Lab 4 : Lockin Amplifier Light Detection

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1 Objective

Can we use the lockin amplifier to measure increasingly more obstructed light, and then use that data to construct a graph similar to our theory.

2 Setup

Figure 1: Picture of Setup

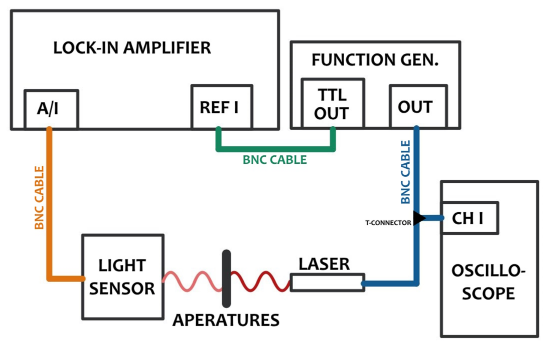


Figure 2: Dragram of Setup

Being our last lab before the practical, the setup was rather heavy. First we used a function generator to create a wave at 400hz. This wave was split to two seperate components, one as a reference for a lock-in amplifier. The other connection was split between an Oscilloscope to keep track of our frequency, and a red laser. This red laser would pass through a aperature at set diameters, and then into a light sensor. This light sensor then gave its signal to the lock-in amplifier. The lock-in amplifier than compares the reference signal to the light sensor's signal to find the intensity of the beam of light.

Because of the reference signal, the lock-in amplifier already knew what frequency to measure at, and would give me a measured voltage. I would then write down the voltage into my notes and repeat the trial for 4 total attempts.

3 Code

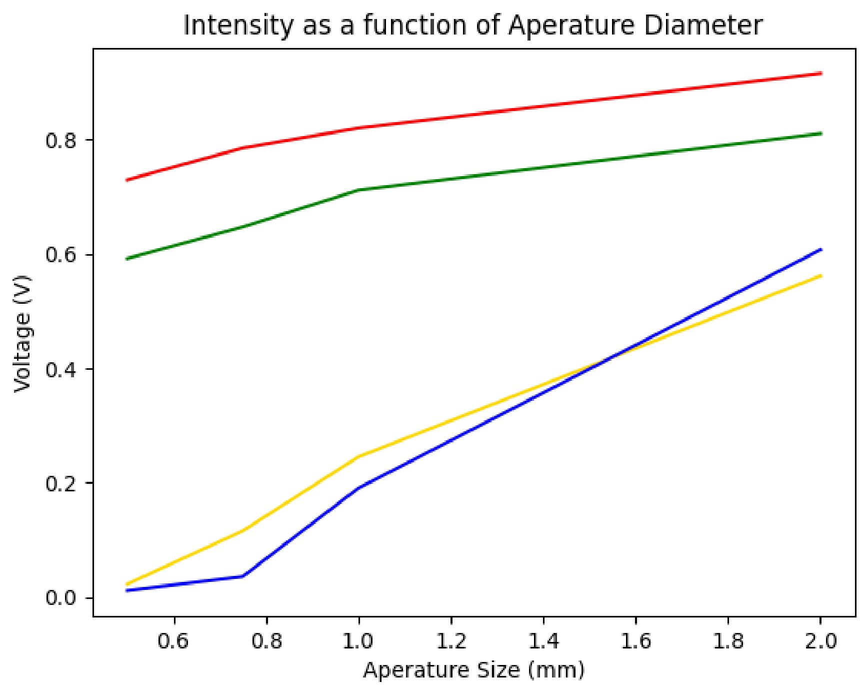
For my code, I decided against using the numpy generate from text to use my csv. I found that process very restricting and would much rather have an array that I can manipulate however I want. So instead I used pandas to convert the csv into a 2d-array. Using this, I created lists of the values I got for each trial, I also created a reference list of all the aperatures. I plotted each trial as a seperate color, and eventually plotted our theoretical prediciton in black. As for all my other changes to the code, that will be covered in the following section.

4 Data

This lab's data is very simple, because of that trying to record everything digitally would be more tedious than just writing it down. In total I did 4 trials, and as I did these trials I kept correcting for slight errors, hopefully this will show as the measurements get closer and closer to theory. For Trial 1 in Red, I did it normally with little regard. Trial 2 in Yellow, I realized I should press autophase before I make a calculation so that it is more consistent. For Trial 3 in Green, I realized that the angle the laser hits the aperature at greatly effects the intensity of the light, so I started to allign everything with the wood grain of the table. For Trial 4 in Blue, I realized that my Ipad would shine light, as well as my face reflected light onto the sensor so I took started sitting behind the sensor, I also started to write down the absolute maximum voltage I could find while adjusting the aperature position.

4.1 Voltage Versus Diameter

Here is the data of the intensity versus the diameter of the aperature.



4.2 Voltage Versus Diameter Squared

However, As we remember in Physics 207, Intensity is a function of Area

$$Intensity = Power * Area \tag{1}$$

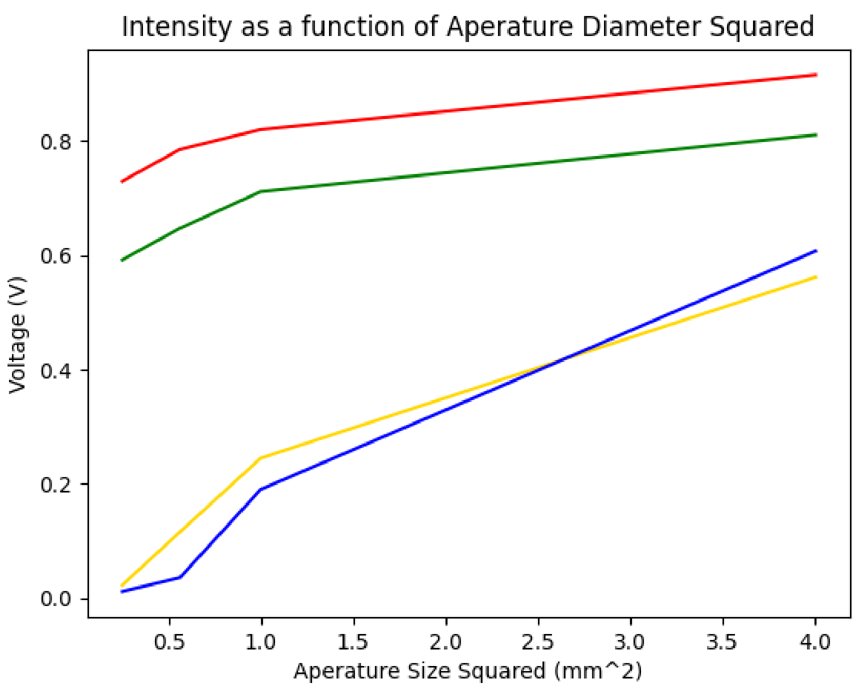
We now Assume that I is proportional to Voltage Out, and that Power is Proportional to Voltage In, as well as replace Area with it's definition

$$V_{out} = V_{in} * \frac{\pi}{4} d^2 \tag{2}$$

The important part for us right now, is that all these are constant per trial except for diameter thus the relationship

$$V_{out} \propto d^2 \tag{3}$$

In other words, we should probably compare voltage to the diameter squared. Doing that we get the following graph.



These should be straight lines, but for whatever reason they all fall off at low aperatures.

4.3 Theory and Normalization

How does our data compare to theory? To answer this question, we must first look at one of our previous equations.

$$V_{out} = V_{in} * \frac{\pi}{4} d^2 \tag{4}$$

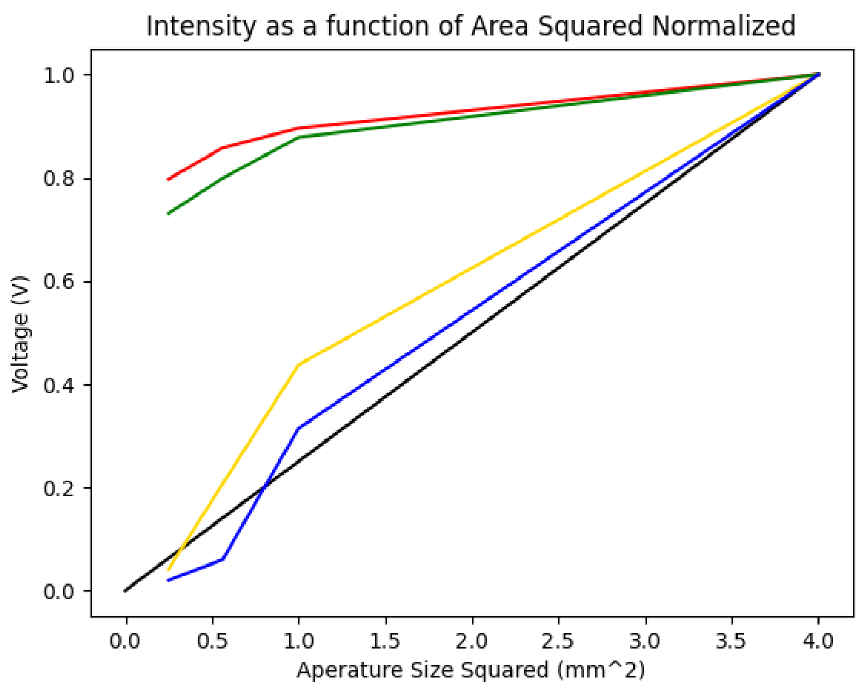
If we set the diameter to 2, our largest size we get the following relationship.

$$V_{2,out} = V_{in} * \pi \tag{5}$$

We can now use this to normalize all our equations so that at a diameter of 4, the voltage is always 1V

$$V_{normal} = \frac{V_{out}}{V_{2,out}} = \frac{d^2}{4} \tag{6}$$

To do this in python, we devide each value in our trial by the value given with a 2mm aperature. As a result of this normalization, our equation for theory can apply to all trials at once and it is very easy. In theory, at an aperature of d=0, intensity should be 0. At our max aperature 2mm, all voltages are normalized to give 1V. So our theoretical prediction is a line at origin with a slope of a fourth, very simple. Here's what that graph looks like with our theoretical prediction in black.



What we see is that Trial 4 was the closest to our theoretical prediction and 2 was right behind, but trials 1 and 3 are not very good. Why is this?. From what I see is that red and green where the higher intensity beams, I know that each laser was dialated larger than the aperature size, so there should be no discrepancy between a higher and lower starting voltage. However, after thinking about it for longer, I know exactly why the higher voltages are worse off. I overloaded the Lock-In Amplifier. My guess is that with higher intensities, The lock-in will reduce the apparant voltage coming through in order to not break. Another reason could be that the photo-transistor sensor was getting overloaded, but I can't prove that. My guess is that at a certain point the transistor gets close to it's maximum opened state and starts to curve off at higher values.

5 Links to Data and Code

-CSV File of Data Link
-Python Code for Trial Graphs Link