PH 481 **Physical Optics** **Winter 2016**

Laboratory #7 Week of February 21

Read: pp. 325-333,400-407 of "Optics" by Hecht

Do:
1. Experiment VII.1: Law of Malus
2. Experiment VII.2: Linearly polarized light
3. Experiment VII.3: Interference in the microscope slide.
4. Experiment VII.4: Absorption of Materials

Experiment VII.1: Law of Malus

The goal here is to verify the Law of Malus (Hecht, p. 333, eq. 8.24). This law describes how the intensity of light transmitted through a linear polarizer varies as a function of the angle θ between the polarizer transmission axis and the plane of polarization of the incident light. Malus's Law is

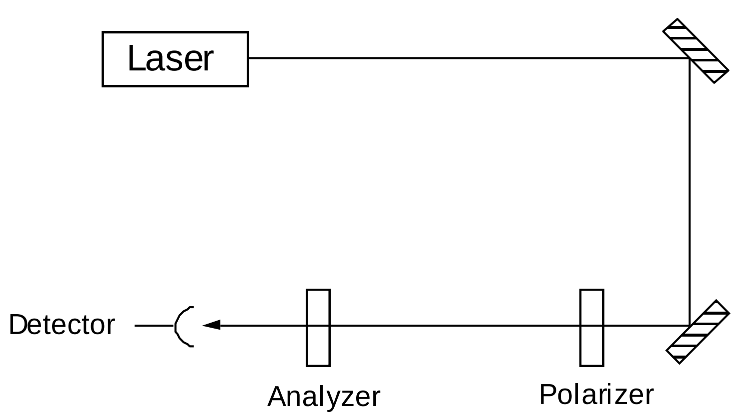
$$I(\theta) = I(0)\cos^2\theta,$$

Theta is the absolut angle with respect the angle at which we are getting maximum intensity
- be careful of not getting saturation over the photo diod

where $I(0)$ is the transmitted intensity when the polarizer transmission axis and the plane of polarization of the incident light are parallel.

To verify Malus's Law, you will use two polarizing sheets and a photodetector as shown in the figure (see also Hecht p. 332). By convention, we will call the first polarizing sheet the Polarizer and the second the Analyzer. The Polarizer ensures that the light reaching the Analyzer is linearly polarized. Since the laser is already linearly polarized, the Polarizer can also be used to adjust the amount of laser light used in the experiment so that the photodetector is not saturated. In practice, you want to make sure that the maximum signal you measure from the photodetector is no more than the half the battery bias voltage (12V). Not necessary

Only one of the polarizing sheets is mounted in a rotation mount; use that one as the Analyzer. The Polarizer can simply be held in a filter holder. Measure the power transmitted through the Analyzer as a function of the rotation angle of the Analyzer. Measurements at 5° or 10° intervals should be sufficient, except near θ = 0° and θ = 90° where more points will be needed. It is useful to first find the minimum and maximum points and eliminate noise, so that $I(0)$ can be properly determined.



Plot your results and compare them with the theory.

Experiment VII.2: Linearly polarized light

-Mention it is a practical way to get laser output linearly polarized

Identify the transmission axis of the polarizer using the Brewster angle technique from week 3 (Experiment II.1). Recall that you should first verify that your laser is polarized at approximately 45° with respect to the vertical. Adjust the polarizer and the glass plate (microscope slide or cover slip will work fine) so that the reflected beam is minimized. The polarizer is then aligned to transmit P polarized light. Remove the polarizer so that the incident beam is a mixture of S and P polarizations. Then use the polarizer to verify that the reflected beam is indeed polarized. Is it S or P?

Using camera works fine here.

We just need to figure 2 angles at which we can get sequential maximum. Then using equation given in hecht and using snells law we can find the thickness.

Experiment VII.3: Interference in the microscope slide

1) Position a clean microscope slide into the expanded s-polarized laser beam. Observe the interference pattern in reflection as a function of angle of incidence. Explain what happens.

   This equation is for refracted beam. Use snell's to find incident angle

2) Now measure the angles at which adjacent minima occur and use Hecht Eq. 9.37 to determine the thickness of the slide.
3) Repeat the same procedure with a cover slip. How is the interference pattern different from that from the microscope slide? Observe the interference pattern in transmission – why is the contrast so much lower compared to that in reflection?
4) Heat the slide with the hot air gun or the soldering iron – what happens? Explain.

Experiment VII.4: Absorption of Materials

Explain for them why we need a wide spectrum lamp, tell them about how the setup of spectroscopy work in both reflection and transmission scheme. Then Explain about the background noise.

Ask them about reference signal in both cases, when we are in transmission/reflection

Use the spectrometer set up to measure the transmission (T) and the reflection (R) of a thin film. We determine the transmission and reflection by measuring the intensity of the light that transmits through or reflects from the sample divided by the intensity of the lamp. To account for any background signal (including stray light and detector dark noise), we calculate the transmission and reflection with the following equations, where $R_{reference}$ is the reflection coefficient of the mirror used to take the reference spectrum.

In reflection scheme we place a Mirror instead of the sample to get the lights back. Then we need to compensate the Reflection coefficient inconsistencies of mirror by multiplying that by reflection coefficient of mirror. I have the file from Thorlabs for Alluminum mirrors.

$$T = \frac{I_{sample} - I_{background}}{I_{reference} - I_{background}}$$

Set:
Boxcar avg=5
integration time: 500msec
Data average=3
Make sure to find the background signal for two different schemes.
we can save the reference/Background from the spectrometer software. It does it by itself. We can get Reflection/Transmission spectrum by the software

$$R = R_{reference} \frac{I_{sample} - I_{background}}{I_{reference} - I_{background}}$$

With the spectra, calculate the thickness of the film using the thin film interference data. Beer's Law states that the absorption of a material is exponentially proportional to the thickness and absorption coefficient.

$$T = (1 - R)e^{-\alpha d}$$

For thin samples (at the order of 800 nanometer) we will see FP effects on the Transmission/Reflection spectrum. We will see some oscillation in the spectrum. Free spectral Range (Pk2Pk distance on spectrogram) helps to find the thickness of sample. By having R/T and 'd' we can find absorption spectrum (alpha)

Using Beer's Law, plot the absorption as a function of wavelength. Comment on the shape and structure of the absorption plot.
Next look at the transmission spectrum of 3 colored slides. Plot the transmission as a function of wavelength and explain why each film is the color it is.

Equipment needed:

Item	Qty	Source (part #)
Helium-Neon Laser	1	Melles Griot 05 LHP 121
Al mirror	3	Newport 10D10ER.1
Polarizer	2	Edmund A38,396
Microscope cover slip	1	Edmund A40,002
Rotation Mount	1	Thor Labs RSP1
Filter holder	1	Thor Labs DH1
Photodetector	1	Thor Labs DET1-SI
Voltmeter	1	Fluke 75
Hot gun or soldering iron	1	
Lamp	1	Ocean Optics USB-DT
Spectrometer	1	Ocean Optics USB4000
Spectrometer Cage	1	