LUNDS TEKNISKA HÖGSKOLA

FAFF30 VÅGLÄRA OCH OPTIK

Summary of the Polarisation lab

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1 Preparatory problems

1.0.1 Polarised light

a) The y-component is a cosine-wave, i.e. a sine wave shifted by $\pi/2$ rad, meaning the phase difference is $\pi/2$ rad. The light is circularly polarised.

b) $cos(x) = sin(x + \pi/2)$ combined with the negative sign creates a phase shift of π radians, giving linearly polarised light.

c) The light is phase-shifted by $\pi/2$ but has different amplitudes, meaning it's elliptically polarised.

d) There is a phase shift of $\pi/3$ rad, and the amplitudes are the same, meaning it's elliptically polarised.

1.0.2 The law of Malus

The amplitude of the electric field passing through an ideal linear polariser is given by

$$E = E_0 cos(\theta)$$

where θ is the angle between the polariser and the linearly polarised light. Because the intensity is the square of the amplitude, this gives the intensity

$$I = E^2 = E_0^2 cos^2(\theta) = I_0 cos^2(\theta)$$

which is the law of Malus, giving the intensity of the light passing through the polariser.

1.0.3 Birefringence

Different materials have different internal structures. Light, which is electromagnetic radiation, oscillates the electrons in a material when propagating through it. Glass, for example, is amorphous, and the atoms are randomly distributed. Light entering the glass approximately meets the same resistance to oscillation and therefore has the same refractive index for all polarisations of light.

Some materials (e.g crystals) are organised in such a way that it is harder to oscillate the electrons in some directions than other. This means the same material has two different refractive indices depending on the polarisation of the incident light, and this is called birefringence (sv. dubbelbrytning).

If two axes are chosen, called the ordinary and the extraordinary axis, one may define two refraction indices for linearly polarised light incident on these axes. If the refraction index along the ordinary axis is called n_o, and along the extraordinary axis n_e, the difference between refractive indices can be determined, $\Delta n = n_e - n_o$.

1.0.4 Unpolarised light

In unpolarised light the electric field is oscillating in all possible directions perpendicular to the propagation direction. In a birefringent crystal the refraction index in the extraordinary direction n_e is depedent on the polarisation direction of the incident electric field. When light enters the crystal, it is refracted at different angles depending on the polarisation. This leads to the unpolarised beam being split into two beams when it exits the crystal[1].

1.0.5 Reflective grating

Using the equation for reflective diffraction gratings, equation 1, we can see that all necessary values are given, in table 1.

$$d(sin(\alpha_2) - sin(\alpha_1)) = m\lambda, m \in Z \tag{1}$$

Variable	Value
λ	550 nm
m	1 (first spectral order)
d	1/300 mm
α_1	$15°$

Table 1: Given values in the problem

Substituting these values into equation 1 and solving for α_2 gives $25°$ compared to the normal, which is reasonable.

2 Birefringence and difference in refraction index

In this part, we were tasked with finding the difference in refraction index between the ordinary and extraordinary axes in a quartz crystal. The crytal was $d = 3\,\mathrm{mm}$ wide, and we were given intensity data for the visible light spectrum, for parallel and crossed polarisators. I chose to work with the parallel polarisators, and the spectrum data was plotted in MATLAB to create figure 1. Three maximas were chosen in this figure, and the

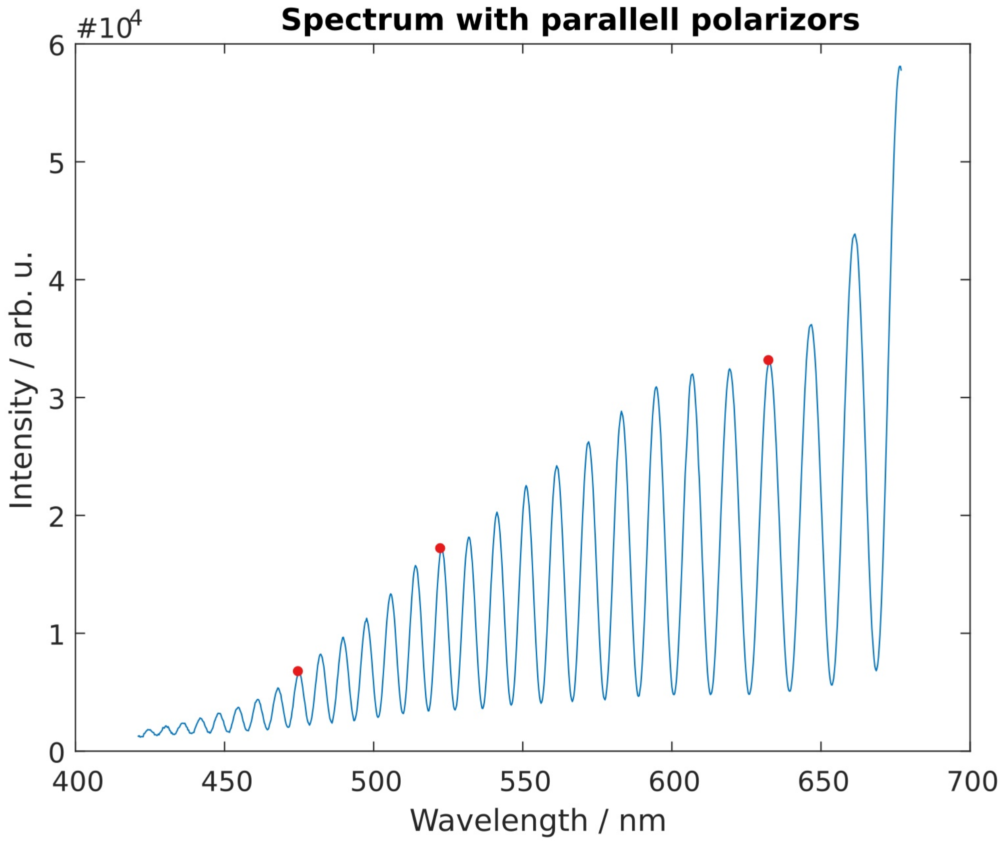

Figure 1: Spectrum data for visible light. The red dots indicate which maxima where chosen for the analysis.

wavelengths were measured, λ_1 was the first chosen maximum, λ_2 the second, p maximas away from the first and λ_3 the third, q maximas away from the first. The difference in

Variable	Value
λ_1	474.9 nm
λ_2	523.1 nm
λ_3	632.7 nm
p	6
q	16

refractive index $\Delta n = n_e - n_o$ is given by Cauchys formula, equation 2. Combining this with the criterium for maximum for the crystal gave us a system of equations, 3.

$$\Delta n(\lambda) = A + \frac{B}{\lambda^2} \tag{2}$$

$$
\begin{aligned}
d(A + \frac{B}{\lambda_1^2}) &= (2m+1)\frac{\lambda_1}{2} \\
d(A + \frac{B}{\lambda_2^2}) &= (2(m-p)+1)\frac{\lambda_2}{2} \\
d(A + \frac{B}{\lambda_3^2}) &= (2(m-q)+1)\frac{\lambda_3}{2}
\end{aligned}
\tag{3}
$$

This system, with three unknowns (A, B and m), was solved using MATLAB's `fsolve` function. A and B were plugged into the $\Delta n(\lambda)$ function, equation 2, and the function was plotted for the visible wavelengths. The result is shown in figure 2. The table value for

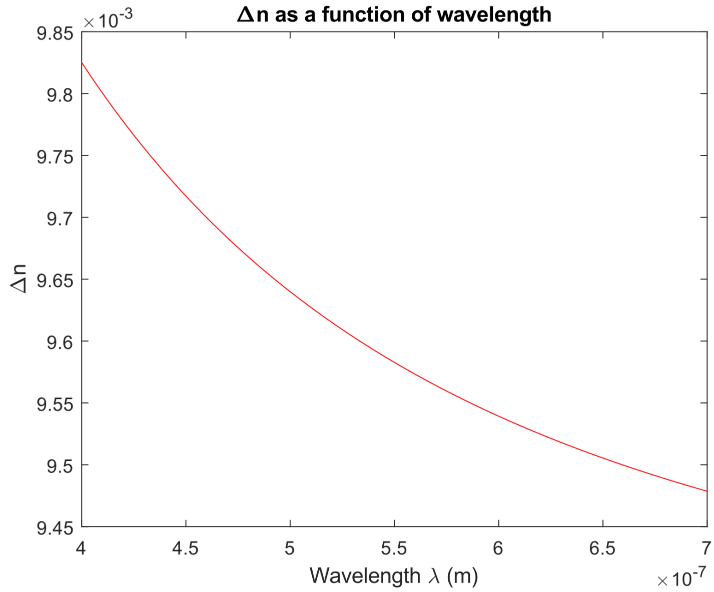

Figure 2: The resulting function

Δn at $\lambda = 590\,\mathrm{nm}$ is 0.009[1], and in comparison the values acquired from the experiment seem reasonable. The difference in values can be attributed to the simple model used for the wavelength dependence of the refraction index.

References

[1] Wikipedia. Birefringence. Accessed 2020-05-12. Available at `https://en.wikipedia.org/wiki/Birefringence`