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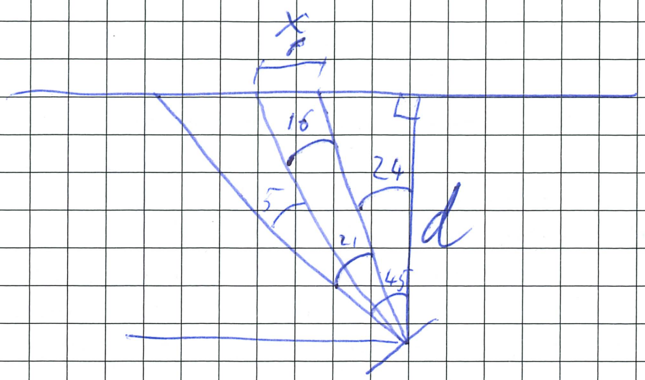
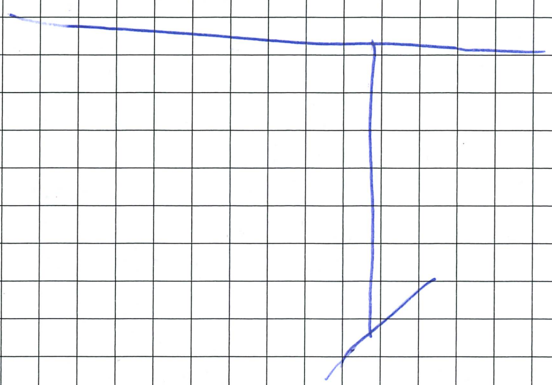



$$x = d\tan\left(\frac{16+24}{\cancel{40}}\right) - d\tan(24)$$



Equation of the grating is

$$m\lambda = d_0(\sin(\alpha) + \sin(\beta))$$

with $\alpha$ and $\beta$ defined as


We have measured $\alpha$ and $\beta$ with $m = 1$ and found $\alpha = 45^\circ \pm 2^\circ$ and $\beta = 10^\circ \pm 5^\circ$. This gave us a $d_0 = 7.4982 \cdot 10^{-7}$ m for the grating separation.
We have then found a formula for $\beta$ as function of $m$ and $\lambda$ as

$$\beta = \arcsin\left(\frac{m\lambda - d_0\sin(\frac{1}{4}\pi)}{d_0}\right)$$

We further calculated the length l ~~of the~~ between the zeroth order spot and a spot of order m and wavelength $\lambda$ on the screen as

$$l = \text{distance\_screen} \cdot \tan\left(\frac{1}{4}\pi - \beta\right).$$

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This gave a distance of 6cm of the ~~wavelength~~ wavelengths ~~400~~ 380 - 600 nm of order 1, which matches our findings.

We then made a Littrow configuration which sends the first order light emitted by ~~the~~ the laser and ~~seppe~~ sepperated by the ~~diff~~ grating back into the laser itself via reflection by the grating. We then measured the power of the laser with and without the feedback and without the grating and found:

- Without the grating the power reached was the highest at around 30 mA with lasing beginning at ~28 mA.
- With the grating the power was reduced due to the sepperation of the laser beam also ~~seppe~~ reducing the power of the zeroth order beam. The threshold of lasing was around 28 mA
- With feedback the lasing threshold got reduced to 25 mA and the power is higher than without feedback but with the grating.

We ran into issues with our power measurements due to the power meter fluctuating a lot at 28 mA the fluctuations where between 50 - ~~2~~250 μW. We measured again with another power meter and found the above results which ~~is~~ also includes graphs on github.

Notes of programming the CCD:
We found that the microcontroller that we were using was not setting its own clock correctly (it was set to 84 MHz but we found it to be more around 16 MHz). We adjusted the values of the timers so the oscilloscope shows the correct values. We found for the Master-clock ($f_\emptyset$) the values:

ARR = 13 - 1
CCR = 6 - 1

SH: ARR = 850 - 1
CCR = 10~~7~~8 - 1

ICG: ARR = 201600 - 1
CCR = 244~~8~~0 - 1

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This gives an integration time of .311 μs

We found that to get a correct delay between the rising edge of ICG and the rising edge of the SH pulse we need to set the timers up in a master-slave condition. This would allow the timers to start with the correct delay between them and keep the delay.

We chose TIM2 for the ICG and TIM4 for the SH both operating in PWM mode channel 1. The master timer (TIM2) is set to enable MSM pin and ~~Reset~~ the trigger event is Update event. The slave timer (TIM4) is set to trigger mode with source ITR1 because of the tables

| Slave TIM | ITR0 | ITR1 | ITR2 | ITR3 |
|---|---|---|---|---|
| TIM2 | TIM1 | Tim8 | Tim3 | TIM4 |
| TIM3 | TIM1 | Tim2 | " 5 | " 4 |
| TIM4 | TIM1 | " 2 | " 3 | " 8 |
| TIM5 | TIM2 | " 3 | " 4 | " 8 |

Here for example if TIM3 is set as slave (Row) then setting the trigger source to ITR2 would make TIM5 the master.

We set in the slave configuration panel the MSM bit ~~a~~ to Enable and Trigger condition to Reset and Polarity to Low.

In the main.c file we wrote

```
HAL_TIM_~~B~~PWM_Start(&htim3, TIM_CHANNEL_1);
   "                  (  htim4,   "          1)
   "                  (  htim5,   "          1)
   "                  (  htim2,   "          1)

-- HAL_TIM_SET_COUNTER(&htim4, -10);
```

The last line causes the SH timer to start ~~last~~ 10 clock cycles later than the ICG and this results in the desired delay between the ICG and SH.

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We noticed that there was flickering of the CCD output and attributed that to a faulty cabels we replaced the cables but could not solve the issue we then saw the effect ~~the~~ of replacing the breadboard vertically and started to measure more. We measured the clocks that ~~micro~~ inverter produced and noticed they were more sinusoidal than stark. We

12-06-2023

We are trying to see if the master clock timing and duty cycle have effect on the noise.
To research this we are trying to have a master clock setting of ARR=12-1 CCR=6-1 and scaling the other clocks accordingly. This unfortunately was not helped in fixing the noise.

13-06-2023

We are trying to see if some wire is causing the noise. We did not find it. Maximillian then suggested to put the ~~output~~ impedence of the oscilloscope to 100MΩ instead of 50Ω because the voltage is higher at this impedence so the noise could be less. This also did not help. We then tried to let the microcontroller and the scope have the same ground by connecting it to the same group of outlets but this also did not help. Trishan then turned the lights of for his measurement of the laser and suddenly the noise went ~~away~~ ~~a~~ away so we think the fluorescent lights caused the problem. We also tried to ~~m~~ measure the output of the CCD directly instead of putting it through a transistor. We do not know if this was helping in reducing the noise.

14-06-2023

See github

15-06-2023

We are having difficulty calibrating the spectrometer with the neon light due to the ~~peaks~~ wavelengths not having truly peaks but more hills. This makes the peak guessing much more difficult.
We now chose four peaks ~~to~~ from which we calibrate
585,25 nm at pixel ~ ~~2362,42~~ ~~pixel~~ ± 18 px
1736,72

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Then a 640,00 nm ± 2 nm peak at pixel 2756,45 ± 20 px, Then another peak at 650,65 nm at 2968,9 pixels ± 20 px. And then a peak at 614,31 nm ± 2 nm at 2198,79 pixels ± 20

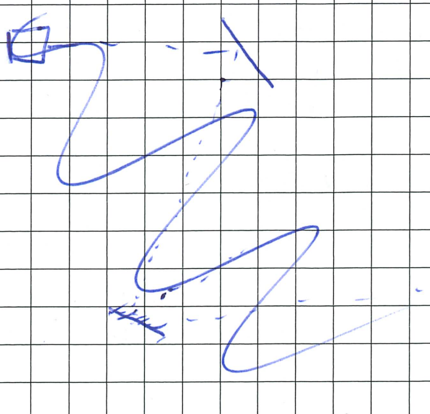
This gives $\delta = 222{,}033$ $A_1 = 0{,}38820$ $A_2 = 9{,}00035$ $A_3 = 1{,}26870 \cdot 10^{-8}$ with no errors as I have not calculated them yet Robin B working on it.

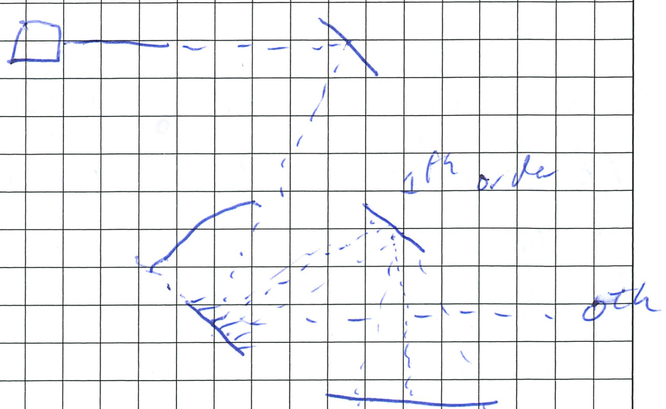
16-06-2023

~~was~~ The setup had fallen of the stand so we are recalibrating the whole spectrometer again. While trying to setup the ~~calibration~~ spectrometer for calibration I found that the weird highest peak of the neon Lamp ~~at~~ which was not the 586 nm peak was also slightly present in the spectrum of the flash light.

Peeks:

| ~~...~~ wavelength | ~~time~~ position (time oscilloscope) | pixel |
|---|---|---|
| 585,25 nm | 3,00 ms ± 0,1 ms | 1593,82 ± 50 |
| 640,00 nm ± 2nm | 4,92 ms ± 0,1 ms | 2613 ± 50 |
| 650,65 nm | 5,30 ms ± 0,1 ms | 2814 ± 50 |
| 614,31 nm ± 3nm | 3,85 ± 0,1 ms | 2044,26 ± 50 |



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UNIVERSITEIT VAN AMSTERDAM VU VRIJE UNIVERSITEIT AMSTERDAM

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Photo 34 beginning with measurement cases

44 question [illegible]

50 ~~not~~ use not 19-06-2023

57 Calibration 1 19-06-2023

58 Measurement flashlight 1 19-06-2023

59 current 25, no feedback

integration time 100 [illegible]

60 current 28 (lasing), no feedback

61 current 28 (zoom), no feedback

~~62~~

integration time 223 [illegible]

64 current 28, feedback first peak. 5.00°

65 current 28, feedback second peak. 5.03°

66 current 28, feedback 5.07°

67 current 28, feedback 5.14°

68 current 28, feedback 5.23°

69 current 28, feedback 5.35°

70 current 28, feedback 5.42°

71 current 28, feedback 5.45°

~~72~~ current 25, feedback 5.23°

67/68 (new)

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19-06-2023 We measured the laser spectrum ~~at~~ with feedback and without and lasing and not lasing and found the results as is posted on github. What was odd is that the laser emitted a peak clearly to the left of the ~~6~~640 nm peak from the neon lamp and but the laser itself was specified at 858 nm. This discrepancy we put down to inaccurate measurements and/or calibration. We further found that the peak of the laser moves to the left (smaller wavelength) as we increased the angle of the grating. ~~we with the~~ We ~~also~~ also tried measuring ~~at~~ a different light and the sun but the signal we got was too weak for the CCD to detect it. We will try again tomorrow and also make the poster.

20-06-2023
I calculated the Full width half maximum of the peaks at 25 mA and 28 mA no feedback of the laser and found the FWHM of 25 mA is 7,34 nm and FWHM ~~of~~ at 28 mA is 3,10 nm.
I also recalibrated the CCD photo 67 in [illegible].
We found that while adding the error on the calibration that it would vary ~~wildly~~ wildly

21-06-2023
We processed more of the data of the laser measurements ~~dr~~ by calculating the maximum peak of the laser at 25 mA ~~and~~ no feedback and ~~taking~~ making all the measurements ~~rel~~ relative to that peak by setting the peak at 1 and ~~the~~ dividing every ~~p~~ datapoint by that peak.
We also tried to add the errors ~~on~~ on the ~~wave~~ photos but we found them not represent the data well enough and also it was clutted with it. Therefor we decided to have the errors be present in the x-axis label. The y-axis showing the relative intensity ~~plus~~ the errors included.

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Universiteit van Amsterdam

VU Vrije Universiteit Amsterdam

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For instructions on the CCD program, it is on github.

22-06-2023

~~td~~ I and Tristan made the poster draft we encountered some difficulties but managed to make it work in the end. I also needed to adjust some graphics for better display on the poster.

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