

Friday 10th March - Materials Decathlon - Challenge n°4 - 40'

CHROMADEPHT

Enjoying the pictures using ChromaDepht glasses

- Put on the glasses that you have been given and have a look at the exhibition. Don't run from one picture to the other and take your time to stare at each one: it may take a while to get the full effect! Answer the questions you find under some of the pictures. Write down what you see and everything else which maybe of importance.
- Then join your team to discuss and merge your observations to answer the following questions.

Q1. What's the effect of looking at the pictures through the glasses?

Q2. Which is the perceived order of the colours from nearest to farthest? Is it random?

Q3. Describe what you see when you follow the instructions on picture n° 25 in the exhibition and you alternatively close one eye at a time. With coloured pencils make a picture of what you see:

 - when you close the left eye;
 - when you close the right eye;

Q4. In picture n°7 close one of the eyes and look at the magenta square through the glasses. Then close the other eye. Describe what you see. What happens with the yellow square? What do you think would happen with a cyan square? Why?

How are the ChromaDepht glasses working?

The following questions/activity may help in your research/comparison

- Look at the light sources around you. What do you see when you have ChromaDepht glasses on?
- Which optical devices do you know that transform incident white light in a rainbow of colours made of the full spectrum?
- Revise how a prism works and how a diffraction grating works. Make a sketch of both devices and highlight the difference in result.
- In the picture on the answer sheet draw both a red and a blue ray coming from the light source (circle) and reaching the eyes after they have gone through the two prisms. Is it exactly like in a diffraction grating ?

One of you has a **diffraction grating** in its badge: now use it to explore comparing and contrasting the two devices (ChromaDepht and usual diffraction grating).

- Looking at light sources:** how does the spectra appear through the two devices?
- One pair of ChromaDepht glasses has been cut into two. On the lenses you have L and R to remind which was originally the left and the right lens. Now shift the lenses (put L-lens on right eye and vice versa): what do you notice? What about a couple of diffraction gratings? Is it the same?
- Using a laser:** compare the pattern obtained shining the laser through the diffraction grating and the ChromaDepht glasses first one lens and then the other one. Write down your observations.
- Just go with your **finger nail** along one of the faces of the lens: on one side it will appear perfectly smooth, on the other one it will produce the typical noise of something on grooves,
- Under a USB microscope:** can you see anything? Take a snapshot!

At the end of all these investigations write down on the answer sheet a **Table** evidencing the different behaviour between Diffraction Grating and ChromaDepht glasses in the observations you made.

Building your own ChromaDepht picture

Now that you understand how ChromaDepht glasses work, design your own ChromaDepht composition! On the desk you have black and coloured cardboard and scissors. Best one will get extra-points!



OUTPUT WANTED :

Answer to Q1-Q4 + Final Table + 1 photo with the USB microscope + your own ChromaDepht composition

Answer sheet

GROUP N° _____

Ch.4 --- CHROMADEPTH

Q1

Q2

Q3

Q4

Complete the picture [See point 4 in the student sheet]

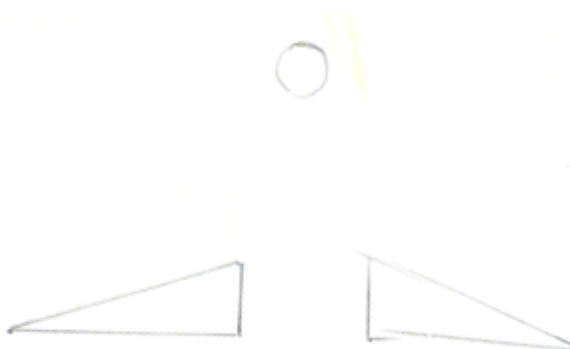


Table: [You can also use the back of the sheet]

<u>Observation:</u>	<u>Diffraction grating</u>	<u>Cromadepth</u>

PICTURES [Sent by Whatsapp to your group – See general instruction to share pictures or files]

- Picture1 description:

Teacher's notes

Technical notes:

The student sheet is meant to be used together with the pictures selected for the Chromadepht exhibition. You may find many of these pictures online just googling Chromadepht. A good starting point is <http://chromatek.com/art-and-design/gallery/>. Our selection contained WoW effect pictures, application of chromadepht techniques to embed an extra layer of info to 2D pictures and pictures that guide you to understand how the glasses work.

Organizational notes:

- Each student will keep a copy of the students' sheet but the group will collectively fill in the answer sheet and give it over to the teacher in charge at the end of the lab.

Correction grid

Question or Request	Note	Max. score
Q1	See key to answer	2
Q2	See key to answer	2
Q3	See key to answer	2
Q4	See key to answer	2
Picture to Complete	See key to answer	2
Table	Mark 2 points for each (correct) observation evidencing difference between diffraction grating and CromaDepth	2*3=6
CromaDepth	Mark 2 points only to the <u>best</u> one	2
Picture*	Meaningful (Yes/No: 1 point); beautiful (Yes/No: 1 point)*	2

***Pictures:** are the pictures meaningful? [To evaluate the "meaningful" see also the "Picture Description" on the Answer Sheet] Are they focusing on significant details or clearly showing the apparatus structure or the investigation results? Are they aesthetically beautiful?

Key to Answer

See the following considerations

Area: micro optics, DOE (diffractive optical elements), light interacting materials, light manipulation for 3D and VR .

What has it got to do with sustainable materials? It's a very cheap way to create 3D with many applications in building overlaying information on the same picture (therefore saving time, money, paper...) and it demonstrates the full potential of lighter, more portable, more affordable optics.

The activity can be proposed at different levels

- Elementary and qualitative -1st and 2nd year to complete refraction (prism) and spectra enquiry with diffraction grating
- Advanced and quantitative- in the 4th year (light as a wave). Structured as an open inquiry on unknown material where students revise and apply the already known concepts (such as refraction and refraction index, how a prism and a diffraction grating spread light of different wavelength; from diffraction pattern back to the object's characteristics, light spectra, additive and subtractive colour system
- At all levels in a specific module dedicated to 3D: techniques and applications

[Background reading](#) (from Chromatek websitedesign guide)[1] <http://chromatek.com/>

Artists have made use of colour to encode and induce depth perception for centuries. A well-known example is the application of aerial perspective. In general, we tend to perceive colder colours as more distant than warmer tones. **See slide from n° 1.1¹**

One possible explanation is **a subtle natural chromatic aberration** induced by the lens **of our visual system**. Usually, this effect is rather weak, but strong enough if accompanied by other technical tricks such as the parallel decrease in size.

Traditional stereoscopic visualization (3D effect) requires either special projection technologies with polarized glasses or special display technologies with LCD shutter glasses to display depth. Other processes such as Red/Blue anaglyph process work both in print and on a computer screen but produce incomprehensible images when the glasses are not worn.

ChromaDepth® glasses - designed and implemented in **1990** by Steenback-use **prismatic filters** that separate the image into the visible spectrum. Each color is shifted a different amount, resulting in various planes of perceived depth. **See slide from n° 1.2 to 1.9.**

In the *RGB on Black* model - Red is closest and Blue is furthest (with Black at infinity).

In the *CMY on White* model - Cyan is closest and Yellow is farthest away (with White at infinity).

See slide 2.7.1 and 2.7.2

The core concept of ChromaDepth is: encode depth into an image by means of color, then optically decode the color using sophisticated but inexpensive micro-optics to create a true 3D image. This process - turning colour into stereoscopic depth- is known as **Chromostereoscopy**.

The choice of **background color** is the most important factor in determining the colours which should be used to achieve C3D™ effects. The easiest and most commonly utilized background colours are black and dark blue. The color palette, RGB on Black/Blue, apply to both of these background colours. If dark blue is used, it must be a very pure, very dark blue. ChromaDepth® uses red for the most foreground object, dark blue for the most background object, and green for the middle ground. The other colours fall in between according to the colours of the rainbow. Thus one could use red, orange, yellow, yellow-green, green, blue-green, blue, and dark blue, in order, from foreground to background thus defining a different number of layers. Such an effect can be further stretched: theoretically an infinite number of colours may be used to divide the space between red and blue.² Contoured or rounded surfaces can be shown by smoothly blending from one colour to another across the surface. Be sure to use black patterns on the surface to help define its shape.

See slide 1.3

¹ The slides refer to the specific images shown in the exhibition. In any case you should choose one or more pictures that focus on the point illustrated next to the slide number.

² **On a black or dark blue background Palette 2** - Another color model that is very effective on a black background is the 'Patriot' color model; Red-White-Blue on Black. See the C3D™ Color Palettes page for details. **Prova**

Computer monitors use the **primary additive colours, RGB**, in different combinations of brightness to create the appearance of a full spectrum of colors (the same happens with a RGB LED). Three unique wavelengths to produce any colour.. Intermediate colours are in fact obtained by displaying those unique wavelengths side-by-side. Close your left eye first

See slide n 3 and slide n 2.8 /1.10 (it's the same).

This tends to discretize the depth of the ChromaDepth scene somewhat. This is why this technique usually looks better color-printed than on a monitor. (put monitor and paper printed pictures one next to the other) slide n 2.8 /1.10

Conventional four colour printing, or process printing, **uses the primary subtractive colors**, cyan, magenta, and yellow, plus black for contrast control (called the **CMYK** system) in various combinations to represent a the spectrum of colours. Since in printing a wider range of wavelengths/colours may be used, its range of depths can appear more continuous.

Experimental part

Part 1 – Engage: the Exhibition

All the team members will put on ChromaDepth glasses and have a look at the pictures in the exhibition.³ Some of the pictures are just to be observed, others have questions to answer. Students are required to write down what they see and infer and everything noticeable.

Part 2 - Explore : Let's do some science!

Then they will discuss notes with their team and merge observations to reach the right conclusions [See Student_Sheet and Student_Sheet_Answers]. A list of questions may help students to focus on specific aspects and leads the way through their exploration.

- What happens when you look at the pictures through the glasses? *3D effect*
- Do you see any difference when you look at the SAME picture on the PC and on paper? *no*
- Does the effect change when you are changing the viewing angle? *The process is insensitive to the head position of the viewer.*
- Which is the order of the colors from nearest to farthest? *It depends on the background but it's not casual. On black: red is nearest and blue is the farthest, in between you have all the colours of the rainbow from longer to shorter waveleght.*
- When does it happen? Has it got to do with background , with colour mixing? Describe!
- Some colours appear to “ jump up” at you, while others seem to lay in the background. Is this a totally random effect? Can you guess the logic behind it? *(the rainbow, decreasing wavelength, increasing depth)*
- How much important is the background colour? Do the same colour palette works as well with any background? What about RGB and CMY? On which background does the combination work best? What happens to CYM on Black? Why? What do you think may happen to RGB on white? Try it out!

Part 3 – Explain -Exploring the device! How are the glasses actually made?

³ The full exhibition is in the PPT ChromaDepth_Exhibition.pptx with the picture in the right order plus the occasional questions. Put in the exhibition also a blue and a red LED next to each other. Blue light will appear on the foreground pag. 5 Funded by EU under the Erasmus+ KA2 grant N° 2014-1-IT02-KA201-003604_1. This work is licensed under a [Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License](https://creativecommons.org/licenses/by-nc-sa/4.0/)

Now students concentrate on the optical device: ChromaDepht glasses. At the end of the exploration students should be able to have a rough idea on how the glasses are made and make some kind of sketch of the lens profile to illustrate it. Depending on their background and level you can let them be completely free to explore and infer or guide them with a few questions

Look at the white BLUE and RED LEDs again: what do you notice? They should see a SPECTRUM → they should hypothesize that it's similar to a diffraction grating or to a Newton's prism BUT....

The following questions may help them.

- The glasses seem to “move” and bend differently the different wavelengths /colours. Which devices do you know that may accomplish this? a) a prism, b) a diffraction gratings.
- Revise how the two work⁴ (ask the students to plot blue and red ray through a prism and a diffraction grating).
- **Do you think there could be a similar diffraction grating inside the glasses? How could you test it?** Explore comparing and contrasting ChromaDepht and diffraction grating. Fill in a table with your observations .

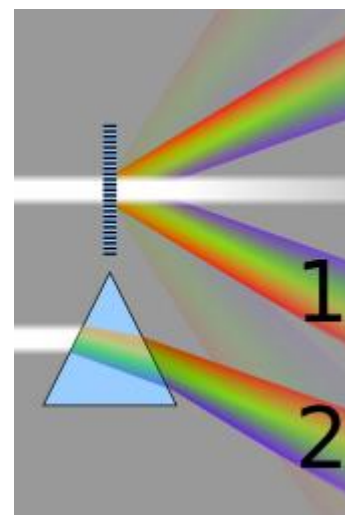


Fig. right- By Cmglee (Own work) [CC BY-SA 3.0 (<https://creativecommons.org/licenses/by-sa/3.0>) or GFDL (<http://www.gnu.org/copyleft/fdl.html>)], via Wikimedia Commons

Action	Diffraction grating	Chromadepht glasses

A list of possible suggestions:

Look at the exhibition pictures with a diffraction grating first and then again with chromadepht...

#Look at light sources first with a diffraction grating and then with the chromadepht glasses. Do they behave alike? If you look out of the window or at many commercial light sources you will notice a definite spectra produced by the diffraction grating and a very soft effect, almost non-existent with ChromaDepht.

However there are some LED lamps which produce a dramatic difference; you notice it better looking with just one lens! You will see blue on one side and red on the other one, while on the contrary the diffraction grating is perfectly symmetrical with a full spectrum at both sides of the central maximum. In Chromadepht colours at the end of the spectrum (red and blue) look “stretched” but asymmetrically

#If you rotate both the grating and the ChromaDepht lense around the horizontal axis in the second one you will notice a very definite change of colour (from RGB to CMY!!!) while the

⁴ Give them a sheet of paper to draw the rays path in both prism and diffraction grating
pag. 6 Funded by EU under the Erasmus+ KA2 grant N° 2014-1-IT02-KA201-003604_1. This work is licensed under a [Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License](https://creativecommons.org/licenses/by-nc-sa/4.0/)

common diffraction grating produces always the same output! *move, flip and rotate the device as you watch a light source...*

Shine a laser through the two devices

- Which kind of info on the grating can you get from the diffraction pattern? the periodicity= distance between two slits from distance between diffraction spots . from the equation $\lambda L = yd$.)Refresh what you expect from the diffraction grating: a series of dots on a line normal to the lines of the diffraction grating. Now shine the laser through the glasses first one lens and then the other: you still see dots supposedly normal to the grating BUT the intensity of the dots is not symmetrical with regard to the centre
- Plot left lens effect=Plot right lens effect So the diffraction grating has been designed to have more light intensity on one side (how can you achieve that?) You can now calculate the spacing of the glasses diffraction grating: on the usual diffraction grating you can read the lines per mm. Do you think the spacing of the glasses is greater or smaller? Why? Actually the periodicity of the grating is approx 30 microns...



- **Are the two R and L lenses perfectly identical?** (close first one eye and then the other as you look through the glasses at the parallax **slide n° 3.6**: Do you see EXACTLY the same thing?). You may want to use the already cut pair of glasses and “shift “lenses. Repeat the procedure. What do you notice? On the left the original disposition. On the right the shifted lenses (WATCH OUT you have to cut a pair of glasses to do that!)⁵. The effect is reverted. This is quite clear in the slides 3. And 3. Here when you shift lenses and make blue jump forward, the geometric solids look queer!
- **Has each lens a symmetrical axis?** Compare with a diffraction grating... see (1)
→ There's a diffraction grating but it's clearly not symmetrical → prisms
- **Are the two sides (front and rear) of the lenses perfectly identical?**

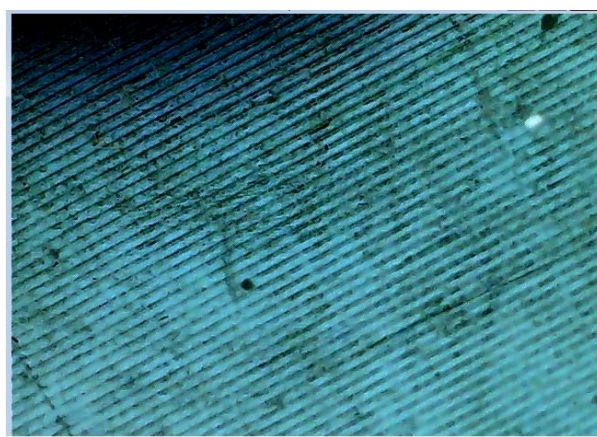
Check for prismatic grooves

- Try to run your fingernail on the lens (go gentle!). What can you infer? There's a grating on one side : prisms! The other side is perfectly smooth instead.
- With Audacity you may want to record and then amplify the sound produced in both cases (front and rear). You Will notice that where there are the prisms there's a periodicity in the sound

Look at them under a microscope

With a USB 500X microscope: right Chromadepht, left classical diffraction grating. The prismatic grooves are finally quite evident.

⁵ In the photo the part in contact with the face.



N.B: A macromodel for ChromaDepht prismatic filter is **Jungbecker** linear asymmetrical deglaring sample (see bottom pictures, taken at the microscope too). Actually if you look at the LED bulb through this sample you will notice the same asymmetrical spectra with bluish on one side and reddish on the other as Chromadepht!...



However watching the LED with undulated or other linear recurring schemes (such as the 90° scheme) the same effect visibly appears, therefore we are not really able to say how much inclined the prisms are

STEP 4 - For advanced level: have the students build the image for left and right eye as shown in slide 3. to 3.

STEP 5- Extend: building your own chromadepht picture

Using specific colour palettes you can sort of divide the space in more regions along the depth direction
SHOW THEM some colour palettes (different number of planes) and have a look at the different shallowness effect.

1. Now that you have understood how Chromastereopsis works have a try at it! You have black and coloured cardboard and scissors: **design your chromadepht composition**. The best one will get points!

Have you got a new idea about a possible application of the 3D chromadepht glasses?

2. Take **the best picture ever at the microscope** and submit it/them for extra points (add a short comment to the picture explaining what it represents).

Extra challenges for bonus

- 1) Black on white through the glasses it looks weird ... in which sense? Why?
- 2) Magenta looks weird why? Yellow idem vedi 3d PPT slide

MoM resources (<http://www.mattersofmatter.eu/mom-materials/>)

- MoM_PRESENT_Wednesday_Micro optics
- Ch3_TEACH_EN_Portable microscopes

References

1. <http://chromatek.com/>
2. <http://www2.ece.ohio-state.edu/~anderson/Outreachfiles/3DOpticsPowerpoint.pdf>
3. <http://slideplayer.com/slide/7596509/>

Acknowledgments

- Jungbecker through IntertekTrading for micro optics donating samples www.intertektrading.com/
- American Paper Optics for donating Chromadepht and diffraction grating glasses to the project <http://www.3dglasesonline.com/>



Where to buy

- <http://www.3dglasesonline.com/>



Co-funded by the
Erasmus+ Programme
of the European Union

This project has received funding from the European Union's Erasmus + Programme for Education under KA2 grant 2014-1-IT02-KA201-003604. The European Commission support for the production of these didactical materials does not constitute an endorsement of the contents which reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.



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