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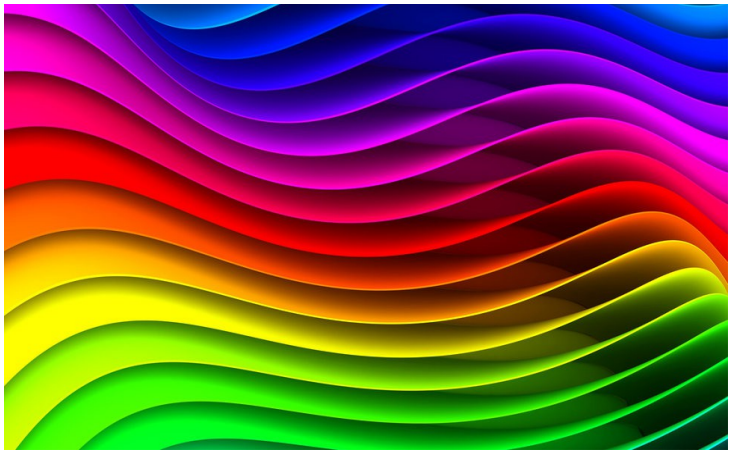
Systemtheremino



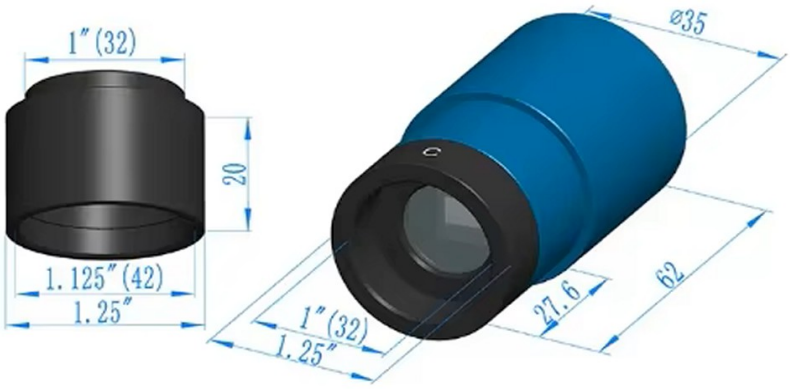
Theremino Spectrometer Construction with WebCam

Construction - With ToupTek WebCam

Lately (end of 2024) we finally found the perfect WebCam, it's called:

TOUPTEK ASTRO GPCMOS02000KMA

You can find it for around 90 Euros, shipping included, on AliExpress and it has outstanding features.

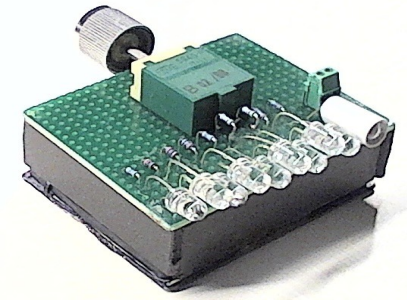


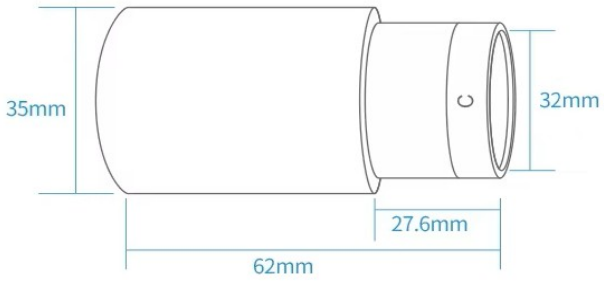
Characteristics:

- The best WDM driver we have ever seen.
- If that wasn't enough, it also has two additional panels with all kinds of options.
- Exposure times from 100 uS to 1000 seconds.
- Exceptional sensitivity.
- “Gain” control which further multiplies the sensitivity by 50 times.
- Natively black and white, so no color or IR filters to remove.
- Constant sensitivity from 400nm to 1000nm***(Note 1)***
- "C" mount for the lens, so you can use all kinds of recovery lenses.

Note 1

To measure the sensitivity we used our multi-led device calibrating the resistor of each LED for a constant brightness, measuring it with a fairly accurate luxmeter. And we found that the **GPCMOS02000KMA** It has a reasonably constant sensitivity across the spectrum. This does not mean that it is within 1% but something like +/- 20%. While the color WebCams tested so far, even removing the filters, showed differences in response of up to 5 or 10 times (500% and more) at the extremes of the range.





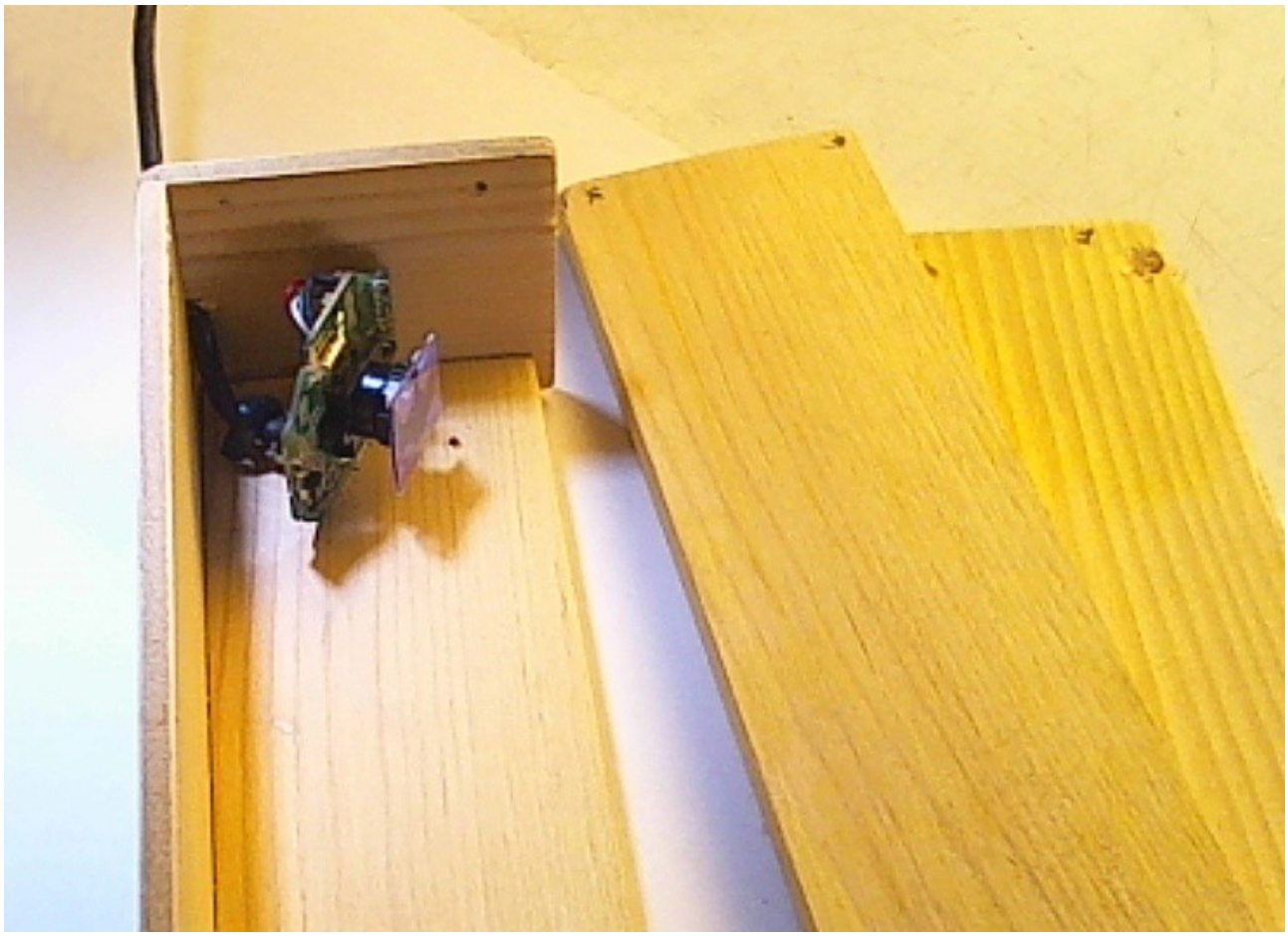
The ToupTek room is a bit large, but you will surely find a way to make a bench suitable for it.

We don't have time to take pictures but it is not difficult to fix it. We recommend tightening it on the cylindrical body with two wooden or plastic jaws and fixing the reticle in front of the lens with an independent support. In this way you can focus without moving the reticle.

On the following pages you will find instructions for making benches suitable for small WebCams..

Construction - With small WebCams

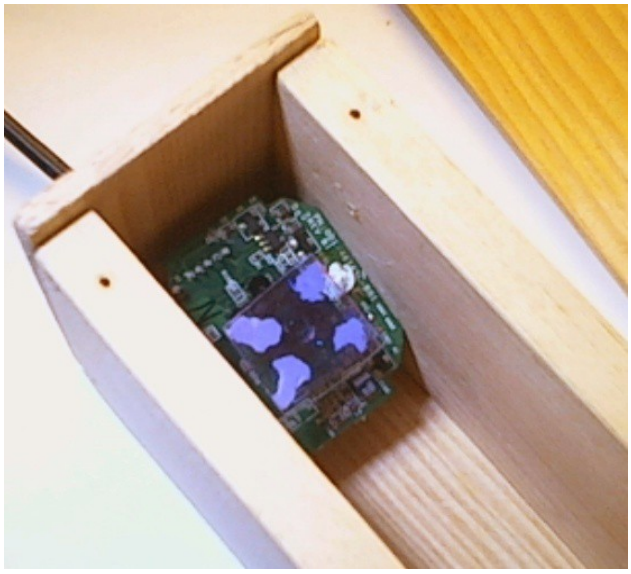
This document shows a simple but effective realization. With about ten pieces in total you get precision and resolution of about one nanometer. These are sufficient features for a small laboratory, for teaching and even for some scientific research on a limited budget.



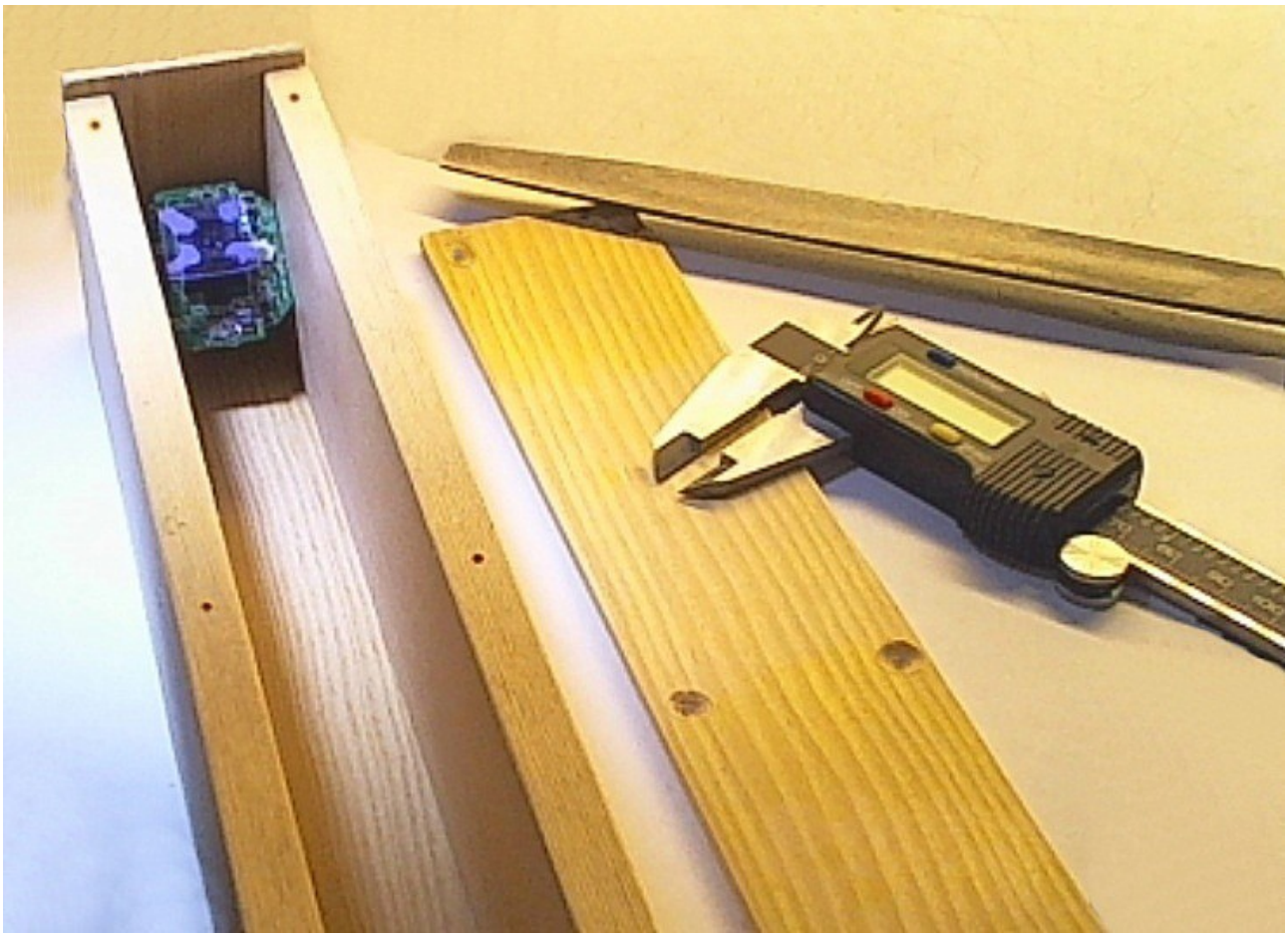
You will need some wooden strips, about twenty screws, a webcam and a DVD cutting.

The container is composed of two thick side strips, arranged vertically.

The other four pieces of wood are thinner.and they screw together above, below, in front and behind.



Materials to use

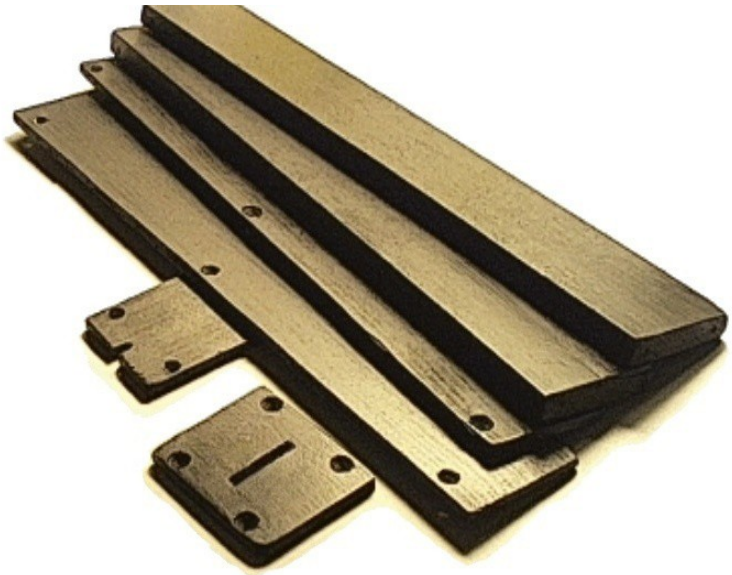


With wood and small screws, you can build lightweight containers that are easy to open on each side and easy toedit for testing.

The best wood for these constructions is beech. It is easily found in "Brico", it is light and does not break even if you make holes for the screws very close to the edges.

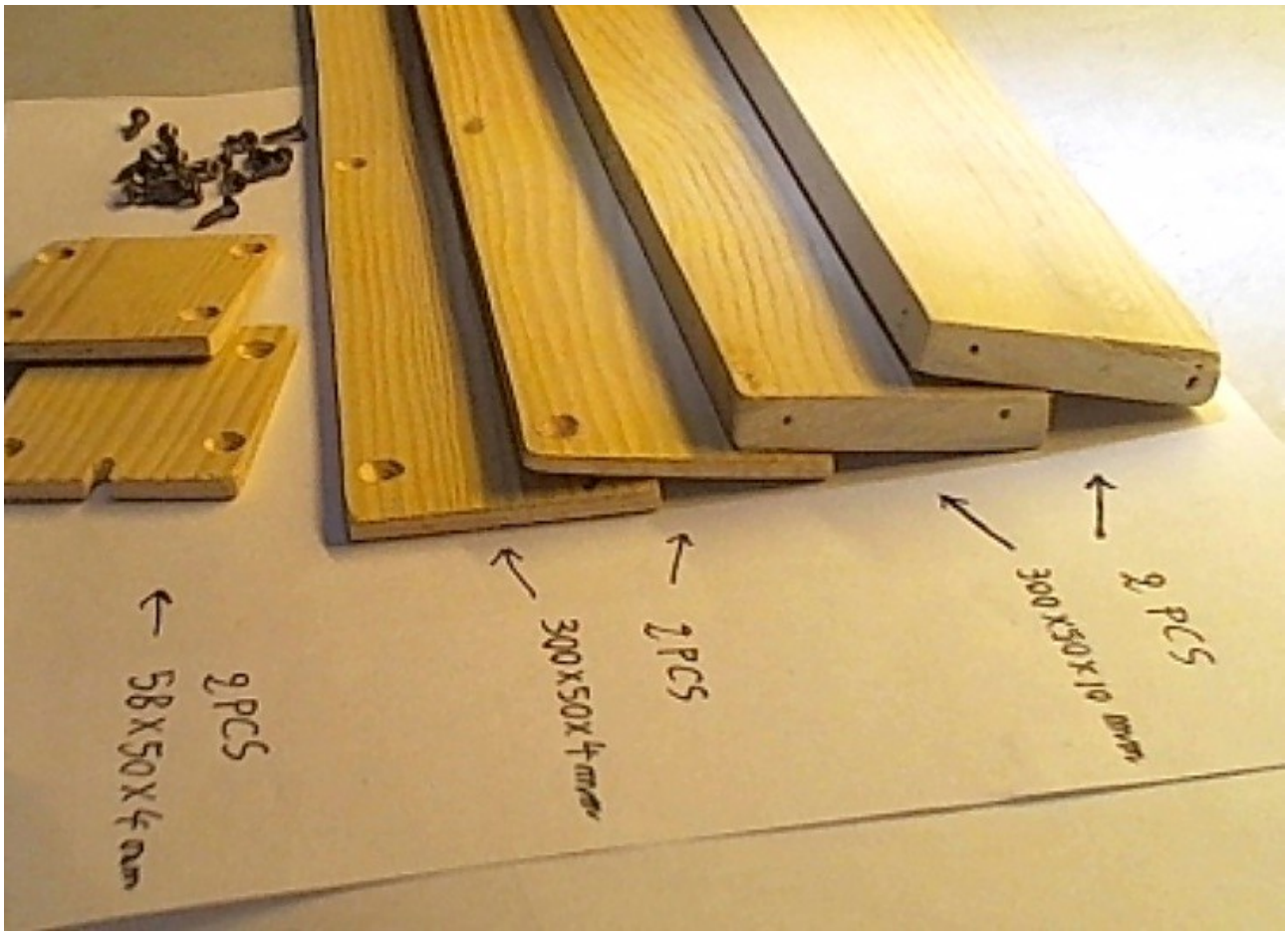
First, the holes are drilled and the box is assembled as a test.

Once everything is in place, give it a splash of matte black paint and you have beautiful looking, easy to assemble pieces.



List of materials for the container

These instructions are for a fairly long (30cm) housing that provides good resolution even with a fairly wide (about 3mm) light entry slit to collect more light. A long housing also makes it easier to focus and angle the camera. The length could be reduced to 20cm with little loss of performance or down to 10cm if absolutely necessary.



Get 252.5 x 8mm bronze screws,10 mm strips and 4 mm sheets (if they are made of beech they are more resistant but other woods can also work)

The piecesthey should be cut as follows:

- 2 pieces of 300 x 50 mm, 10 mm thick
- 2 pieces of 300 x 50 mm, 4 mm thick
- 2 pieces of 58 x 50 mm, 4 mm thick

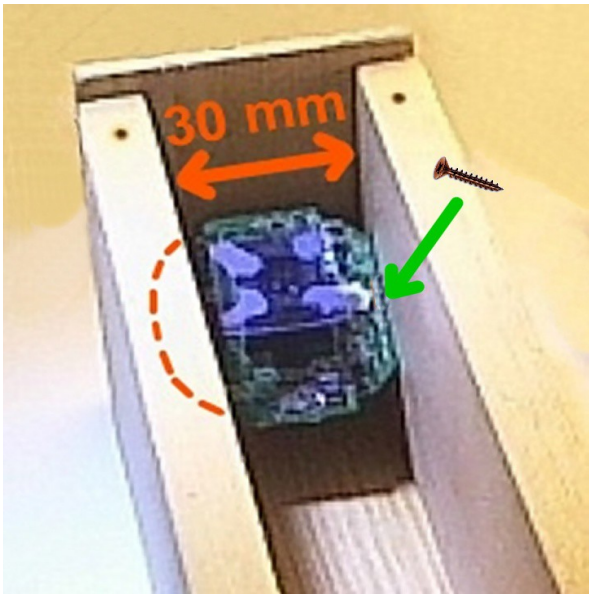
When you buy the strips and sheets you can also ask to cut them, usually DIY stores do this service for free.

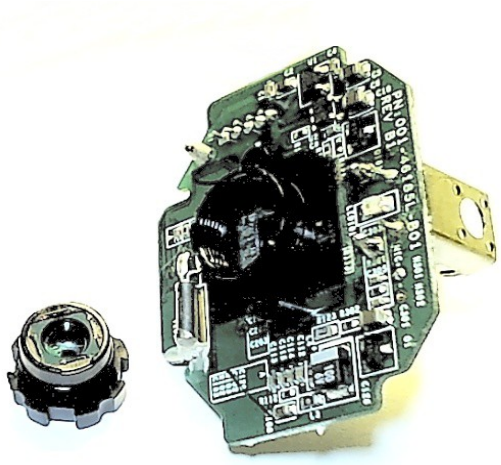
Container width

Be careful that the container width it's just enough for the camera eight Trust WB-6250X, which is very small.

Note that we are talking about container width and chamber height, this is because the camera is mounted with its "top" towards the right wall (where you can see the screw and the green arrow).

Since the WB-6250X is a few millimeters taller than 30 millimeters, the left wall has been hollowed out by about 5 mm (as indicated by the dotted line).





The chamber is screwed to the right wall at the point indicated by the green arrow.

The right side was originally the top of the WebCam (where the button was). In the webcam image you can see that the button has been removed. The hole that remains after removing the button is used to screw the camera to the right wall.

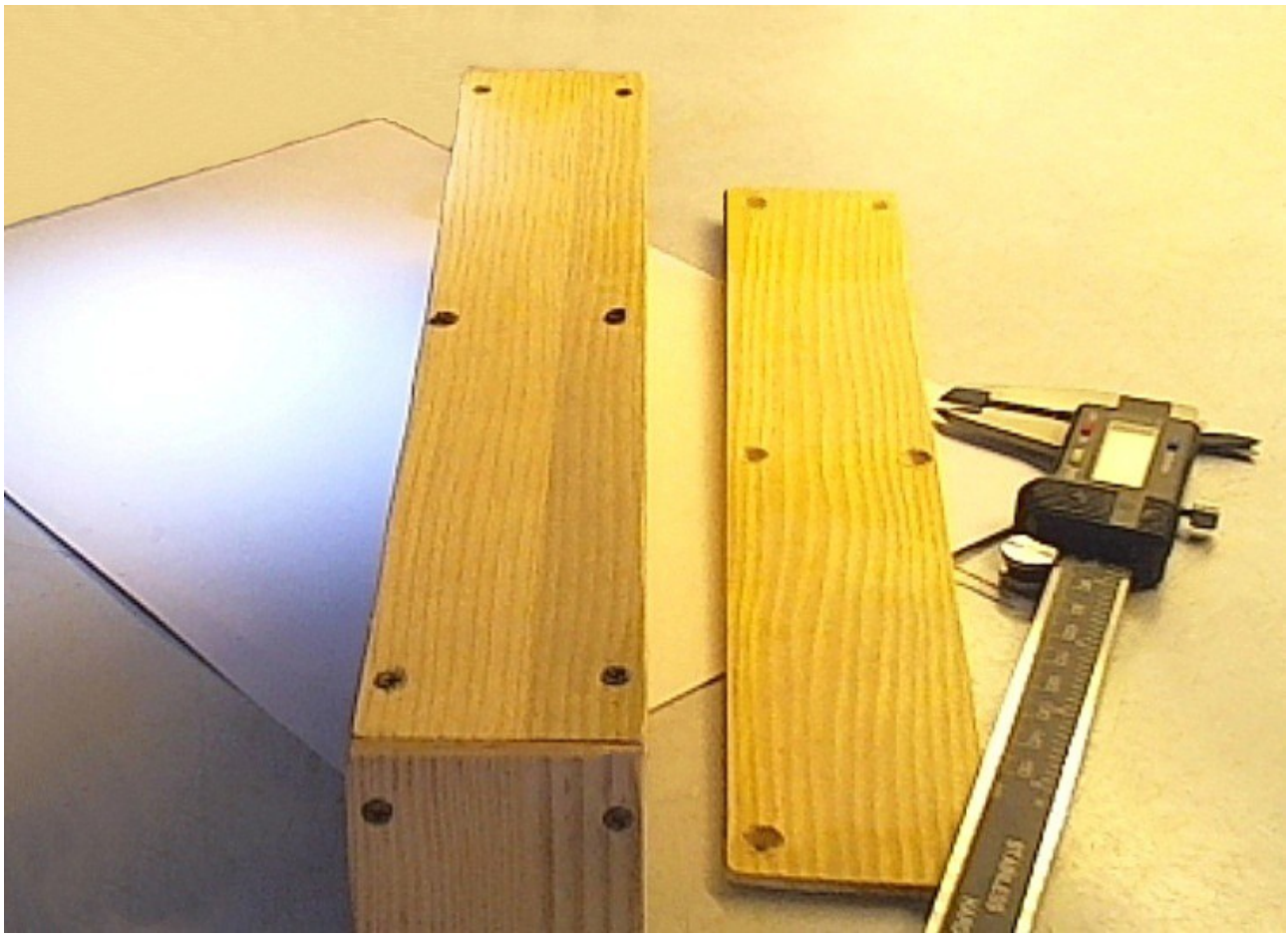
Increase width

The webcam in these images is just over 30mm high. In case you use a highest camera you should increase the width of the container.

To increase the width you need to increase the width of the 4 pieces of thin wood (the 4mm ones)

The width of these pieces will have to be equal to the height of the webcam's PCB plus the thickness of the two side strips which is 10 + 10 mm. So, for example, for a 45 mm webcam the width will no longer be 50 mm but 45 + 10 + 10 = 65 mm

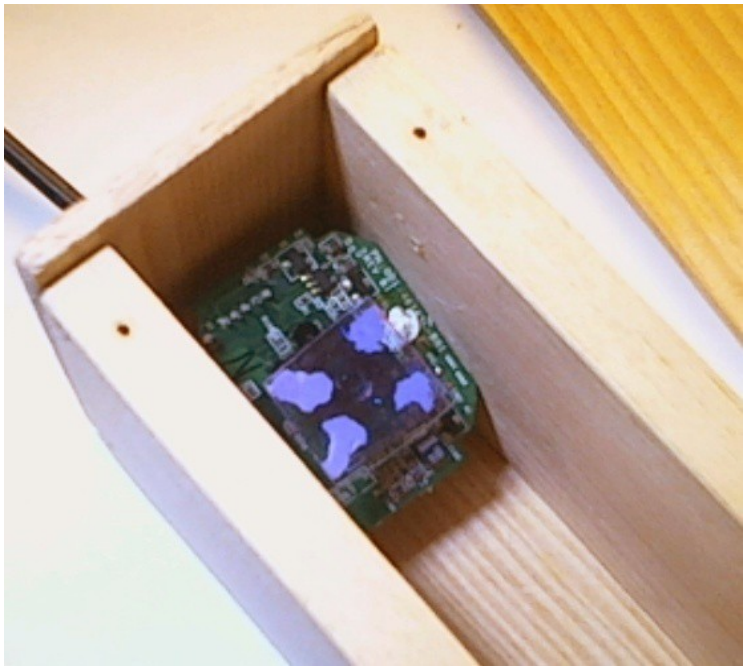
Holes and screws



All holes should be made on the 4mm pieces. On the two long pieces, make six holes, three on each side. On the two terminals, make four holes. The holes should be made with a 2.5mm bit and should all be 5mm from the edge. Finally, the holes should be countersunk with a large drill bit (about 6mm).

In the image on the right you can see that with the holes 5 mm from the edge the screws hit exactly halfway through the side strips which are 10 mm thick.

Use 2.5 x 8 mm, bronze-plated, countersunk screws.



Preparing the webcam - 1

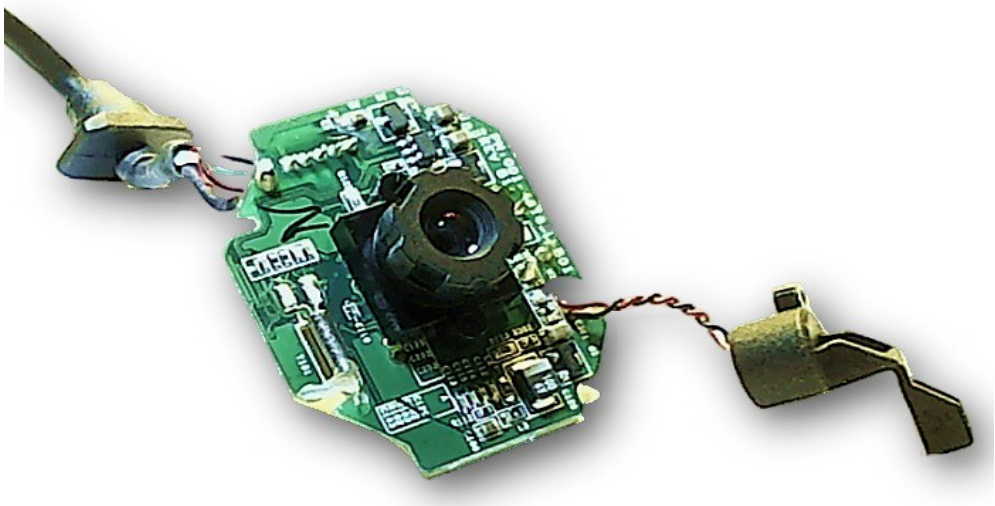
In this document we plan to use a Trust WB-6250X camera, which is quite inexpensive and has a true hardware resolution of 1280 x 1024.
http://trust.com/en/all-products/15355-megapixel-webcam-pro

Another webcam that should be fine (but we haven't tried it) is theTrust WB-5400, also with 1280 x 1024 true hardware resolution.
http://trust.com/en/all-products/15007-megapixel-usb2-webcam-live-wb5400

Even webcams costing a few euros, with a resolution of 640 x 480, can work well. The important thing is that they are small and have an easily fixable printed circuit board.

Other essential features are that the lens has a flat, easy-to-remove infrared filter and that the exposure and sensitivity controls are manual and work well. Trusts generally have these characteristics. If the camera is not a WB-6250X, check that the infrared filter can be removed and that it has manual, well-functioning exposure controls, **before you change it**.

Separate the chamber from the base and unscrew the small screw that holds the two halves of the shell together. Separate the two halves of the shell by pulling hard, without fear, at the end the shell will split and you can extract the printed circuit board.

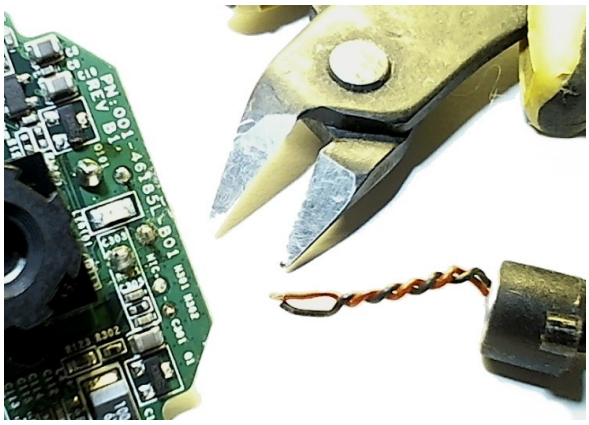


Preparing the webcam - 2

Cut the two small wires that go to the microphone, or bend them repeatedly, near the PCB, until they break at the base.

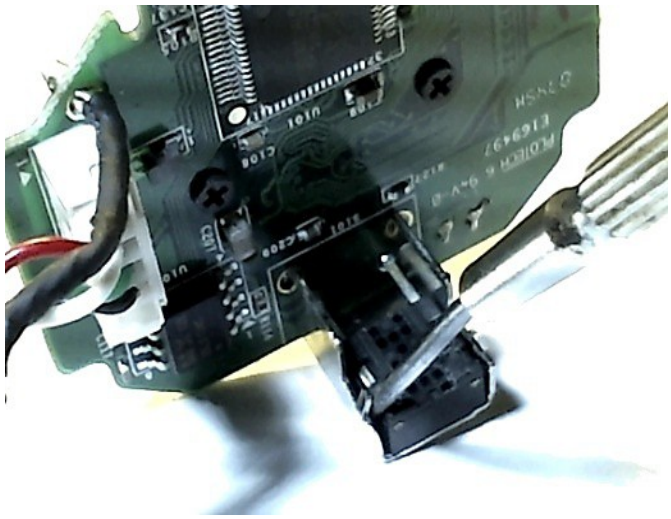
Also remove the LED by unsoldering it, breaking it or cutting it with wire cutters, otherwise its light would prevent good spectra from being made.

Check with a magnifying glass that there are no pieces of wire left that could make contact with adjacent tracks.



Locate the button and use a screwdriver to lift the two metal tabs holding it in place.

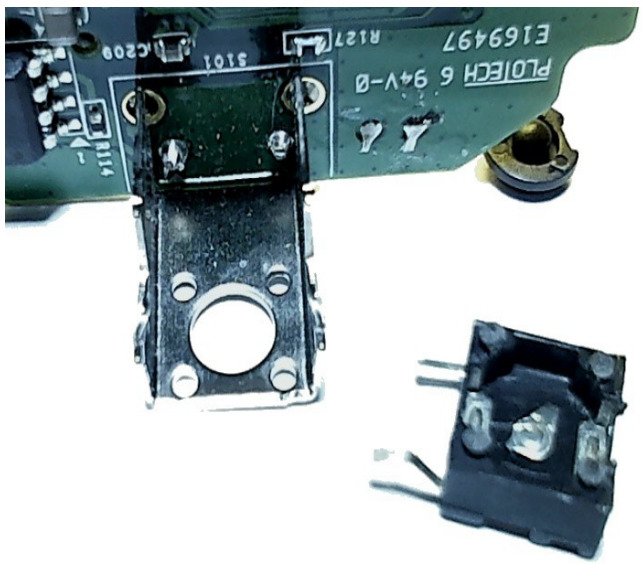
Bend the button a few times to break its leads, preferably near the PCB.



If the button terminals are still attached to the PCB, cut them off at the base using wire cutters or small scissors.

Check with the magnifying glass that there are no pieces of terminal left that can make contact with the walls of the bracket.

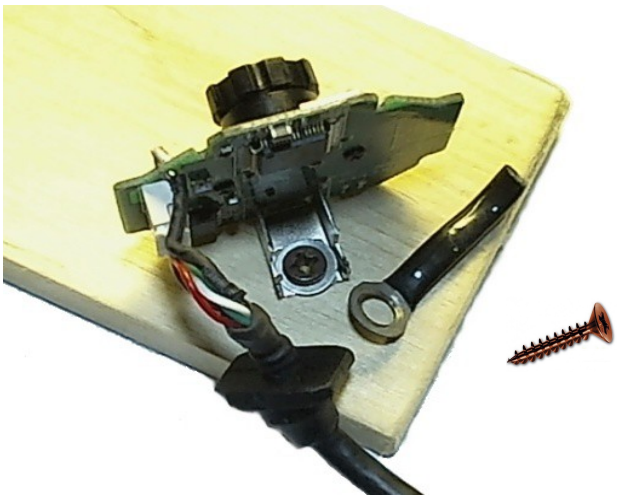
Finally, in place of the button there is a bracket with a convenient hole to fix the camera.



Fix the webcam

To attach the webcam you need:

- A 2.5 x 8 mm bronzed screw(like the ones in the container)
- A long cable lug, with a 3mm hole, covered in black heat-shrink tubing.
- Possibly a washer to place between the wood and the metal bracket, so as to make the rotation of the webcam smoother, even when the screw is tightened.



Remove the rubber grommet by cutting it with the wire cutters. (Be careful not to damage the insulation of the cable)

Use the cable lug to secure the cable, as seen on the right.

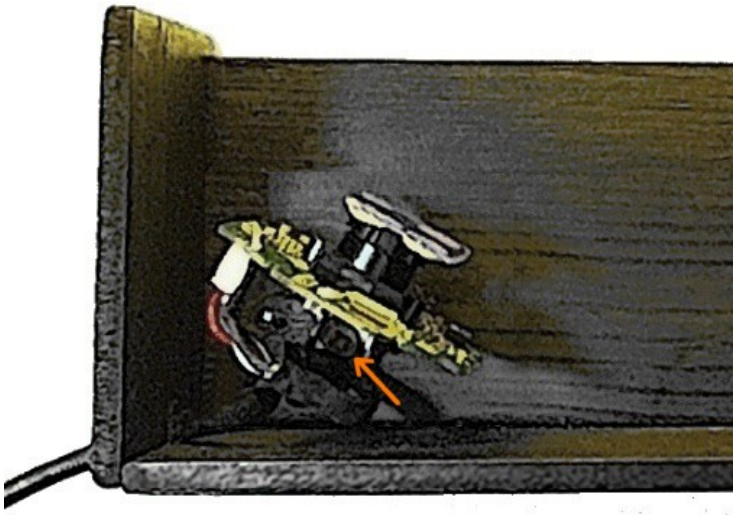
In these pictures the webcam is screwed on a test wood, just to show the fixing method. The correct position is shown on the next page.

Webcam and slot location

Screw the chamber to the thick side wall.

Position it as low and to the left as possible, but leaving room for it to rotate about ten degrees, up and down.

The orange arrow indicates the position of the fixing screw.



The light entry slit should be horizontal and approximately at the height of the tip of the lens.

The 30 degree tilt provides a good compromise between resolution and the amount of light collected, but you can experiment with different angles. Decreasing the angle increases the resolution, the lines shift to the left and the light intensity decreases, increasing it does the opposite.

Depending on the light sensitivity of your webcam, the focal length of its lens, its number of pixels, the number of lines in the grid (CD, DVD, or 500 or 1000 line grid), and how much resolution you want to achieve, you may choose an angle other than these 30 degrees.

The angles to experiment with range from 20 to 45 degrees. When you change the angle of the webcam the lines move and you have to redo the calibration. Increasing the angle beyond 30 degrees you start to lose part of the infrared area. To measure the wavelength of the infrared LEDs it is good that the scale reaches at least 950 nm and therefore you should not exaggerate with this angle.

Remove the infrared filter

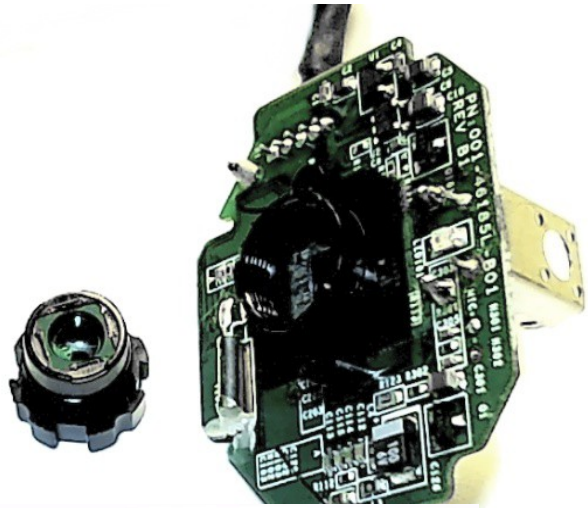
In order to also measure infrared light (from approximately 750 nm up to 1000 nm) it is necessary to remove the infrared filter located on the rear side of the lens.

Not all webcams have an infrared filter that can be removed. Sometimes the filter is curved and forms part of the lens, in which case the webcam is not suitable.

So before modifying the webcam, check the back of its lens.

If the filter is flat, square, and glued on the sides, then you should be able to remove it.

This operation is not easy because the filters are glued with a wicked resin. Some authors have written that heating is easier, but even heating does not change much. We always had to use force, until we broke the glass of the filter.



Be very careful! The fragments can scratch the lens underneath and if you make a mistake it will be difficult to find another lens that is the same.

So be prepared with plenty of light, goggles and sharp tools.

Diffraction gratings

Read the document "Theremino_Spectrometer_Construction_Gratings"

Focus the lens

Important but very difficult operation!!!

We're looking for a way that's a little less terrible than trial and error...

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A good solution is to screw an “L” shaped bracket onto one side of the container, with the long end protruding in front of the lens and the reticle glued to the tip of the “L”.

This way you can rotate the lens to focus while keeping the reticle still.

The system works well but we don't have any images to show yet, we will publish them in the next versions.

Anti-reflection diaphragms

The inside walls of the spectrometer are hit by light very slantingly and therefore reflect light, even if well painted in matt black and even if covered with black paper. This diaphragm, if well constructed and of the right size, can completely eliminate reflections.

Starting from the 10mm thick strip, cut a piece 50mm high and 30mm wide (or wider if you have built a wider container)

Dig a rectangular hole 25 mm high and 15 mm wide. To make this hole, start by making many holes with the drill, then join the holes and finally straighten the walls with a flat file.

For best results, the hole should be countersunk (enlarged from the camera side) so that it has clean edges toward the incoming light. This way, the incoming light does not hit the inside walls of the rectangular hole and create reflections.

Even better would be to make the hole much larger than necessary (30 x 20 mm) and then close it with black cardboard, cut with a cutter and fixed above and below, with two drawing pins.

To achieve complete elimination of reflections, the hole should be as narrow and low as possible. Since the height of the lens above the entrance slit can vary from one construction to another, the best way to find its ideal size is to place a strong light behind the slit and test with black cardboard how tight the four walls of the hole can be tightened.

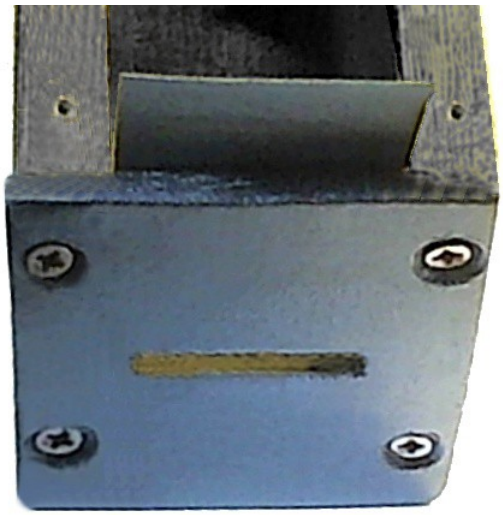
In our tests, a good position for the diaphragm was the point indicated by the orange arrow, about a third of the way up the container and closer to the inlet slit than the chamber. If the diaphragm width is accurate, it can be easily slid in and out to try out different positions and to change the size of the black card.

The light entry slit

When measuring a bright light source it is best to use a narrow slit. But to measure very dim light sources it is necessary to widen the slit and sacrifice some resolution.

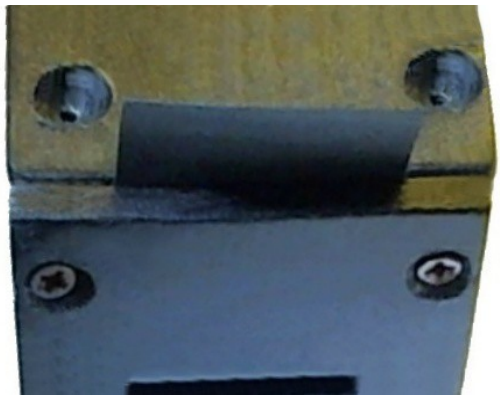
It is recommended to start with a 3mm slit for a 30cm long spectrometer (1mm for every 10cm of spectrometer length).

With a thin sheet of black paper or plastic, you can make an excellent and simple diaphragm to adjust the thickness of the slit.



When screwing the cover on, leave enough space for the diaphragm.

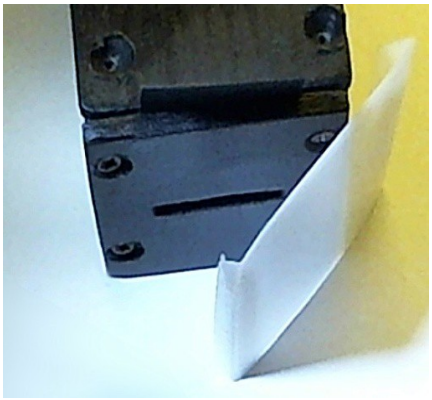
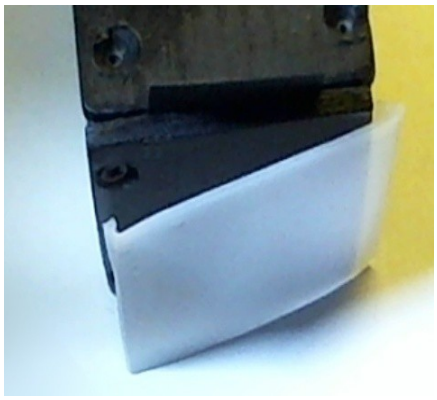
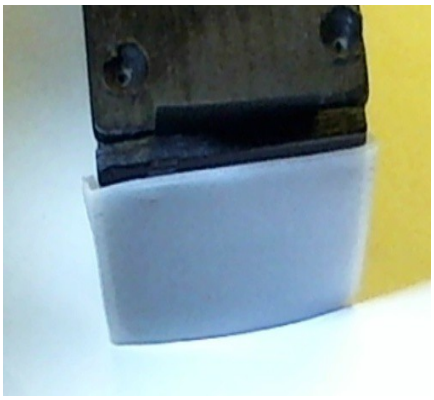
The diaphragm should slide easily up and down, its slight curvature providing the elasticity needed to hold it in place.



The diffuser screen

This screen is used to prevent light rays from entering the chamber directly and causing reflections inside it. With some sources, such as LEDs and lasers, the screen is absolutely necessary but in other cases it is better to remove it.

Without a screen the spectrometer is very directive and this could be useful for measuring distant color areas. For example to see the color differences between different areas of the sky.

The screen is made from a shampoo or shower gel container.

Choose a large jar, with a wide, flat front and back and made of a good, thin, bright white opal plastic.

The right jars are made of opaline polypropylene, which diffuses the light very well and does not dim it. Possibly try different brands to find the best, with the thinnest and brightest plastic.

First you have to remove the labels. Fill the container with very hot water to soften the adhesive. Lift the plastic of the label on one side and pull it slowly so as not to leave glue. If this is not possible, change the jar and find one with labels that are easier to remove.

Cut a large rectangle from the flat area of the jar. Then trim it progressively with scissors and fold it with pliers until you obtain a screen that fits well on both sides of the spectrometer.