Wednesday 8th March - Tools for Materials Science - Challenge n°10 - 40'

DIFFRACTION AT WORK

Micro-optics indicates a whole variety of optical structures and components whose dimensions are comparable or even smaller than the diameter of a human hair. Micro-optics is now considered a key-enabling technology in the rush towards a miniaturized, empowered, lighter and low cost optics. Micro-optics devices harvest light making its manipulation and redistribution extremely easy and affordable. In such a landscape DOE = Diffractive Optical Elements, which all contain microstructures and combine more functions, play a key role opposed to ROE = Refractive Optical Elements (= classical lenses). Many of them are printed or carved on thin film flexible substrates, namely plastic![1]

CAUTION! Laser beam. **Do NOT shine into eyes! Do NOT stare at the beam and reflections! Beware of people standing around you: DO NOT shine in their face !!!**

Engage

1. On the desk you have a couple of laser pens and a few numbered plastic sheets. They actually are DOE! Take ***Plastic sheet N°1*** and observe the squares and circles. You may want to use the lens magnifier app of your smartphone or the microscope to observe each pattern. Do you see anything?

2. In ***Attachment n°1*** are shown some of the squares as you can see them at almost naked eye and the corresponding diffraction pattern. However the squares are all mixed up! Do you think you can find the right match?
   Actually this is almost impossible because diffraction works in a very different way to what we are used with refractive optics, and most often the diffraction pattern seems to have no link with the original pattern.

Q1. The size of the features of the original pattern is actually comparable to ***light wavelength*** which means that their ***order of magnitude*** is ... ?

3. But let's turn the laser on and enjoy the show! Shine the laser beam through the different spots of the plastic sheet onto the screen adjusting the distance for a clear vision. What do you see now?

4. Take ***Plastic sheet N°2*** and enjoy some more diffraction patterns obtained from an even thinner sheet of plastic.

Diffraction and internal structure

5. ***X-ray diffraction*** has been and still is widely used to investigate atomic structure of crystals and molecules since the X-rays wavelength is comparable to atomic dimensions. Take ***Plastic Sheet N°3*** and shoot the laser through it, in the **circled spot**: what you see is very similar to what appeared to Rosalind Franklin in 1953 when she exposed a strand of DNA to X-rays.

Q2. At that time nobody knew about the real structure of DNA but diffraction clearly proved that DNA shape is ...? [*Justify your answer on the bases of what have you seen.*]

6. Generally speaking from diffraction patterns thanks to the so called ***Inverse Lattice Law*** you can get plenty of info about the original structure. To get "a taste" of this we will simulate the technique using laser light instead of X-rays and ***diffraction gratings*** (or ***diffraction grid***) instead of crystals.

[1] Acknowledgment: Nemo Project www.micro-optics.org

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Q3. Rotate the orientation of the diffraction grid: what happens to the diffraction pattern?

7. Now take the second diffraction grid and compare (with the previous ones) the widths between the lines. [*You can read on the diffraction grid the* ***number-of-lines/mm.***] Shoot the laser and observe the new pattern on the screen.

Q4. How does the diffraction pattern change with the grid width?

Measuring with diffraction

8. Now we will use the diffraction pattern to measure the ***width of the mesh*** of ***EMR*** (Electro Magnetic Radiation) ***screening textiles*** and ***filters***.
   We will use the following equation: $\boxed{d = L \times \lambda / W}$ where:
   - **d** is the mesh width you have to find;
   - λ is the laser wavelength (it will been given to you by the teacher);
   - **L** is the distance between object (the sample you are studying) and screen (where the diffraction pattern is projected onto);
   - **W** is the distance between the first and second light spots on the screen.

   Fill in the **Table A** on the answer sheet with data collected and calculations request.

☞ **OUTPUT WANTED:** **Answers to Q1-Q4 + TABLE A**

Pictures at the microscope of DOE elements

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Answer sheet

GROUP N°___________

Ch.10 --- DIFFRACTION AT WORK

Q1

Q2

Q3

Q4

Table A: ***Width of the mesh of EMR screening textiles: (d)***

λ =			
Sample	**L** (m)	**W** (m)	**d** (m)

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

- **Pictures description:**

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Teacher's notes

Technical notes:

- ???

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	Evaluate if well motivated on observation	2
Q3	See key to answer	2
Q4	See key to answer	3
Table A	For each sample: 2 point for row filled in table A 1 more pint if NO evident mistakes are present	3*3 = 9
Pictures (globally evaluated)	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

Q1. [from 400 to 700 nanometer] tenth of micrometer

Q2 X shaped

Q3. It also rotates (in opposite direction): see experimental confirmation with the diffraction grating actually used.

Q4. The higher the number of lines/mm of the grating (that is to say the wider the distance between the lines) the greater is the distance between the light spots. See the equation in the student's sheet.

Acknowledgements:

The images in Annex1 and Attachment n°1: Key to Answer are from ***NEMO EU Consortium in Microoptics*** who *developed through an EU grant a "NEMO Educational Kit on Micro-Optics at the Secondary School "Vrije Universiteit Brussels*. ***contact*** *Nathalie Debaes* ndebaes@b-phot.org .

Where to buy The DNA diffraction slides used in Q2 to Q4 are from ICE DNA OPTICAL TRANSFORM kit http://ice.chem.wisc.edu/Catalog/SciKits.html

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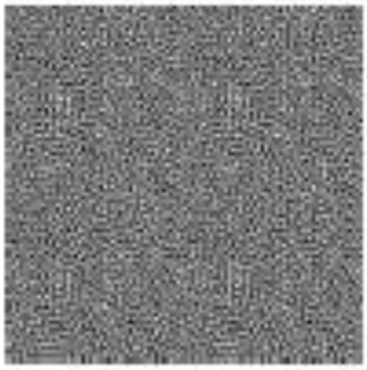
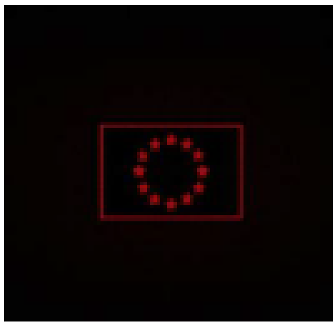
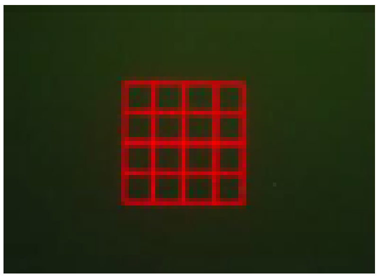
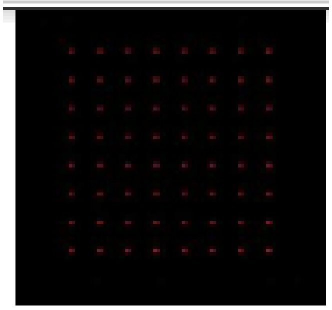
Attachment 1









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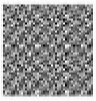
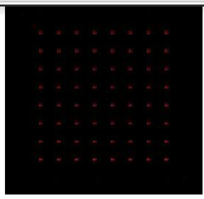
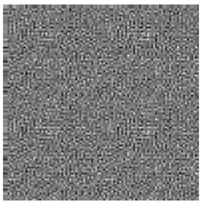
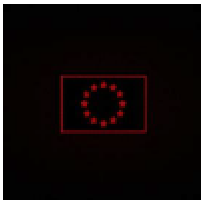
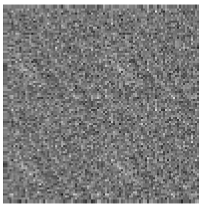
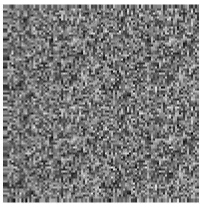
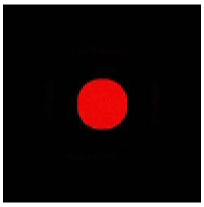
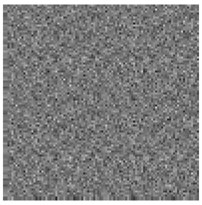
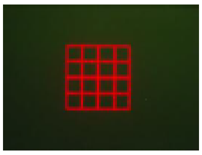
Attachment n°1: Key to Answer

8x8 PF2			Elemento di distribuzione. Maschera binaria. Il periodo è 256 μm.
Prifilo EU PF6			Produzione dell'immagine della bandiera dell'Europa da un PF-DOE a 16 livelli Il periodo è 512 μm.
Logo NEMO PF5			PF-DOE a 16 livelli che genera il logo NEMO. Il periodo è 512 μm.
Profilo piatto in asse. PF3			Generatore di profile piatto. PF-DOE a 16 livelli. Il periodo è 512 μm.
Griglia PF4			PF-DOE a 16 livelli che genera una griglia. Il periodo è 512 μm.

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