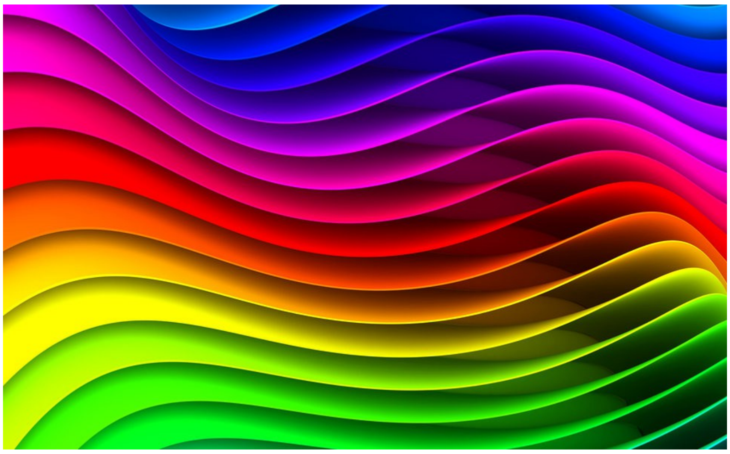
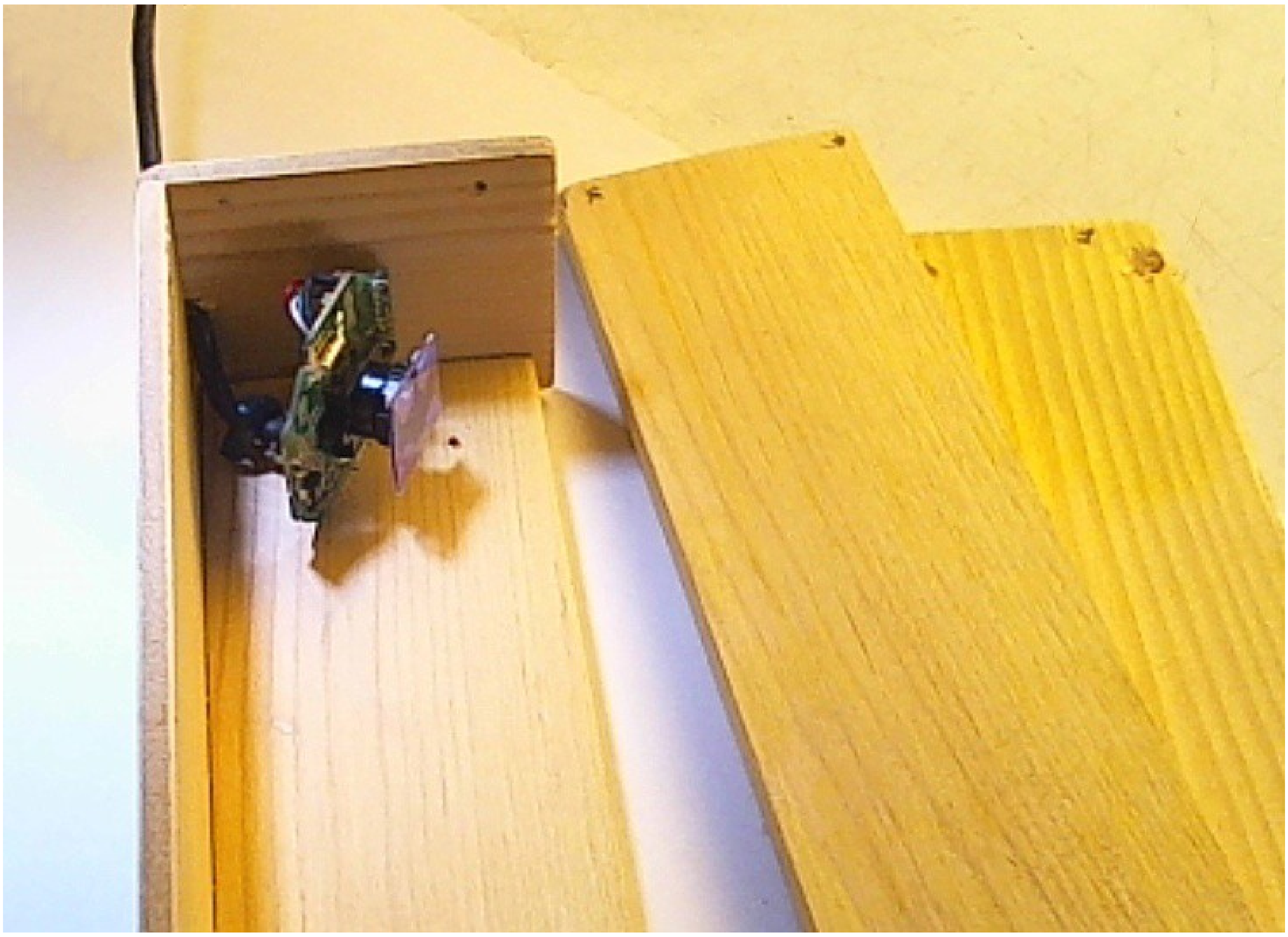
Theremino System



Theremino Spectrometer Construction

Construction of the spectrometer

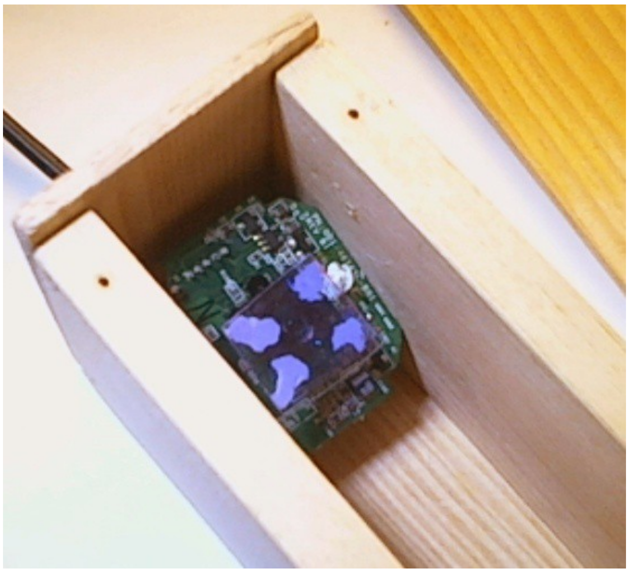
This document shows a simple but effective construction. With a dozen pieces all are obtained accuracy and resolution of about one nano-meter. There are enough features for a small laboratory for teaching and also for some scientific research on a budget.



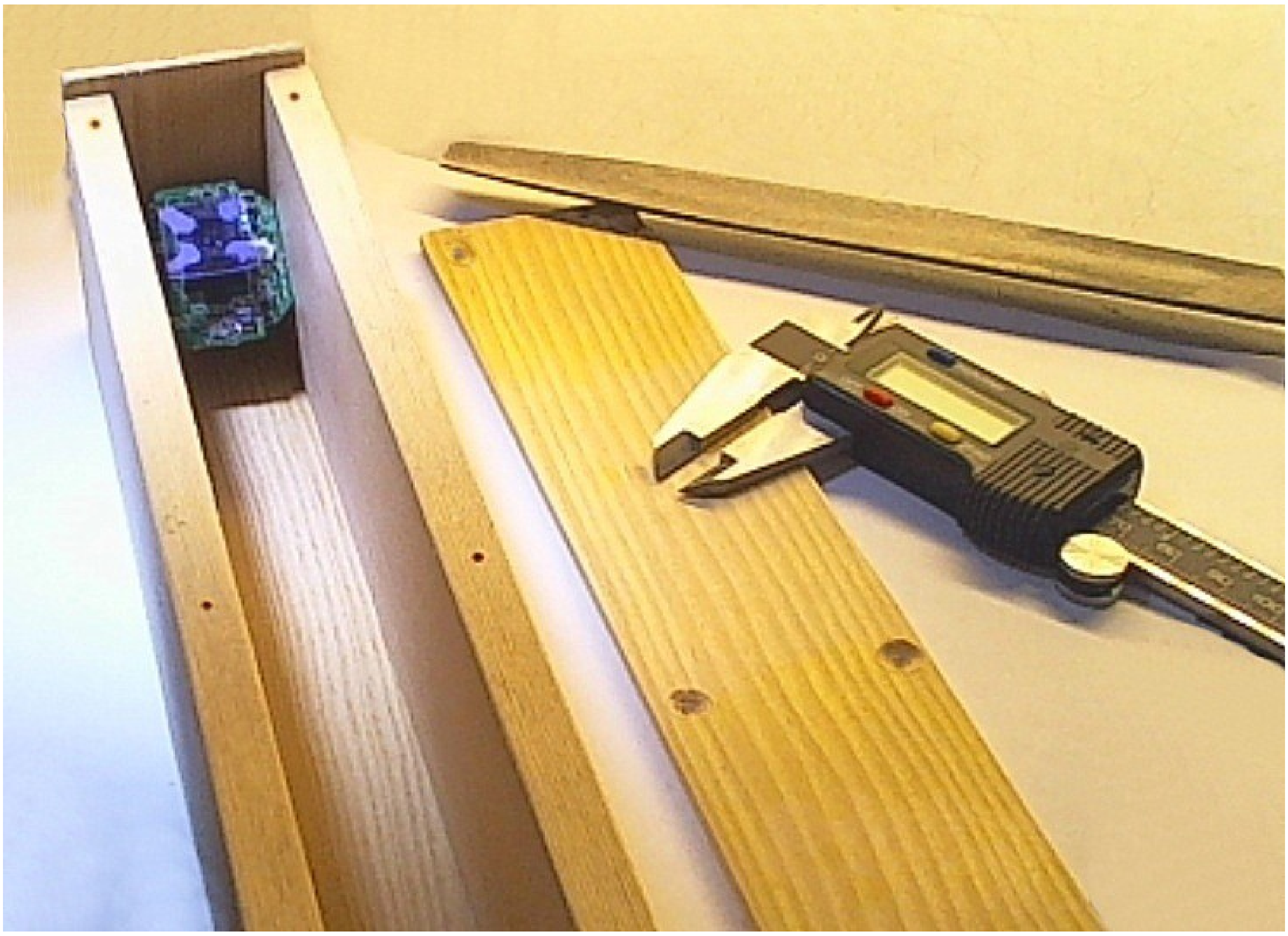
Serve some strips of wood, about twenty screws, a webcam and a DVD of clipping.

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

The other four pieces of wood are thinner and you screw them up, down, front and back.



Materials to be used

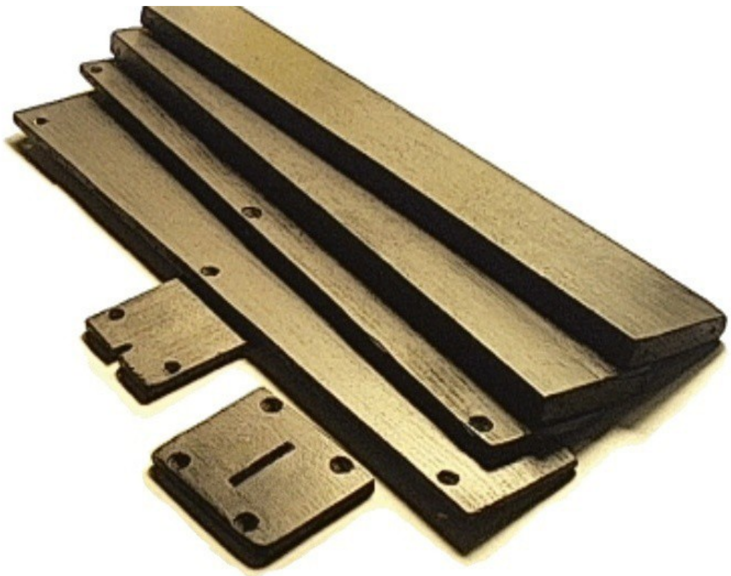


With wood and small screws you can build lightweight containers, easy to open on each side and easy to modify for the tests.

The best wood for these buildings is the beech. You can find it easily in the "Brico", it is lightweight and does not break even if you make holes for the screws very close to the edges.

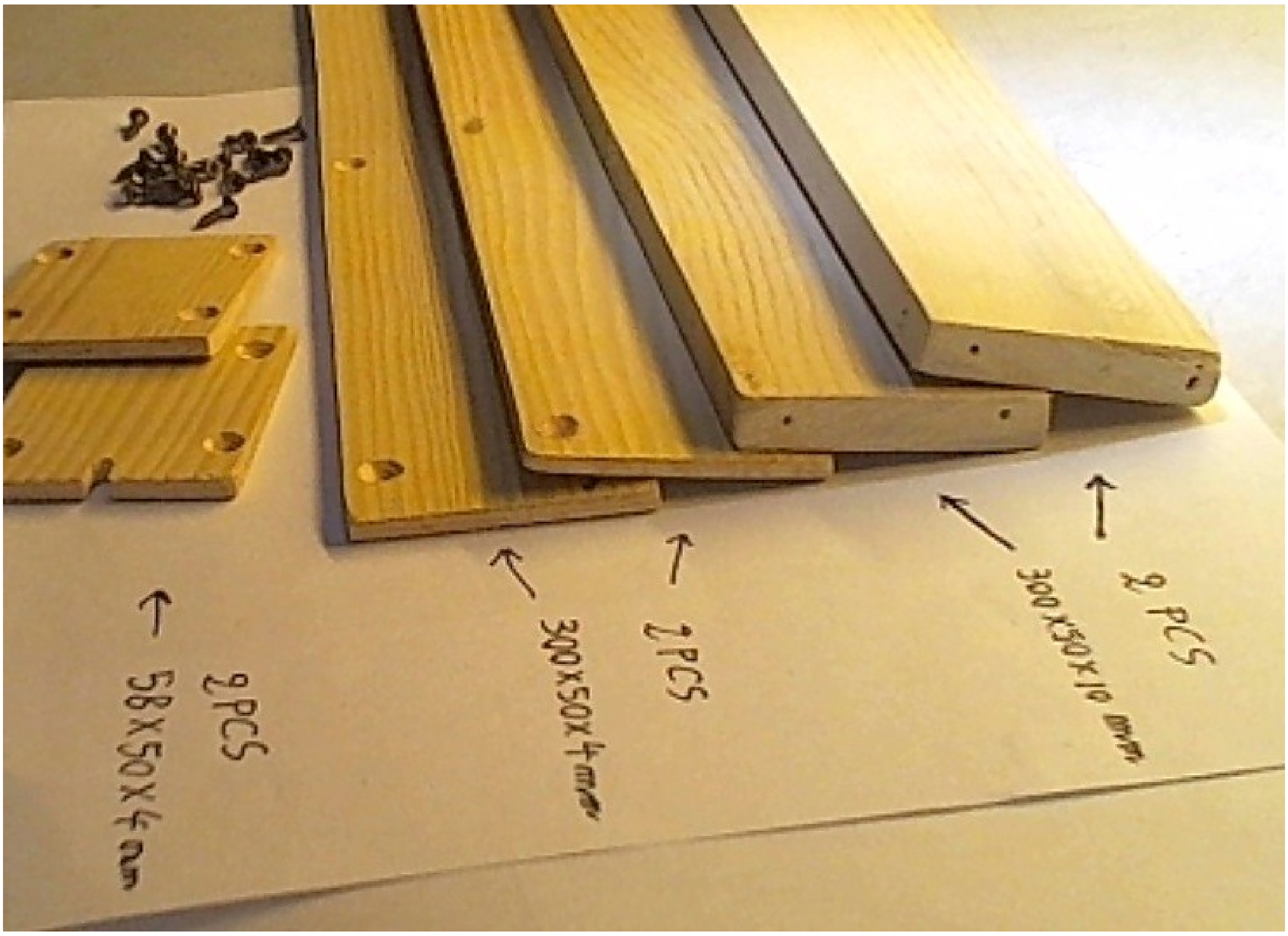
Initially you make the holes and mount the box to test.

When everything is in place, it gives a splash of flat black paint and you get beautiful pieces to see and easy to assemble.



List of materials for the container

These instructions are for a container rather long (30 centimeters) that provides good resolution even with a slit light input wide enough (about 3 mm) to gather more light. With a long structure is also easier to focus and adjust the angle of the WebCam. The length may be reduced to 20 cm, with little loss of performance or up to 10 cm, if really necessary.



Obtain 25 bronzed screws 2.5 x 8 mm, 10 mm strips and 4 mm sheets (beech is more resistant but may also fit other woods)

The pieces should be cut as follows:

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

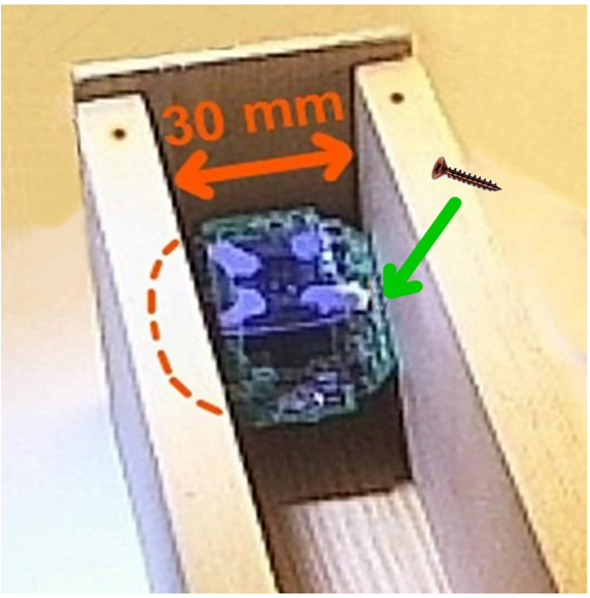
When you buy the strips and sheets you can also ask to cut, usually Brico do this service for free.

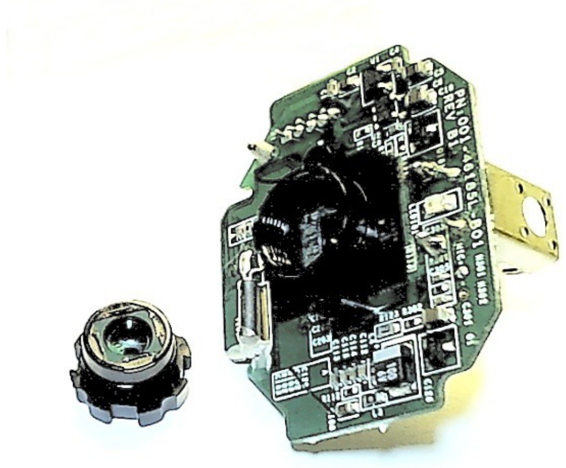
Width of the container

The width of the container is just sufficient for the height of the WebCam Trust WB-6250X, which is very small.

Note that we speak of container width and WebCam height. This is because the WebCam is mounted with its "up" towards the right wall (where you see the screw and the green arrow).

Since the WB-6250X is high few millimeters more than 30 mm, the left wall has been excavated to about 5 mm (as indicated by the dashed line).





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

The right side was originally the top of the WebCam (where there was the button). In the WebCam image the button has been removed. The hole left after removing the button is used to fasten the WebCam on the right wall.

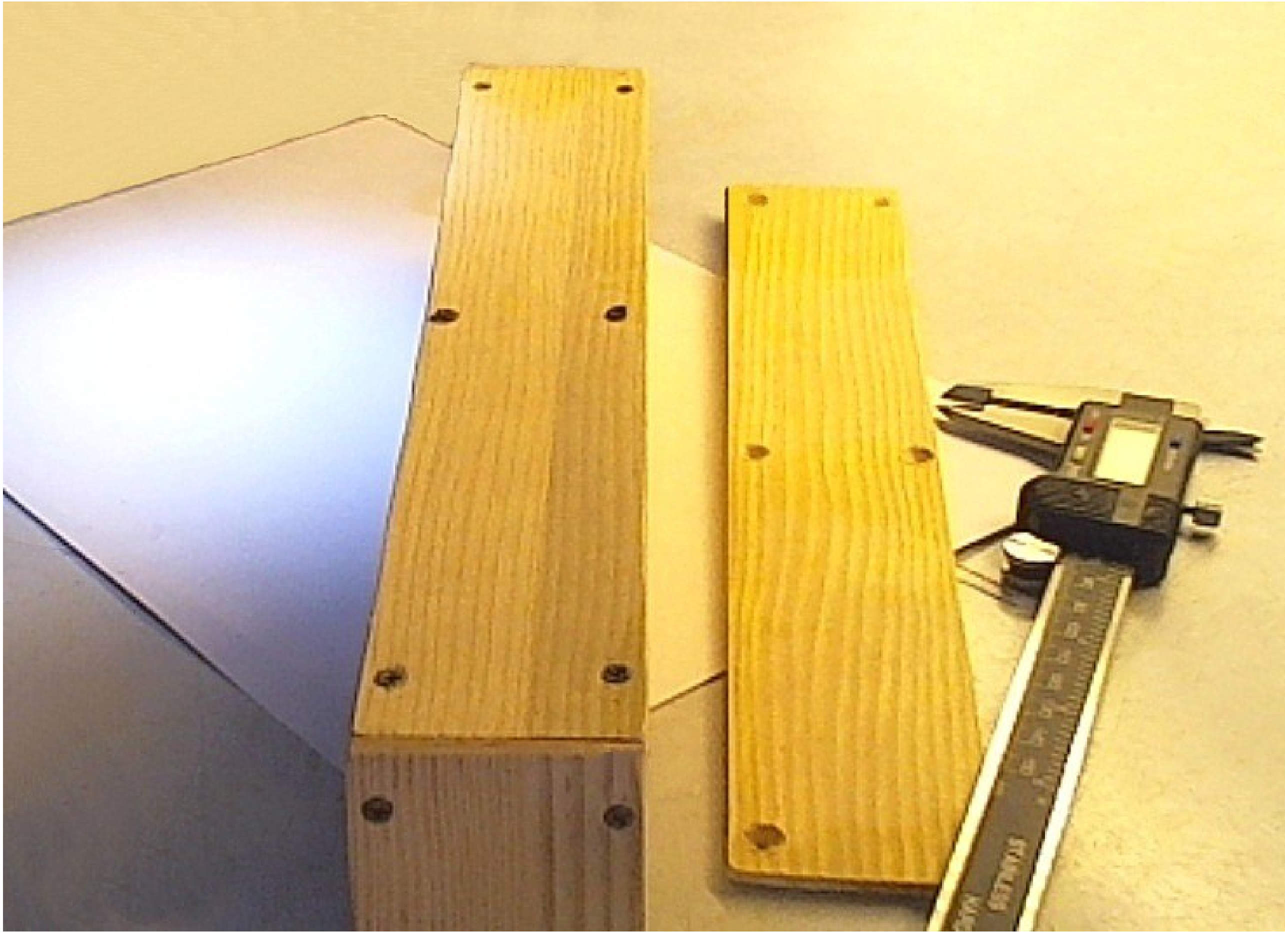
Increasing the width

The WebCam of these images is high just over 30 mm If you used a higher WebCam you should increase the width of the container.

To increase the width you must increase the width of the 4 pieces of thin wood (those from 4 mm)

The width of these pieces will be equal to the height of the printed circuit of the webcam plus the thickness of the two side strips which is 10 + 10 mm. So, for example, to a webcam 45 mm width will not be more 50 mm but 45 + 10 + 10 = 65 mm

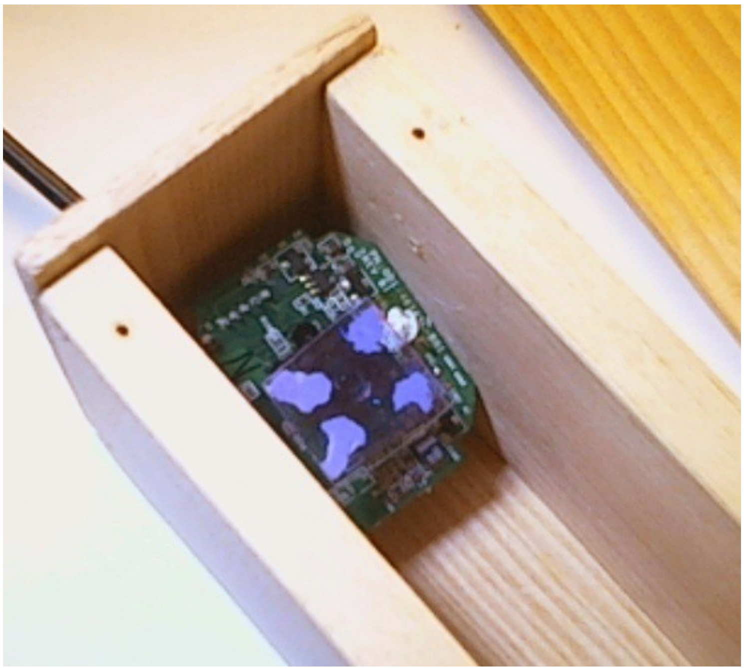
Holes and screws



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

In the picture on the right you can see that with the holes at 5 mm from the edge, the screws take exactly half of the side strips, that are 10 mm thick.

Use screws 2.5 x 8 mm, bronzed and with a countersunk head.



Prepare the webcam - 1

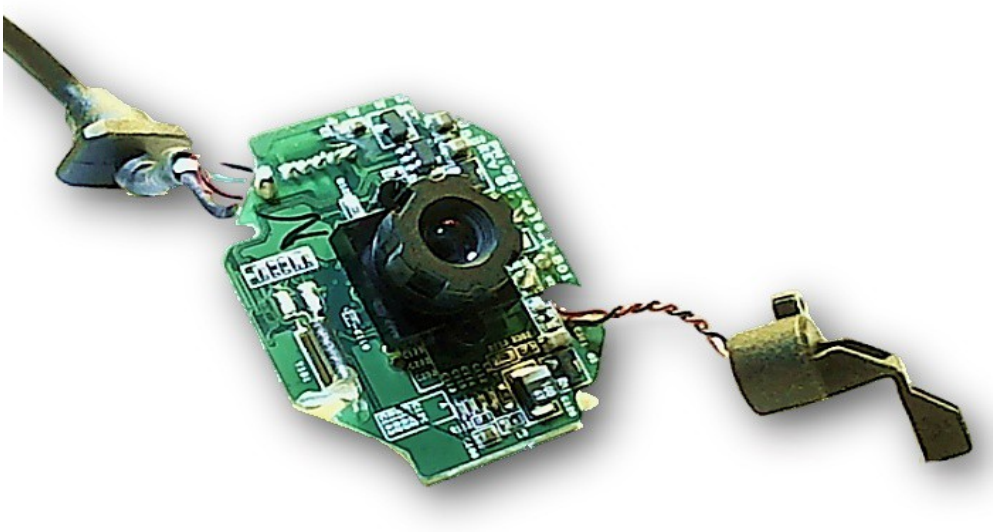
In this document you plan to use a room Trust WB-6250X, which costs relatively little and has a true hardware resolution of 1280 x 1024.
http://trust.com/en/all-products/15355-megapixel webcam-pro-

Another webcam that should be fine (but we not tried it) is the Trust WB-5400, also with 1280 x 1024 resolution of real hardware.
http://trust.com/en/all-products/15007-megapixel-usb2-webcam-live-wb5400

They can also fit the webcam from a few Euros, with a resolution of 640 x 480 The important thing is that they are small and with a printed circuit board easily fixable.

Other essential features are: the infrared filter for flat and easy to remove and that controls exposure and sensitivity manual and well working. In general, the Trust have these characteristics. If the WebCam is not a WB-6250X, check that you can remove the IR filter, and that the cam has well-functioning manual exposure controls, **before to modify it**.

Separate the room from the base and unscrew the small screw that holds the two halves of the shell. Separate the two halves of the shell by pulling force, without fear, at the end of the shell splits and you can extract the PCB.

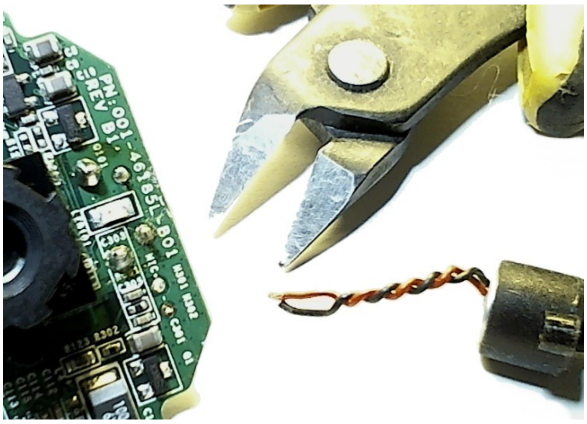


Prepare the webcam - 2

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

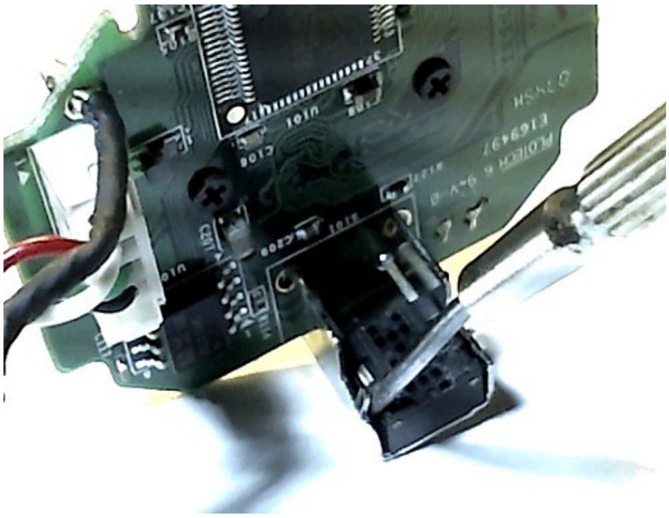
Check with a magnifying glass for any remaining wire bits that can make contact with the adjacent tracks.

Also remove the led, un-welding, breaking, or cutting it with the clippers, otherwise its light would prevent us from making good spectra.



Locate the button with a screwdriver and lift the two metal tabs that hold it.

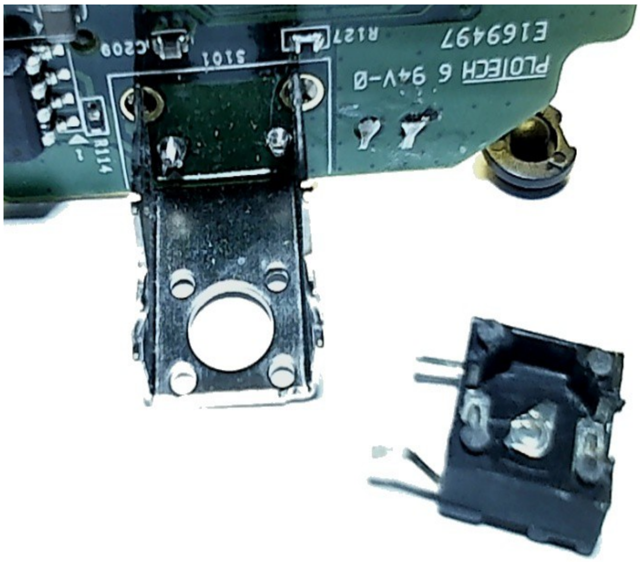
Fold the button a few times to break its terminals, as close as possible to the PCB.



If the button terminals were attached to the PCB, cut at the base, with small scissors or clippers.

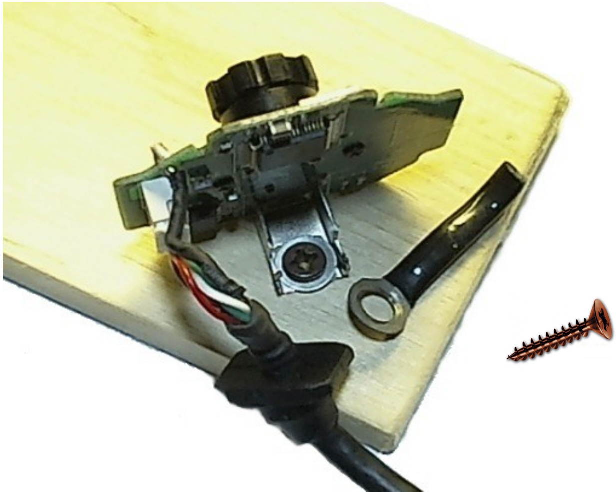
Check with the lens that there are not pieces of terminal that can make contact with the walls of the bracket.

At the end, instead of the button remains a bracket with a convenient hole to attach the camera.



Attach the webcam

To attach the webcam you need:



- A bronze screw 2.5 x 8 mm (Such as those of the container)
- A lug along with 3mm hole, covered with heat shrink tubing black.
- Possibly a washer to be placed between the wood and the metal bracket so as to make softer the rotation of the webcam even when the screw is tightened.

Discard the rubber grommet cutting with the clippers. (Be careful not to damage the cable insulation)

Use the lug to secure the cable, as shown at right.

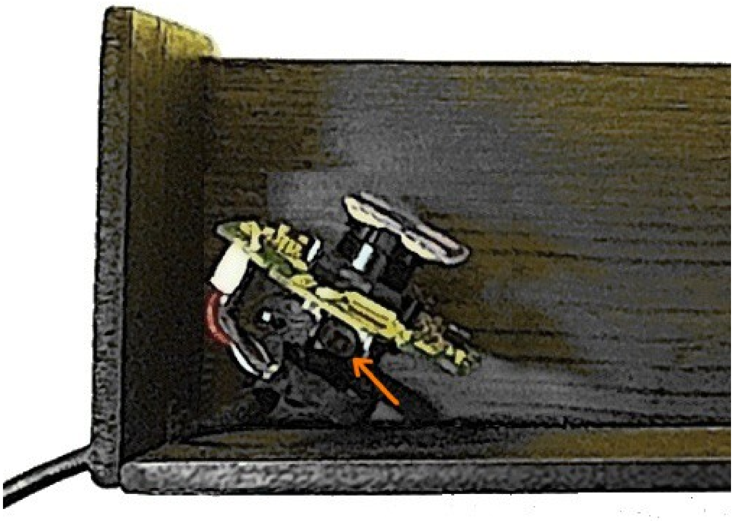
In these images the camera is screwed on a test wood, just to show the method of attachment. The correct position is shown on the next page.

The WebCam position

Screw the room to the thicker side wall.

Locate down and to the left as possible, but leaving space for turning of ten degrees, top and bottom.

The orange arrow indicates the position of the screw.



The inlet slot of the light must be horizontal and more or less at the height of the tip of the lens.

The 30 degrees of inclination provides a good compromise between resolution and amount of light collection but it is possible to experiment with different angles. By decreasing the angle the resolution increases, the lines move to the left and the light intensity decreases, increasing the reverse happens.

Depending on the light sensitivity of the camera, the focal length of its objective, its number of pixels, the number of rows in the grid (CD, DVD or network 500 or 1000 lines) and how much resolution you want to get, you might choose an angle different from these 30 degrees.

The angles from experience ranging from 20 to 45 degrees. When you change the angle of the webcam the lines moving and you have to redo the calibration. Increasing the angle of over 30 degrees you begin to lose a portion of the infrared. To measure the wavelength of the infrared LEDs is good that the scale arrivals to at least 950 nm and therefore you should not overdo this angle.

Remove the infrared filter

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

Not all cameras have the IR cut filter that can be removed. Sometimes the filter is curved and constitutes part of the lens, in these cases the webcam is not suitable.

Then before you modify the WebCam, check the back of his objective.

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

This is not easy because the filters are bonded with a strong resin. Some authors have written that warming will do best, but also warming does not change much. We always had to force, to break the glass of the filter.

Be very careful! Fragments can scratch the lens that is below and if you fail it will not be easy to find another target equal.

So get ready with plenty of light, goggles and sharp tools.

Prepare the DVD

Use a blank disc, separate the two halves of the disc with a boxcutter or a razor blade.

Discard half of the disc with the writing and use the other.

Tear off the thin silver layer with adhesive tape.

If you can not try to cut the silver layer with the boxcutter to ease detachment. Make a radial cut from the center outwards and start detaching from the cut.

With some types of discs, it may be easier to lift a corner of the film, with the boxcutter and to start from the raised position.

When the disk is divided is easy to cut with scissors. Obtain a square from the outer area of the disc (where the lines are less curved). If the square is too large it will be finished later.

In all cases, be very careful not to scratch the surface and do not touch it with your fingers.

Use a true diffraction grating

A few days ago we received the diffraction grating bought on eBay from an Isreaelian, which seems to be the only one in the world to sell them. These patterns also cheap. We had a problem with the first shipment, which was without tracking code and there is never arrived. The seller "shy_halat" was very kind and sent us free of charge, this time with tracking code, a second envelope that arrived with no problems.

The first tests have now shown that these "Highly efficient embossed Holographic Optical Elements (HOE)" produce a spectrum much brighter than the DVD. It is therefore easy measure also not very bright sources.

The defects of this grating compared to a fragment of the DVD are:

- The resolution is slightly lower, because this grating has only 1000 lines / mm instead of 1350 lines / mm of the DVD and then deflects a bit less.
- The fragment of the DVD is stiffer and therefore easier to handle and fix to the lens.

The defects of the diffraction gratings are amply rewarded by their greater brightness. So please buy a sheet as soon as possible on eBay. It takes some time for the shipment from Israel so buying it now will come at the right time, at the end of the construction of the spectrometer.

This is the link to the eBay page:
http://www.ebay.it/itm/Diffraction-Grating-Roll-Sheet-Linear-1000-lines-mm-Laser-Holographic-Spectrum-/280859388704?pt=LH_DefaultDomain_0&hash=item4164862b20

And this is the title of the page:
"Diffraction Grating Roll Sheet Linear 1000 lines/mm Laser Holographic Spectrum"

The paper that sold on this page (for only 2.88 Euro + shipping 4) is 6 x 12 inches, which are 15 x 30 cm. There is something to do for all the friends and spectrometers are still fresh enough to do some fancy glasses to give to childrens.

Buy only the type 1000 lines per millimeter, the other two types, 500 lines / mm and 13500 lines / inch, are not good for the spectrometer.

Fix the DVD fragment (or the grating)

For now .... do this with pattafix (a adhesive gum).

The lining should be horizontal (outer edge of the DVD at the top)

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Very important: In front of the lens, between the lens and the reticle, there should be about 5 or 10 mm tube black. In this way you eliminate the light hitting the lens by smear and the spectrum is improved.

In some WebCam, such as those shown in this document, the lens barrel is long enough to do himself a good lens hood. In all cases it would not be a bad idea to try to extend it by a few millimeters, with a piece of black pipe for electrical installations.

- - - - - -

We have not yet images to display, we publish them in future versions.

Focus the lens

Operation important but difficult !!!

We are looking for a somewhat less terrible than “trial and error” ...

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A good solution is to screw a bracket "L" on one side of the container, with the long part that protrudes up front of the lens and the grating glued on the tip of the "L".

In this way one can rotate the lens to focus, maintaining the grating in the same position.

The system works well but we have not images to display, we publish them in future versions.

The anti-glare diaphragm

The inner walls of the spectrometer are affected by very light smear that reflect light, even if well painted matte black, and even if coated with black paper. This diaphragm, if well built and just the right size, can completely eliminate glare.

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

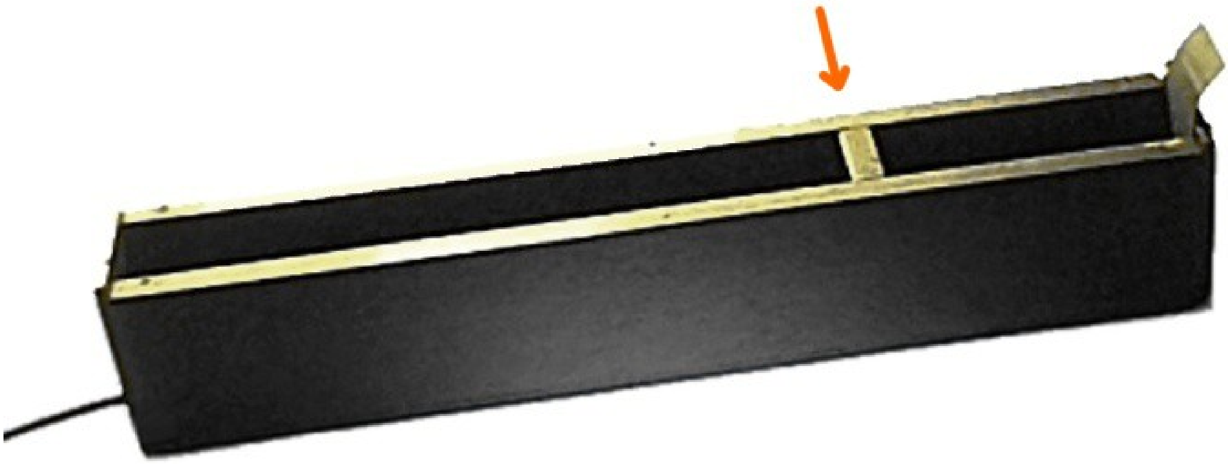
Dig a rectangular hole 25 mm high and 15 mm wide. To do this you start doing a lot of holes in the hole with the drill, then join the holes and then straighten the walls with a flat file.

For best results, the hole should be countersunk (expanded from the camera) in order to present sharp edges toward the inlet. In this way the incoming light does not strike the inner walls of the rectangular hole and does not create reflections.

Better yet would be to make the hole much larger than necessary (30 x 20 mm) and then tighten it with black cardstock, cut with a utility knife and fixed top and bottom, with two thumbtacks

To obtain a complete elimination of the reflections the hole should be more wide and high as possible. Since the height of the lens with respect to the inlet slot can vary from one building to another, the best way to find your ideal size is putting a strong light and try with black cardboard, to what extent can tighten the four walls of the hole.

In our tests a good position for the diaphragm was the point indicated by the orange arrow, about one-third of the container and closer to the entrance slit of the room. If the width dl diaphragm is accurate you can easily insert and remove in various positions and to try to change the size of the black card.

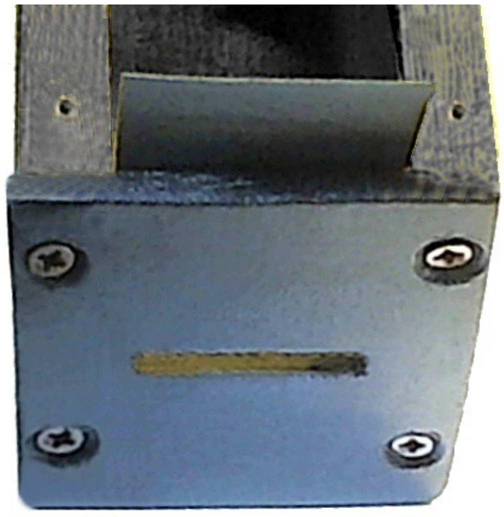


The light inlet slot

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

We recommend starting with a slit 3 mm for a spectrometer 30 cm long (1 mm each 10 cm of length of the spectrometer).

With a slip of paper or plastic, thin black, you get a very good and simple diaphragm to adjust the thickness of the slit.



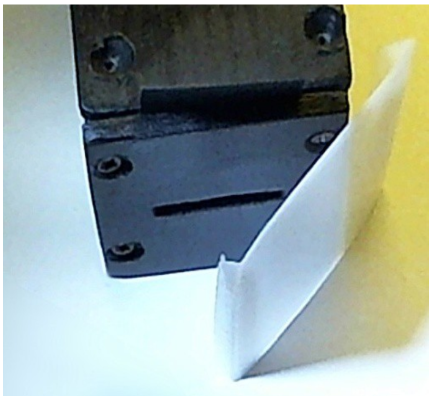
When screwing the lid leave the right space for the diaphragm.

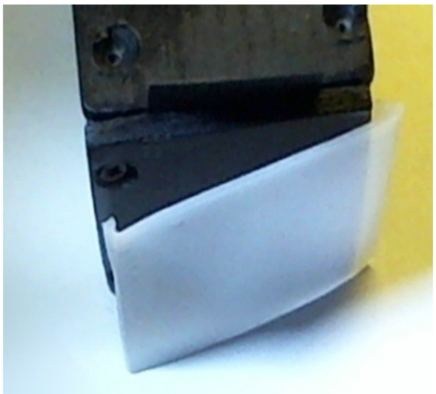
The diaphragm should slide easily in the top and bottom, its slight curvature provides the necessary elasticity to hold it in position.

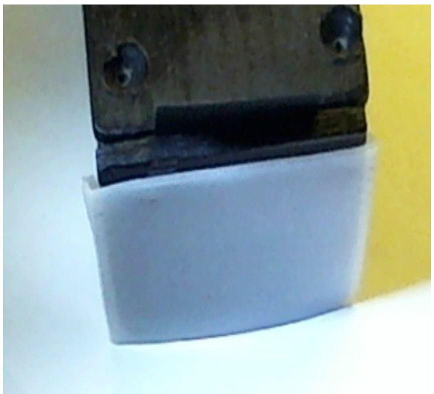
The diffuser

This screen serves to prevent the rays of light from entering directly into the black room and cause reflections inside. With some sources, such as LEDs and lasers, the screen is absolutely necessary, but in other cases it is better to remove it.

Without the diffuser the spectrometer is very directive and this could be useful for measuring color zones away. For example, to see the color differences between various areas of the sky.







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

Choose a large jar, with the front and rear wide and flat and made of good plastic opal, white, thin and light.

The jars are just fates of opal polypropylene which diffuses light very well and does not dim. May have to try different brands to find the best, with the plastic thinner and brighter.

First you need to remove labels. Fill the container of very hot water to soften the adhesive. Lift the plastic of the label on one side and pull it slowly to leave no glue. If you can not, change jar and find one with labels easier to remove.

Cut a large rectangle from the flat portion of the jar. Then progressively refine it with scissors and bend with the pliers until you get a screen that snaps right on both sides of the spectrometer.

Calibration light source

For periodic calibration is good idea to have a compact fluorescent lamp (the so-called energy saving bulbs). Those lamps generates two mercury rows that are perfect to calibrate the spectrometer.

This lamp should be of low power (a few watts maximum, otherwise too hot) and you should enclose it in a cylinder opaque (black tube internally coated with white or reflective material) so as to direct the light forward, and not to be dazzled during calibration .

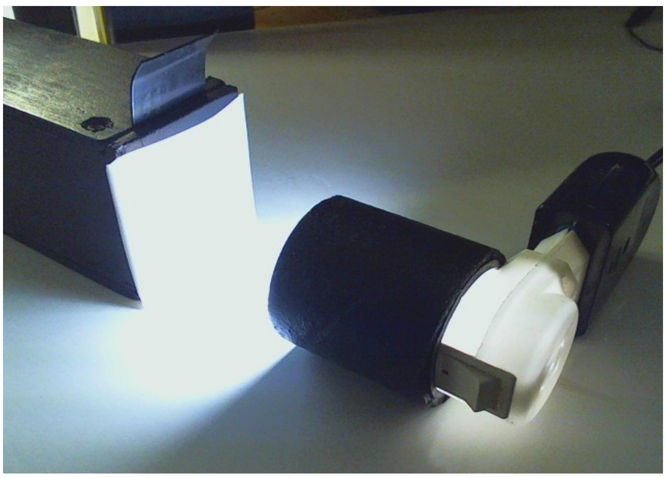
The lamp you see here on the left consumes only 1 watt and warm very little. You can find it on eBay for less than 3 euros, shipping included.

Search for "night lamp with plug", there are also other models but make sure that it is not light "glowing" or "Led". Make sure it is "Glow"

Or look for in a supermarket a few energy-saving lamp Watt, 2 or 3 watts maximum.

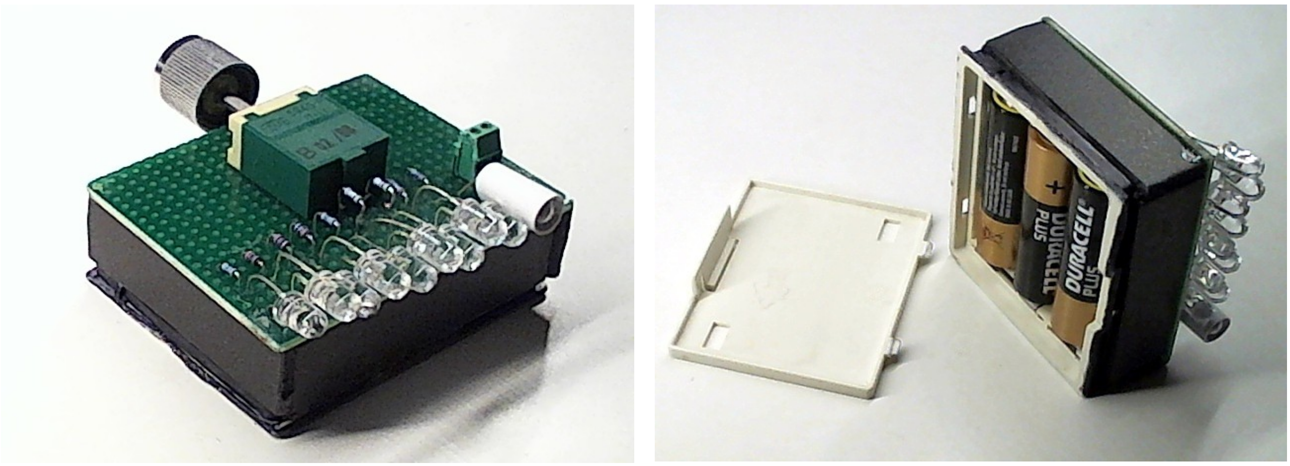
The lamp on the right is 3 Watt, is located on eBay searching for "Fluorescent 3W", or in supermarkets. There are models with the little connection (E14) or the large (E27)

Please note that sometimes write "Glow" but then it turns out that it is a "LED" lamp, like this image. Please read the entire listing carefully, paying attention to the word "LED".

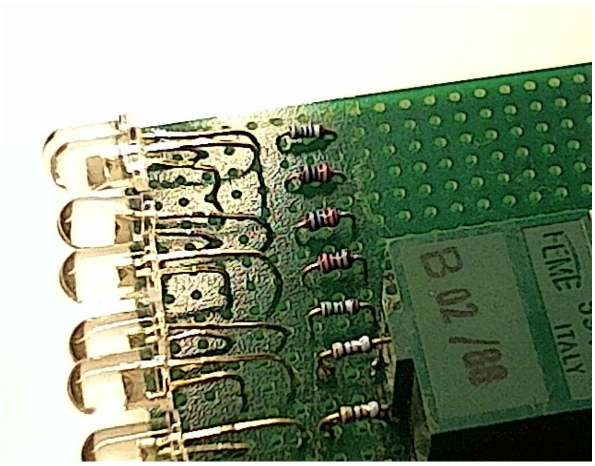


Test light sources

To develop the spectrometer and improve its resolution is useful to have light sources with different wavelengths.



With a container for three AA batteries, a switch and some LEDs we build a small device very useful. Do not underestimate it, with this device all becomes much easier.

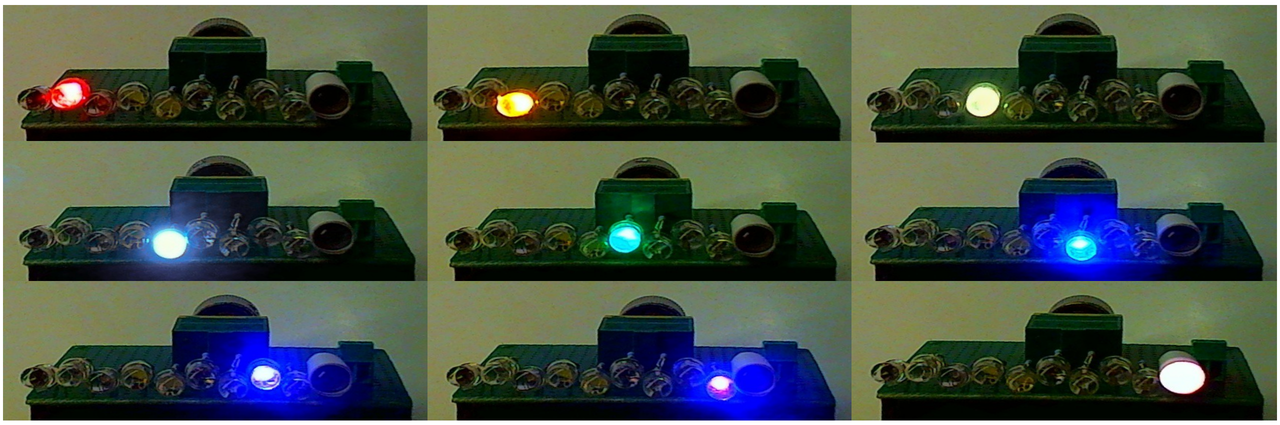


Here you see a particular of the resistors (one for each LED) and the 12 positions switch.

As LED you can use what you find. In this example, the LEDs are: Infrared, Red, Amber, Warm White, Cool White, Green, Blue, UV 407nm, UV 395 nm and a filament light bulb (150mA at 6Volt).

The resistors of the LEDs are 100 ohm but some were raised to 150 and the other 220 ohms to approximately equalize their peaks in the spectrum.

The height of the LEDs from the table top must be more or less the same as the entry slit of the spectrometer. The inlet slit must be covered with diffusion filter otherwise the location of the LEDs become too critical.



The first led to the left is Infrared and has not been turned on in these images.

Light sources for absorption measurements

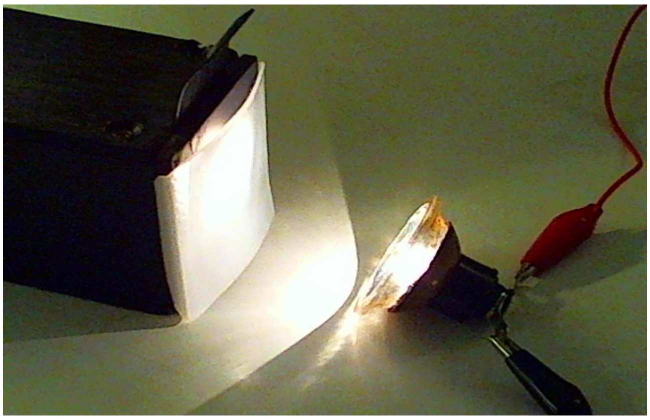
The absorption measurements are used to measure the response curve of the color filters and the absorption of various substances, for example olive oil.

To measure the absorption, it is necessary to have a source that emits light in the entire spectrum. The sources of this type are called "Broadband".

A broadband source should not have a perfectly flat spectrum (the software compensates for changes when you press the button "Reference"), but should provide enough light energy in the whole area of interest.

The energy ratio between the areas where the source emits a lot of energy and those where it emits little, shall not exceed 2 or 3 times, otherwise the glare and reflections from regions of high energy cover those of low energy and it becomes impossible to measure strong attenuations. (In areas where the lamp emits little the line never goes to zero even if the filter under measurement greatly attenuates those wavelengths)

A "broadband" source should cover at least the visible (400 to 700 nm), but even better if it would cover the whole field measurable (from 350 nm to about 950 nm)

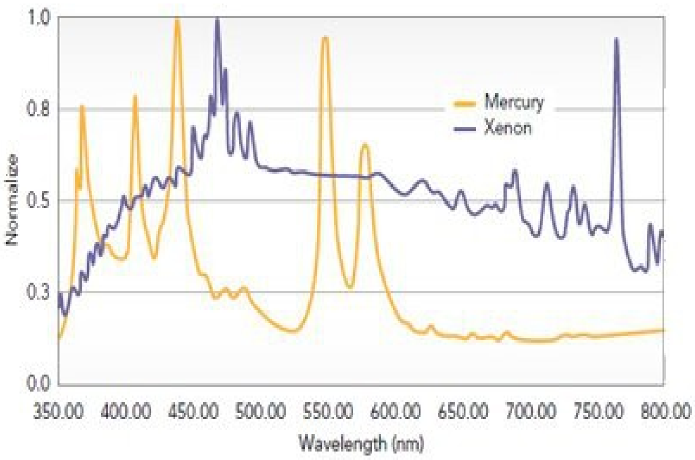


With an incandescent bulb, ranging from 500 nm to infrared energy but below 450 nm is very little and there are significant differences in intensity between different areas of the spectrum.

A halogen lamp is better but the energy around 400 nm is always a small fraction of that in the red zone.

To cover the whole spectrum from ultraviolet to infrared, we could use a xenon lamps.

The xenon lamps produce a fairly uniform energy from 400 nm up to 800 nm

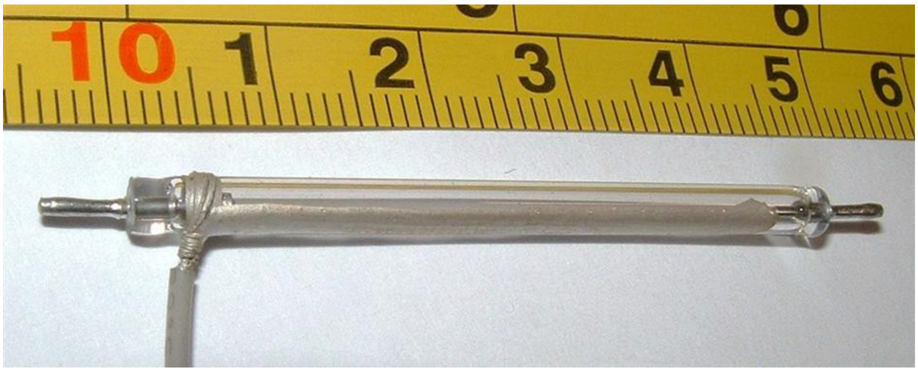


Xenon broadband sources

Modifying strobe units (about ten euro on eBay, shipping included) or flash lamps of the old cameras disposable (a few Euro on eBay), we can avoid to give $ 934 to OceanOptics ($ 418 for a single bulb part)

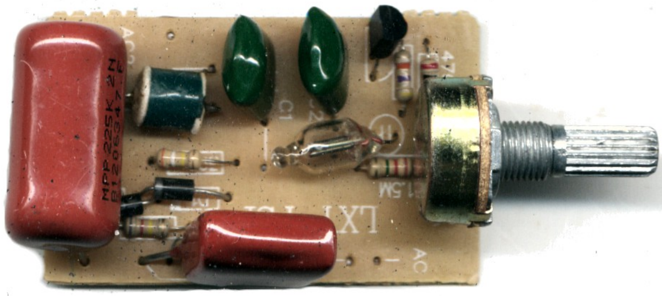
Of course a OceanOptics (http://www.oceanoptics.com/products/px2.asp#output) has features more thrusts, comes to more than 200 Hz repetition and 9.9 Watt, while we content ourselves with 50 Hz and 3 Watt (which in practice are just as good).

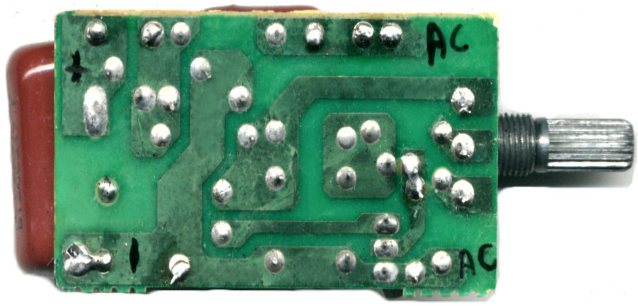
All other features are very similar. The principle of operation is the same and the light of the some Euro Xenon lamps is the same as the 418 dollars lamps.



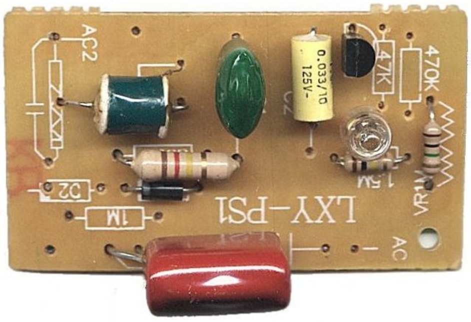
Note the gray paint that covers the conductive wire of ignition and extends along the lamp. Be careful not to overexert this thread, because the paint may crack. In this case begin to twinkle in the breaks and flashes become unstable.

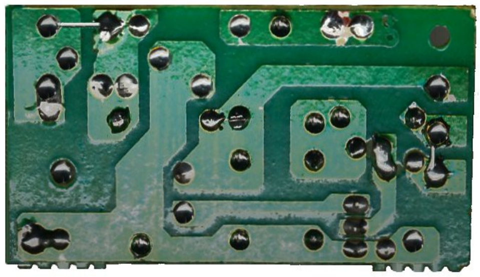
Xenon source obtained from a strobe lamp



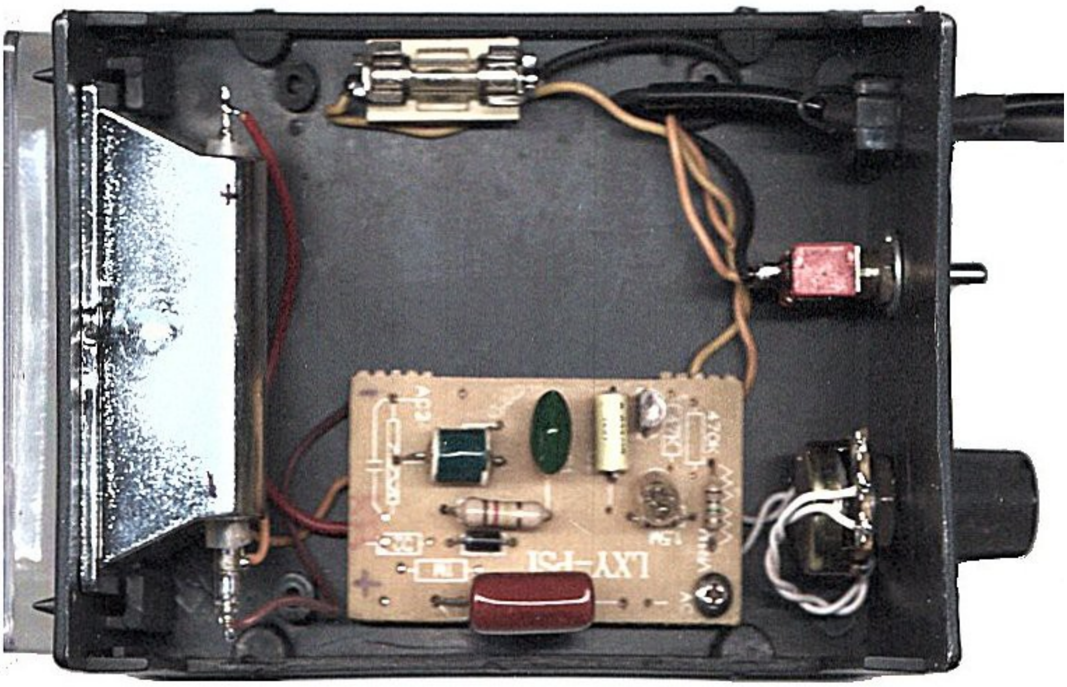


In the original circuit the potentiometer regulated the frequency of the pulses, but it was not possible to exceed 8 or 10 Hz. (Wiring diagrams are on the next page)



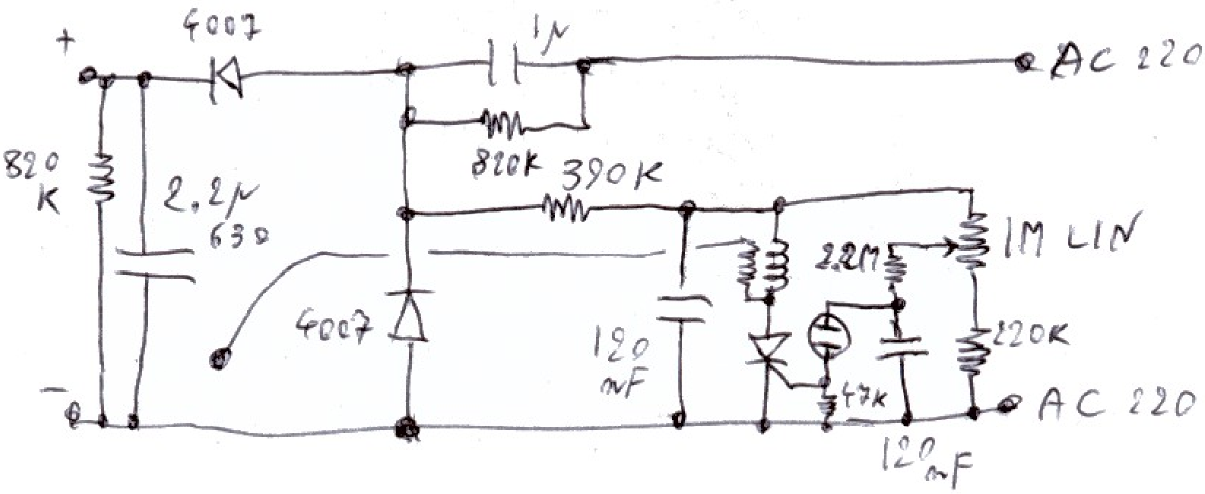


The modified circuit flashes at 50 Hz and fixed the knob adjusts the intensity of the light produced. The new version is more simple and put forward some components, which are useful for other projects (mainly the large capacitor on the left 2.2 uF / 250 Vac)

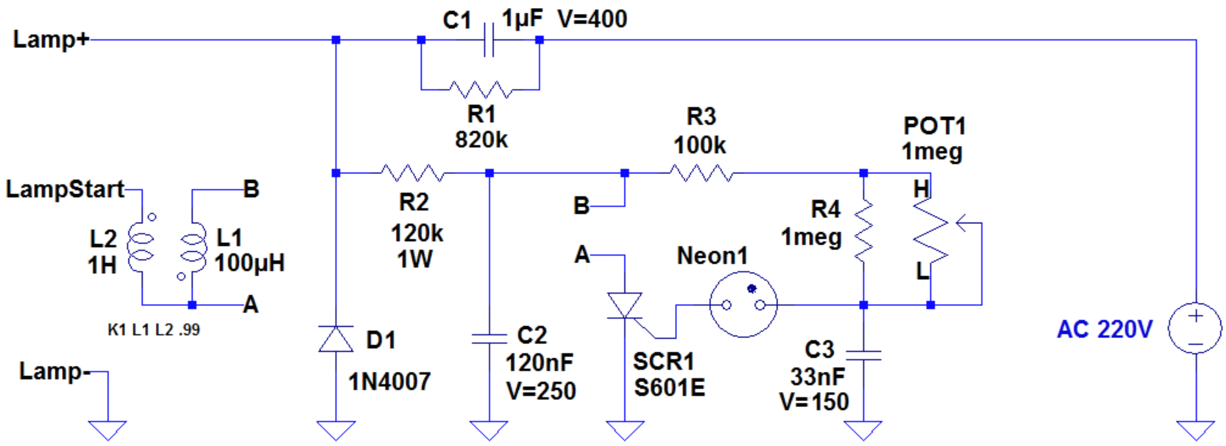


It is a good idea to fix the circuit with a screw (it was originally attached to the potentiometer and rather unstable). And also add a power switch and a fuse holder. A 1 Amp fuse is fine but you could try to get down to 200 mA.

Xenon source obtained from a strobe - schematics



Original: The maximum frequency was 8 Hz and the energy of the lightning was unstable, because the flashes were not synchronized with the 50Hz mains.



Modified: The flashes are synchronous with the 50Hz and the knob adjusts the intensity of the produced light.

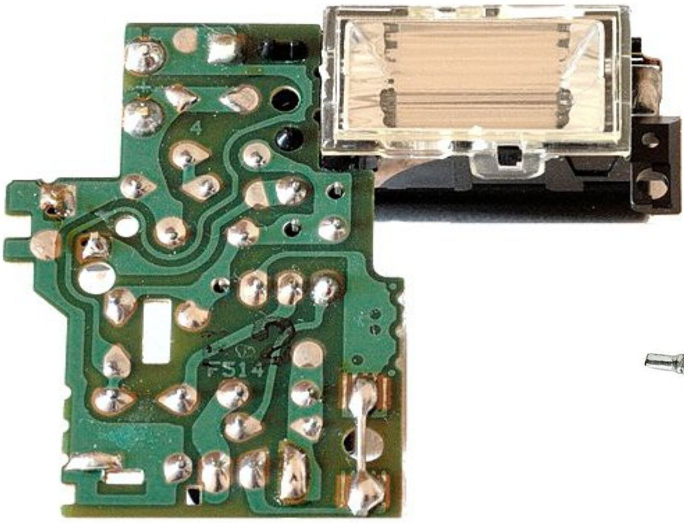
R2 adjusts the driving voltage of the ignition transformer and so the voltage on the "LampStart" wire, with 120 k will have about 180 volts on the transformer and a few thousand volts on the lamp. If the brightness is unstable, you should lower R2 to increase the voltage, but the noise increases dramatically and there is also the risk of exceeding the maximum voltage bearable. If the transformer or wires sparkle stability gets worse instead of better.

Lacking the 2.2 uF capacitor from the energy reserve is one-third (1 uF instead of 3.2 uF total) but since the flash rate is about six times greater, the average power should increase by about 2 Watt original, about 4 Watt. But in practice it arrives just 3 watts, due to the increased series resistance. It would have been easy to gain more power, but do not overdo it, not too much heat lamp. (And attention that it gets very hot, do not touch them with your fingers, not even a cold)

The Xenon lamps are always very unstable due to their nature and also the best vary in intensity from a flash to another. Adjusting the potentiometer can be found positions which make the light more stable.

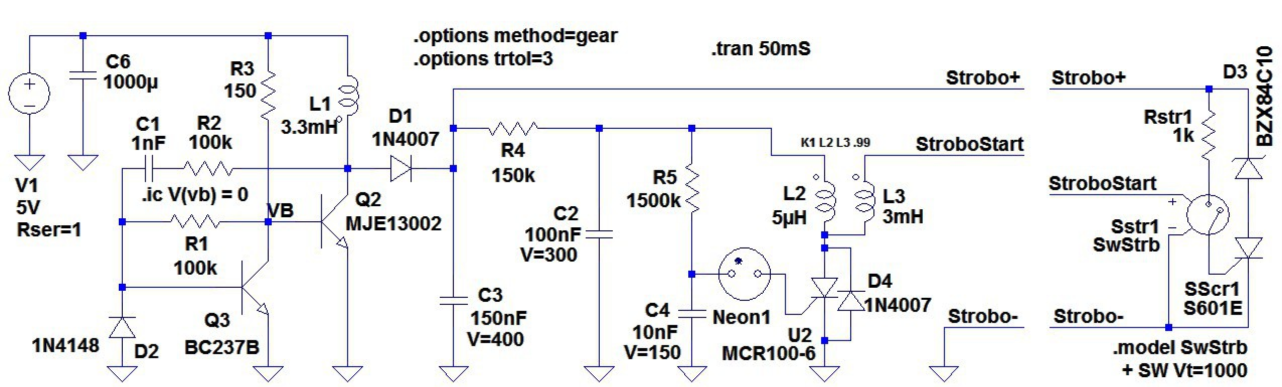
You can download the simulation files: StroboDriver_Original.asc and StroboDriver_600V_50Hz_Final.asc
To simulate use LTSpice and our component libraries: http://www.theremino.com/downloads/uncategorized#ltspice

Source xenon lamps made from Flash



Open eBay and search for "disposable camera with flash". Some sellers in Germany also sell individual bulbs (or ten at a time). But you will probably spend less to buy a whole disposable camera, and it is easier to find.

Tests with these lamps are not progressing well, we could not make them blink rapidly, with constant intensity. In the specifications of these lamps is that the law can not make more than one flash every 20 seconds. The light emitted is very unstable, to stabilize it must increase energy output at each flash, increasing C3. But increasing energy the lamp gets too hot and there is danger of explosion.



This scheme is approximate, it flashes fine but the light is unstable. Consider it a starting point and make your tests. If we can improve we'll publish it in future versions.

To facilitate researches, you can download the simulation files: XenonFlashDriver_Neon_3.asc
To simulate use LTSpice and our component libraries: http://www.theremino.com/downloads/uncategorized#ltspice

Conclusion: We recommend using the strobe of the previous pages or a halogen lamp.
The halogen lamps have a little less UV, but emit much infrared
and have a spectrum very linear, with no lines.