Phys 270L Experiment 3

Joshua Lau 20630767

Purpose:

The main objective of this experiment is to observe where the CCD responds linearly and where it fails to work.

Data:

Green light was used in this experiment – rs2

Part A

Without box – 1.456 µW +/- 0.002 µW

With box – 0.019 µW +/- 0.002 µW

Lights off with box – 0.000 µW +/- 0.0001 µW

Part B

Brightness at 205 at rs2, 1.049, if we use rs2, 1.05 the histogram goes off the screen. We tried numbers in-between 1.049 to 1.05 however nothing will get us any numbers between 205-255, it jumps to 255 once you hit the 1.05% threshold

Part C

% +/-0.005%	Avg +/- 0.005	Min +/- 0.5	Max +/- 0.5	Std Dev +/- 0.05
1.0	204.55	195	217	2.6
0.75	44.92	38	50	1.18
0.85	129.5	122	140	2.05
0.92	130	122	142	2.05
0.5	7.0	4	10	.50

Note any number that is < 0.5% or >1.05 will result in it not showing in the histogram

Part D

% +/-0.005%	Avg +/- 0.005	Min +/- 0.5	Max +/- 0.5	Std Dev +/- 0.05
0.2	7.01	4	10	0.5
0.5	7.0	4	10	.50
0.4	7.1	4	10	.50
0.3	7.05	4	10	.5
1.03	204.29	192	213	2.59
1.0	204.55	195	217	2.6
1.04	201	195	214	2.59
1.01	203.69	192	214	2.58

Note any number that is < 0.2% or >1.05 will result in it not showing in the histogram, also important note is that from 0.2% – 0.5% you get the same result of about an average of 7.01 however if you dip below 0.2% it goes to 0.

Part E

3000 µsec

% +/-0.005%	Avg +/- 0.005	Min +/- 0.5	Max +/- 0.5	Std Dev +/- 0.05
0.84	116.0	105	123	1.93
0.79	114.1	104	122	1.94
0.82	115.7	104	125	1.93
0.7	13.29	9	17	0.69
0.77	114	104	127	1.93

Note we tested out every number between 0.7 to 0.84 in increments of 0.1 however they result in the same number unit we plugged in 0.77 or greater then it suddenly jumps to the 0.84 bracket. We didn't take note of every number since we were looking for the threshold between the jumps.

10000 µsec

% +/-0.005%	Avg +/- 0.005	Min +/- 0.5	Max +/- 0.5	Std Dev +/- 0.05
0.7	28.21	28	30	0.94
0.69	28.03	28	31	0.95
0.68	27.98	27	31	0.95
0.66	27.26	23	34	0.94
0.65	27.70	24	35	0.96

Note first any number that isn't between 0.65 and 0.7 will result the histogram being out of range. We also tried to find any jumps in between 0.7 by increments of 0.01 % however it results in approx. the same answer.

16000 µsec

% +/-0.005%	Avg +/- 0.005	Min +/- 0.5	Max +/- 0.5	Std Dev +/- 0.05
0.68	38.56	33	48	1.11
0.69	38.34	33	49	1.11
0.7	38.92	34	49	1.12
0.65	39.61	33	49	1.12
0.74	38.57	34	48	1.11

Note first any number that isn't between 0.65 and 0.74 will result the histogram being out of range. We also tried to find any jumps in between 0.74 by increments of 0.01 % however it results in approx. the same answer. Exactly the same situation as 10000 µsec

Part F

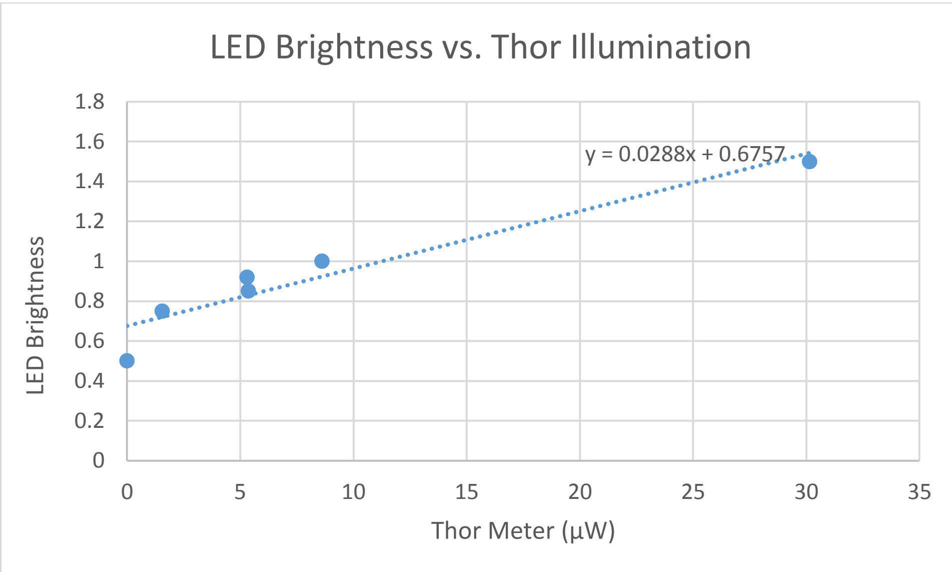
% +/-0.005%	Thor detector (µW) +/- 0.002 µW
1.0	8.60
0.75	1.550
0.85	5.35
0.92	5.30
0.5	0
1.5	30.15

Without the box – 1.369 µW +/- 0.002 µW

With box – 0.018 μW +/- 0.002 μW

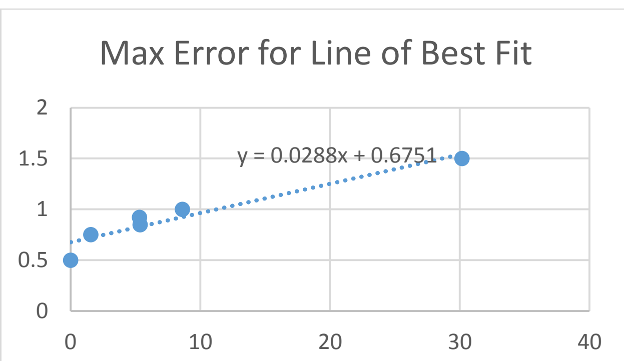
Light off – 0.0

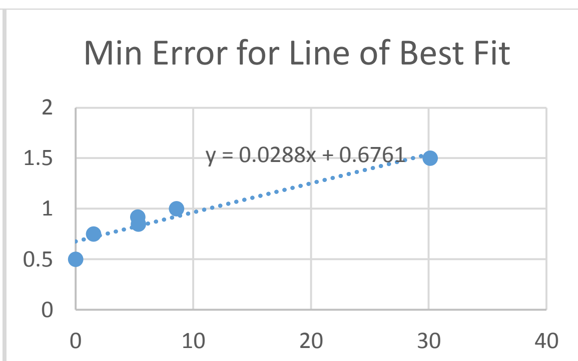
That means with the box the ambient temperature by averaging part A and part F you get 0.0185 μW +/- 0.0015 μW to calculate the error I square root over the square of the error both 0.002 μW and divide it by two since we were averaging over 2 numbers.



At 0.5% illumination the thor meters reads 0 μW that means that that is the threshold that the thor meter cannot read below.

The error in the slope we have to calculate the min and max values of for the slope. Here below are two graphs one of which is if we take the max value of the thor meter using the error +0.02 and the other the min value if we take the thor meter using -0.02.





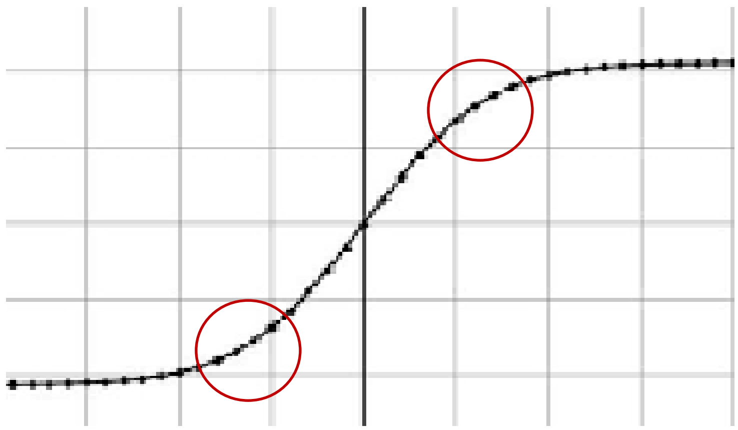
As you can see the slope remains the same since a difference of 0.02 μW was not enough to change the slope however the y-intercept changes where the max is at 0.651 and min at 6761. The y-intercept has an error of +/- 0.0004.

Anaylsis

Part B

When you double the bit from 8-bit to 16-bit you are moving from 8-bit which is 2^8 to 16 bit which is 2^16 in data size. That means your brightness value should be 2^16 which is 65536.

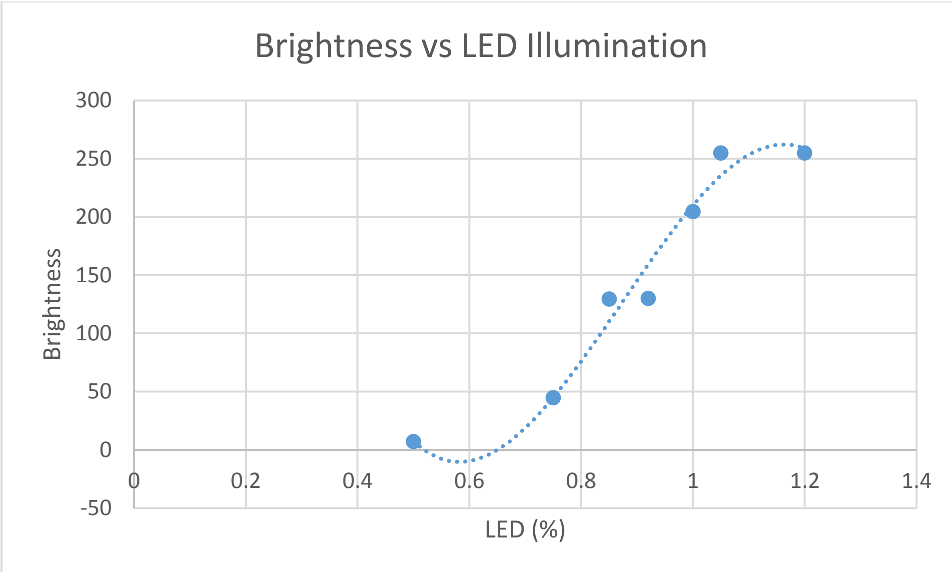
The approximate value we obtain for green is when the brightness % is at 1.049, past 1.05 the value goes off the histogram. It's interesting to note that we tried enter 1.0499999999 however that doesn't change the result meaning that the program only takes number up to the thousandths significant digits. This is because since the CCD's response of a pixel vs exposure to light follow a function like the one below:



It's difficult to try and get the brightness value for the points circle in red and it depends upon how many bits the camera is. For us the "grey" area where we don't know when the linearity stops is around the 1.05% brightness level.

Part C

For this part we found numbers that ranged from both side of the histogram, but since we already knew that at 1.05% you will hit 255 we found the lower bound which is 0.5% where any number below that will result in the brightness value being 0. When we did this experiment it seems there were only 4 "steps" where any number in between will just give you a brightness value of one of the steps the lowest value for the brightness is 7 next is around 44, and 130, and finally 205. Any number from 0.5% to 1.05% will result in a brightness value of one of the ranges. As you can see there is essentially no difference between 0.85% and 0.92%. The following graph is just to show where it seems to be linear and where it fails to work. However this is before I converted the illumination in watts.



I used a 3rd degree polynomial for this graph and it seems that it becomes linear around 0.75% and 1%.

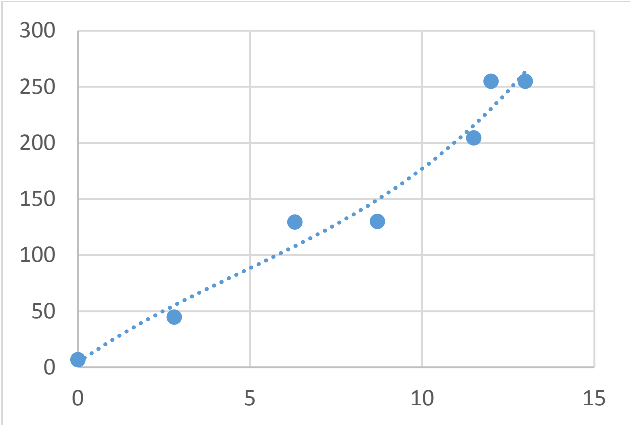
Using the calibration curve from part 4 the curve has an equation y = 0.0288x + 0.67 where y is the LED % if we convert the 1% to watts:

Illumination (µW)	Avg +/- 0.005
11.5 +/- 0.2	204.55
2.8 +/- 0.2	44.92
6.3 +/- 0.2	129.5
8.7 +/- 0.2	130
0 +/- .02	7.0

Error calculation example for first illumination: slope doesn't have an error however the slope has an error of +/- 0.4

If out y value is 1.0% with error of 0.005% and the y-intercept 0.6757 had an error of +/- 0.0004 we just take the root square of the errors which is 0.5x10^-3, now we divide the slope of 0.0288 and also divide the error by 0.0288 since it is a scalar quantity. Which gives you the error of 0.1742 with sig dig of 0.2.

Now if we graph it based on avg brightness vs illumination it come out as this:



This curve looks extremely different then from the one before where it was brightness vs LED percentage. This graph looks a lot more linear even though it should come out as something similar to the previous graph. I believe he problem stems from the conversion between the LED % to the Thor meter. A lot of issues arises from the line of best fit of the LED% vs Thor meter graph since from the line of best fit the smallest % he Thor meter can take is the y intercept 0.67 before it can read any illumination. That means if we used a 0.5% for example and received a brightness however if you convert that into illumination you will get a negative value of µW.

Part D

% +/-0.005%	Avg +/- 0.005	Illumination (µW)	Avg +/- 0.005
0.2	7.01	-16.3	7.01
0.5	7.0	-5.9	7.0
0.4	7.1	-9.4	7.1
0.3	7.05	-12.8	7.05
1.03	204.29	12.5	204.29
1.0	204.55	11.4	204.55
1.04	201	12.8	201
1.01	203.69	11.8	203.69

The chart above is the LED % before and after converted to illumination in µW. It's important to explain that the reason there are negative illumination is because as shown in part F the LED % to thor meter line of best fit had an equation of y = 0.0288x + 67 where LED% is x and y is thor meter so that means from the line of best fit any LED % > 0.67 will result in a negative illumination since it the thor meter can only detect illumination for when the LED% is greater than 0.67. However it seems the threshold around both ends seem to span from 0.2-0.5 at an average of around 7 and on the other end it spans around 1.0-1.04 with an average of about 203.

Part E

3000 µsec

% +/-0.005%	Avg +/- 0.005	Illumination (µW)	Avg +/- 0.005
0.84	116.0	5.9	116.0
0.79	114.1	4.2	114.1
0.82	115.7	5.2	115.7
0.7	13.29	0.35	13.29
0.77	114	3.5	114

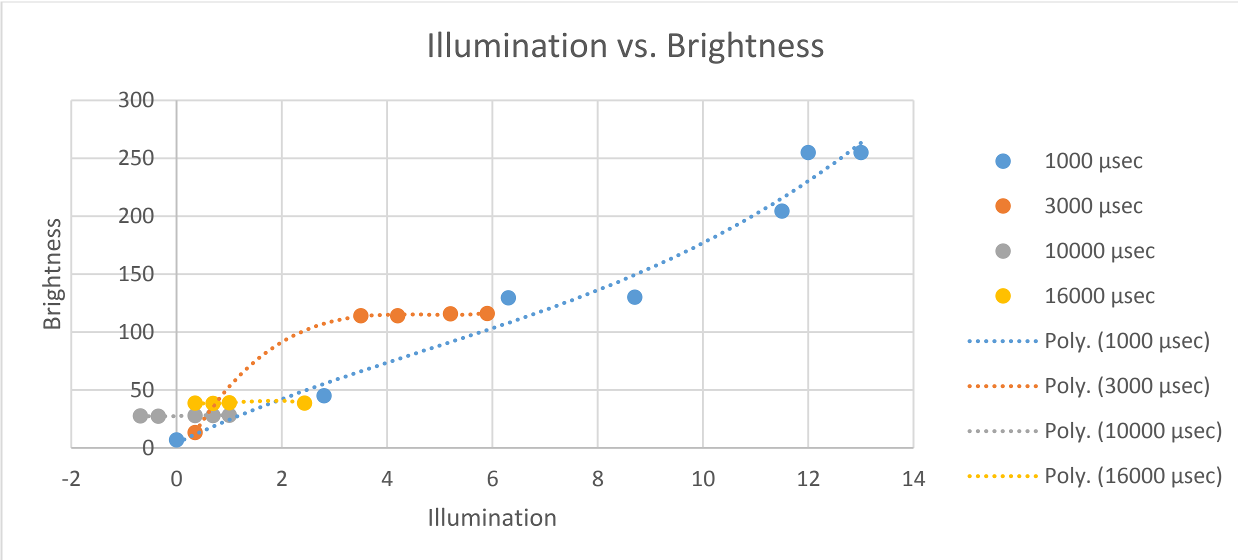
10000 µsec

% +/-0.005%	Avg +/- 0.005	Illumination (µW)	Avg +/- 0.005
0.7	28.21	1.0	28.21
0.69	28.03	0.69	28.03
0.68	27.98	0.35	27.98
0.66	27.26	-0.35	27.26
0.65	27.70	-0.69	27.70

Similarly as the last part because the % was below what the thor meter can measure we get negative (µW) however when I plot I won't be using the points since we don't actually know what the illumination values are below 0.67%

16000 µsec

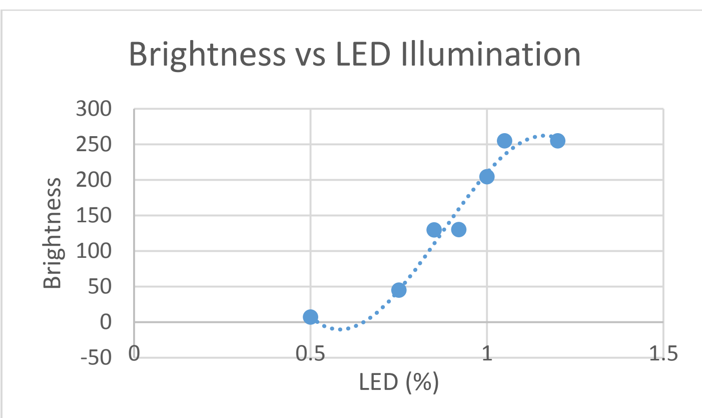
% +/-0.005%	Avg +/- 0.005	Illumination (µW)	Avg +/- 0.005
0.68	38.56	0.35	38.56
0.69	38.34	0.69	38.34
0.7	38.92	1.0	38.92
0.65	39.61	-0.69	39.61
0.74	38.57	2.43	38.57



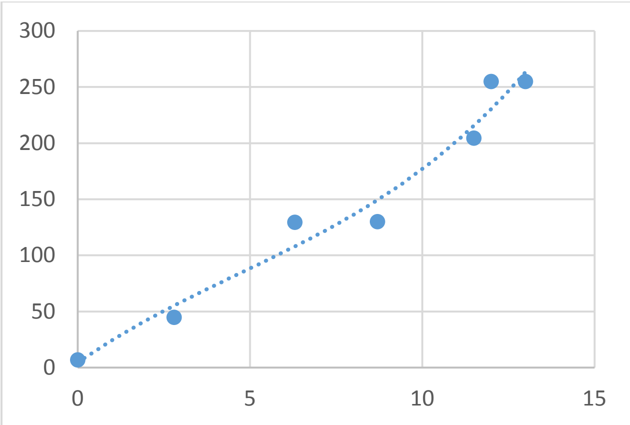
During the experiment we noticed that as we increased the exposure time it seems that the discrete levels between brightness also goes down. For example when it was 1000 µsec we had about 5 jumps brightness where as soon as you hit a certain % it jumps another brightness "bracket". However as we increased the exposure time you will get less and less of these jumps as you go from 3000 µsec to 16000 µsec.

Conclusion

Initially we had graphed that agrees with the theory that there is a discrete linear regime in the graph Illumination vs brightness as seen below:



However problem arises once we convert the LED % into the Thor meter we get a graphed that is much more linear then what it's supposed to look like:



I discussed how a major factor is due to the error in measuring the ambient lights in part A and part F where we try to associate the LED % with units of µW of the Thor meter. Finally I also discussed the difference between exposure time and brightness is that as you increased the exposure time you get less discrete jumps of brightness.