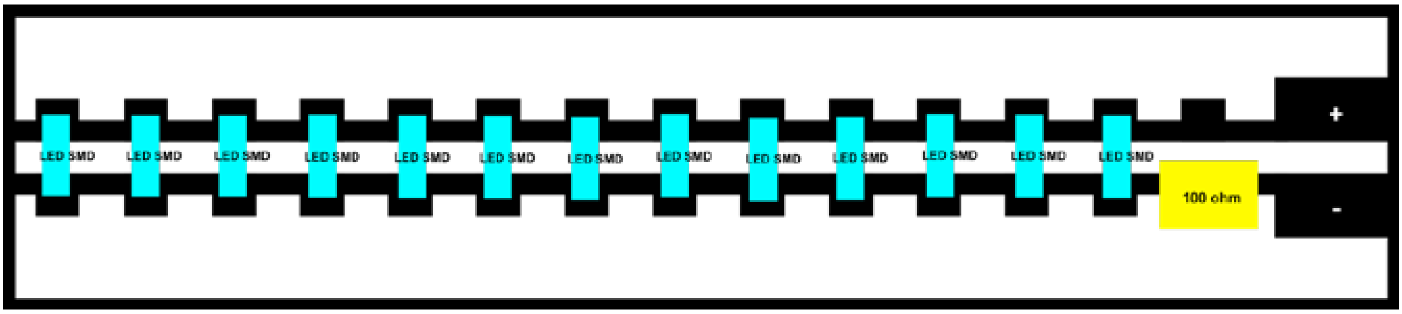


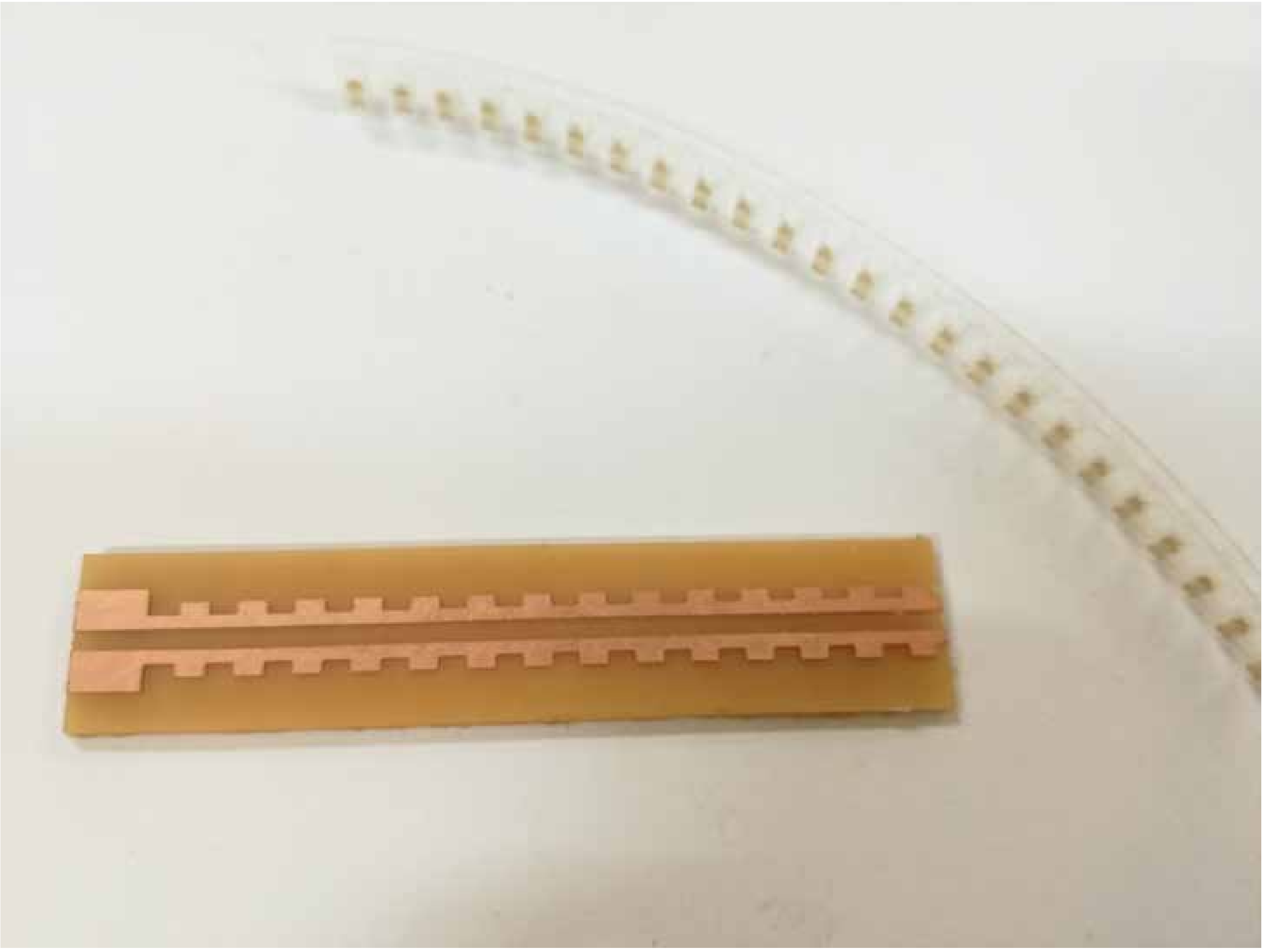
TIP : *In the Z axis, bring the milling bit down to a few mm above the blank and then loosen the chuck to let the milling bit drop to the surface. Only then Zero the Z axis.*

VIDEO : 2_Milling PCBs

STEP 11: SOLDER AN LED CIRCUIT

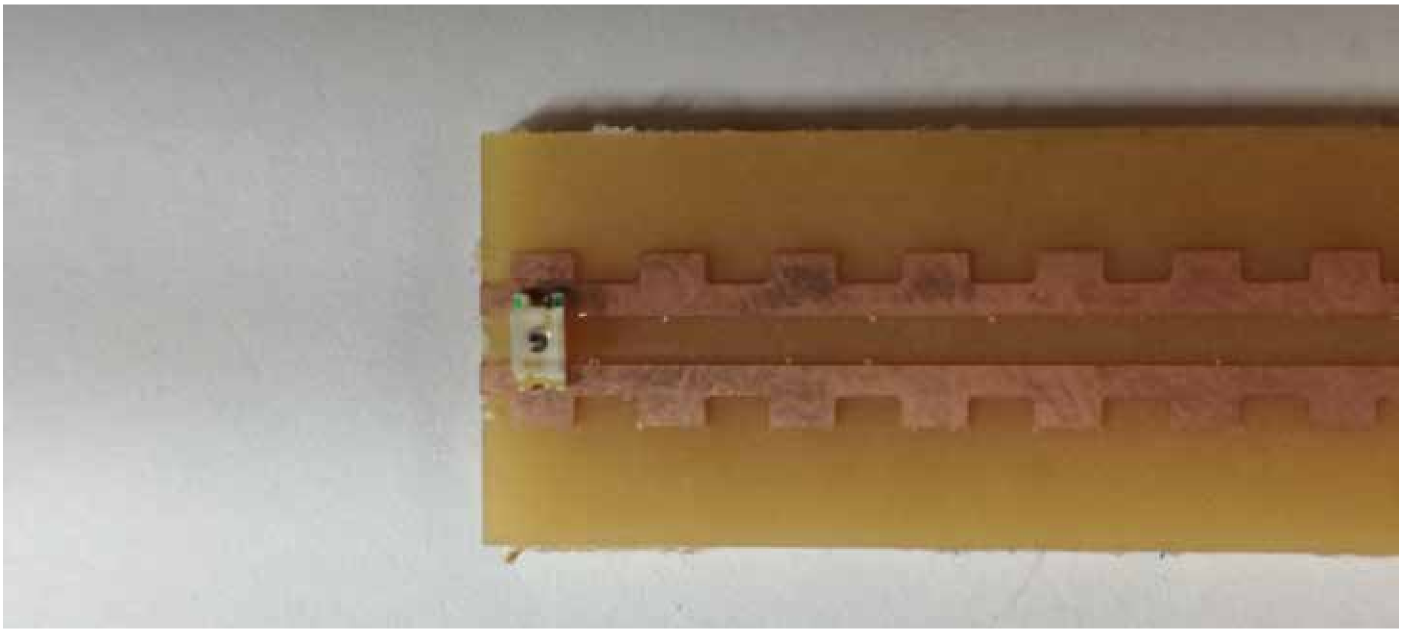
We will now need to place and Solder the white clear [LEDs (Light Emitting Diodes)] to the PCBs and connect the 9v battery to and switch to the circuit also. We have made the PCBs to work in series but all connected to the same traces. This powers the LEDs as if they were one.





The most important factor of this is to know that the LEDs have a polarity with a positive and negative side. The positive side is that with connects to the 100 ohm resistor.

TIP : *Identify the positive side or (Anode) of the LED by the green mark.*



Next you should place the LEDS onto the locating traces all with the green strips on the same side of the first PCB you have cut. Use some tweezers to help you and the magnifying glass is useful also!

Next is to solder the Legs to to the PCB traces checking that you have created. To do this you will need to have a Soldering Iron, a roll of Solder and some flux to help you with the connections.

The Soldering operation will happen in 3 steps.

1 > The first objective is to solder the pins of the LEDs to the traces.
2 > Second is to solder the both Red and Black wires to the switch and to the battery socket and to the 150 ohm resistors.
3 > The final step then is to Solder the Black and Red wires to the circuit board with the Red positive placed on the locating tabs.

VIDEO : Soldering an LED

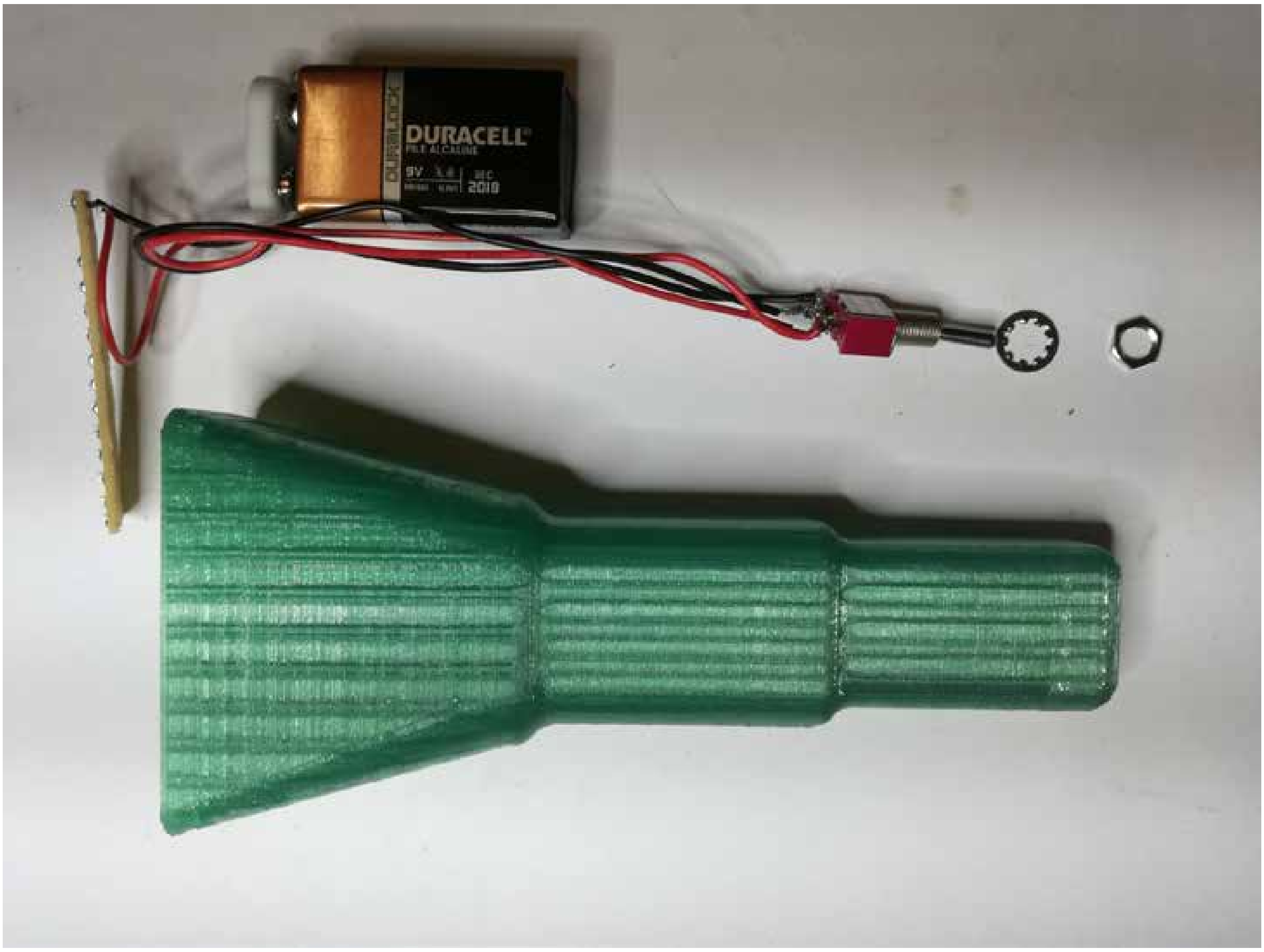
To Solder the switch it is more simple to solder both the wire and the battery cable to the pins at the same time. There are holes in the pins that you can push the wires through.

VIDEO : Connect the Circuit

STEP 12: ASSEMBLE THE LIGHT BRUSH

You will now have all the components that you need to be able to assemble the Torch. You will start by pushing the Switch all of the way through the casing housing so that it protrudes through the bottom hole.

TIP : *Use some string to pull the switch and guide it through the casing and out of the hole.*



[VIDEO : Assembly](#)

Last step: End result & conclusions

What we learned?

List what the participants have learned during this workshop.

Concluding thoughts

In this part you can tell more information about the technology of light used in this workshop.

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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