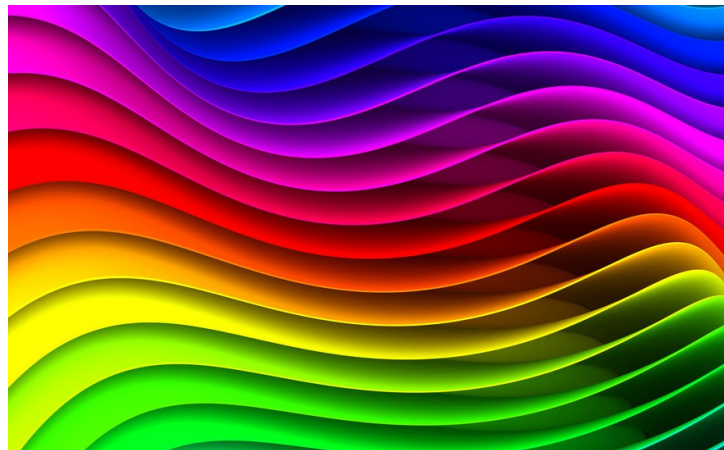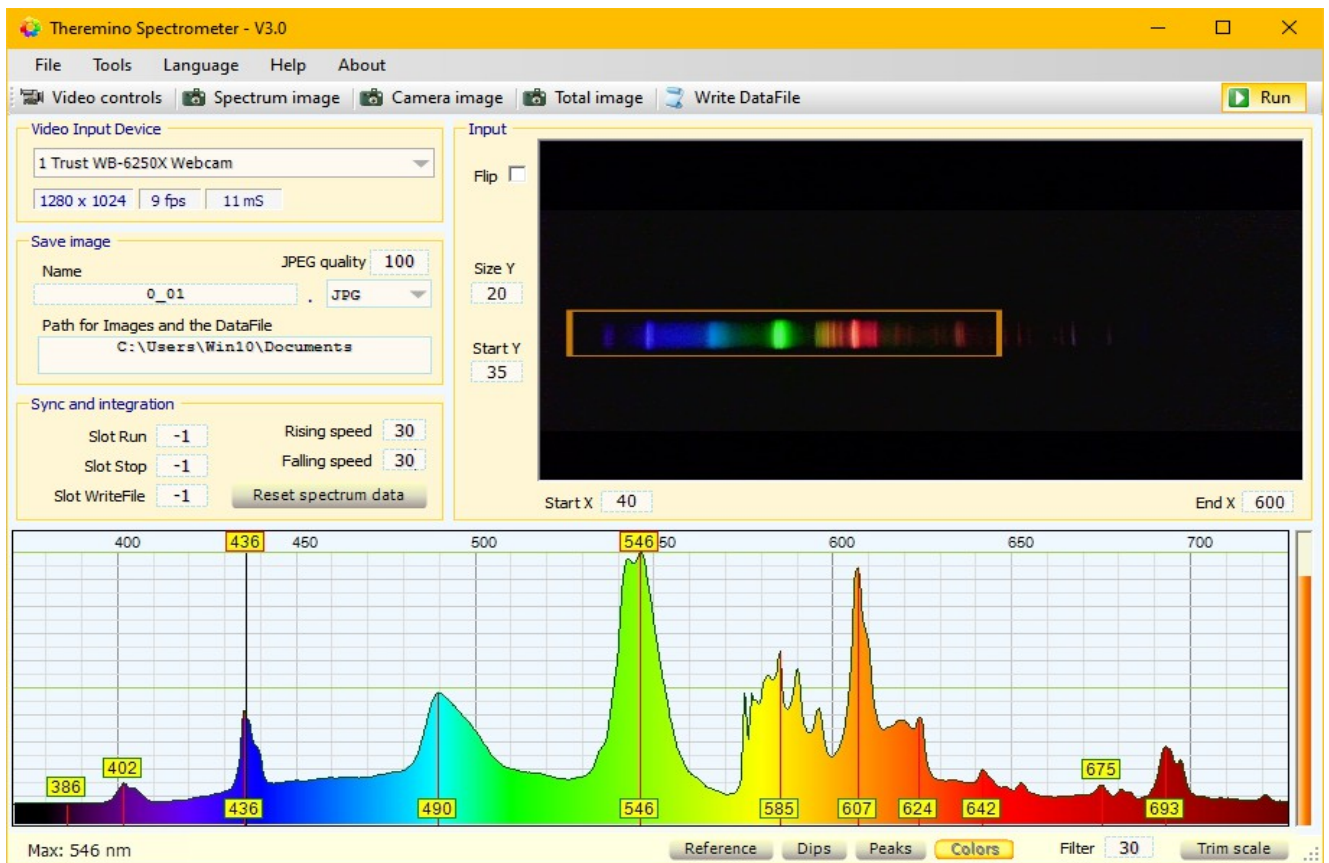Theremino **System**

Theremino Spectrometer Instructions

Theremino Spectrometer

This application is written specifically to derive the ==best possible features from a spectrometer based on Webcam.==

If the operator knows his instrument and keeps the measurement conditions within the tolerable range, it can ==save a few thousand Euro and get the same results== you would get with professional tools.

The weaknesses of a spectrometer based on webcam are:

- Dynamics Limited. You must be familiar with the instrument and use the right amount of light and appropriate exposure settings. If the light and the sensitivity is too high, they appear artifacts that distort the spectrum. If they are too low, the lower rows disappear.

- Strong dependence on the characteristics of the WebCam. With a few WebCam results are much better than with others. Some drivers may be completely unsuitable and even color settings and sensitivity can cause significant variations in the quality of the measurements.

- Accuracy and resolution limited. The resolution of the camera and the non-linearity caused by the deflection grating and by the objective lens, limits the accuracy to about one nanometer.

- Only wavelengths can be measured, not the amount of light. The Webcam (and all cameras) have a response not linear so quantitative measurements are impossible. You can not measure the amount of light, but only appreciate relative and approximated differences.
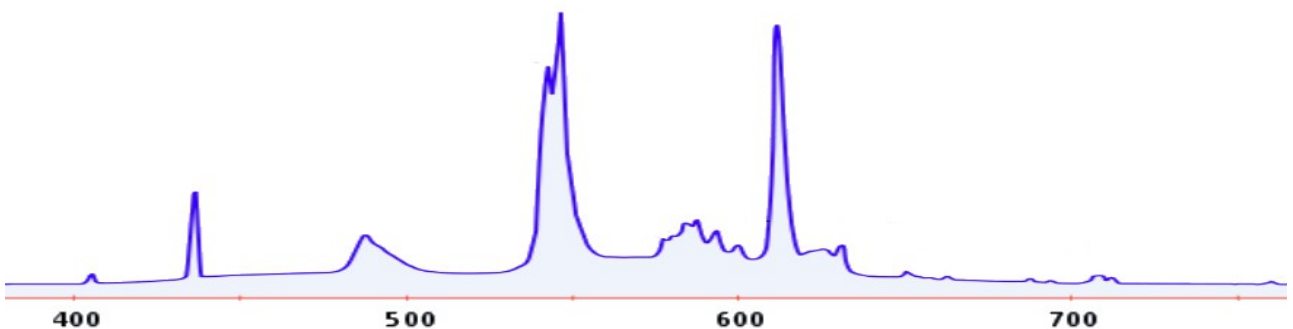
However, the ==features are good for teaching and for small laboratories.==

Performance

With good construction, good WebCam well and adjusted parameters, you can get graphics very similar to those of the best professional spectrometers.
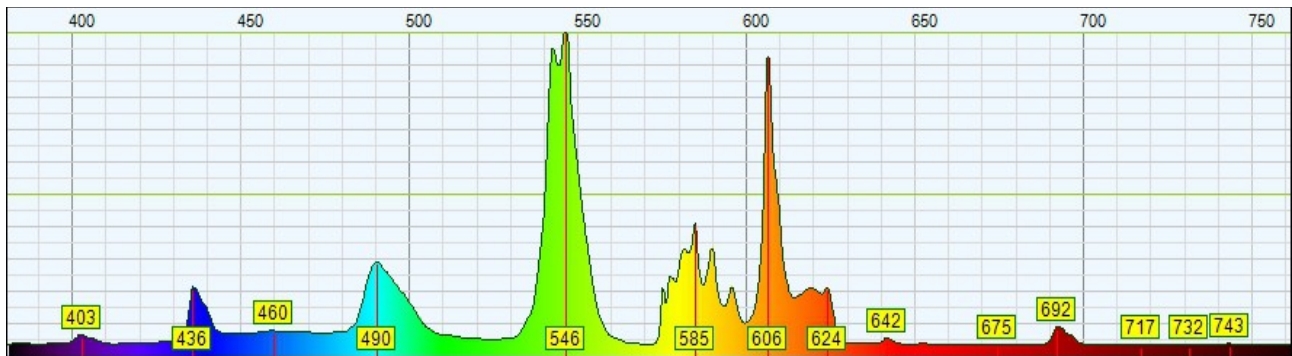
Spectrum of a fluorescent lamp obtained with Theremino Spectrometer

Spectrum of a fluorescent lamp obtained with a professional appliance (An "Ocean Optics HR2000 High-resolution Fiber Optic Spectrometer" which costs about $ 1,200, those interested can find them used on eBay for about $ 600)

The high cost of professional equipment is justified by other features, not visible in these spectra. The professional appliances are the most sensitive, have a greater dynamic range (the ratio between the minimum and maximum measurable light) and can also make quantitative measurements.

Similar spectrometers

We did not invent anything new, there is for example the PublicLab spectrometer. We, however, need not be connected to the internet and does not ask for the email address to work. There would also be some other advantages, to use our Theremino Spectrometer (mainly that it works). To test their software start here: http://spectralworkbench.org

We have attempted to use their long-Spectral Workbench, but we could not do the calibration and the yellow line does not move either on on Firefox than on Google Chrome (they themselves write that does not work well). We also tried with Internet Explorer, but it is even worse (the "Legacy" does not open its own). But an interesting point of PublicLab is selling a kit to build the hardware, just $ 40, including WebCam. Someone might be interested in buying it: http://store.publiclab.org/products/desktop-spectrometry-kit

Their KIT works for sure with our software. In the pictures published has little resolution but it could also depend on a poorly tuned. If necessary, give it a try and let us know, thanks.
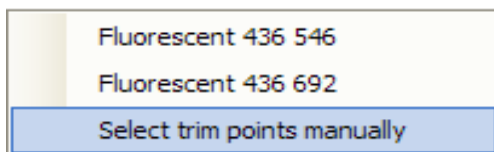
The menu commands
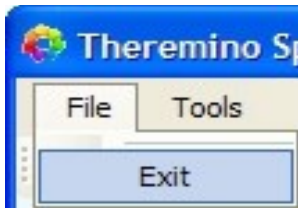
The menu "File" has only the "Exit" command, that can be used to close the application.

To close the application you can also use the white cross on a red background in the upper right corner of the window.
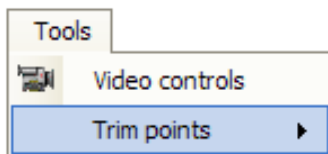
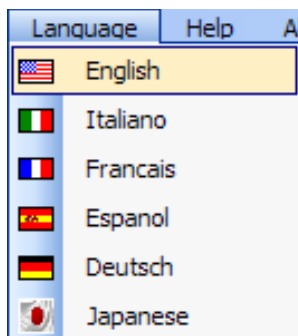Opening of the WebCam control panel.

Opening the sub-menu of the calibration points.

Setting the standard calibration points.

Setting the alternative calibration points .

Manual setting of the calibration points.

Choice of languages.
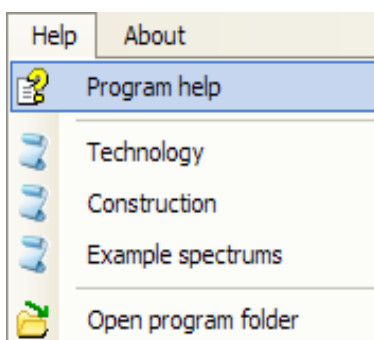
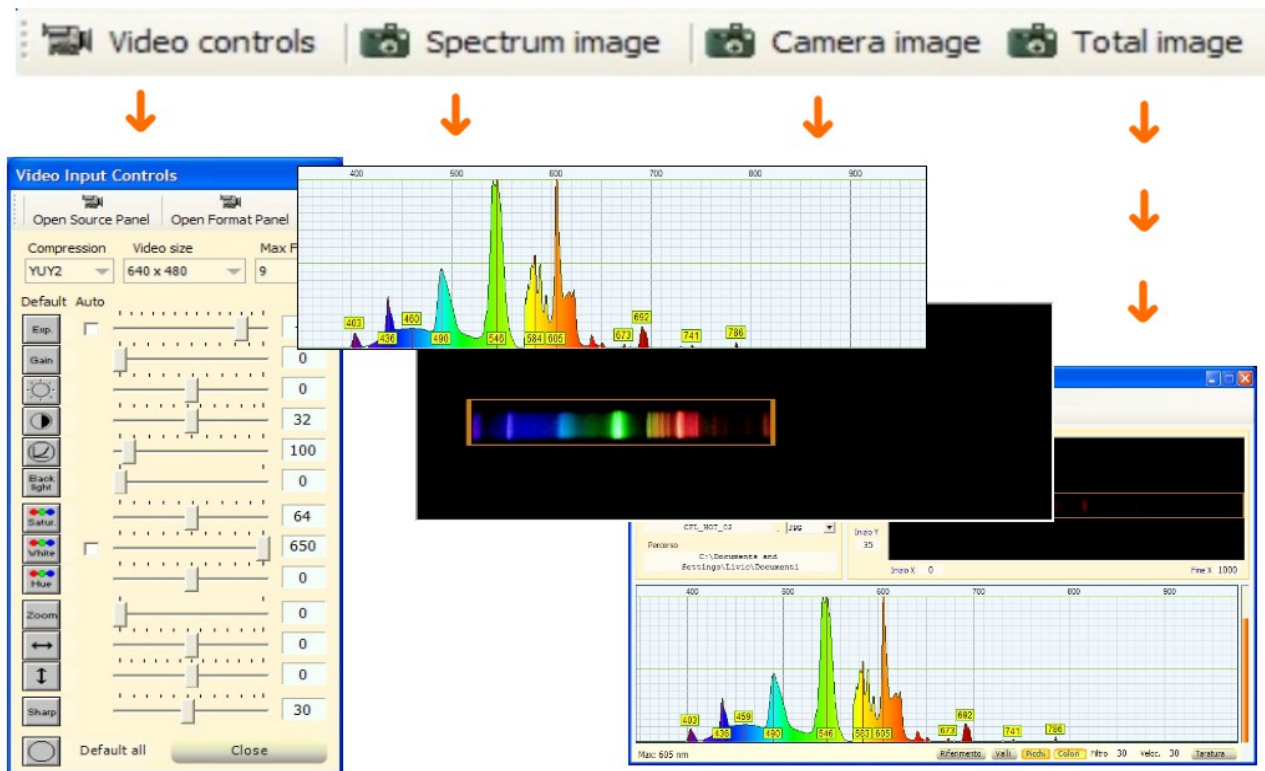Operating instructions (this document).

Principles of operation of the spectrometer.

Instructions for the construction and adjustment of the instrument.

Various information on the spectra and light sources.

This command opens the application folder, to control and edit documents of languages and other files.

The tool bar controls

Video Controls
With the button "Video Control" opens the panel to adjust the parameters of video input (see page 7).
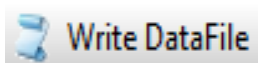
Save image spectrum
With this button you save the image of the spectrum area.

Save camera picture
With this button you save the image of the camera area.

Save image total
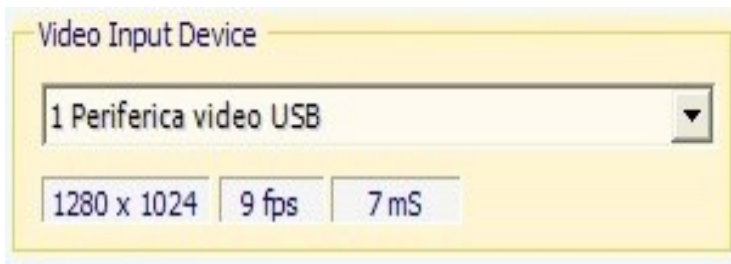With this button you save the image of the total application area.

Write data file
With this button you write the spectrum data to a file.

Run
With this button you start or stop image acquisition.

The Video Device panel

Selecting the video input device

Clicking on the name you choose the input device. When you buy a device to be careful not to be fooled by the many mega-pixels that are often declared. The mega pixels interpolated by software always very much more of the real hardware resolution, but you have to identify the real resolution, which is often the usual 640 x 480.

Information boxes of video input device
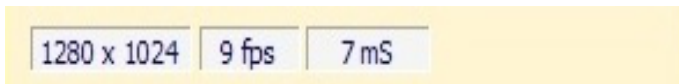
The first box shows the currently set resolution.

The second box shows the frames per second "actual". When you set a high value for the parameter "Exposure" does not fall below the value of the frames per second set in the control panel.

The third box indicates the milliseconds used by the software to process the image. This time determines the CPU usage and it is good that it is as low as possible. Depending on the characteristics of the PC and what options are used in the program, this time can go from a few milliseconds, up to a maximum of a few tens. The total consumption of the CPU is given by milliseconds multiplied by the frames per second.

To limit the CPU consumption do not overdo it with the resolution of the camera. Set over 1024 or 1280 at best a waste, because it is definitely a resolution "fake," interpolated into the driver.

Always to limit the consumption of CPU is recommended to limit the frames per second in the settings of the video device (the panel of the next page). Setting 9 or 10 frames per second is obtained a considerable saving of the CPU, while maintaining a reasonable speed of response.

Adjusting input video parameters

These properties are only accessible if you use devices with video driver type "WMV". If you only have drivers "VFW" it will be necessary to use "Open source panel" and "Open format panel" as shown on the next page.

Depending on the device selected video some of these properties may be missing or disabled.

	Video Input Controls
	Open Source Panel Open Format Panel
	Compression Video size Max FPS
	YUY2 640 x 480 9
	Default Auto
Exposure time	Exp. □ ———— -3
Gain	Gain 0
Brightness	0
Contrast	32
Gamma	100
BackLight	0
Saturation	64
White Balance	□ 650
Tint	0
Zoom	0
Pan	0
Tilt	0
Sharpness	30
Default for all parameters	◯ Default all Close
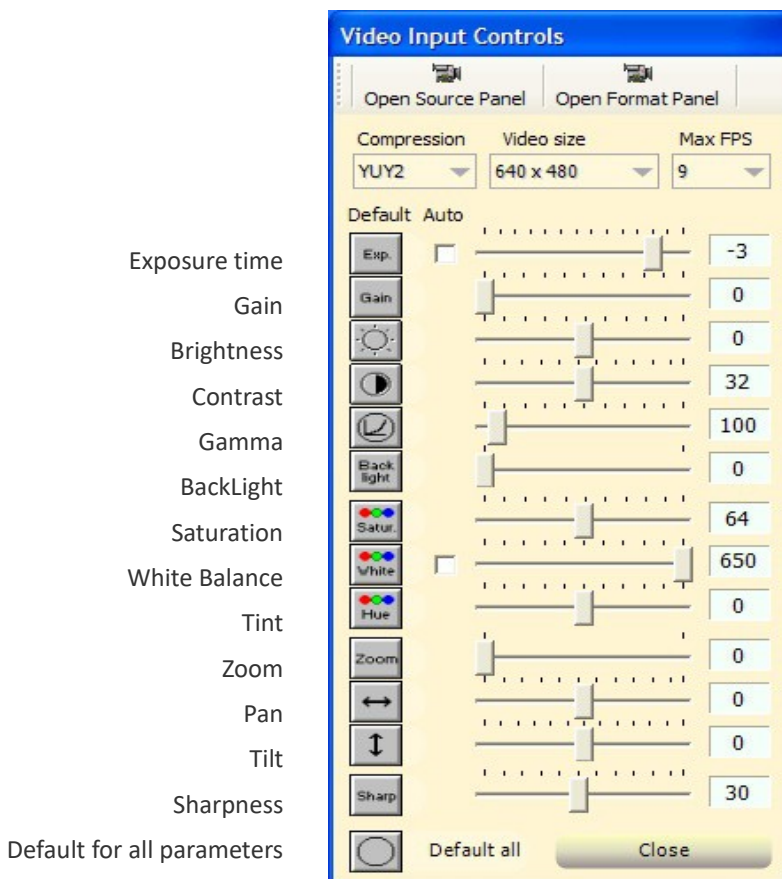
Many device drivers video contain errors or have been written in a "rough". One of the most common defects is losing the settings (you reopen the program and something of this panel is changed). Some drivers rehabilitate the boxes "Auto" every time you turn on the computer or changing the USB port. In other cases it also happens that at the start, the actual settings of the "White Balance" or "compression" are not the ones that are shown in this panel.

These defects are not due to the Theremino Spectrometer application, if you replace the driver everything is in place (or defects change).

If you do not find a better driver you need to get used to its flaws. Give a look at these settings each time you start a session of measurements and possibly change some of the controls until the video device behaves correctly.

This panel can be docked to the right or left of the main window, or placed wherever you like on the screen. Moving it with the mouse, its position will be remembered.

Adjusting properties for VFW devices

If the video device driver (webcam) is a WFV its properties are accessible only through the "Settings Panel" and the "panel sizes."

With some drivers, some control of lesser importance might be accessible only by means of these panels.
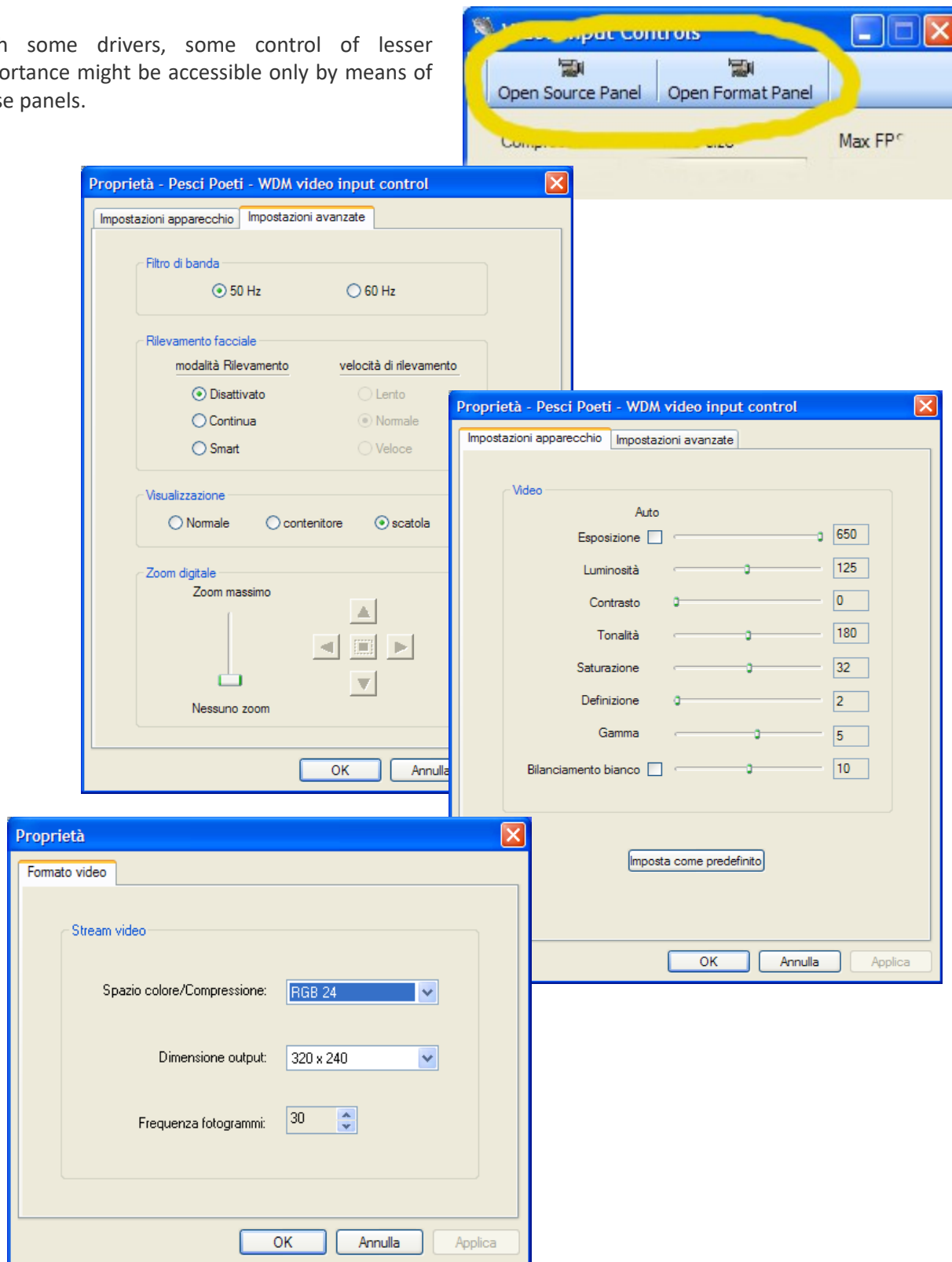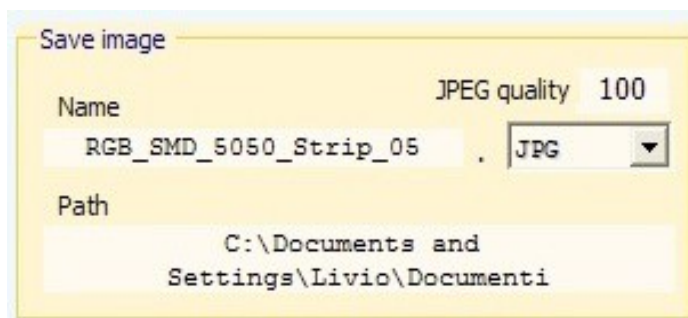
Image files settings

Name
Here you can set a name for the images to be saved, with every shot the final figures will be increased automatically.

The number of digits is respected so if you want a four-digit numbering must be low, for example, with "xxxx 0001" which will be incremented into "xxxx 0002", "xxxx 0003" etc ...

No matter what's left of the digits, space or hyphen or another, the first non-numeric character from right is considered the end of the name.

The name can not begin or end with a space, any leading or trailing spaces are automatically removed.

Path
The box labeled "Path" indicates the destination folder, to change it double click on the box, select a folder and press OK.

You can also change the "Path" manually or by copying and pasting.

JPEG Quality
Usually you use a quality equal to 100, the resulting files are still quite small (about 100k to 300k). If you must have very small file reduce this parameter. With 50 images are still reasonably good, under 30 flaws become apparent.
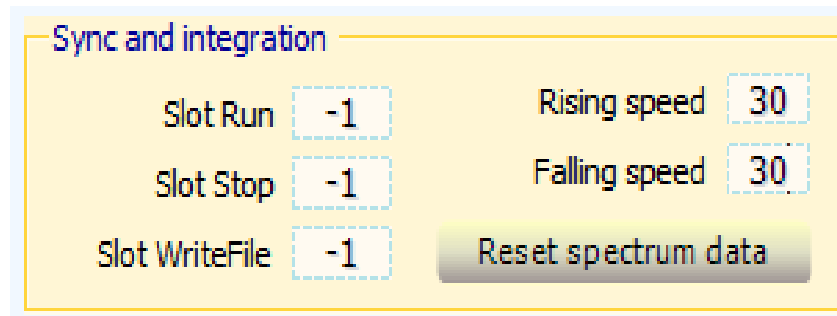
File Format
Usually you use the JPG format with quality 100. If you want a higher quality PNG is a good format that uses a compression without loss of information.

If a JPG image is loaded and then saved a very large number of times, should theoretically worsen gradually (but in practice you do not notice any change). Instead PNG images can be saved and reloaded an infinite number of times and are always identical to the original.

Even TIFF, EXIF and BMP formats are lossless but produce unnecessarily large files.

Sync and integration - The Slots

Slot Run

Slot number to press the Run button (to start the image acquisition).

Slot Stop

Slot number to release the Run button (to stop the image acquisition).

Slot write files

Slot number to write the spectrum data file.

Operation of Slots

Through the Slots other applications of the theremino system can synchronize the operation of the spectrometer. For example, you could use the Theremino AudioInput application and start the acquisition with a sound of a certain frequency and stop it when the frequency changes. Or you could save the data file when a particular sound occurs.
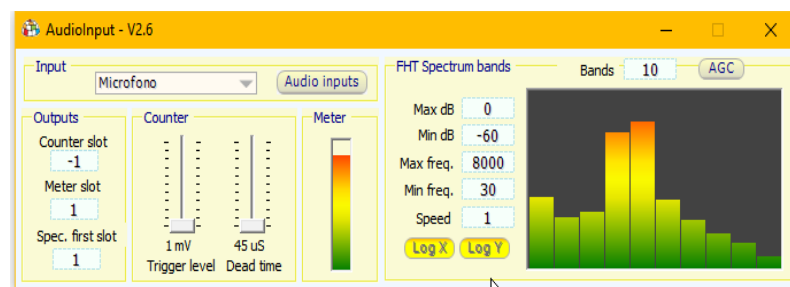
◆ To disable the operation of a Slot, write the number "0" or "-1".

◆ If the box contains a number from 1 to 999, then the Slot is active.

◆ The function is activated when the Slot value indicated rises above the value 500.

◆ The function works only once and to reactivate it the Slot value must go below 500.

Sync and integration - The speed parameters

Rising speed

Raising this speed to 100, the spectrum data is updated to the peak value of the light received for each frequency. With lower numbers, the average is made between the current value and the new data coming from the camera.

Falling speed

This is the rate at which stored data fades over time. This speed can be lowered to zero and in this case the data accumulated in the spectrum does not attenuate, but remains unchanged until the "Reset spectrum" is pressed. Be aware that when accumulating data it is not possible to change the minimum and maximum frequency settings, otherwise the data will be lost as if the "Spectrum Reset" button was pressed.

Reset spectrum data

With this button you can manually reset the spectrum. It is mainly used to reset previously collected data before making a new integration.

# Operation of the rising and falling speeds

Normally both these speeds are kept at 30. With this value, an integration over time is obtained, which reduces noise, while maintaining a fairly fast response to light variations.

These two values can be lowered to obtain long or even infinite integration times (with descent speed equal to zero). One can then accumulate incoming data from multiple single events, which could be, for example, the brief light emissions caused by the plasma excited by the laser in a LIBS spectrometer.
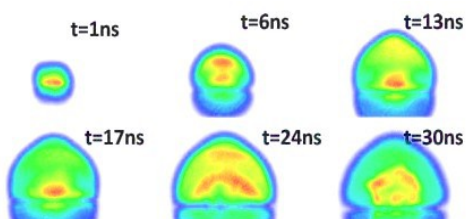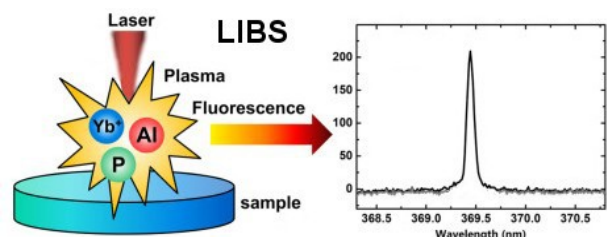
Long integration times could reduce noise and improve both the sensitivity to small signals and the spectral resolution.

Adjustments of the image
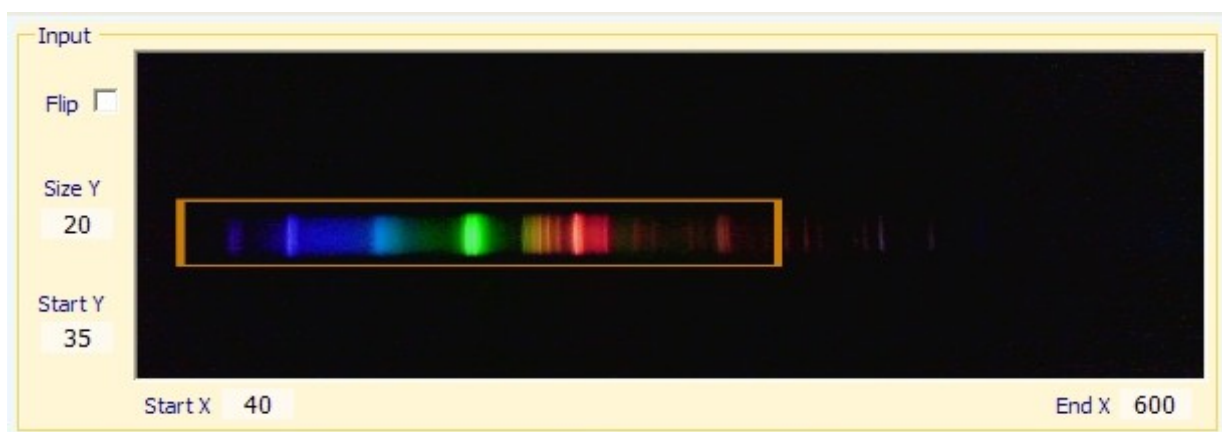
Flip

Horizontal flip of the image. Use this command causes a small additional load for the CPU. So it should be used only if your webcam is fixed on the wrong wall of the spectrometer or upside down. If possible correct the spectrometer to not have to use it.

Dim. Y

This value determines the number of rows of pixels used for the analysis. The software makes the average of the values of all the rows and this improves sensitivity and reduces noise. Another advantage of using an area composed of many lines is that they are tolerable even small errors in the vertical position due to an imperfect alignment of the spectrometer. We recommend that you normally use a value of at least 10 or 20, so as to leave a little 'margin above and below the spectrum. In some special cases (diffraction grating slightly unaligned) you can get a slight increase in resolution, setting this value from 1 to 5 and by placing the rectangle in the center of the spectrum.

Start Y

Adjust so that the measurement area is centered on the spectrum.

Start X

With this box you set the beginning of the scale, resulting in enlargement of a limited area of the spectrum.

End X

With this box you set the end of the scale, resulting in enlargement of a limited area of the spectrum.

The parameters **Start X** and **End X** can also be adjusted by enlarging and shifting the graph of the spectrum, as explained on the next page.
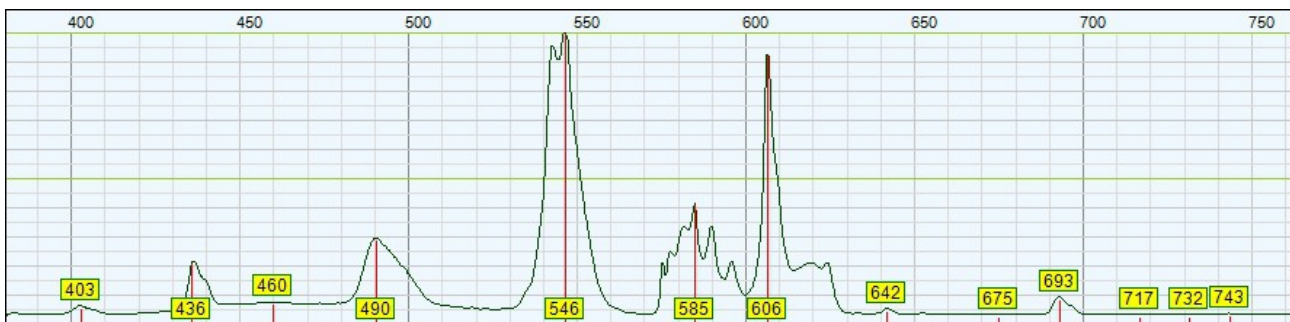
The range and scale of measurement

To enlarge the spectrum you click on it with the left mouse button and then using the wheel.
To move you click with the left mouse button and then move the mouse left and right while holding down the button.
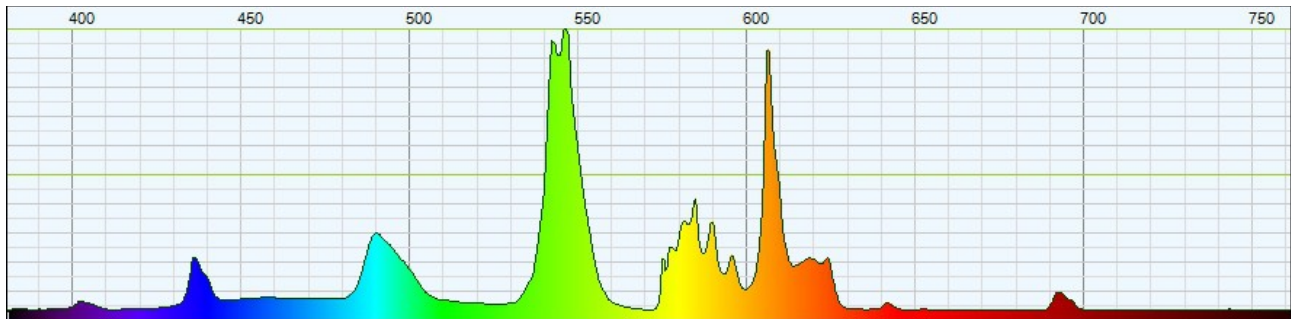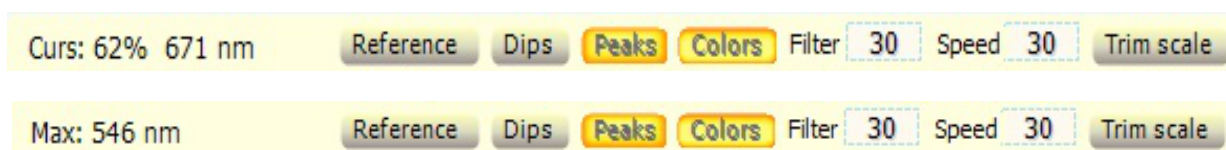

The spectrum can be displayed in several ways, related commands are explained on the next page.

The lower command bar

| Curs: 62% 671 nm | Reference | Dips | **Peaks** | **Colors** | Filter | 30 | Speed | 30 | Trim scale |

| Max: 546 nm | Reference | Dips | **Peaks** | **Colors** | Filter | 30 | Speed | 30 | Trim scale |

Measurement indicator
The first box on the left side of this bar has two functions:

- When the mouse cursor is located in the graph, the box indicates the position of the cursor in a percentage of the maximum and horizontally in nano-meters.

- When the cursor is outside of the chart, the box indicates the value of the highest peak in nanometers.

Reference
Enabling the reference for the absorption measurements. See page 15.

Dips
Enabling labels for the minimums of the graph.

Peaks
Enabling labels for the maximums of the graph.

Colors
Enabling wavelengths relative colors.

Filter
Noise filtering of the graph. Adjust normally to 30. Raising this value up to 50 or in extreme cases, up to 100, you eliminate noises and steps in the chart. In return you have to accept a broadening of the lines and a resolution reduction.

Speed
Speed of response. Adjust normally to 30. Lowering this value to 10 or in extreme cases, up to 1, it integrates the signal and eliminates the short duration noises. In return you have to accept a significant slowing of response. To increase the response speed raise this value up to 100.

Calibration
Enabling the scale calibration mode. See page 14.

Appendix 1 - Adjusting the text box numerical values

The numerical text boxes of this application (and all other system applications Theremino) have been developed by us (note 1) to be more comfortable and flexible than the original Microsoft TextBox.

| Start X | 40 | End X | 600 | | Filter | 30 | Speed | 30 |

The numerical values are adjustable in multiple ways

- ◆ By clicking and holding down the left mouse button and moving the mouse up and down.
- ◆ With the mouse wheel.
- ◆ Using the keys arrow-up and arrow-down on the keyboard.
- ◆ With conventional methods that are used to write numbers with the keyboard.
- ◆ Using standard copy and paste selection methods.

- ➡ The method of moving the mouse up and down allows wide and fast adjustments.
- ➡ The mouse wheel allows convenient and immediate adjustments.
- ➡ The arrow keys allow fine adjustments, without having to look away from the present operation.

(Note 1) *Like all our software, source files are available (Freeware and Open Source licensed under Creative Commons) and can be downloaded from here:* www.theremino.com/en/downloads/uncategorized *(Section "Custom controls") These controls can be used freely in any project without a name but also the source. The Open Source also serves as a guarantee that we have not included malware.*

Appendix 2 – Scale calibration

To calibrate the scale of the spectrometer use a fluorescent lamp.

You can use a energy-saving lamps for home lighting, or you can prepare a convenient source of calibration, following the instructions on the page 19 of the file "Theremino Spectrometer Construction".

Make calibration

- Place the lamp close to the entrance slit of the spectrometer and adjust the "Exposure" to get a graph similar to the following.

- Make sure that the buttons "Reference" and "Dips" are not depressed and that "Peaks" and "Colors" are.

- Press the "Calibration" and locate the two new labels that appear on top, in the upper area of the scale.

- Drag one at a time, labels, hold down the left mouse button until you are on the tip of the two characteristic peaks of mercury at 436 and 546 nm.
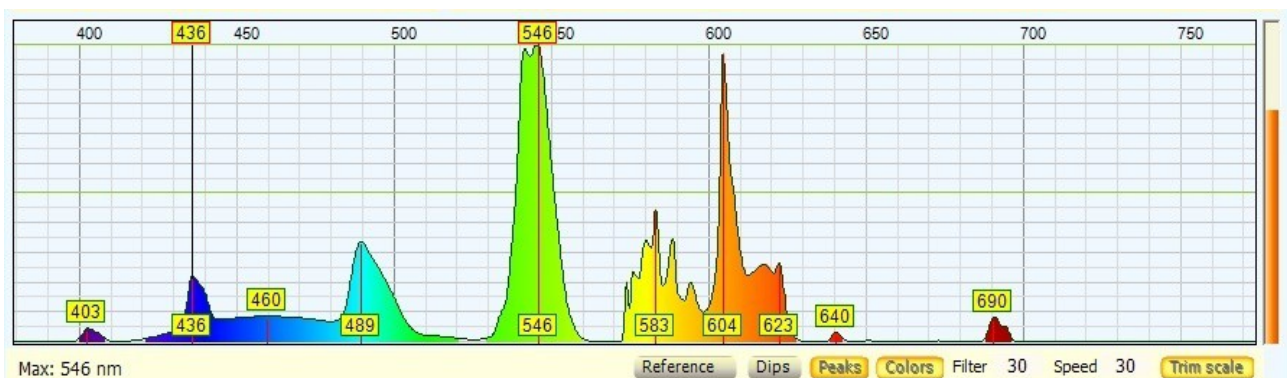
Here you see the two peaks of mercury and labels 436 and 546 that appear when you press "Calibrate"

The calibration points may not even be 436 and 546, to set them see the menu commands on page 4.

To calibrate more accurately, enlarge the area of interest with the wheel and the left button of the mouse. Remove also the lamp so that the peaks do not have the flattened tip and that their maximum is more evident.
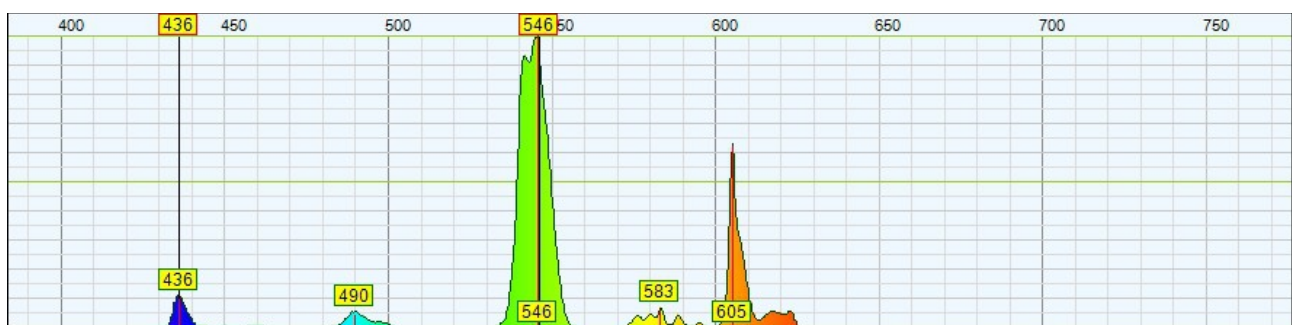
Moving farther the lamp, the peaks shrink and their maximum become more precise.

Appendix 3 - absorption measurements

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

For these measurements, it is necessary to have a source that emits light across the spectrum (or at least in the area that is to be measured). The sources of this type are called "Broadband". The instructions for preparing a "Broadband" source are in the last pages of the file "Theremino Spectrometer Construction".

Make a measurement of absorption

◆ Make sure that the buttons "Dips" and "Peaks" are not pressed and "Colors" is.

◆ Open completely the slit diaphragm to give more light as possible (measurements on the filters do not require much resolution).

◆ Adjust the controls "Filter" and "Speed" with a value of 30 (with very high or low values becomes difficult to make absorption measurements).

◆ Place the lamp next to the entrance slit of the spectrometer, but leaving between the lamp and the spectrometer sufficient space for the filter or the specimen to be measured.

◆ Adjust the position of the lamp to have good lighting.

◆ Raise the control of exposure to cover a wide area of the spectrum. But you should not overdo it with the light and exposure, otherwise occur glare (visible in the black little window of the camera) and the measurements will be biased. If there is too much light and too much exposure the spectrum will never go to zero, even in areas where the filters absorb all the light.

◆ Try, pressing the "Reference", if the area covered is sufficient.

◆ Frame the area of interest with "Start X" and "End X" or with the mouse.

◆ Before inserting the sample to be measured, press the "Reference"

◆ From this moment still keep in both lamp and the spectrometer. If you touch them by inserting the sample then you will have to repeat the reference.

◆ Insert the sample, check the spectrum and possibly save his image without spending too much time (the reference deteriorates over time for the heating of the light source and other mechanical causes).

◆ If it's been a long time or that you have moved the light source, remove the sample and check that the reference is still valid (upper spectrum aligned with the colored line above).

◆ To restore the reference, remove the sample and then disable and re-enable the "Reference".

In the following pages this procedure is explained with images.

Appendix 3 - absorption measurements (images)
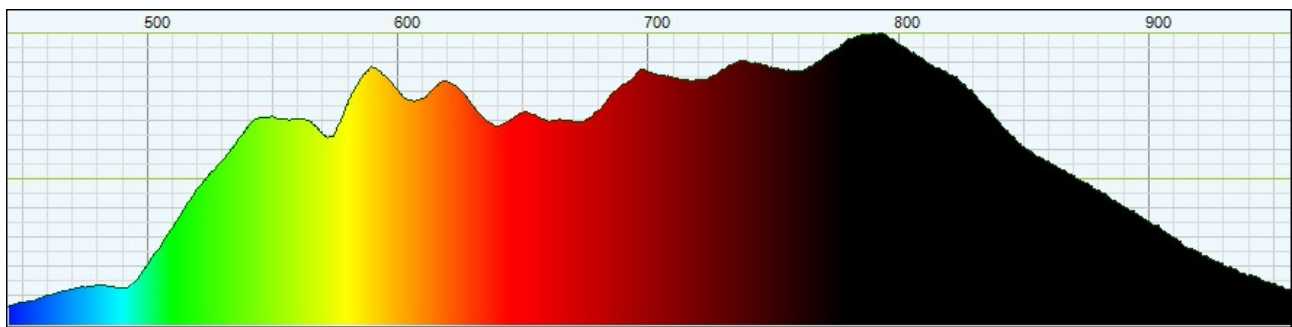
**This is the spectrum of a small incandescent lamp.**

For this lamp useful area ranges from 450 to 950 nm for which we set the scale to see only this area. (It is considered as "useful area" the area in which the lamp emits at least a 15-20% energy).

It would have been preferable to have a more uniform light source (a broadband or at least one halogen), but such sources are expensive, difficult to build and very hot. So for these examples will be enough.
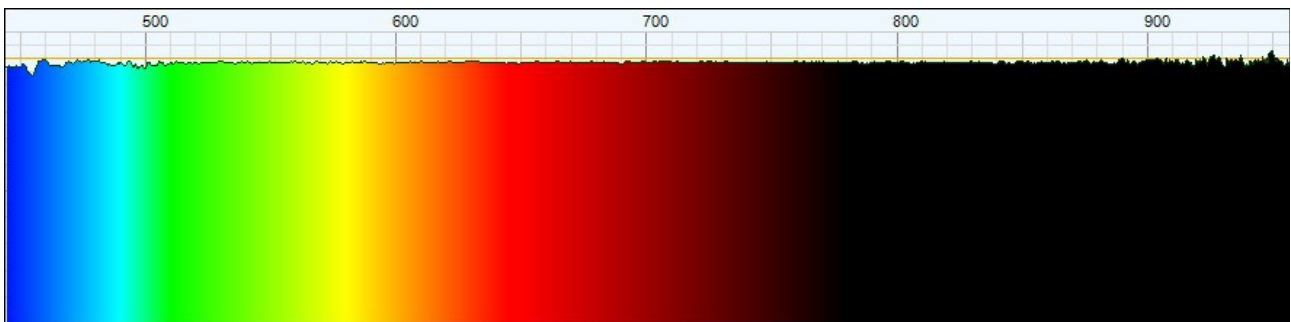
Pressing the "Reference" occurs that the chosen area is actually all usable.

Note that in the end zones, where the energy is low, the line becomes rougher. In these areas the measures are still possible but will be less accurate.
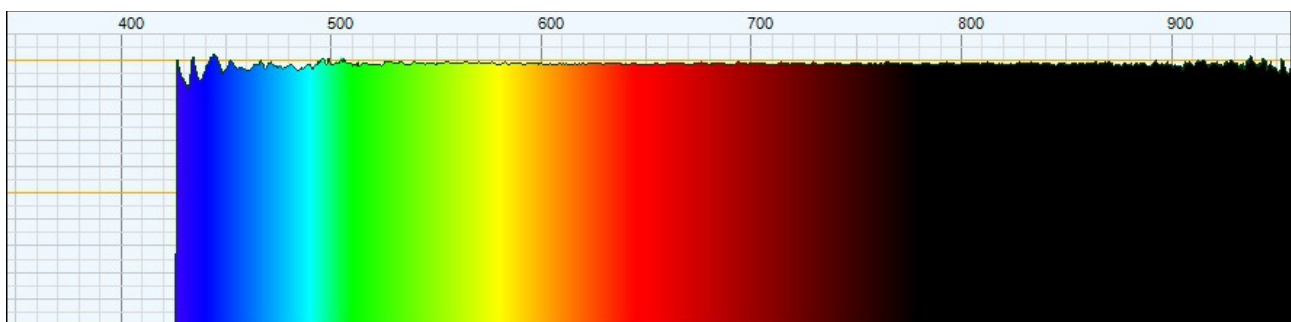

Here we see what happens if you press the "Reference" using too wide an area.

The area below 450 nm has too little light for the measures, and becomes progressively less smooth. Here you do not see the movements but this area as well as inaccurate is also very unstable.

Going down further, below 425 nm, the software determines that the area is too weak and unstable and discards it completely.
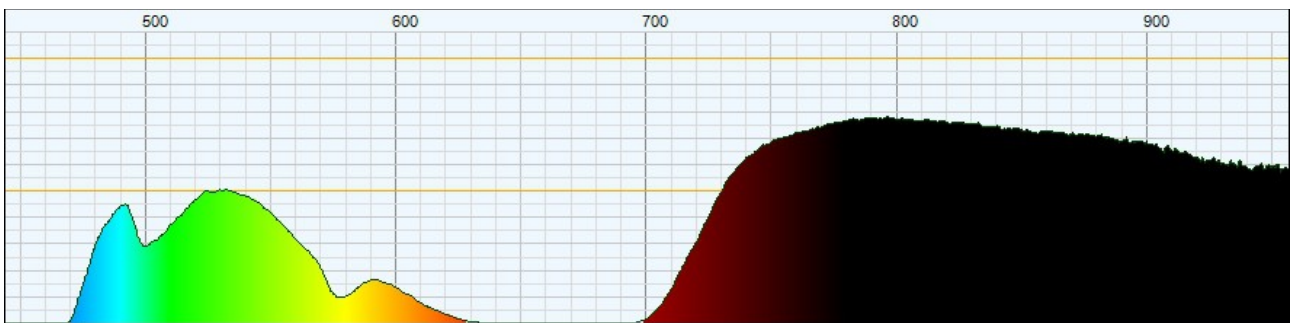
Appendix 3 - absorption measurements (images)

In the next picture you can see the specter of some colored filters.
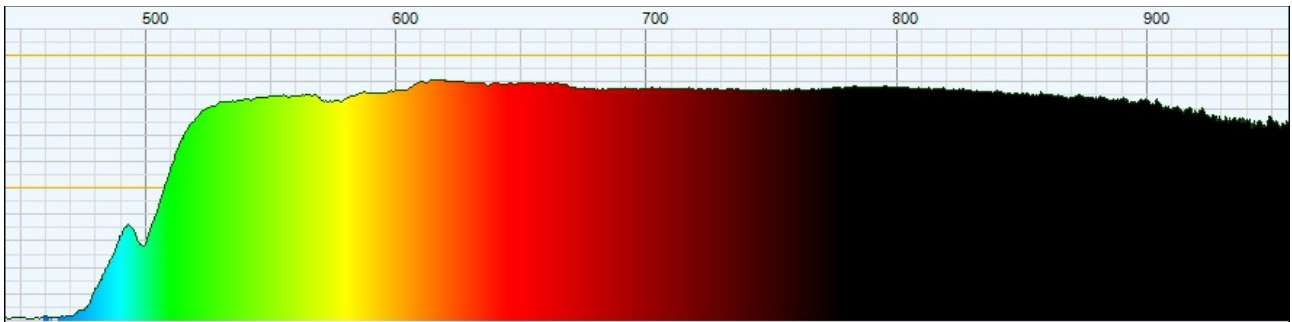
Interposing a yellow filter the spectrum is not more than 100% (where the line is colored top).

This filter attenuates yellow so decided by 500 nm down and let good, 80 to 90%, all other colors, into the infrared.

This is the spectrum of a green filter.

This filter passes the green with 50% of energy and attenuates all other colors except the infrared. Almost all filters allow the infrared headlights because otherwise they would heat up to ruin them.
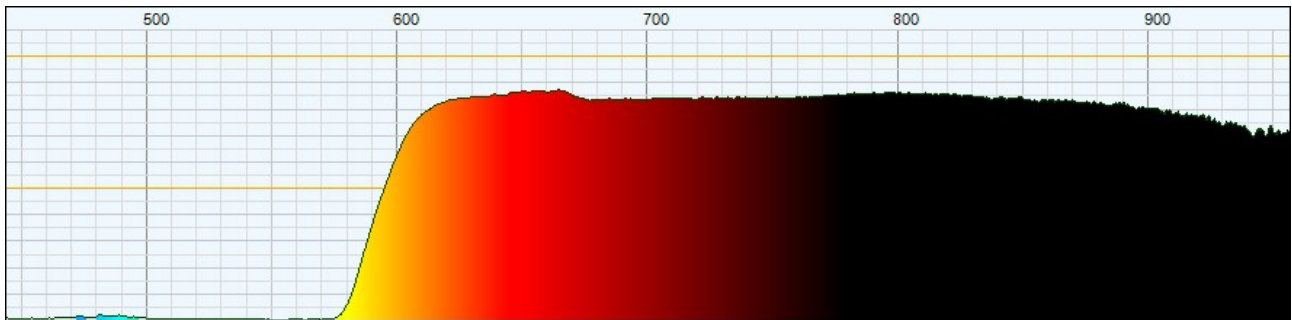
This is the spectrum of a red filter.

Also this filter, in addition to its favorite color, transmits infrared very well.

- - - - -

These spectra show the light that passes, not absorption. It would be more correct to call them "transmission spectrums" but the term "absorption" is more used.

To understand each other, when the line of the spectrum is high it means that a lot of light is able to pass, when it is low it means that the sample has "absorbed" much light.

Appendix 3 - absorption measurements (images)

Here you see a simple construction for the measurement of color filters, using a small bulb made from a flashlight.

To consume little and make the batteries last longer, we used a light bulb for a little over 1 Watt (300mA at 6 volts) that fed a 4.5 Volt, consumes only 200mA.

With so little power you need to have a good parabolic reflector.

You can get the torch, the light bulb is the reflector, or you could use the torch complete.

The small tungsten bulbs as this little light in the blue and emit almost no light in the ultraviolet.

It would be preferable to use a broadband xenon lamp, or an halogen lamp.

Read the tips for the lamps, in the last pages of the document "Theremino Spectrometer Construction".