PHYS-339 Lab 4

Optical Measurements using a Solid-State Laser

1 Introduction

This lab is an example of an experiment where all aspects (control of apparatus, signal acquisition) are computer controlled, and serves to illustrate how one can fully automate an experiment with Arduino/Python. The tasks are relatively simple so that you can concentrate on the procedures without getting bogged down in details.

The lab also demonstrates some of the advantages of an automated experiment. In particular, the ease with which you can perform high sampling and redo the experiment multiple times to get the best data (while you sit back and relax and watch the data appear). In this lab, the rotation is achieved using a stepper motor. Unlike the electric motors you may be more familiar with, stepper motors turn in discrete steps in response to pulses applied at their input; one step per pulse. Your Arduino has been fitted with a shield (an accessory board basically) that allows it to power a stepper motor with very little technical input from the user. For more information on this shield, check out: https://www.adafruit.com/product/1438.

Once you have investigated the behaviour of both the stepper motor that you use to rotate the glass plate and the polarising filter, and the photodiode that you use to detect the signal you can move onto the core experiments: The transmission of light through polarising filters (Malus' law) and through a glass plate (Brewster's Angle). Regarding the light transmission experiment, it is highly recommended that you look at an in-depth discussion of the background formula in a text-book on Electromagnetism,[1] as it is a very beautiful classic formula (you will see it derived in PHYS342 or PHYS352).

1.1 Some mechanics

See the other posted document for connections, codes and command details.

[1] I recommend David Griffiths', "Introduction to Electromagnetism," section 9.3.3 in 4th edition.

2 The experiments

2.1 Properties/limitations of the Stepper motor system

There are limits to how fast you can drive the stepper motor. Explore *carefully!*

How many steps does it take to complete one full rotation? How well can you measure this? How are you going to define your“zero” angle?

How can you be sure that you are not missing steps?

How long do you need to wait after stepping to a new position before you make a measurement? Why?

2.2 Malus' Law and Laser Polarization

Place the linear polarizer plate in the beam, and measure the variation of the laser intensity as one rotates the polarizer plate relative to the beam. How would you describe your results? Is this consistent with Malus' law? Confirm by performing a nonlinear fit to the appropriate model. Be careful not to saturate the photodiode as it may not give a linear response at high light intensities. A non-linear responsee will distort your observed signal.

Finally, what is the polarization direction of your laser? First determine the polarization direction with respect to one side of the square polarizer sheet. We recommend that you place the polarizer initially with the two sides of the square polarizer oriented along the vertical and horizontal. How can you then determine the *absolute* laser polarization? To do this, you need to determine the polarization axis of your linear polarizer sheet (Hint: consider using your polarizer to look at light reflected with an angle of incidence equal to Brewster's angle).

2.3 Brewster's Angle and Transmission of Light Through a Glass Plate

Determine the light transmission as a function of beam incidence angle on the glass slide. What model would describe your results? Please confirm that your model is appropriate by fitting it to your experimental results. Determine the Brewster's angle for your results. What is the index of refraction of the glass slide? What are the uncertainties on your results? Can you devise a better way to measure Brewster's angle?

2.4 The beam profile – may not be possible this year

Use a linear drive to move a knife-edge across the beam and observe the change in measured intensity at the photodiode.

Can you determine the shape of the beam?

Can you show that this result is valid even though you are making a 1-d cut across a 2-d beam?