Laboratory research №4.7.3 on «Polarization»

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Our aims in this work

- the observation of polarization phenomenon;
- studing the methods of getting a polarized light;
- looking at the aspects of polarization and some magic;
- studing methods for studying the definition of device properties;
- find links between observed RGB color and light wavelength.

The experiment setup

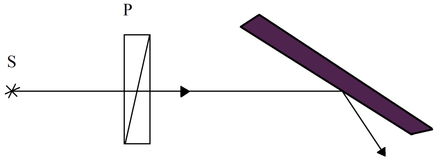


Figure 1: We put a polaroid P and a mirror (violet one) on the way of light.

Now we can make a rough estimation of polarization direction. And by adding the second polaroid we can also etimate it's polarization direction.

$$P_1 : \ -4^\circ$$

$$P_2 : 291^\circ$$

The experiment photos


Figure 2: With the mirror.


Figure 3: The second polaroid.

Theory behind the phenomenon

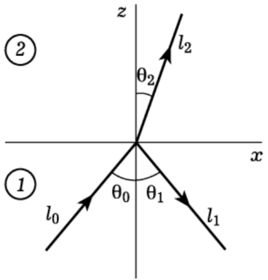


Figure 4: 0 stands for a in-going wave, 1 stands for a transmitted wave, 2 stand for a reflected wave.

The angular encounter of the light with a plane is described as

$$R_{\perp} = \frac{sin^2(\theta_2 - \theta_0)}{\sin^2(\theta_2 + \theta_0)}, \qquad R_{\parallel} = \frac{\mathrm{tg}^2(\theta_2 - \theta_0)}{\mathrm{tg}^2(\theta_2 + \theta_0)}. \tag{1}$$

The main formula

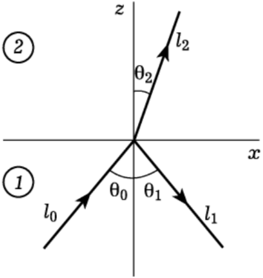


Figure 5: 0 stands for a in-going wave, 1 stands for a transmitted wave, 2 stand for a reflected wave.

An incredible aspect describes the $\theta_p = \theta_0$ wich gives $\theta_0 + \theta_2 = \pi/2$. With this and Snell's law we obtain:

$$\operatorname{tg}\theta_p = \sqrt{\frac{\varepsilon_2}{\varepsilon_1}} = n. \qquad (2)$$

Where θ_p is the angle of polarization or *Brewster's angle.*

Our measurements

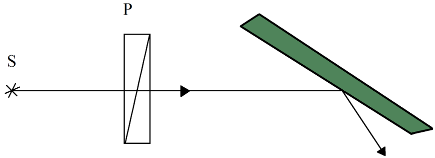


Figure 6: By rotating green ebonite plain we obtain several angles.

name	θ_p	$\mathrm{tg}(\theta_p)$
K	240	1.73
E	237	1.54
K	237	1.54
E	238	1.60
K	236	1.48
E	239	1.66

The measurements were taken apart from each other.

Results

Figure 7: Do not repeat this with a laser beam!

The average refraction coefficient with the formula

$$\boxed{n = 1.59 \pm 0.04}$$

Is pretty close to the real $n_{\text{eb}} = 1.5 - 1.7$.

Observation of reflected and rejected light

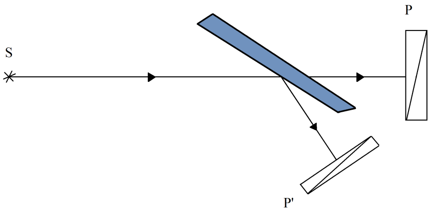


Figure 8: The beam goes right to the stack of glass (light blue) and then splits to two polaroids that we investigate before.

Here we have to observe the with the polaroids from previous observation the direction of vector E.

The polaroids were crossed when:

$$P_1 : 98^\circ$$

$$P_2 : 26^\circ$$

Results

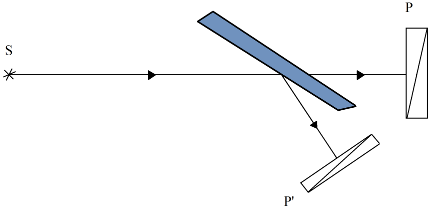


Figure 9: The beam goes right to the stack of glass (light blue) and then splits to two polaroids that we investigate before.

So as was expected the reflected and transmitted light had an orthogonal E.

The polaroids are crossed

$$P_1 : 98^\circ$$

$$P_2 : -265^\circ$$

Pleasant to look at results

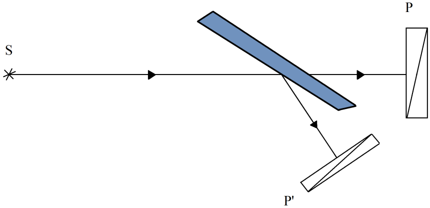


Figure 10: The beam goes right to the stack of glass (light blue) and then splits to two polaroids that we investigate before.

Now we synchronize them by adding the period (2π):

$$P_1 : 98^\circ$$
$$P_2 : 95^\circ$$

So the polaroids are again synchronized, as we expected it to be for transmitted and reflected light.

Experimental set up 1

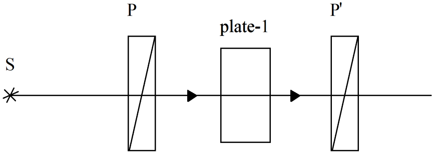


Figure 11: We add two crossed polaroids and the double refracting plate between them.

So, when the polarizations match we observe maximum, and otherwise minimum of intensity.

$$\text{max}: 227^\circ$$
$$\text{min}: 275^\circ$$

Experimental set up 2

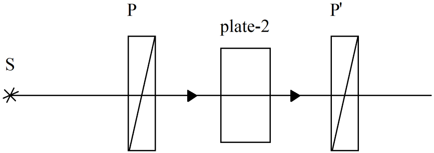


Figure 12: We add two crossed polaroids and the double refracting plate between them.

So, when the polarizations match we observe maximum, and otherwise minimum of intensity.

$$\max: 86^\circ$$
$$\min: 43^\circ$$

The crystal plate

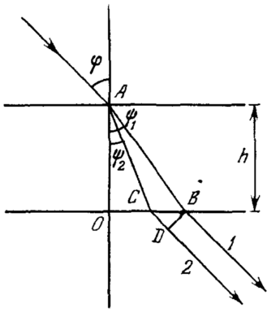


Figure 13: The crystal refract the beam differently.

Going through the crystal plate the light gains the phase difference of

$$\Delta = h(n_2 \cos\psi_2 - n_1 \cos\psi_1),$$

for different refraction coefficient and refracting angles that have a small difference, so

$$\Delta = h\cos\psi(n_2 - n_1).$$

After interferencion

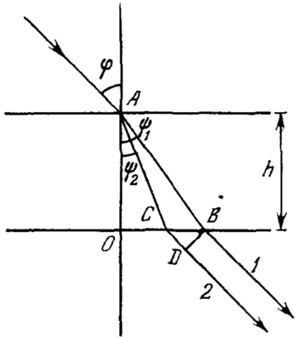


Figure 14: The setup to get an inreferencion of polarized light that is similar to what we had.

We obtain that the key role plays the wavelength of the light

$$\Delta\varphi = 2\pi\frac{\Delta}{\lambda}.$$

So we will differ the plates (K) regarding to relation of its Δ to λ.

Finding $\lambda/4$

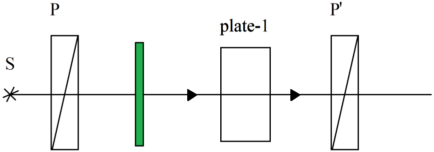
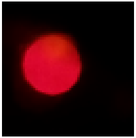


Figure 15: To the previous setup we add a green light-filter. And rotate the first polaraid so it is horizontal and the plate is angled as 45°.

By rotating the polaroid we obtain that plate-1 is $\lambda/4$, because it does not change the intensity, but it changes its polarization and creates phase difference $\pi/2$.

RGB measurement



We measured all the colors received by the system.

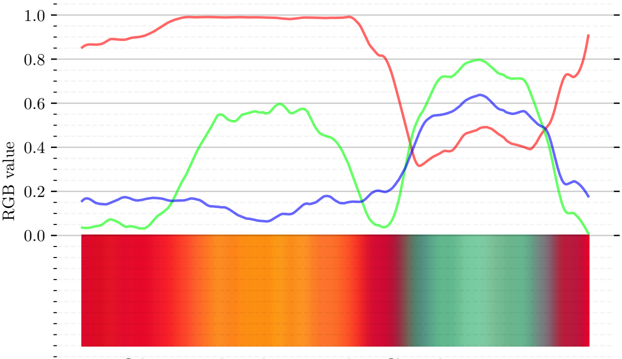


Figure 16: Observed colors and RGB decomposition

Finding $\lambda/2$

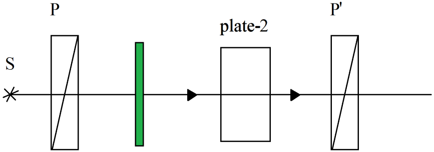


Figure 17: To the previous setup we add a green light-filter. And rotate the first polaraid so it is horizontal and the plate is angled as 45°.

By rotating the polaroid we obtain that plate-2 is $\lambda/2$, due to observing just fluctuating of its intensity. So no color changing here, no magical video then.

Adding λ-plate

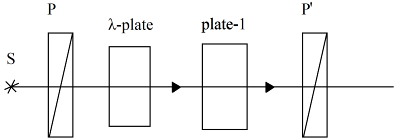
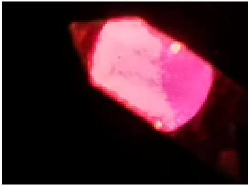


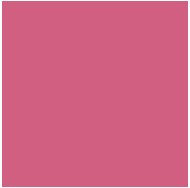
Figure 18: Now we remove green light-filter and add a plate with the arrow on it.

- with green filter and only arrow between we see no result in previous experiment.
- removing the filter with crossed polaroids we see that the arrow is purple.

arrow RGB and Hue measurement

With $\lambda/4$ plate added we can observe the color change when rotating the base of the arrow holder.





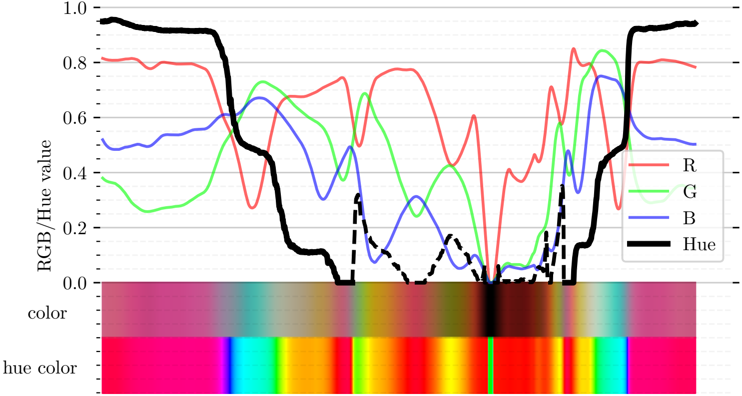
We coud get mean value of rgb color.
It would be interesting to look at RGB in HSV terms.

There are several references to the possibility, in some assumptions to restore wavelength on HSV decomposition.

Figure 19: Hue in the HSV encodings of RGB

arrow RGB and Hue measurement

So, we coud see interesting monotonous gap in Hye, during in arrow rotation:



Investigating the cells

The study of the interference of polarized light was carried out on a mosaic mica plate.

Phase shift in each cell:

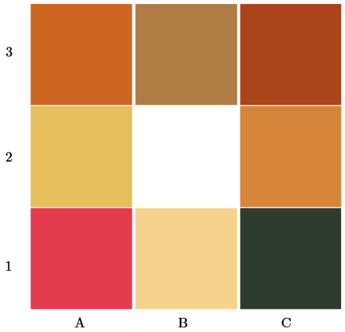
$3\lambda/4$	$\lambda/2$	$3\lambda/4$
$\lambda/4$	0	$\lambda/4$
λ	$3\lambda/4$	λ

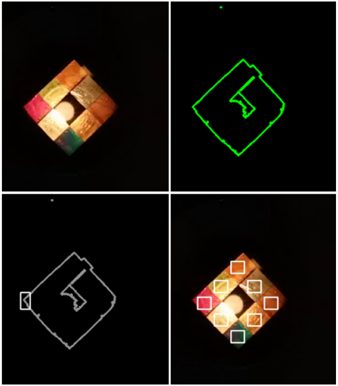
Figure 21: Mica plate photo.

The rotation is observed by period $\pi/4$, as expected, with the coincidence of the main directions with the permitted areas of

Color measurement with mica

The same way we observe color gamma to the grid:
(due to small size of objects we had to detect grid coordinats)





RGB measurement with mica

Finally, observed colors, in polarizator rotation:

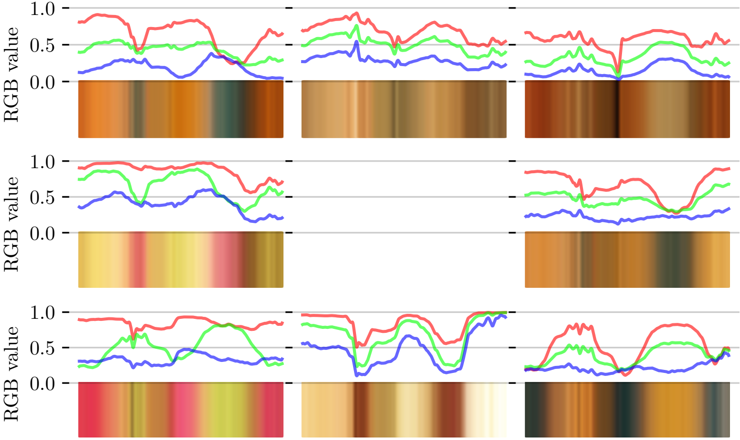


Figure 22: Observed colors and RGB decomposition

Conclusions and thoughts

- Estimated the Brewer Corner for Ebonite.
- Classified plates ($\lambda/2, \lambda/4$).
- Observed the interfering of polarized light.
- Methods for obtaining information about all colors that coul be observed are developed and applied.
- Some corelation (monotonous behavior) between Hue of light and wavelength was discovered. This moment requires a deeper study. It would be interesting, knowing the conditional monochromaticity of the light, to build a relationship between HUE (Oor RGB), and Wavelength.