

theremino
•the•real•modular•in-out•

Theremino **System**

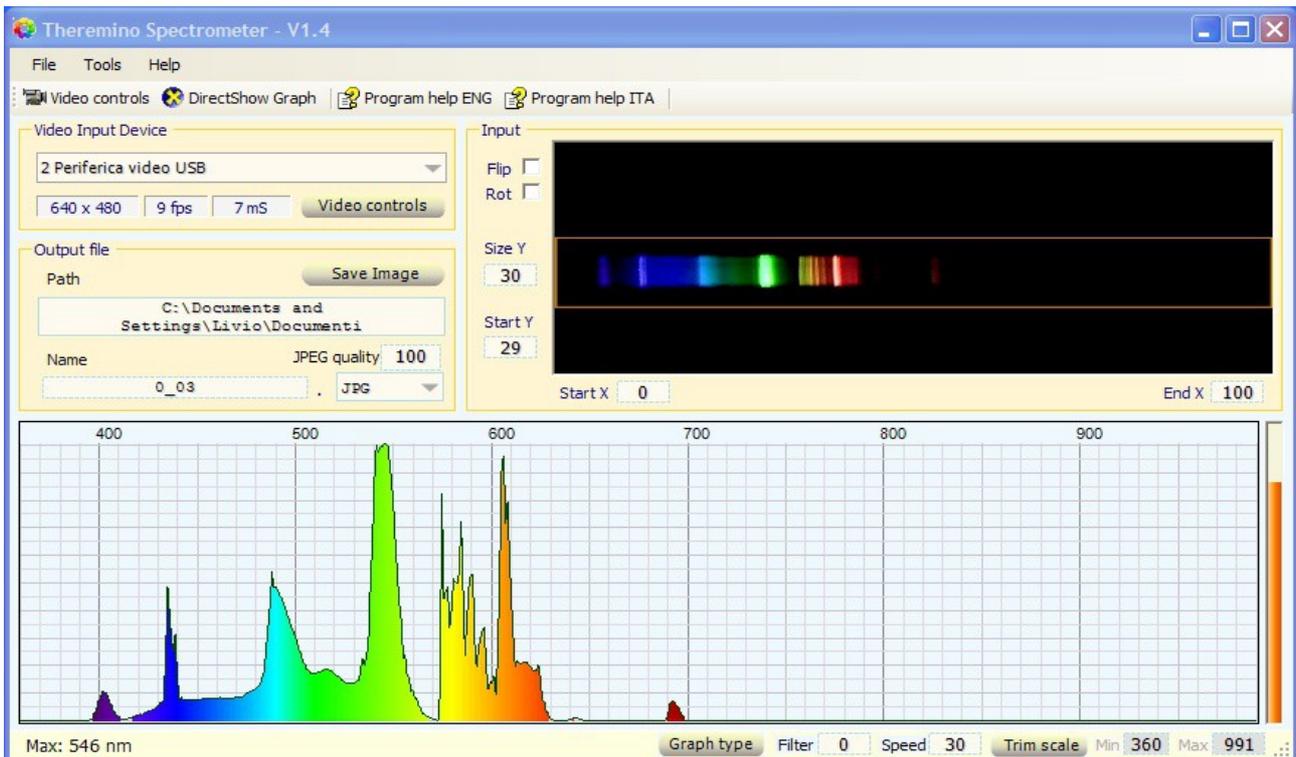


Theremino Spectrometer Technology

Operation principles



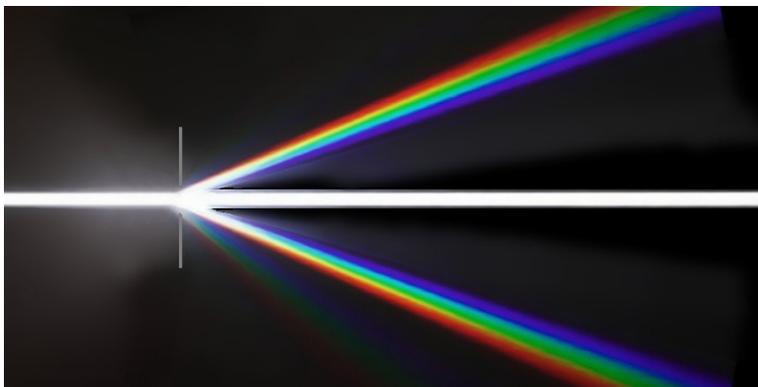
By placing a digital camera with a diffraction grating in front of the lens and **tilting with respect to the incident beam**, we obtain that the blue, violet and ultraviolet light components, hit the leftmost pixel and the red and infrared hit the pixel to the right. In this image, infrared light (invisible) is shown with a dark brown color. To detect the infrared is necessary to remove the camera built-in anti-infrared filter.



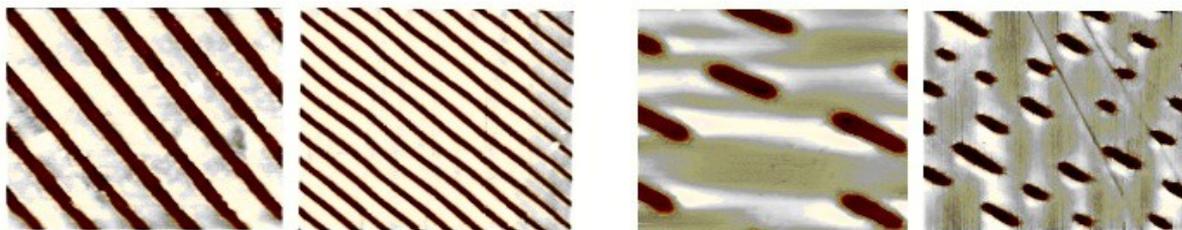
The software calculates the intensity of light striking each pixel and is therefore able to measure the amount of radiation for each color. The camera is not necessary to discriminate the color of photons collected, what matters is only the intensity and the location. Even a camera in black and white would be fine, the red light will hit only some pixels, the green other pixels and the violet, infra-red or violet others.

Diffraction grating with optical discs

CD and DVD are composed of a layer of transparent plastic which, separated from the other layers of the disc, it behaves as a **diffraction grating**. This is because the plastic is engraved by microgroove each other very close, almost invisible to the naked eye.



A light containing several wavelengths, for example white light emitted from a light bulb or from the sun, is decomposed into its components and the light of each frequency is deflected at a different angle.



In these enlarged pictures, you can see the CD lines and the most dense DVD lines. When the discs are written, the lines are broken into small points and functioning as a diffraction grating becomes worse (the scattered light is less intense).

Use CD or DVD?

According to our tests, the best patterns are derived from the DVDs and got better results by using them in transmission (no reflection)

The following pages present various useful possibilities for teaching and for extreme experimenters, commercial gratings, prisms, reflection methods...

Who wants to build a simple spectrometer, without going into the theory, should cut a square of DVD and paste it on the tip of the lens of the camera, then skip directly to the file "Construction".

Commercial diffraction gratings



The diffraction gratings are available in rolls of thin plastic. On eBay they sell them cut into pieces 15x30cm, for about three Euro plus four for shipping. They are available in two versions, 500 or 1000 lines per millimeter. It is advisable to buy them both, paying a single shipment or only buy what 1000 lines, which is the best for almost all cameras.

The diffraction gratings are more efficient than CD and DVD (greater intensity of the scattered light). The characteristics say, "Holographic Diffraction Gratings, highly efficient embossed Holographic Optical Elements (HOE)"

http://www.ebay.it/itm/280859388704?ru=http%3A%2F%2Fwww.ebay.it%2Fsch%2Fi.html%3F_sacat%3D0%26_from%3DR40%26_nkw%3D280859388704%26_rdc%3D1

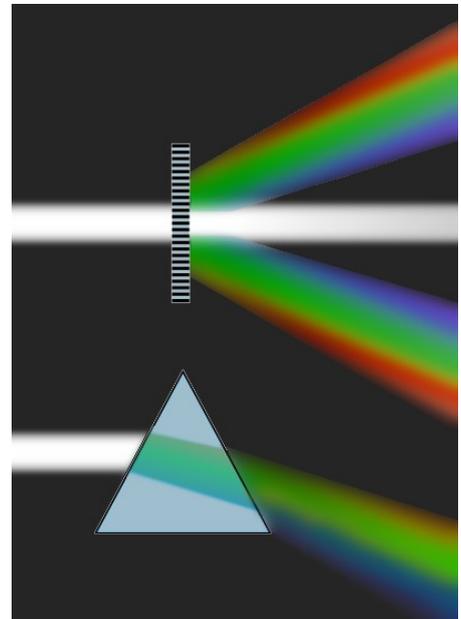
Prisms

The prisms have a behavior similar to that of the diffraction gratings but deflect the light in a different way.

The prisms deflect to one side while the gratings deflect in both directions. So with a prism should have multiple colored light and you would prefer them in theory.

In practice, however, it is best not to use the prisms because widen the area of the blue and compress areas of the red and infrared.

The deflection produced by the prisms is not linear, as shown in the following two images.



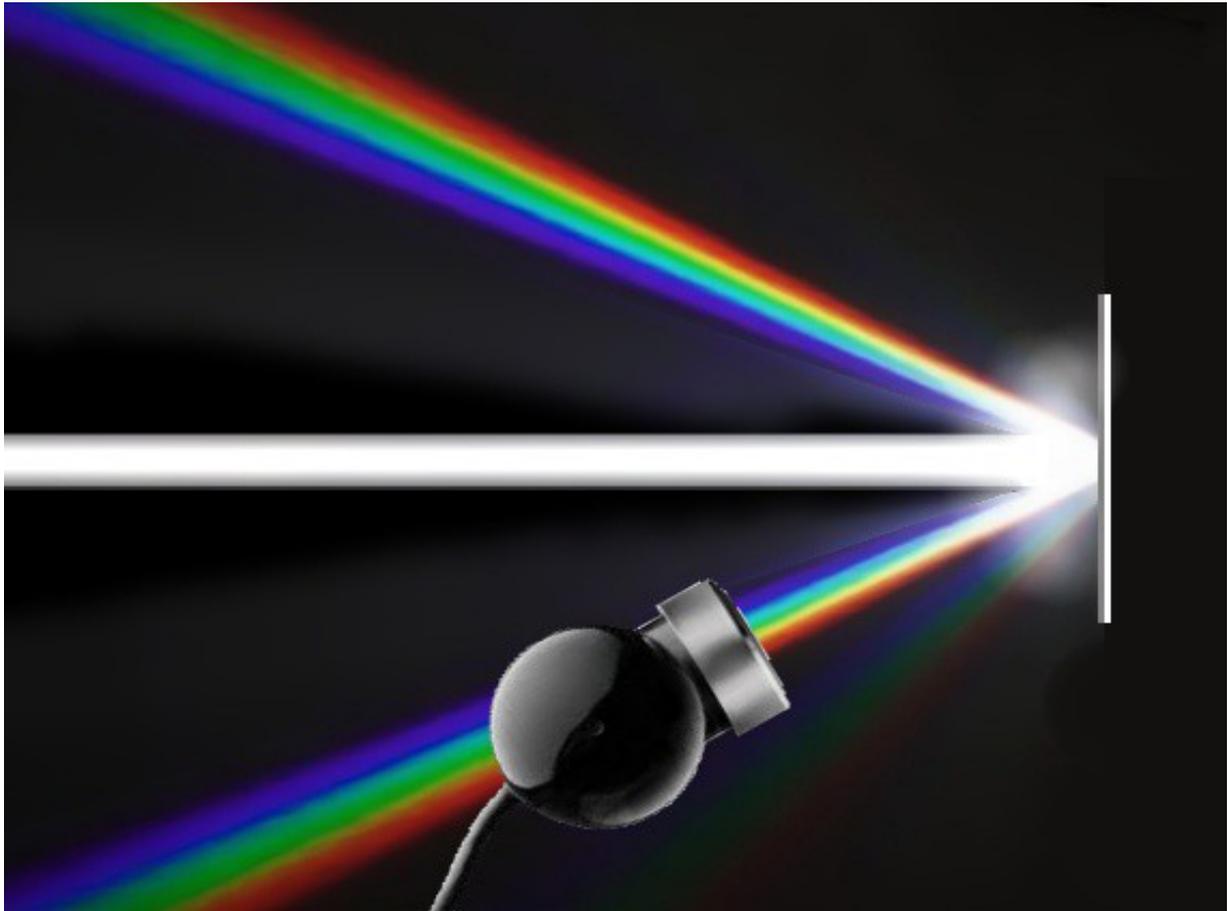
Measurement scale produced by a diffraction grating



Measurement scale produced by a prism

The prism expands the blue and green area and compresses the yellow to red area (and even more infrared) with a prism reference marks wavelengths would not be evenly spaced and calibrations become more difficult.

Reflection mode



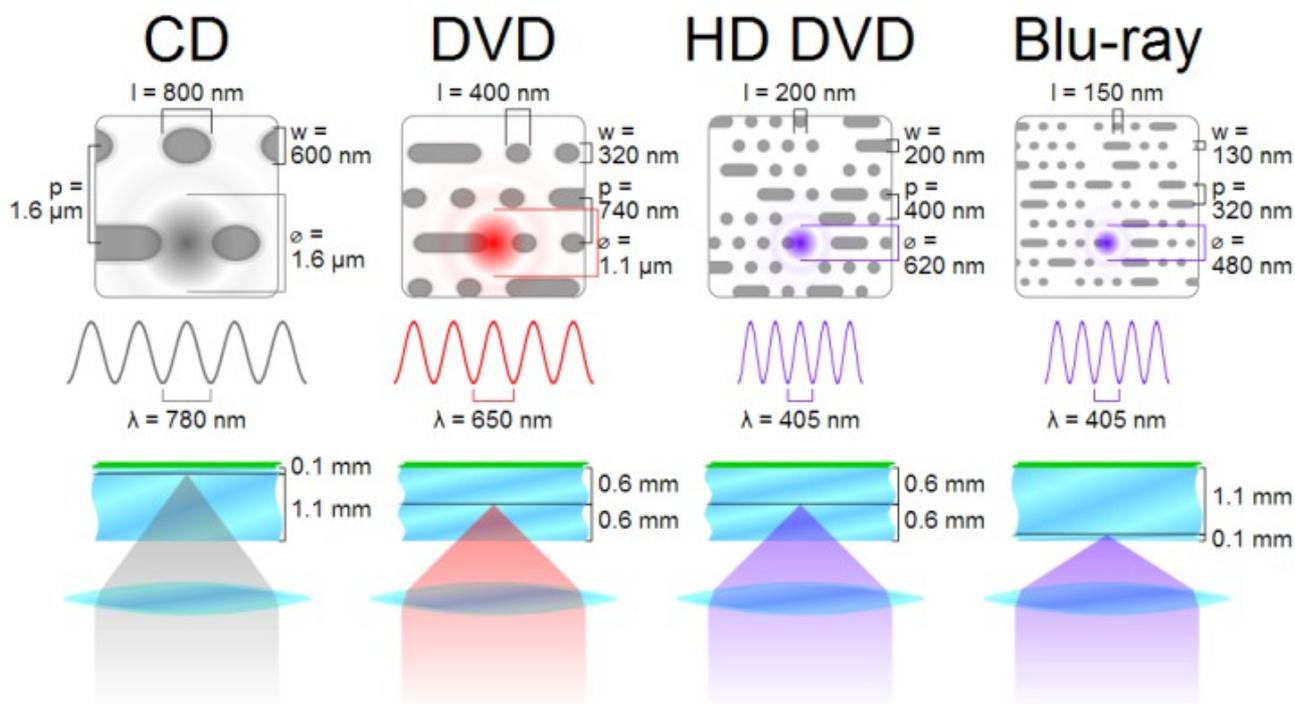
Theoretically the reflection mode should provide a greater intensity of colored light and would also have the advantage of not having to strip the metallization of the DVD.

In practice, however, this mode of operation causes various problems:

- ◆ The layer of transparent plastic is traversed twice (for more different angles) and this tends to diffuse the light and broaden the spectral lines.
- ◆ Not being able to apply the pattern on the lens of the camera, you must suspend it with a special support.
- ◆ The inclinations of the grating and the camera must be settled on two different angles and find the appropriate angles is difficult.
- ◆ If the grating is not perfectly plane causes non-linear distortions of the measurement scale of the wavelengths.

Our tests with the system in reflection gave poor results, lines wider, poor resolution and more reflections and artifacts. Furthermore, the calibration was more difficult and more sensitive to variations in position and rotation, both of the gratings that of the Camera.

Comparison of diffraction gratings, CD and DVD



The microgrooves are more dense in the DVD and is therefore better to use these instead of the CD, to obtain a greater separation between the lines of the spectrum.

Type of grating (reflection)	Lines per millimeter	Line spacing (nm)	Deflection in degrees for various wavelengths					
			400 nm	500 nm	600 nm	700 nm	800 nm	900 nm
CD	625	1600	14	18	22	26	30	34
DVD	1350	740	33	43	54	71	-	-
HD DVD	2500	400	-	-	-	-	-	-
Blu Ray	3125	320	-	-	-	-	-	-
Diffraction grating commercial	500 or 1000	2000	12	14	17	20	24	27
		1000	24	30	37	44	53	64

The formula for calculating the angle is: **deflection in degrees = arcsin (wavelength / distance lines)** and refers to **a lattice perpendicular to the incoming beam**. With the DVD does not seem to be able to detect infrared (above 700 nm), but since we keep the lattice parallel to the lens of the camera we can also recover the infrared.

Depending on the focal length of the camera (more or less wide) might be best to use CD, DVD or gratings 500, 1000 lines per mm. The HD-DVD and Blu Ray can not be used because deflect too much.

If the grating deflects too much, you can not make stand across the spectrum (including infrared, and from 350 nm to 1000 nm) in the visible range of the camera. If deflects little, you have more than 2 nano meters from pixel to pixel, and the resolution is poor. The ideal would be to have about one pixel wide nano-meter or something less. Cameras with more than 640 horizontal pixels help in this, but the CPU work is much increased.

Preparation of CD and DVD



Grating type	Notes
CD	To prepare do not separate into two halves but peels the surface top (The one with the writing), tearing it with tape.
DVD	To prepare divide the two halves and then remove the aluminum lifting it from one side and then skinning.
HD DVD	To prepare divide the two halves and then remove the aluminum lifting it from one side and then skinning.
Blu Ray	We have not tried these discs. Probably to prepare it acts as the CD.
Diffraction grating commercial	They're ready, do not require preparation.