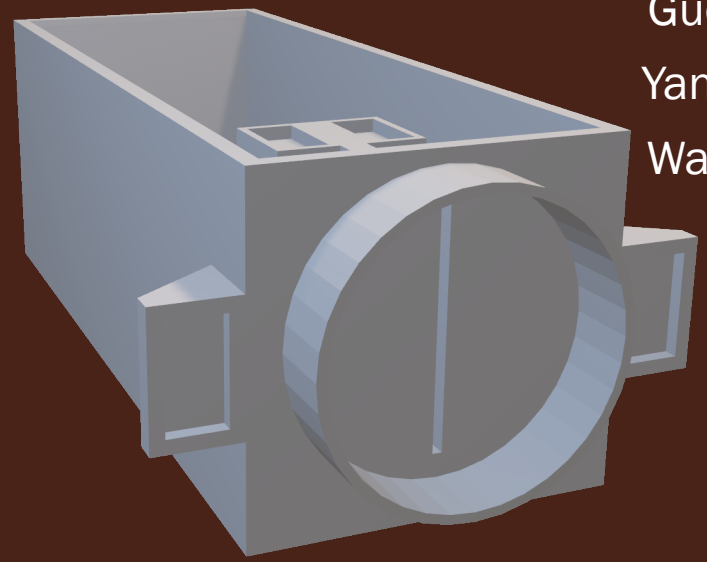
GROUP 4 MIDTERM PRESENTATION



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Outline

- Project Overview
  - *Member List*
  - *Distribution of Work*
  - *Experiment Objective*
  - *Milestone and Timeline*
  - *Budget*
- The Experiment of Diffraction Grating
- Make a Spectrometer
- Application 1: Measure the Plank's Constant with LEDs
- Application 2: Measure the Spectrum Absorption of Copper Sulfate Solution
- Reference etc.

(Every application has individual Methodology and Hypothesis)

DISTRIBUTION OF WORK

Work	Participants
Hardware Design	Guo Yiming
Software	Wang Yiran, Yang Ziou
Background Research/Literature Review	Wang Yiran, Yang Ziou
The Experiment of Diffraction Grating measurement	Guo Yiming
Plank's Constant with LEDs	Yang Ziou
Spectrum absorption of some solutions (for example, CuSO4)	Wang Yiran
Experiment plan design, setup and conduction	Guo Yiming, Wang Yiran, Yang Ziou
Planning project and Budget	Wang Yiran, Yang Ziou
Data analysis	Guo Yiming, Wang Yiran, Yang Ziou

Research Objective

- To determine and compare the grating constant for different brands of CD or DVD.
- To make a spectrometer
- Application:
  - *To measure and investigate Planck's constant with LED*
  - *To measure and investigate the spectrum absorption of some solutions (CuSO4)*

Milestone Timeline

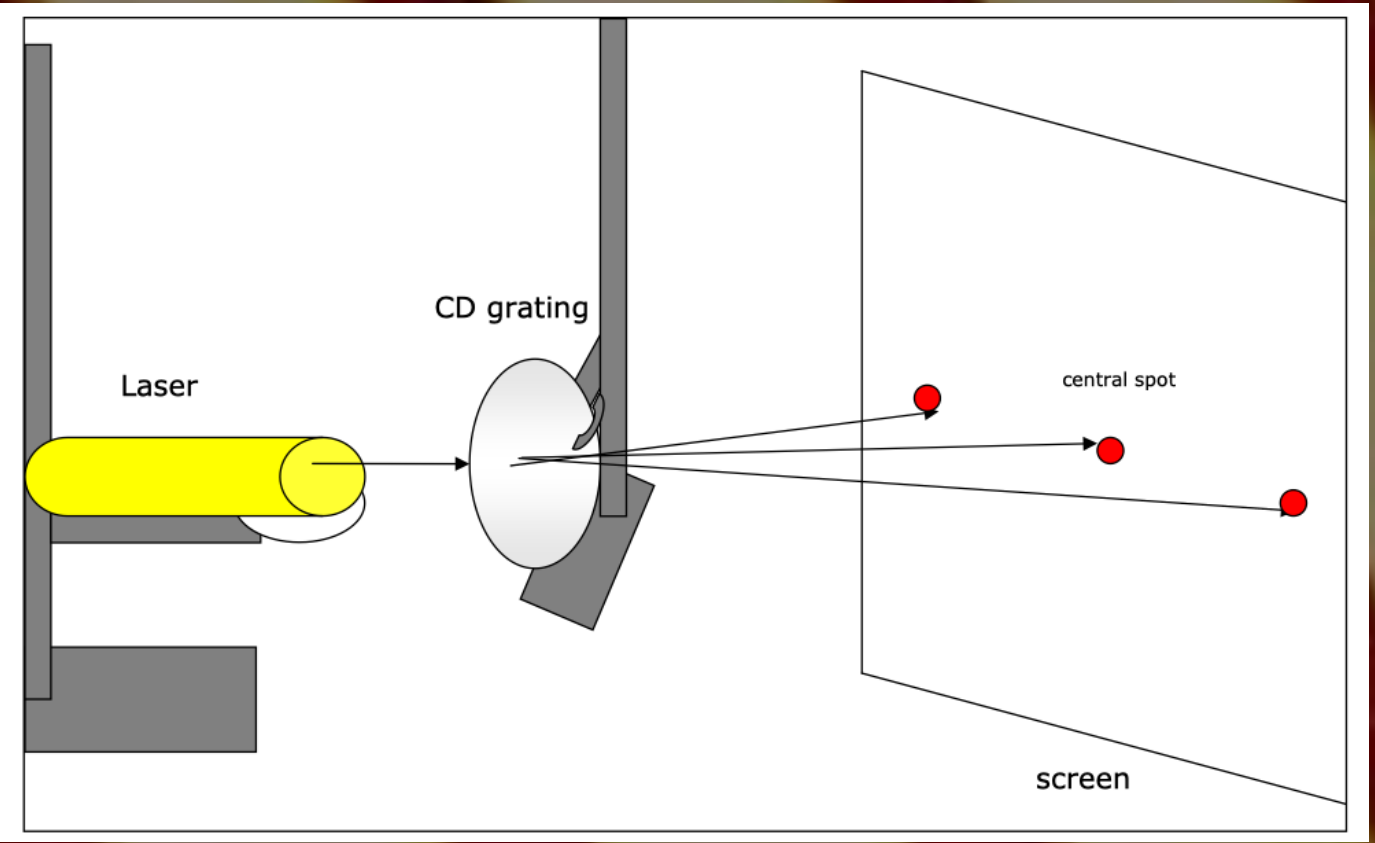
Milestone and Gantt Chart of Group 4 (2022/04)																
	Guo Yiming Yang Ziou Wang Yiran															
	25/04/2022	Week														
No	Milestone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	experimental plan, and background research															
2	prototype testing and software testing															
3	3D modeling, circuit design, assembly and performance testing															
4	Completed the experiment diffraction grating															
5	Completed the experiment Application 1															
6	Completed the experiment Application 2															
7	data collection and organization analyze															
8	Completed the experimental report															

Budget

Budget List of Lab Project 2022/04(Group 4)

Author	Guo Yiming	Update Date	24/4/2022						
Member	Guo Yiming, Yang Ziou, Wang Yiran								
exchange rate(RM-CNY)	1.5	Update Date	24/4/2022						
No	Item	Quanta	CNY Price	RM Price	Total (RM)	reimbursement(1/0)	Purchase Link	Shop Link	Memo
	Part 1: Experiment on Diffraction Grating								
1	CD	2	0.00	0.00	0.00	1			
2	DVD	5	2.68	1.79	8.93	1			
3	650nm red laser emitter	1	11.42	7.61	7.61	1			
					0.00				
	Part 2: Make a Spectrometer				0.00				
4	3D Model Printing Fee	1	200.00	133.33	133.33	1			
5	magnet	20	0.30	0.20	4.00	1			
6	Camera Module	1	20.80	13.87	13.87	1			
					0.00				
	Part 3: Application 1:Planck Constant				0.00				
7	LED light group(8 color)	1	13.80	9.20	9.20	0			
8	DuPont line	1	0.00	0.00	0.00	0			
9	Bread board	1	0.00	0.00	0.00	0			
10	Battery box	2	0.00	0.00	0.00	0			
11	Universal electric meter	1	0.00	0.00	0.00	0			
12	resistance	1	0.00	0.00	0.00	0			
13	switch	1	0.00	0.00	0.00	0			
					0.00				
	Part 4: Absorption spectrum of solution				0.00				
	Cuvette(10mm)	10	2.90	1.93	19.33	1			
	LED Light board	2	7.61	5.07	10.15	1			
					0.00				
	Others				0.00				
	Equipment damage(Unexpected expenditure)	1	50.00	33.33	33.33	1			
	Logistics price	1	20.00	13.33	13.33	1			
	Total				253.09				

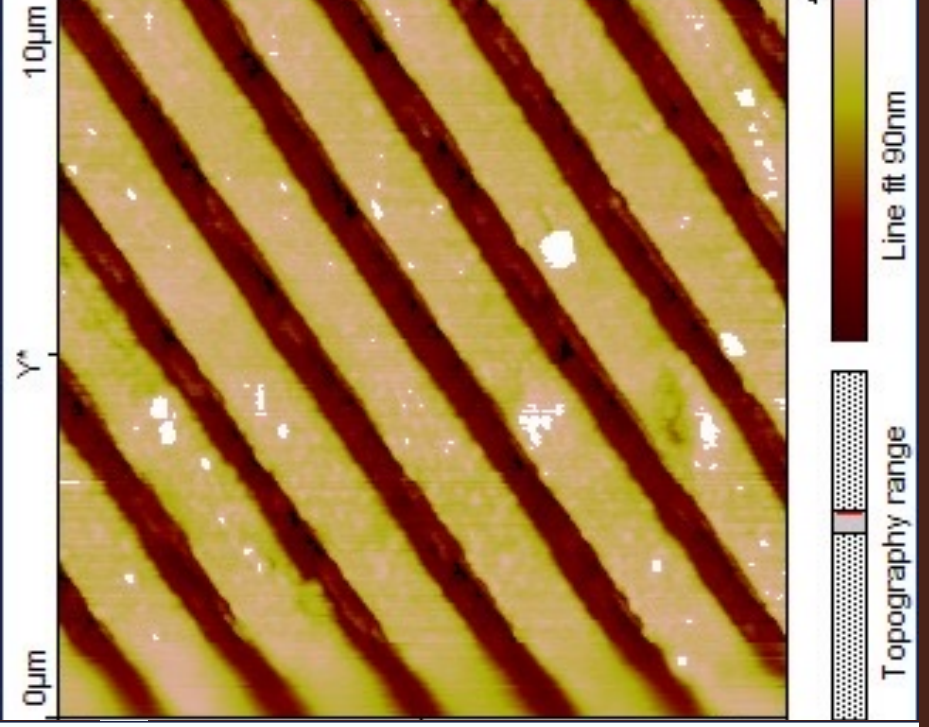
The experiment of Diffraction Grating measurement

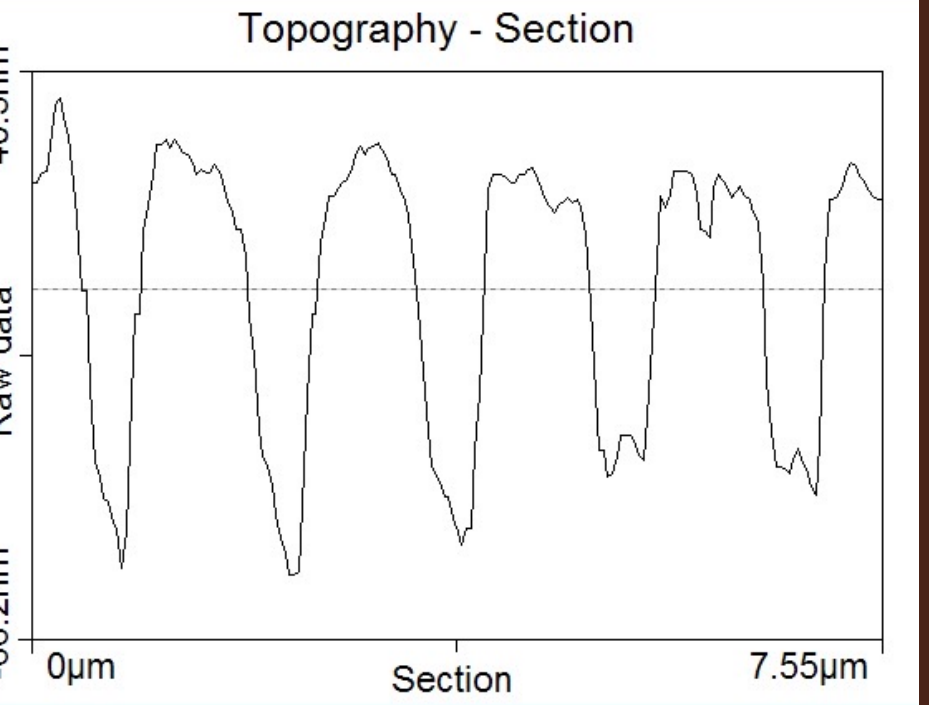


Experimental schematic(Image from Rama Balachandran)

- Experiment Objective:

To determine and compare the grating constant for different brands of CD or DVD.





Literature Review

- In a previous study, NNIN gave a detailed tutorial and experimental procedures as well as experimental data for reference. They used CDs and DVDs as diffraction grids, and also used lasers for their experiments, and gave a form for recording the experiments.
- They also measured the diffraction grating of CDs and DVDs using an AFM microscope. Detailed reference data are given.
- In this part of the experiment. We will try to reproduce the experiment using the tutorial provided by NNIN, and try to use different angles and different distance settings to get more insight into the experiment. This will be used in the subsequent design of the spectrometer.

Image left above: AFM image: CD 750MB

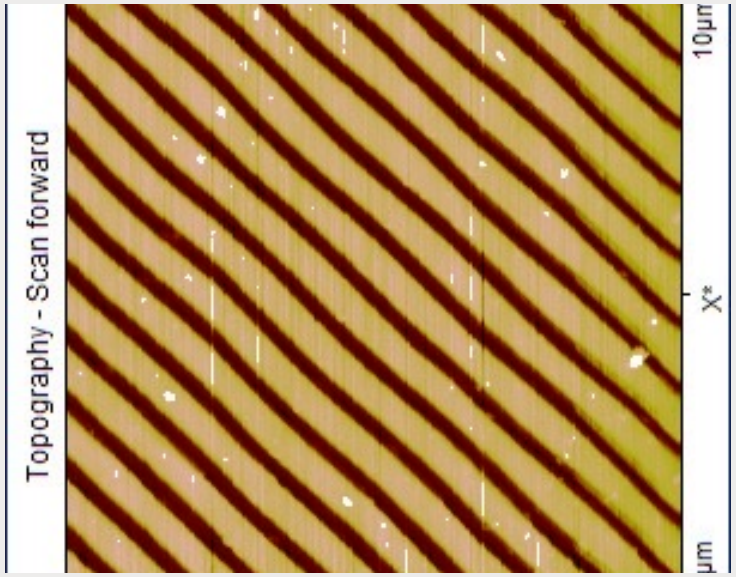
Image right above: AFM line scan of the image

Experiment Hypothesis

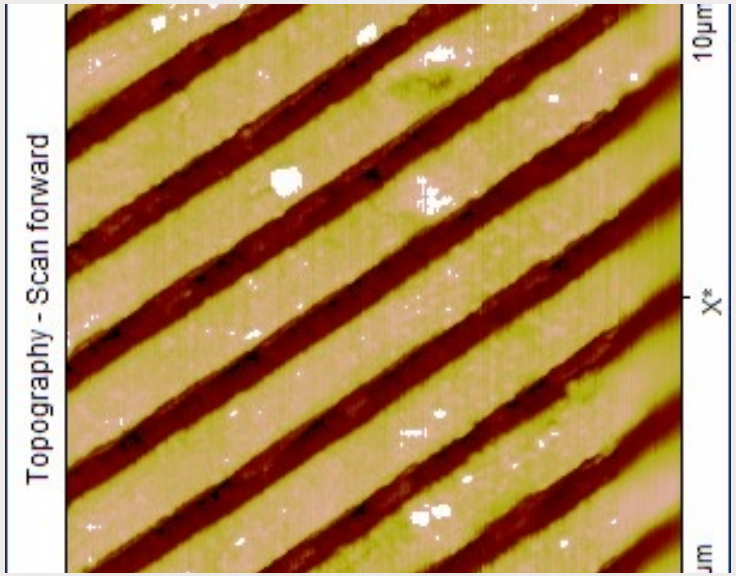
In this part of the experiment, we will try to measure and calculate different experimental parameters and investigate the relationship between the variables.

Hypothesis 1: The closer the laser irradiation position is to the center of the disc, the smaller the distance between the resulting light spots

Hypothesis 2: Other conditions are constant, the more dense the CD/DVD grating, the closer the distance between the generated spots



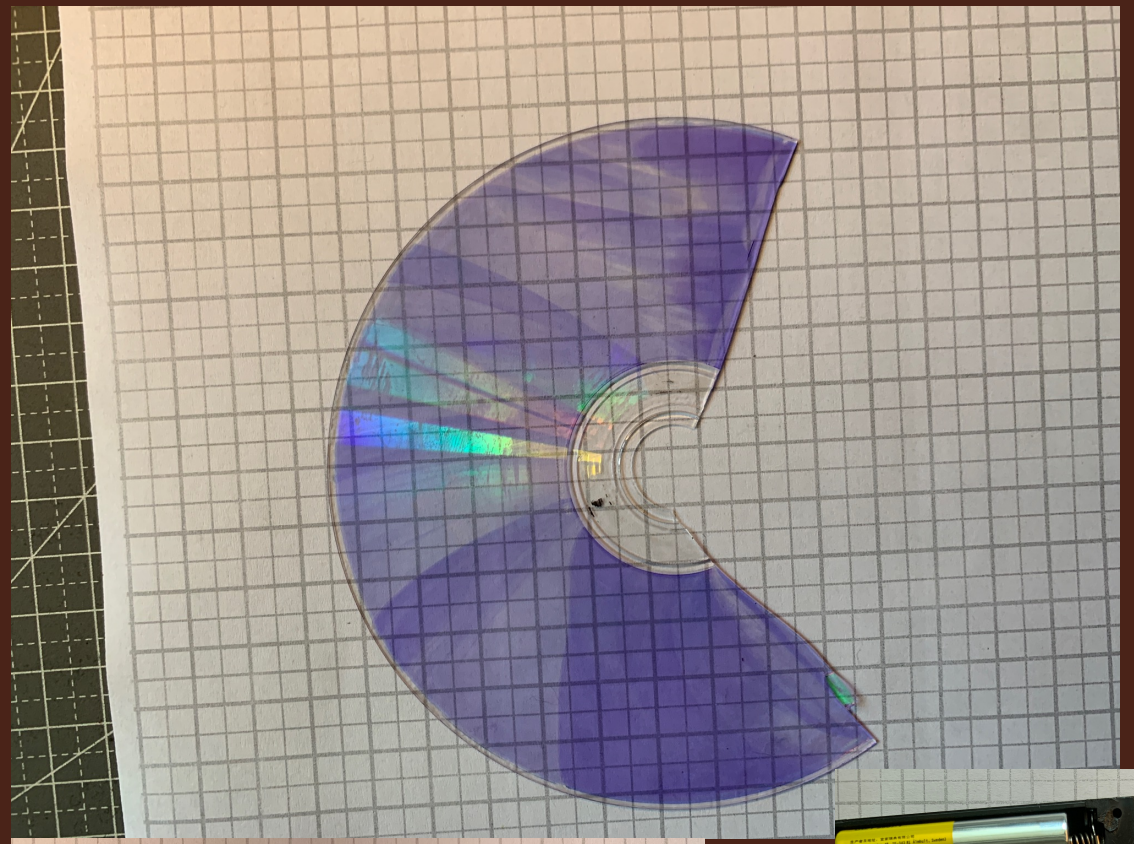
CD(700 MB)

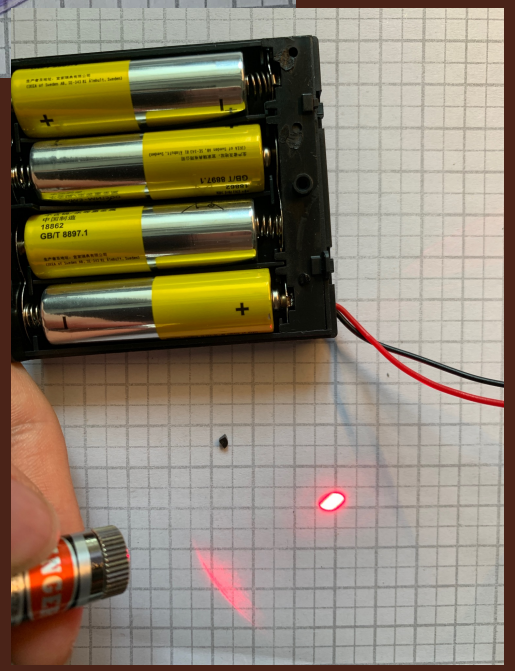


DVD(4.7GB)

Experiment Setup

1. 650nm Laser Emitter
2. CD/DVD(tear off the Sliver Layer)
3. Ruler
4. Several Support stand
5. Battery Case(to turn on the emitter)





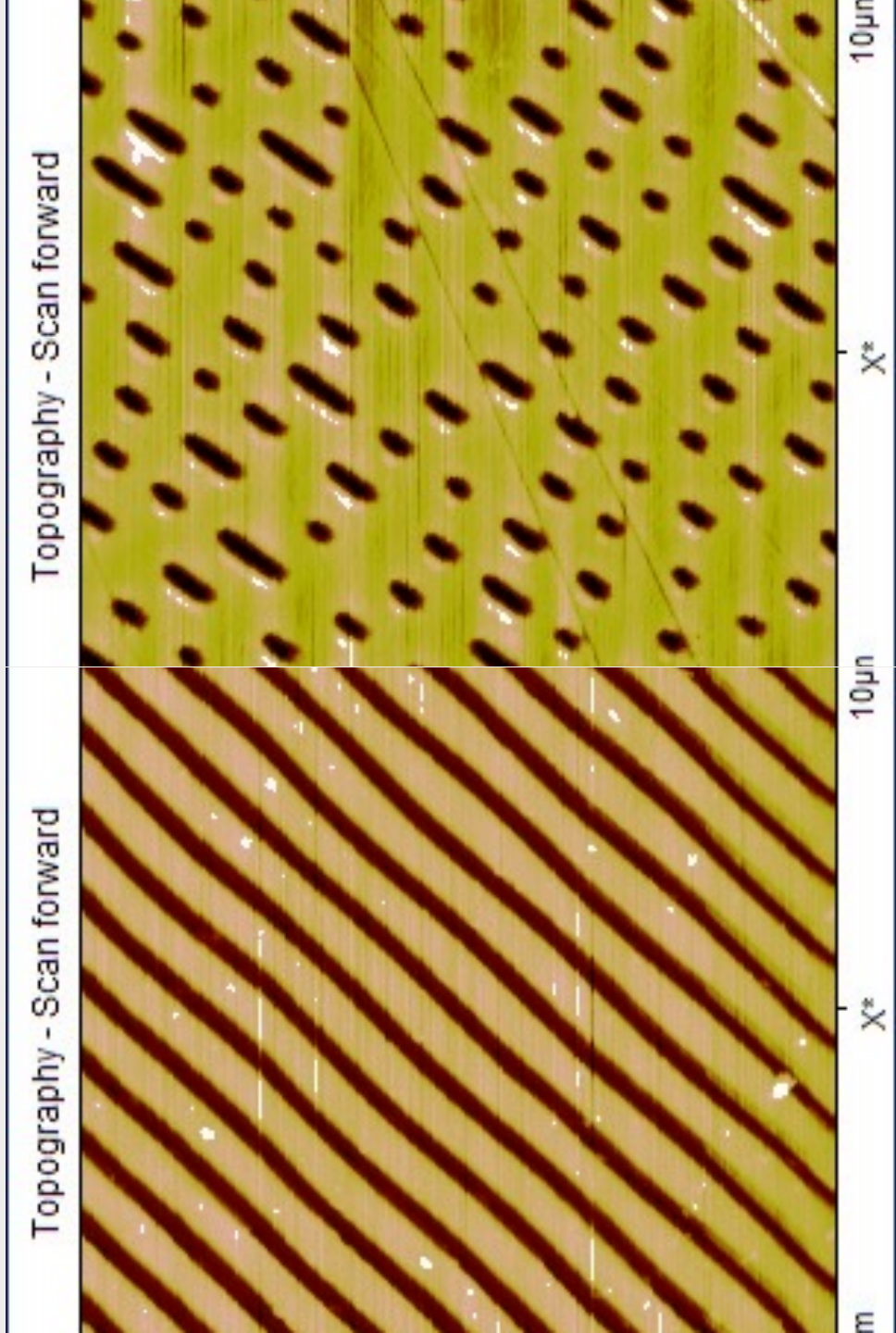
Experiment Methodology

- As previous studies have shown (NNIN) that unrecorded discs have better diffraction, in this experiment we used two unrecorded discs: CD (700MB), DVD (3.7GB) for the experiment.

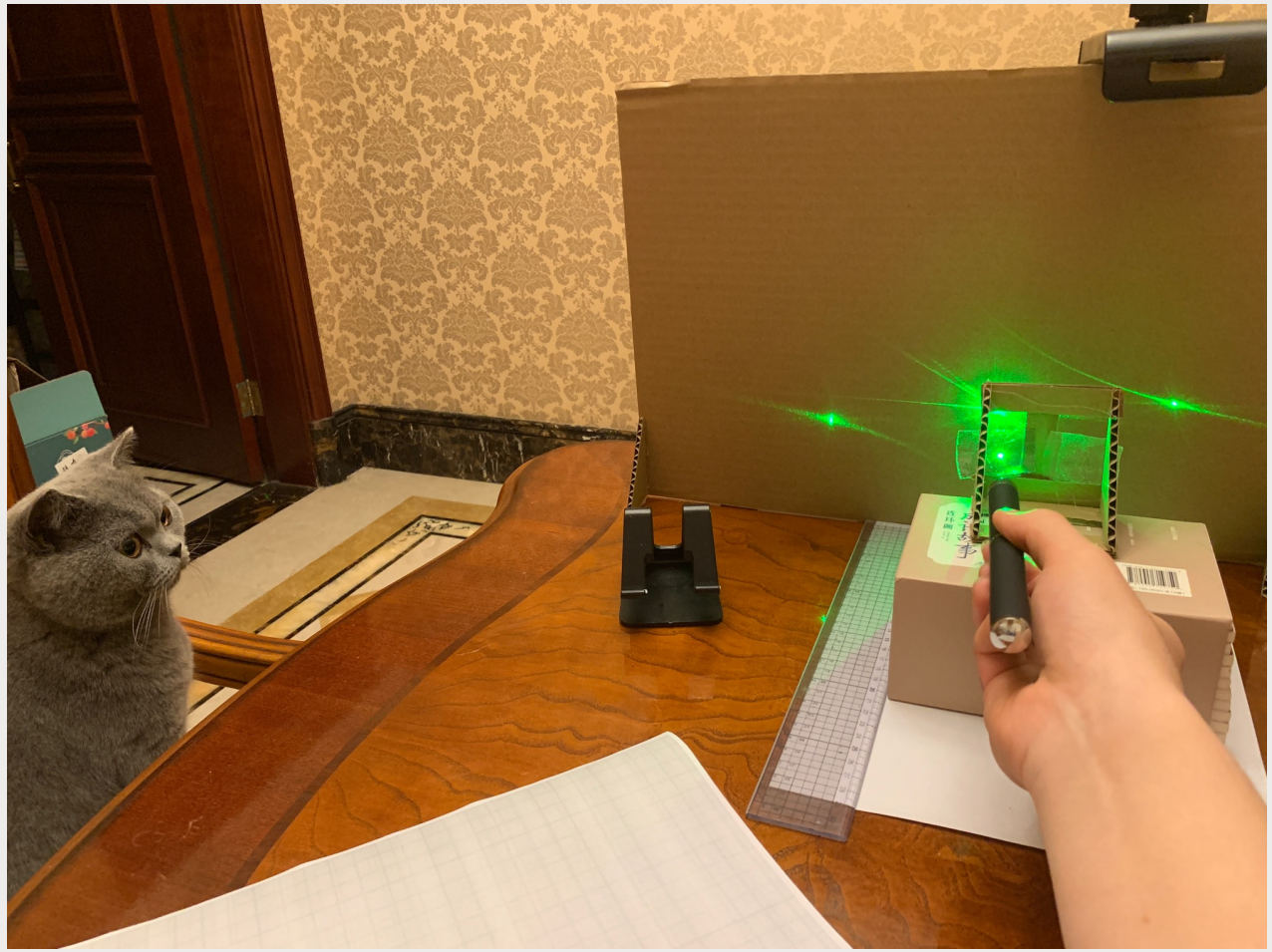
1. The disc with the reflective layer removed was mounted on a stand and was placed on the table vertically.
2. Another projection plane will be mounted 5/10/15 cm in front of the disc (parameters from NNIN).
3. The 650nm red laser emitter/530nm green laser will be fixed at the same height as the center of the disc, illuminating the grating on both sides of the center horizontally.
4. During the experiment, the experimenter will record the two-dimensional coordinates (the most obvious 3-5 points) on the projection screen. Experiments with the same parameters will be performed several times

Image Above: AFM image of burned DVD

Image Below: AFM image of unburned DVD

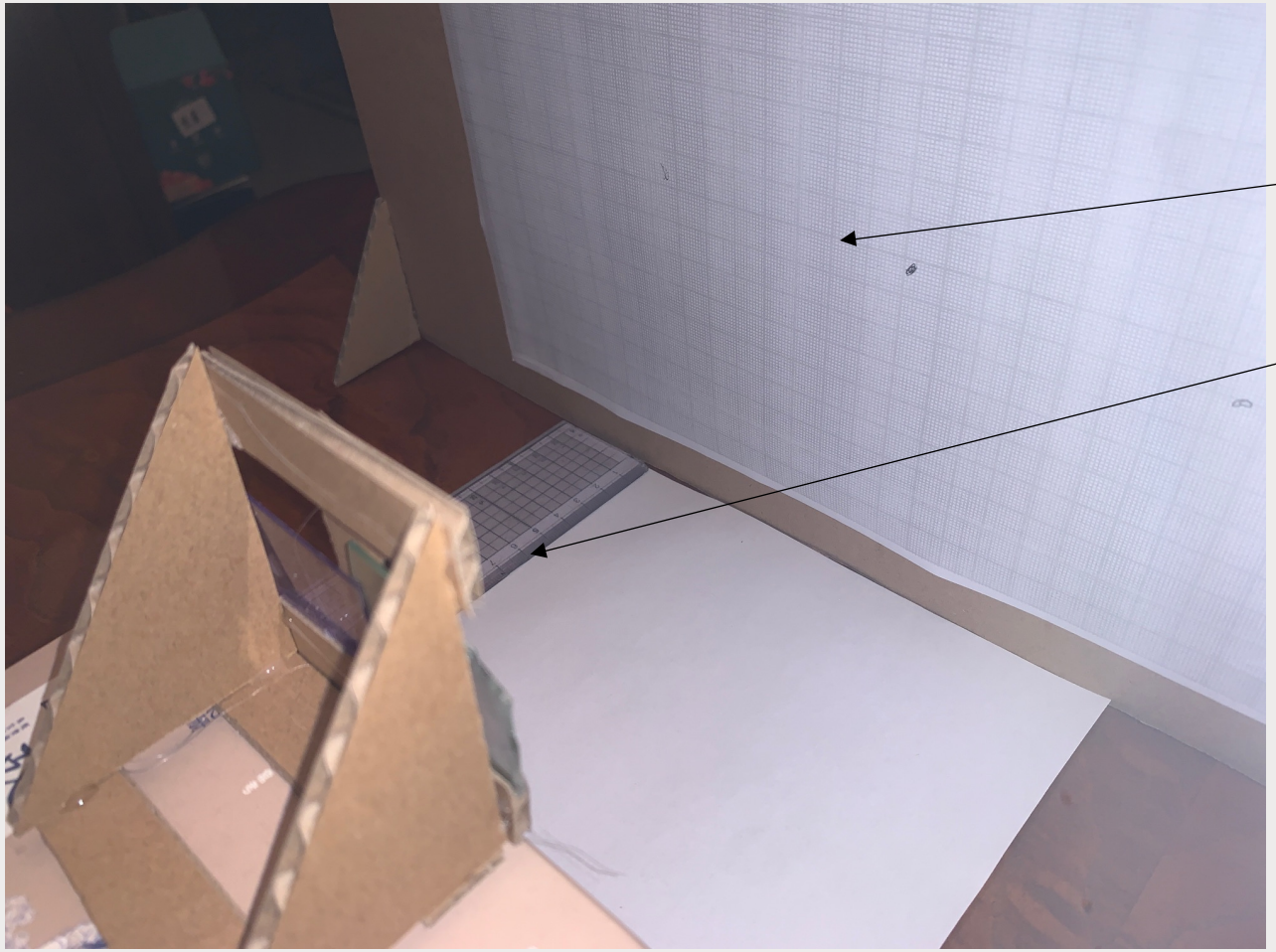


Experiment Methodology

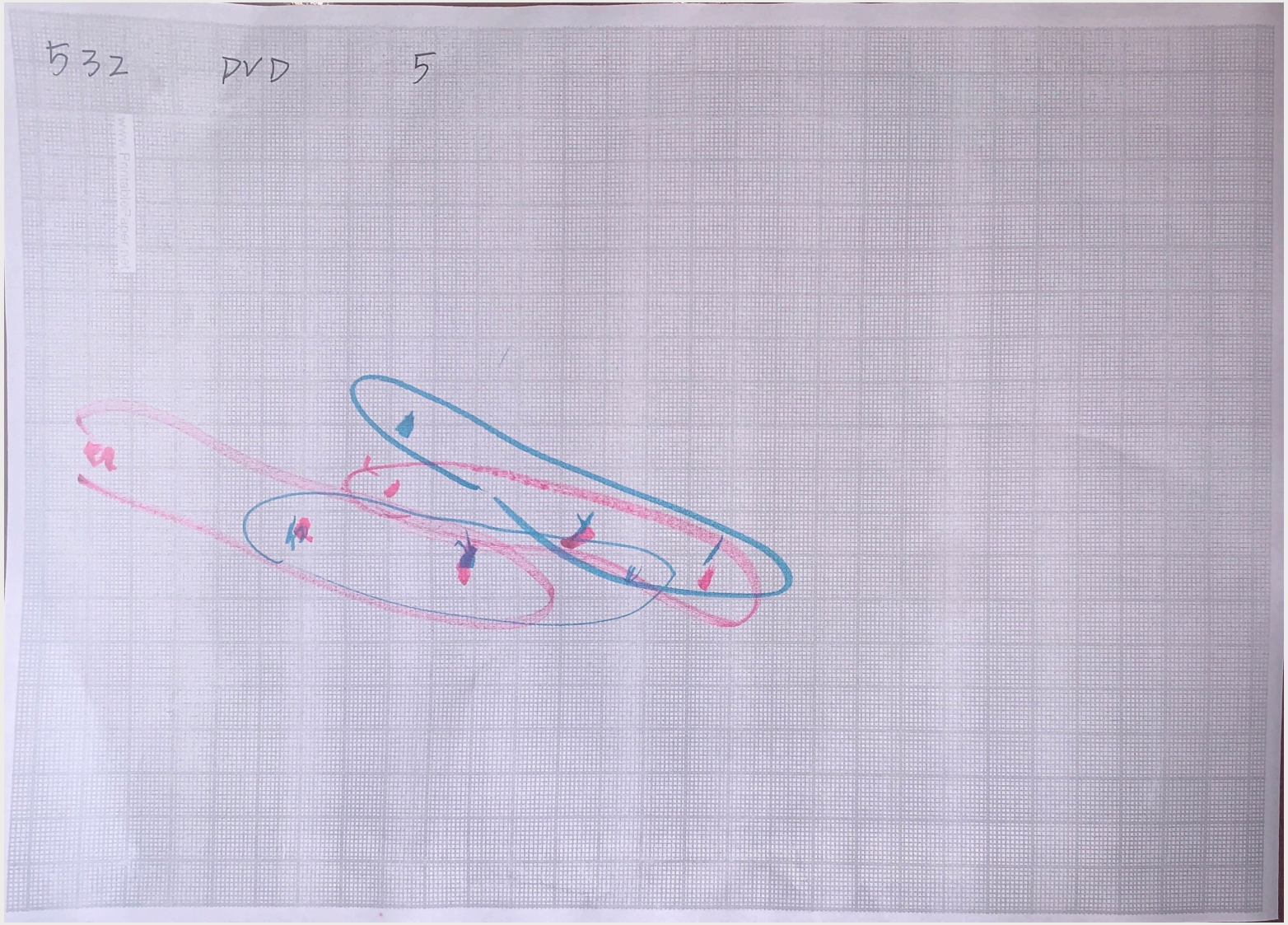


DVD CD

Disc fragile stand


Grid screen
Distance ruler

Result



Experiment analysis

- Here to determine the slit density of the disc, we can first turn out the distance of the slit(d).Here we apply the equation frequently used in double slit interference experiment
- Here by determine the distance between disk and screen and the distance between the light spot. Here we can derive the angle of diffraction

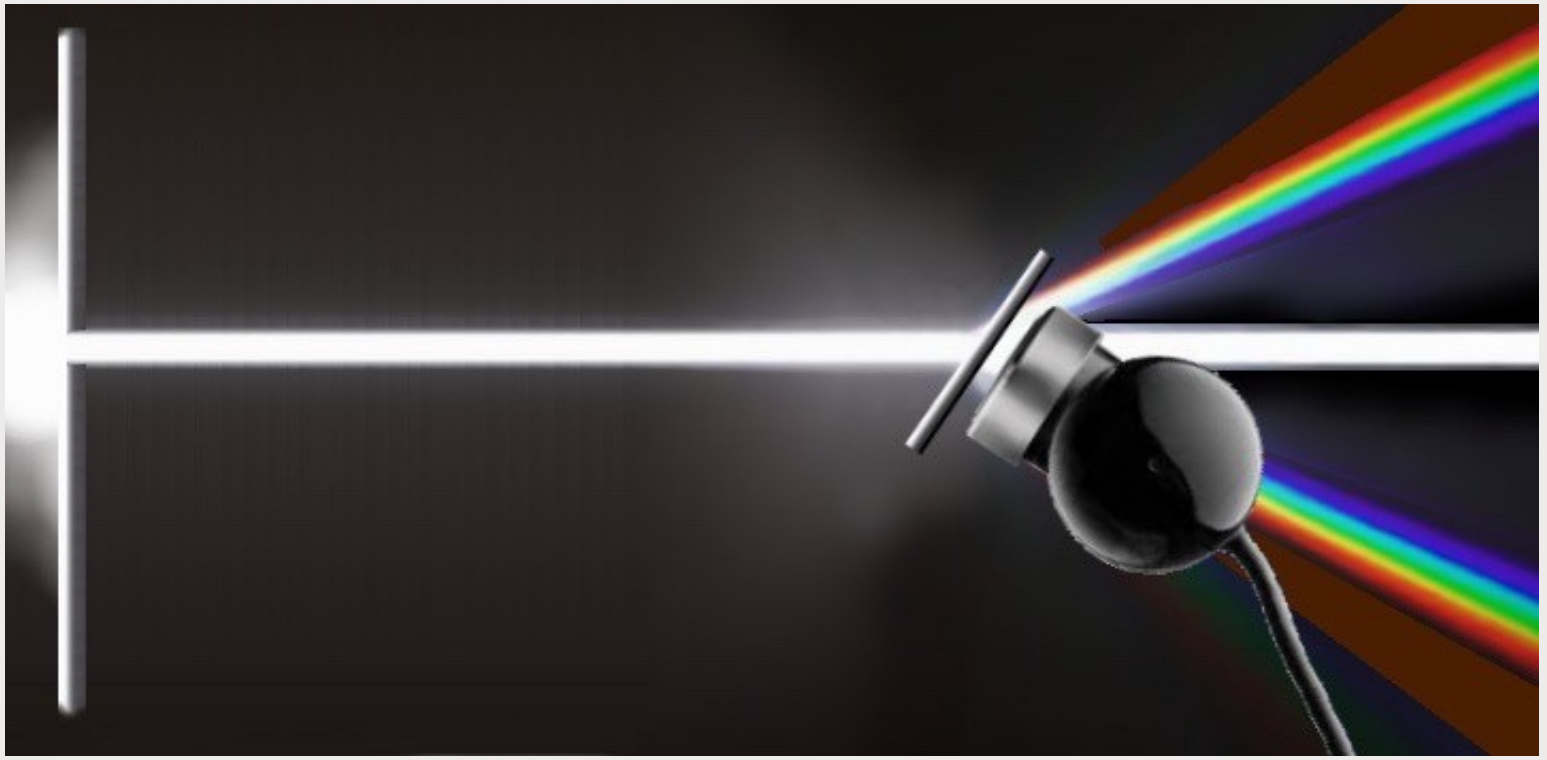
$$\theta = \arctan \frac{D}{x} \qquad d = \frac{m\lambda}{\sin\theta}$$

- After that we can derive the density of the slit and the diffraction grating constant

Make a Spectrometer

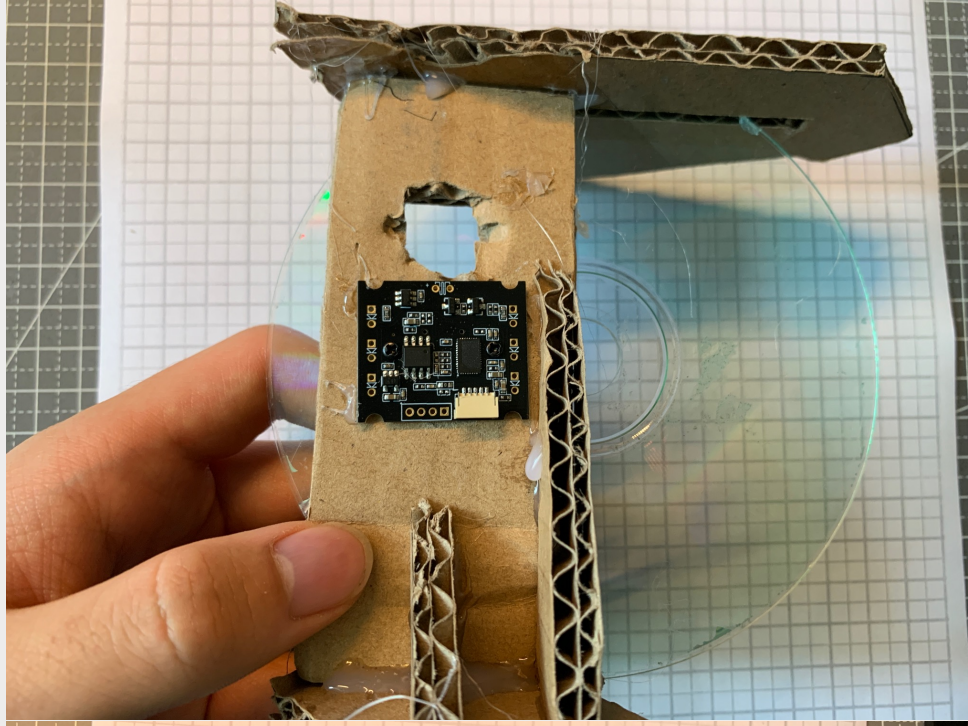
- This part is about the progress of the making a simple non-professional visible light spectrometer.
- Our progress could be separate as the prototype stage and formal stage
- We first used a cardboard box as the subject of the prototype to test the performance of the important components and to measure the relevant parameters to facilitate the design of the 3D model later.

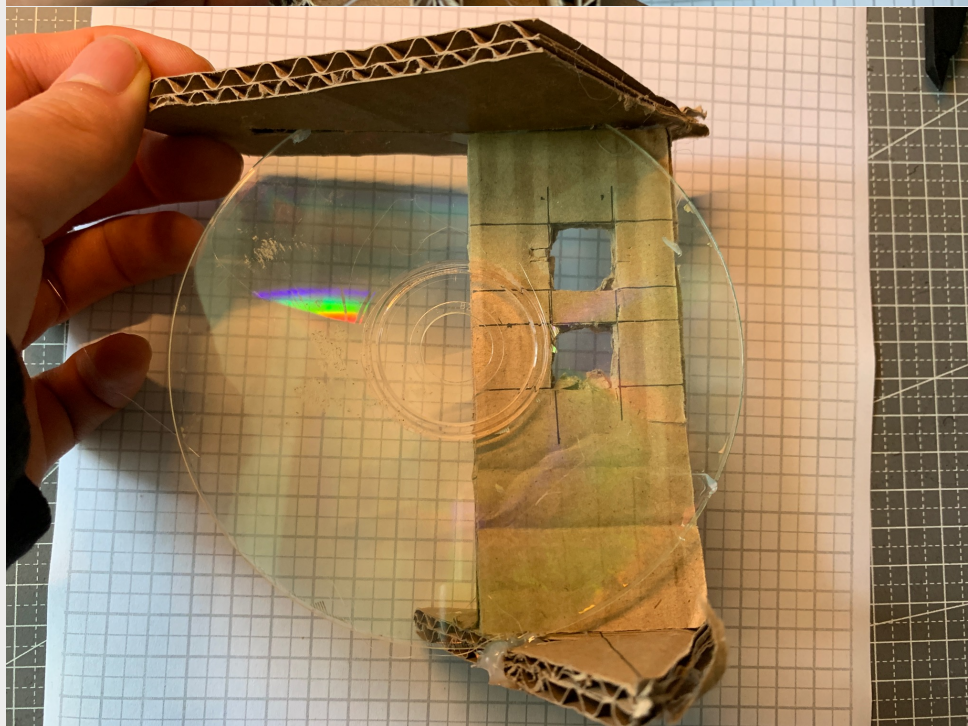
Optical Principle



Make a Spectrometer

- By the prototype of the spectrometer, we can determine several important parameter:
  - *The angle between DVD and CD as a grating and the light*
  - *the length and width of the slit*
  - *the height and angle of view of the camera installation*
  - *the focal length of the camera*
  - *etc*





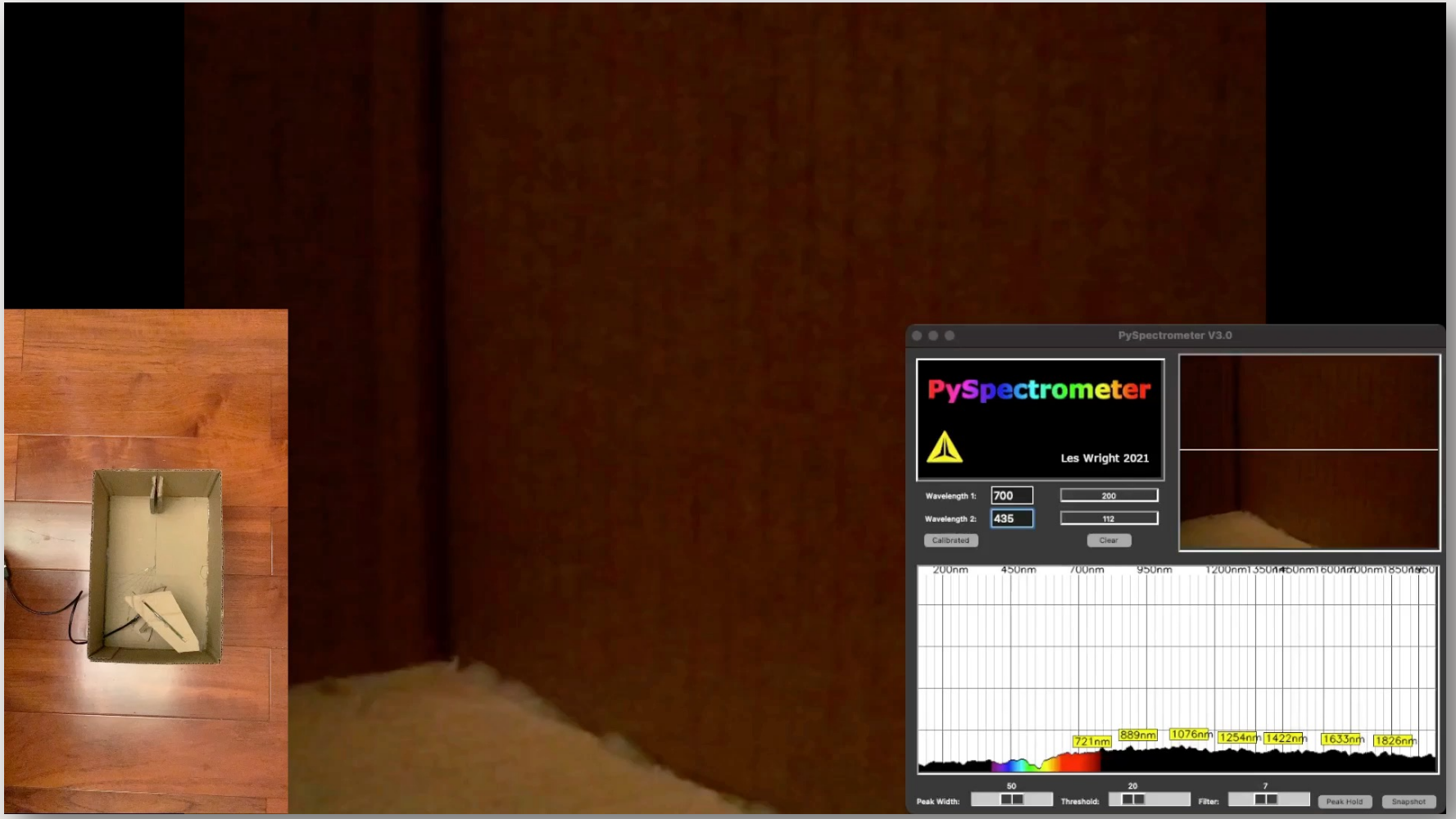
Demo Video of Prototype

Here is the demo video for the prototype spectrometer.

Here we have done a rough initial calibration by pointing the spectrometer to the display showing RGB.

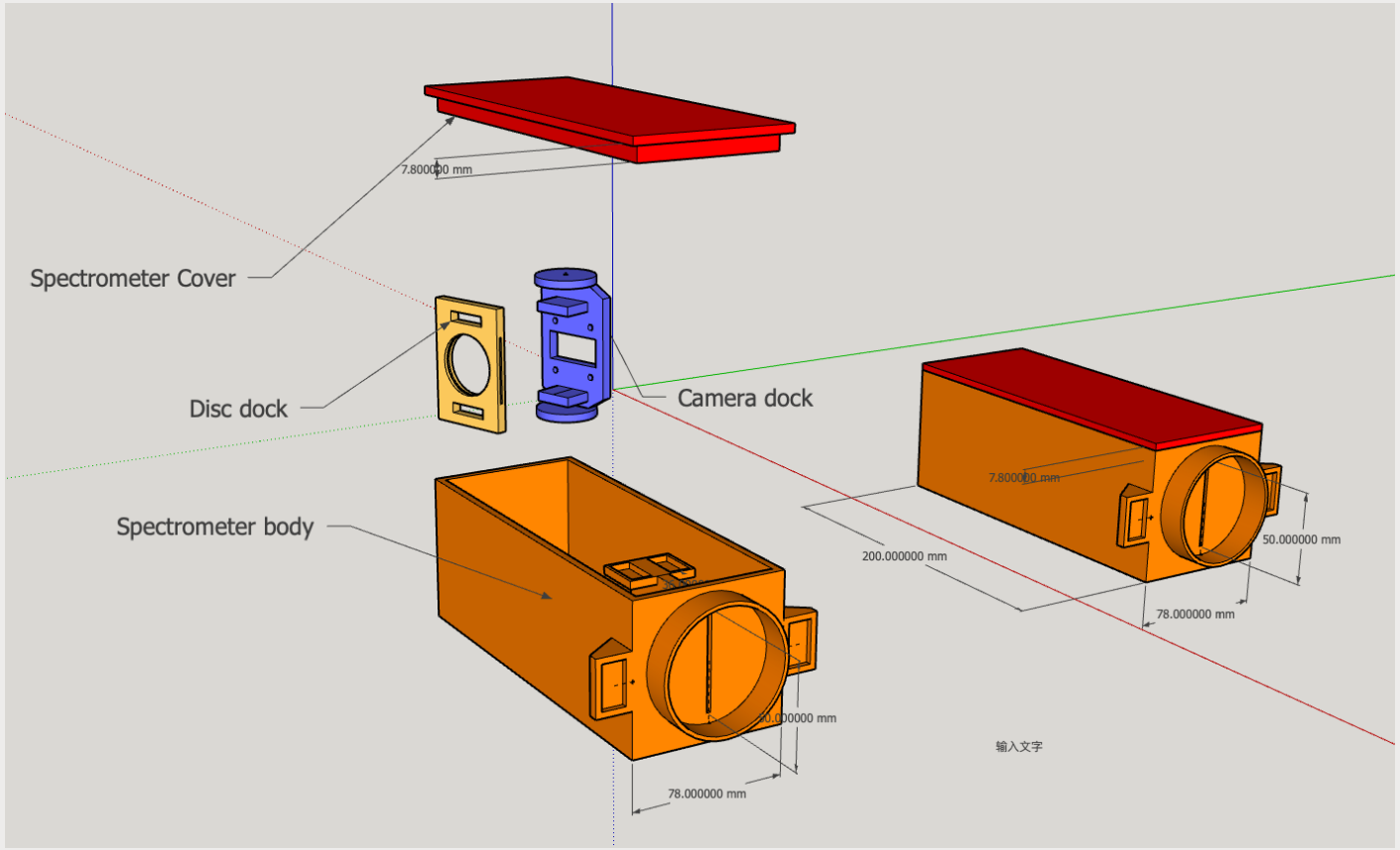
Here we can see the rough spectrum of LED lamp.

Next, we put a kettle between the light and the Spectrometer

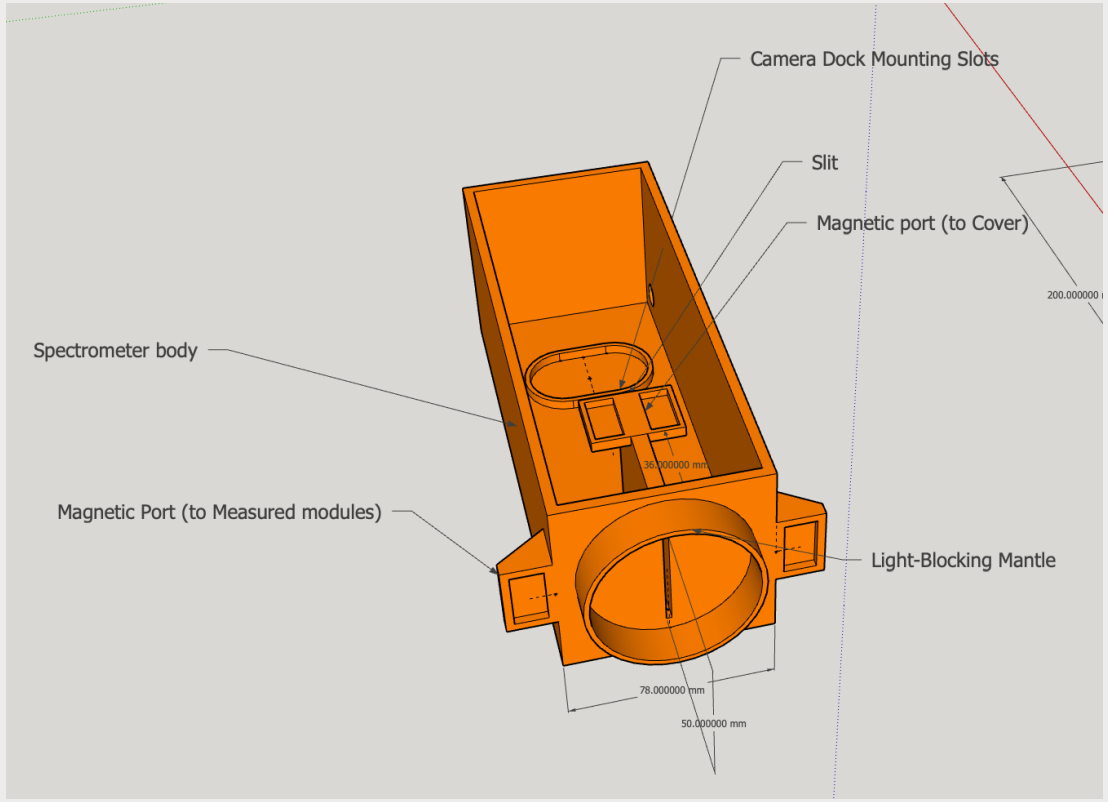


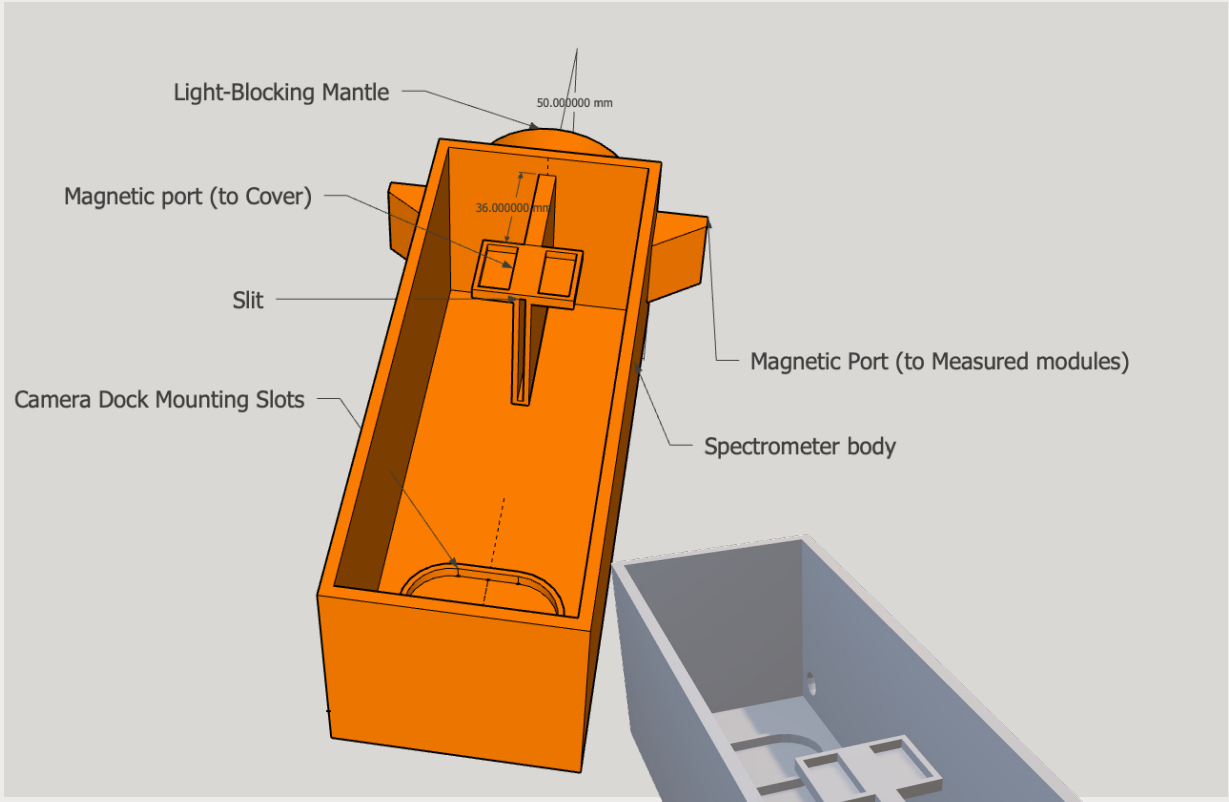
Formal Stage-3D model

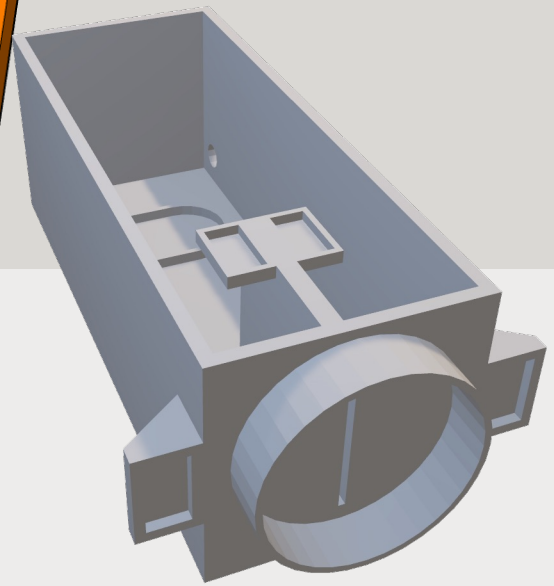
- Here is the design of the 3D model spectrometer, the major parts is:
  - *Spectrometer Cover*
  - *Disc Dock*
  - *Camera Dock*
  - *Spectrometer Body*



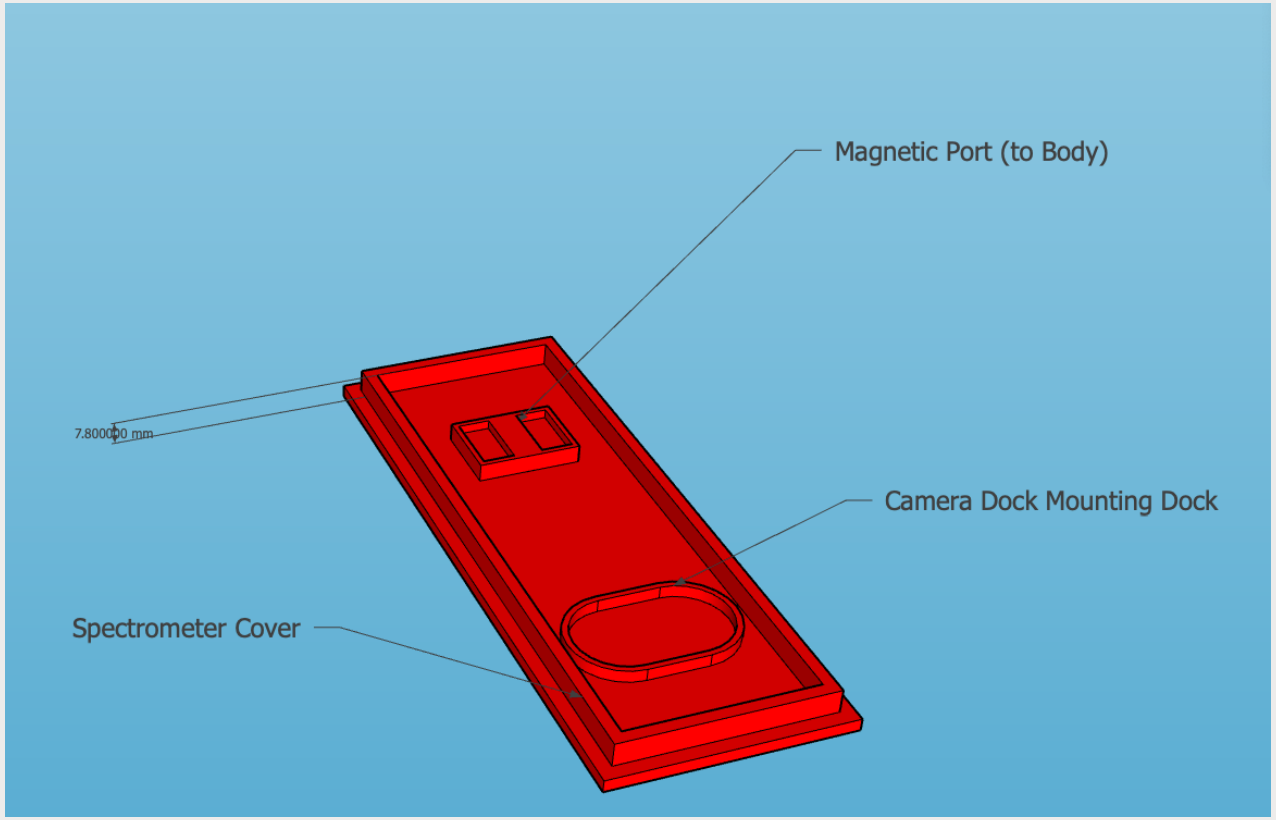
Spectrometer Body

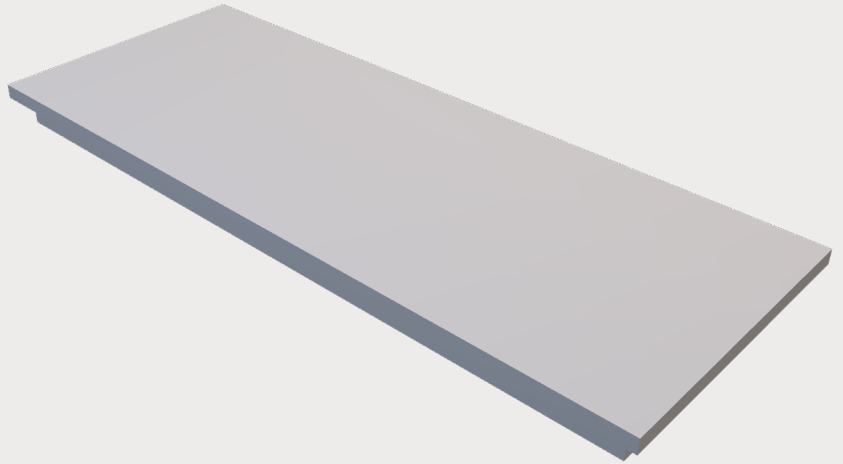




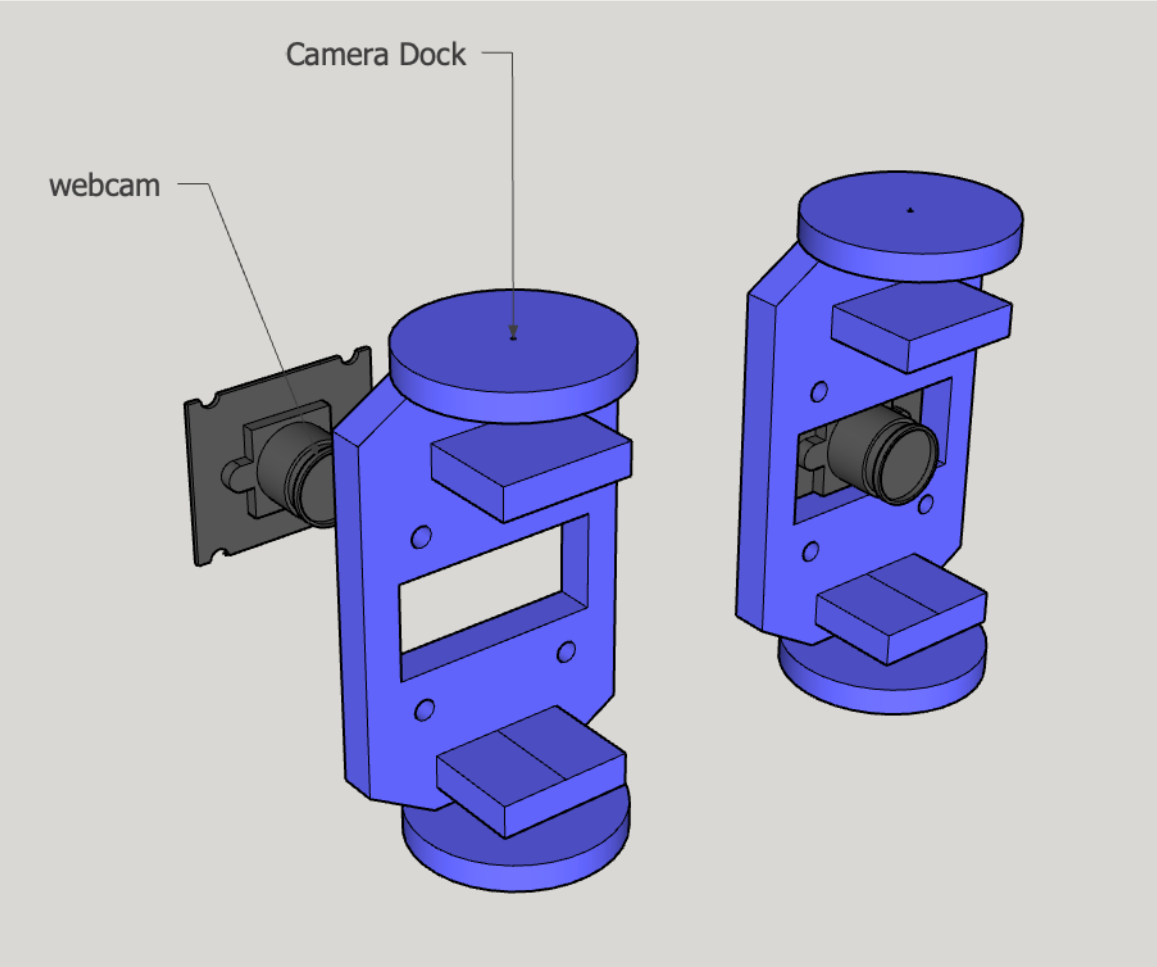


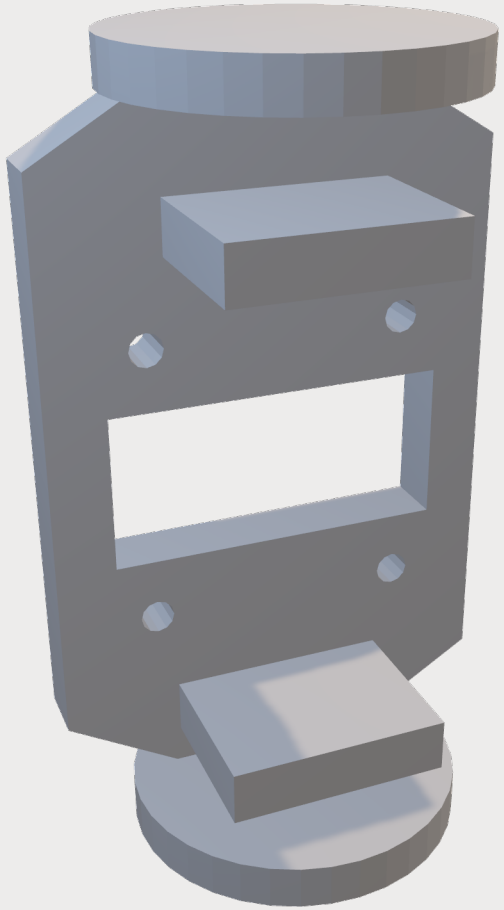
Spectrometer Cover





Camera Dock





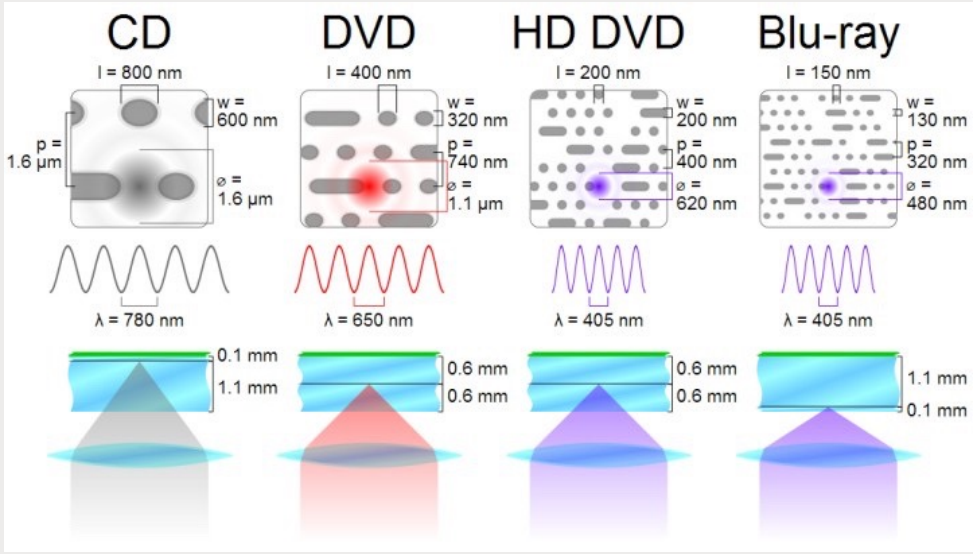
Here we use DVD

Information form theremino
According to our tests, the best patterns are derived from the DVDs and got better results by using them in transmission (no reflection)

The following pages present various useful possibilities for teaching and for extreme experimenters, commercial gratings, prisms, reflection methods...

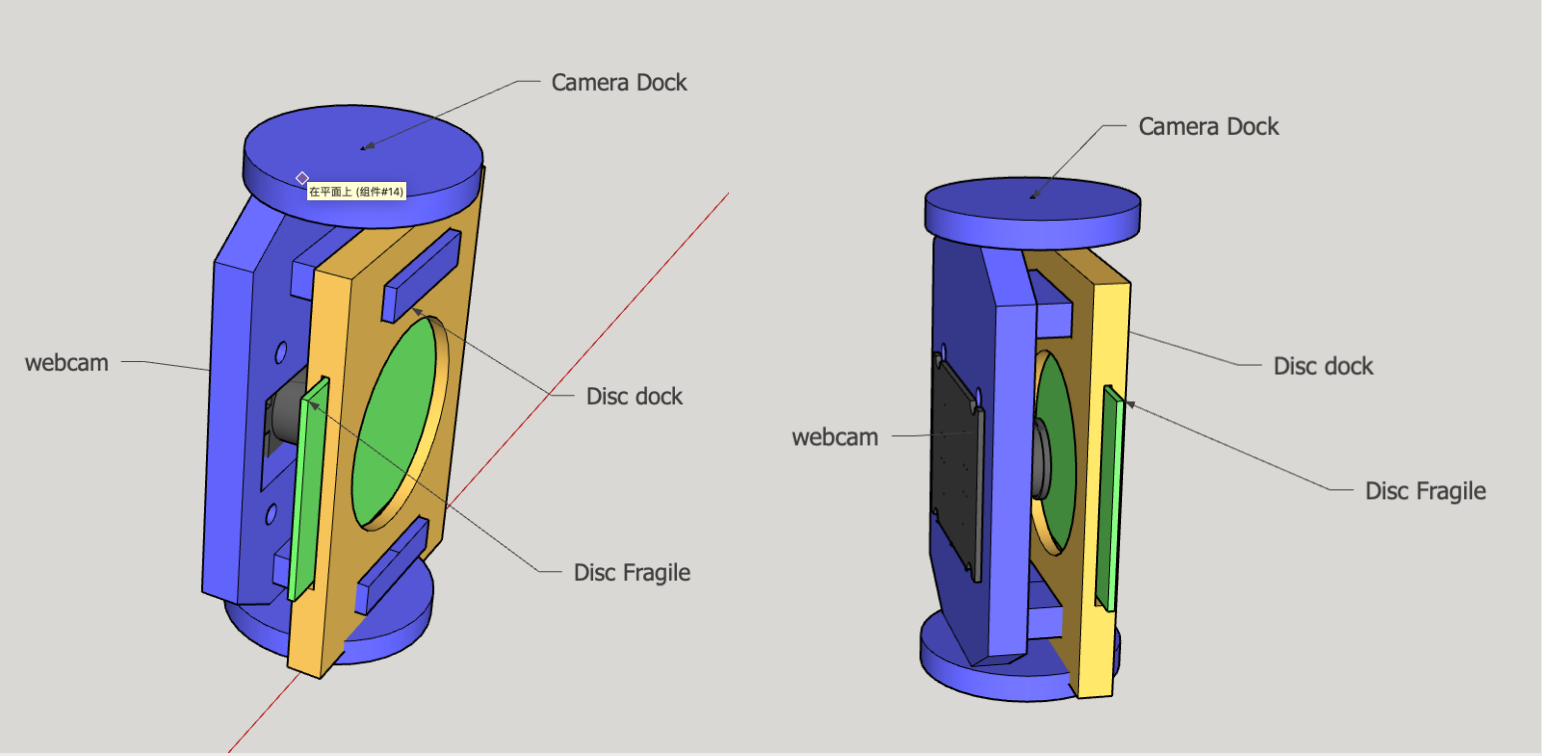
Who wants to build a simple spectrometer, without going into the theory, should cut a square of DVD and paste

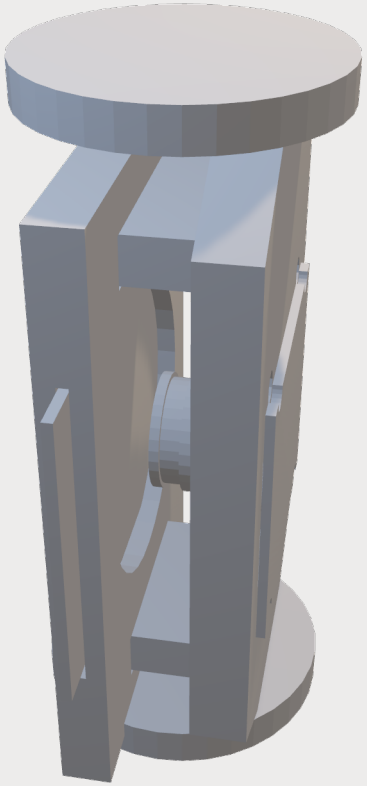
it on the tip of the lens of the camera, then skip directly to the file "Construction".

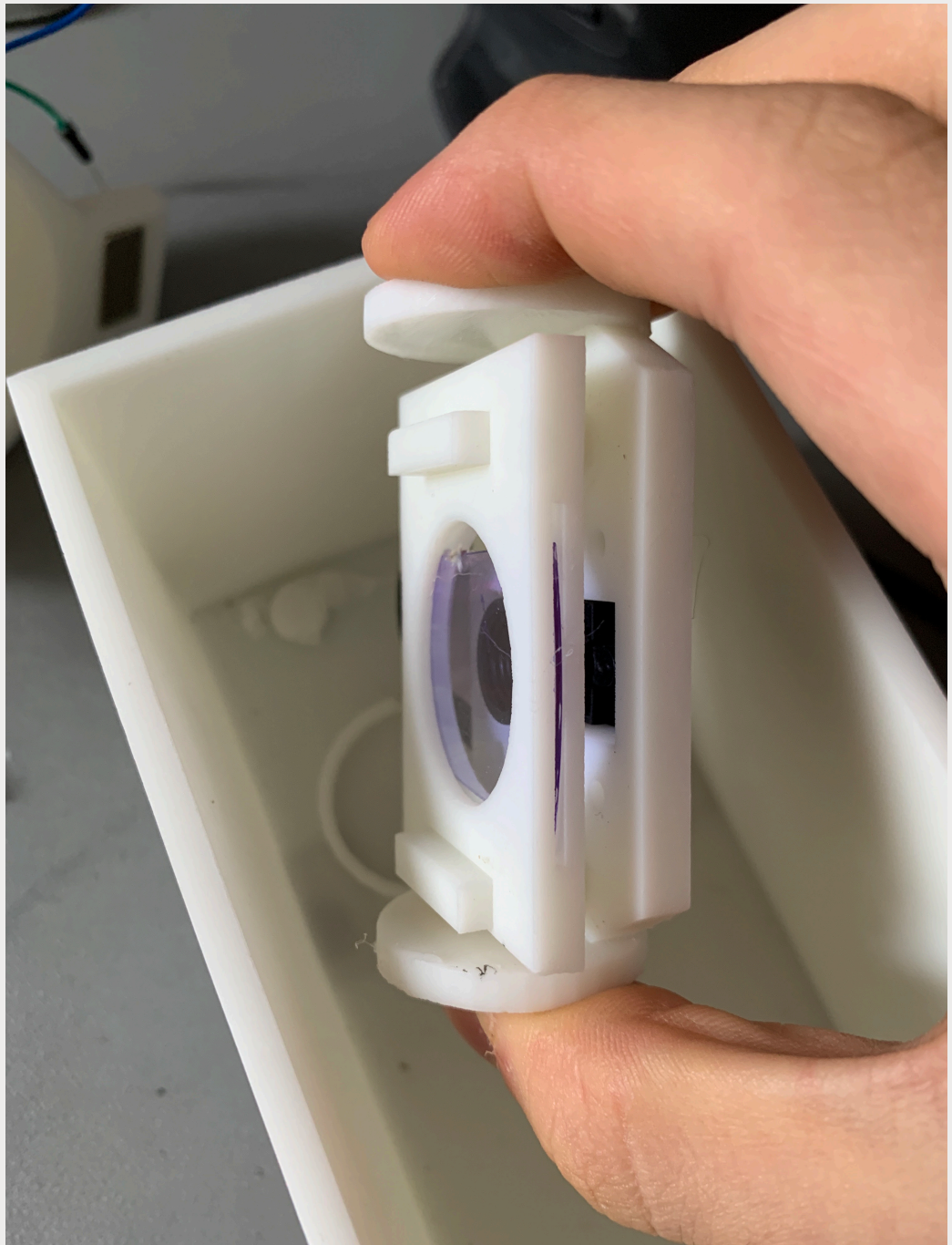


https://www.theremino.com/wp-content/uploads/files/Theremino_Spectrometer_Technology_ENG.pdf

Camera Dock and Disc Dock

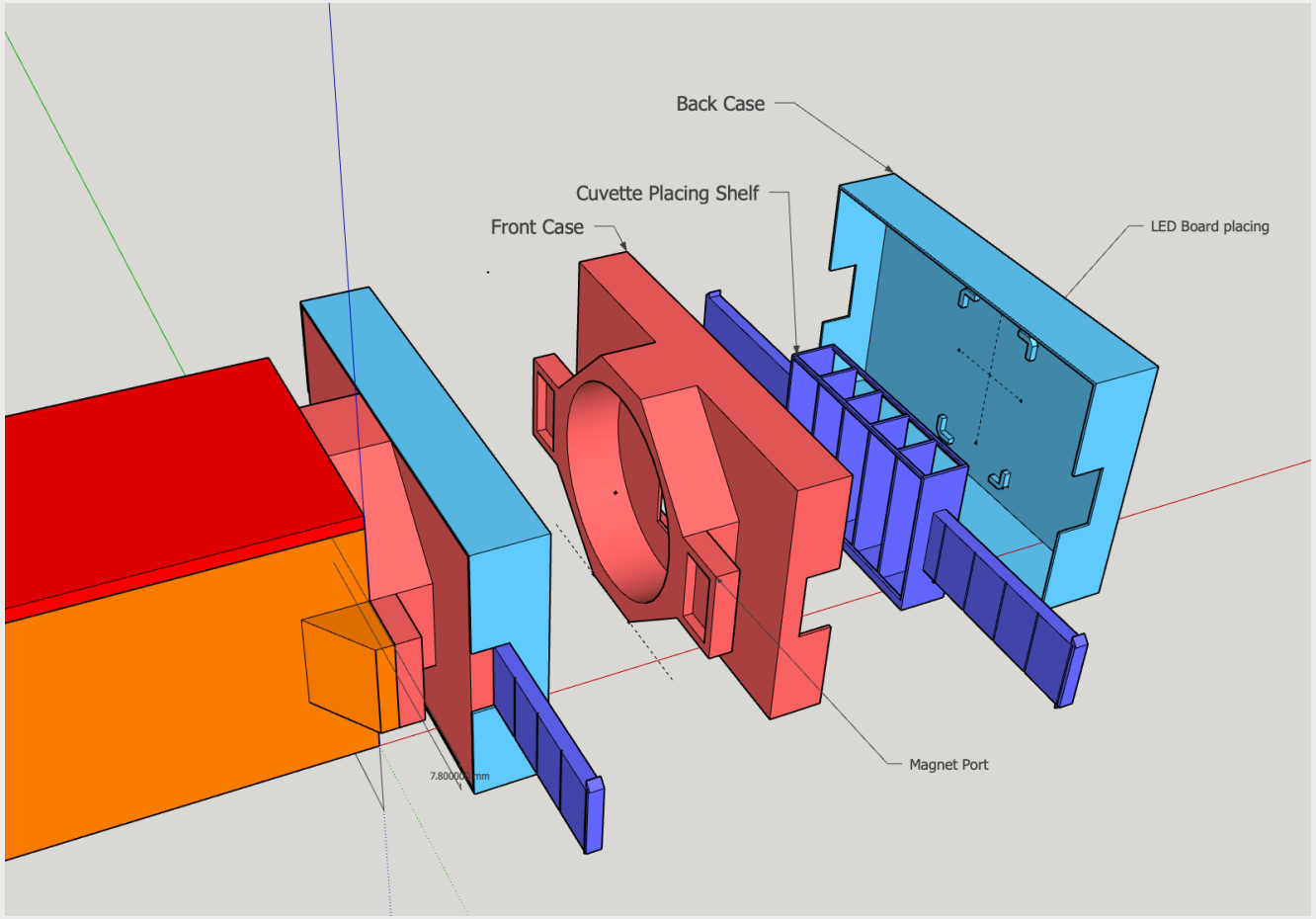


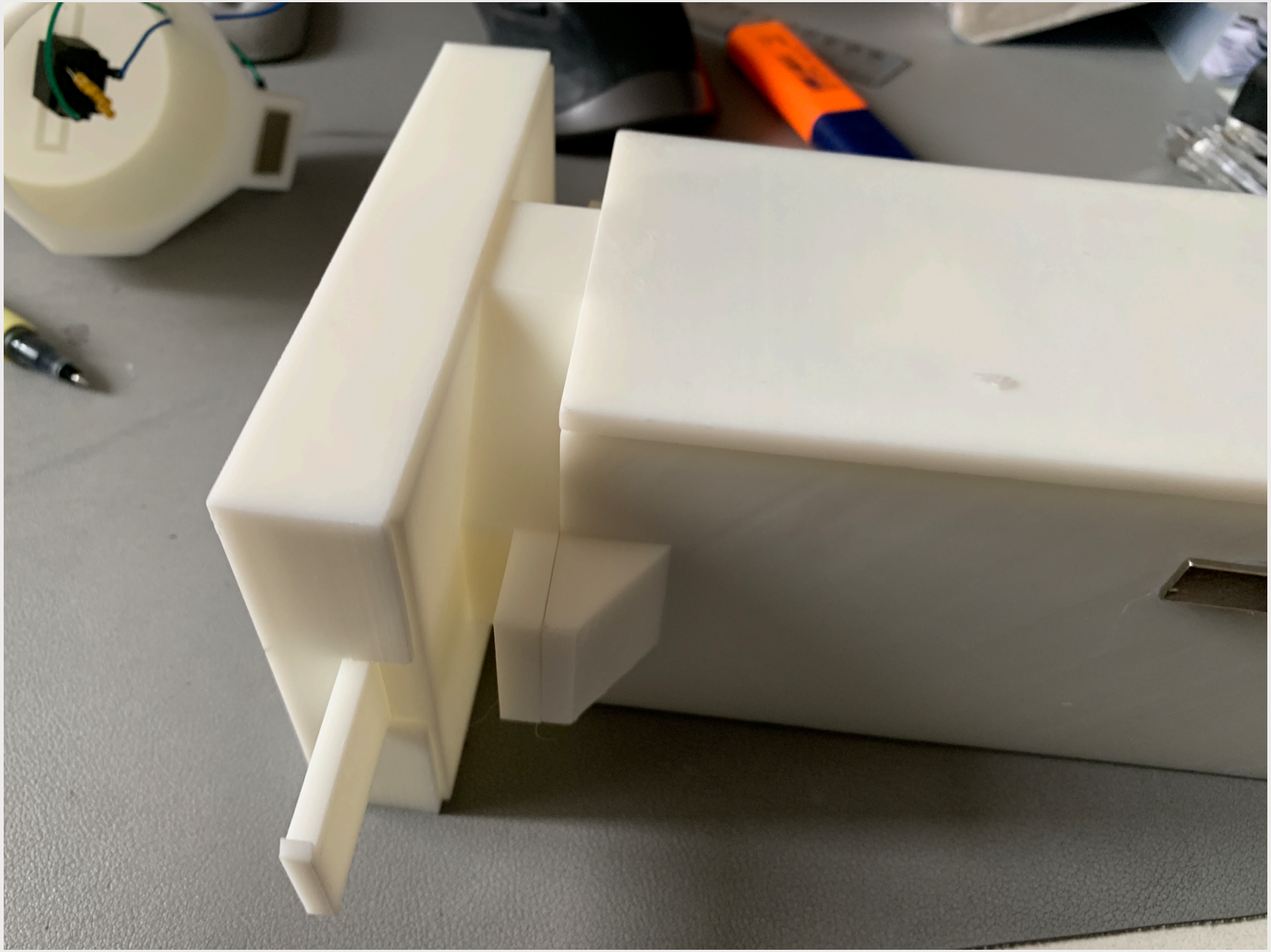




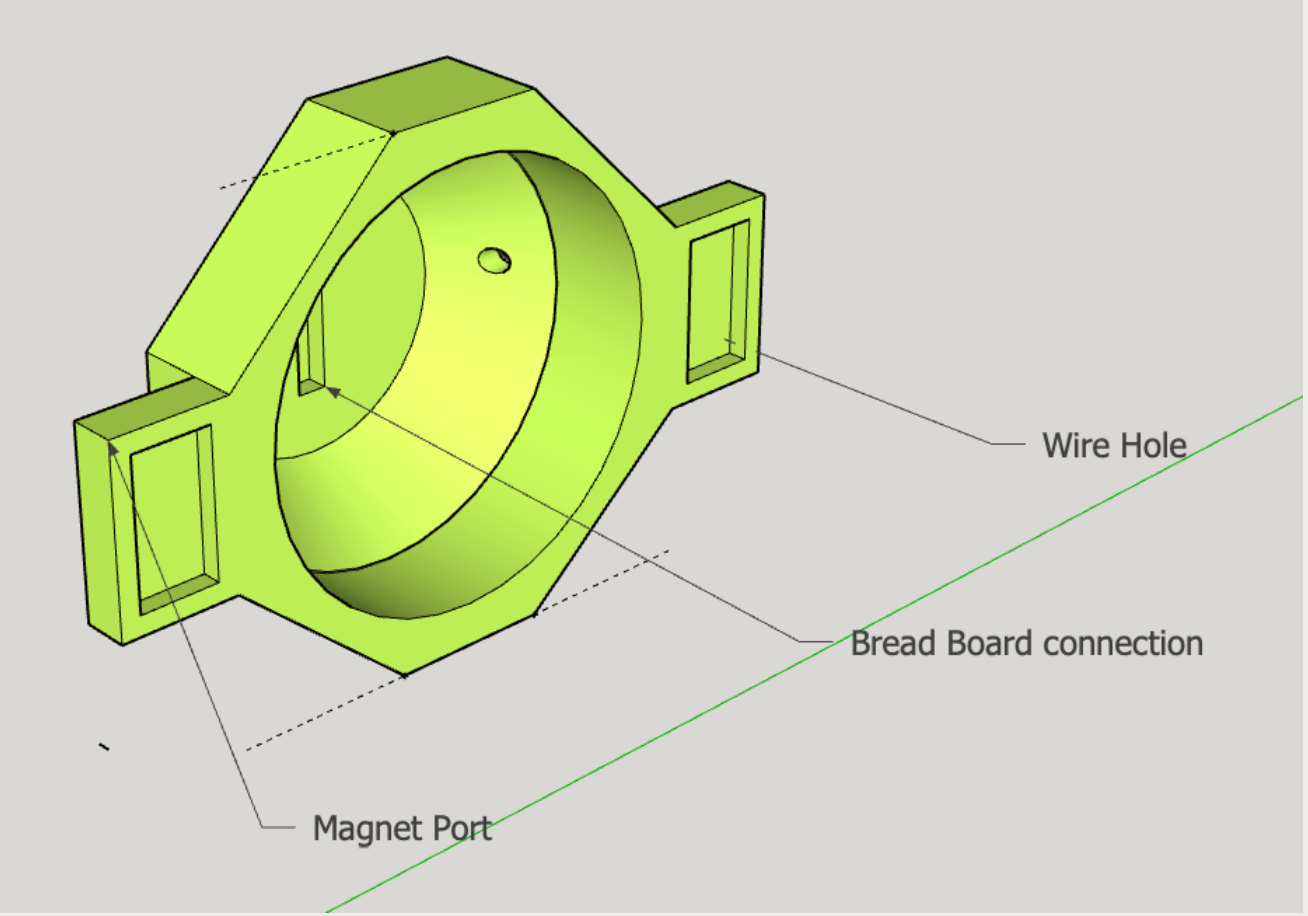
Testing Module

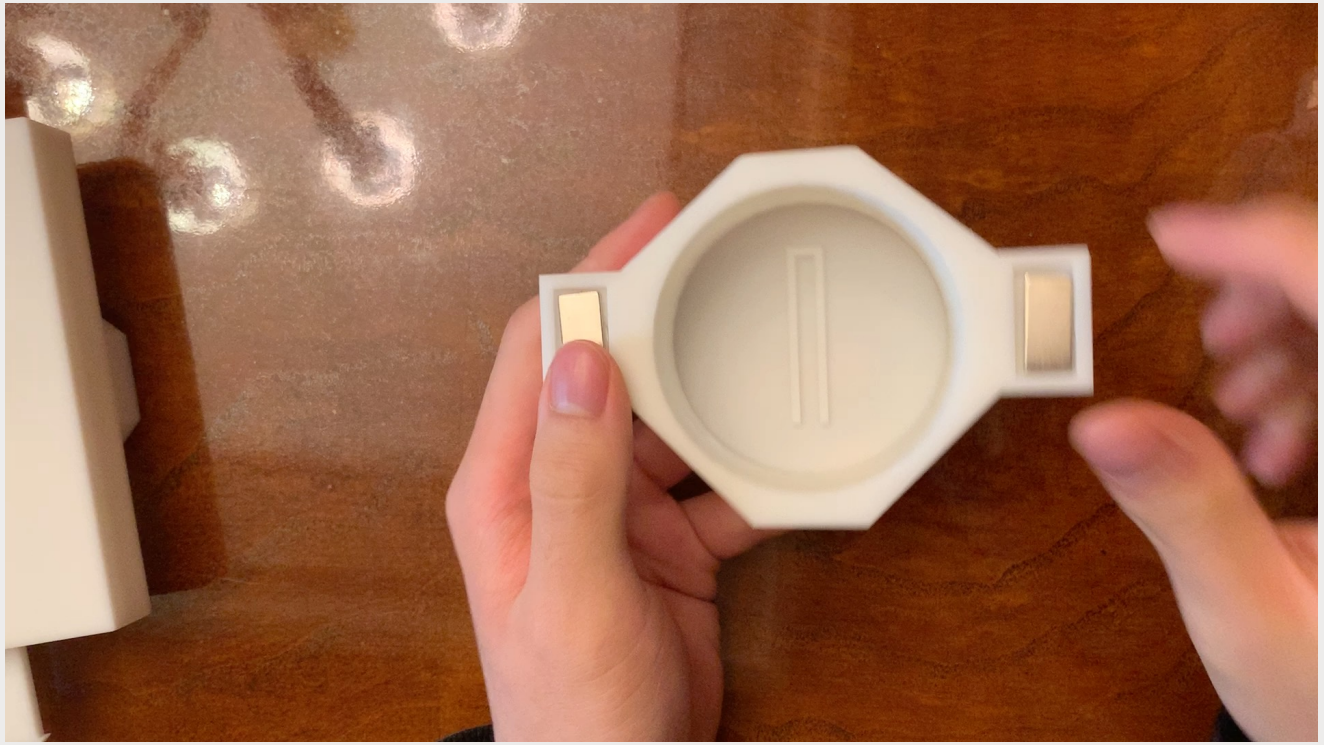
Cuvette Module

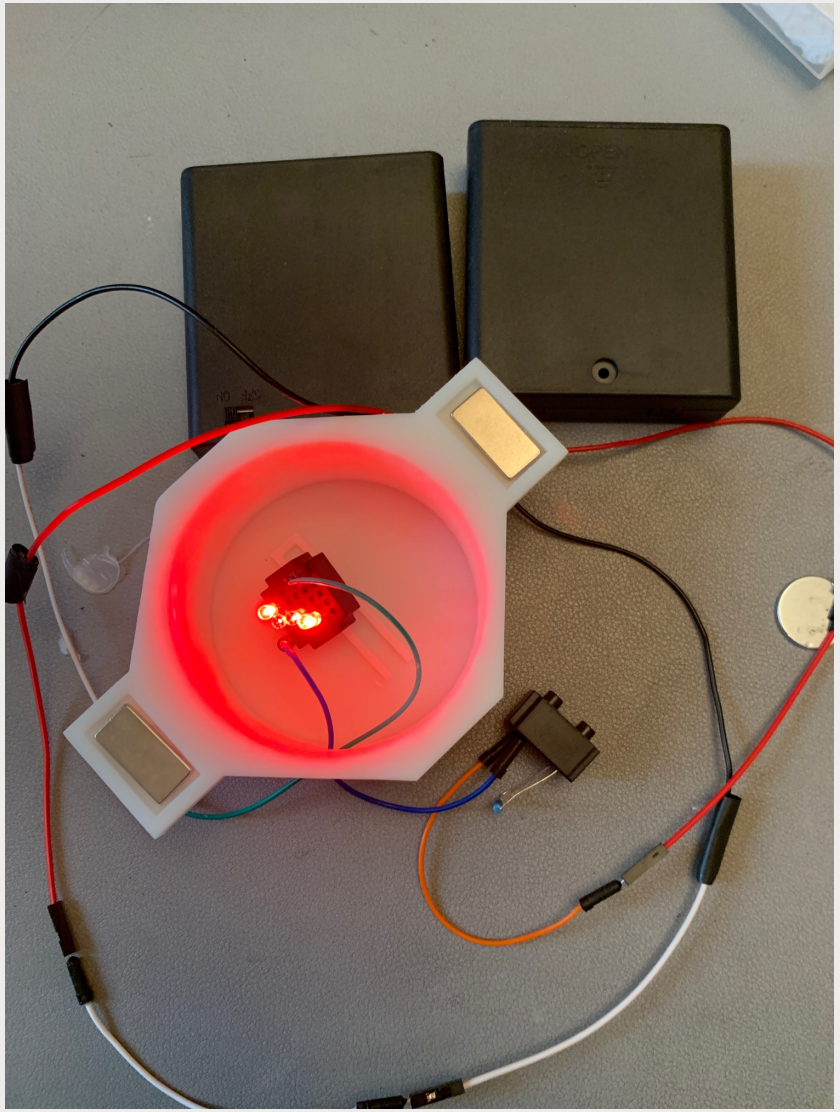


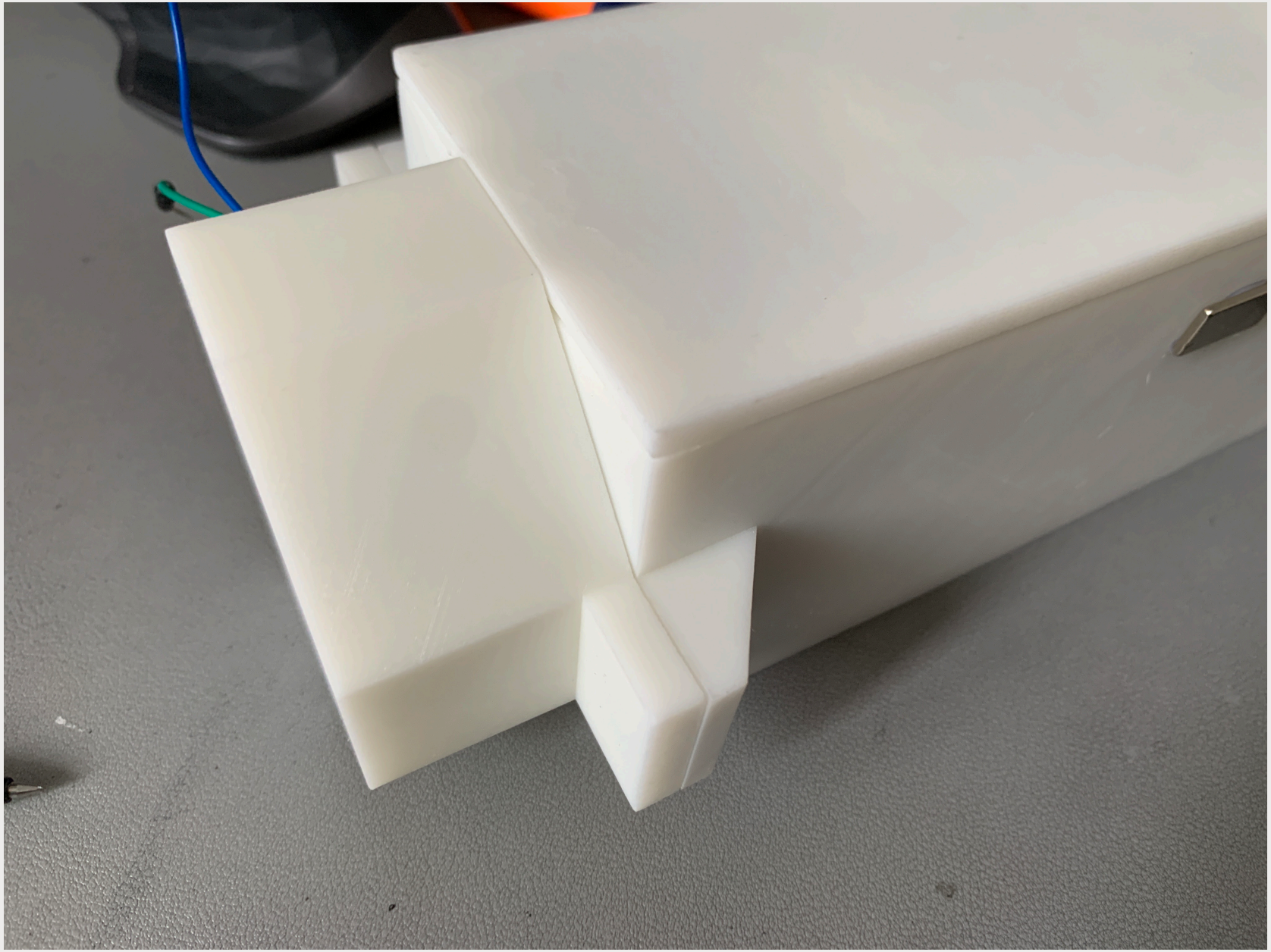


LED Module









Camera

产品参数 Product parameters

产品型号	HBV-W202012HD V33
像　　素	100万像素
感光芯片	OV9726(1/6")CMOS
视场角/焦距	42° /3.0mm　　70° /2.8mm（镜头可选配）
格　　式	MJPG/YUY2
分 辨 率	MJPEG 320x240 30FPS / YUY2 320x240 30FPS MJPEG 640x360 30FPS / YUY2 640x360 30FPS MJPEG 640x480 30FPS / YUY2 640x480 30FPS MJPEG 800x600 30FPS / YUY2 800x600 15FPS MJPEG 1280x720 30FPS / YUY2 1280x720 10FPS MJPEG 1280x800 30FPS / YUY2 1280x800 10FPS
对焦方式	手动调焦（扭镜头）
功能介绍	二维码扫描、人脸识别
输　　出	USB 2.0
支持系统	WinXP/Win7/Win8/Win10/MAC OSX/Linux/Android
线　　材	40cm标配 USB公头测试线（如需更换其他长度尺寸、规格的联系客服）
工作温度	-20°C~70°C
尺　　寸	30mmx25mmx11.3mm
补 光 灯	可外接LED红外补光灯

Resolve field of view/focal length

Resolution

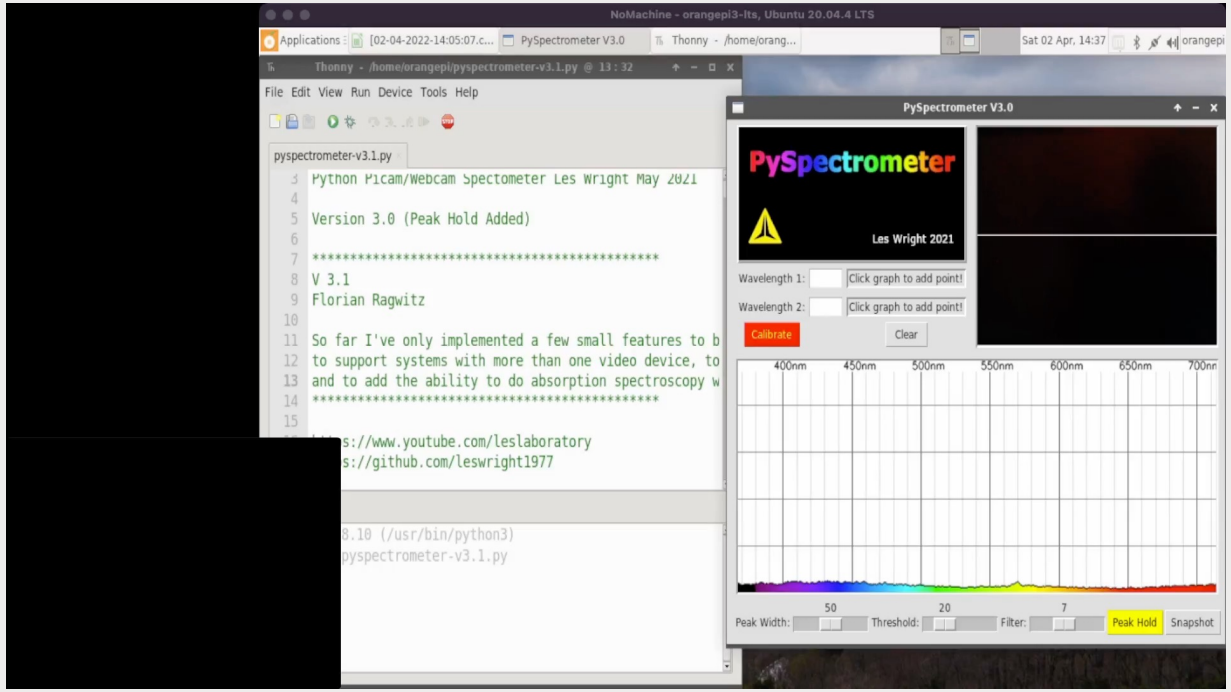
Manual focus / twist lens

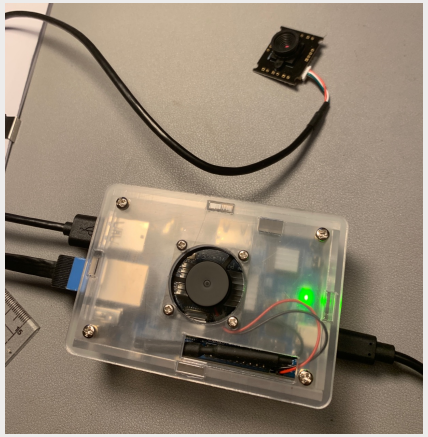
About masking ambient light interference

- We choose to cover the instrument with masking tape, which will protect the instrument from ambient light. Ugly but useful

Software

- [leswright1977/PySpectrometer: Raspberry Pi Spectrometer (github.com)]
- The script run on any platform in Python environment
- It scan the brightness on the central horizontal line, and determine the intensity of light in different wavelength with the calibration data.





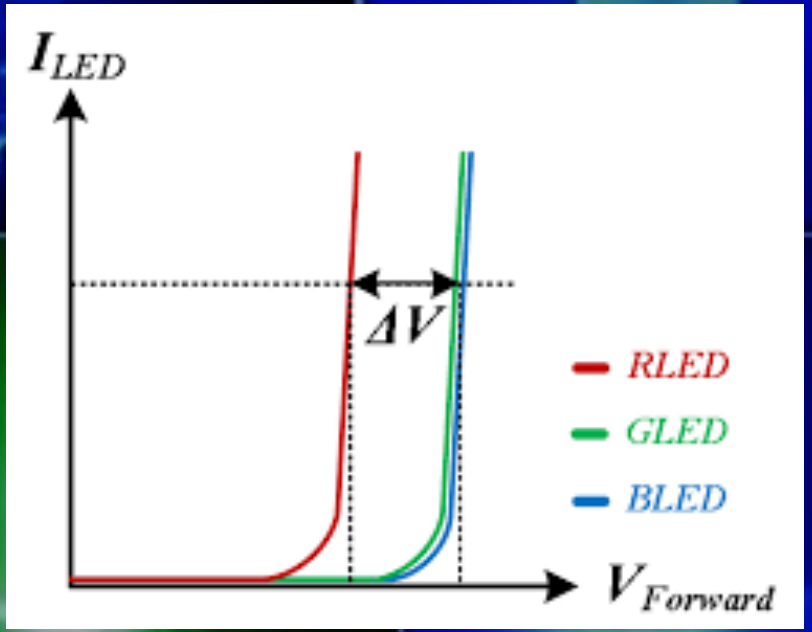
Application 1: Measure the Plank's Constant with LEDs

- Experiment Objective:

To measure the value of the Plank's constant with the LED bulb series and Spectrometer

- Experiment Hypothesis:

The shorter the wavelength of light, the greater the voltage across the LED (forward voltage)



Experiment Methodology:

- Background Information:

The Plank's constant 'h' is one of the most important constants in modern physics. Planck believed that matter could radiate only an integral multiple of some minimum energy, which he called a "quantum of energy," that is E=hv.

For the LEDs, when the P-N junction of the semiconductor material is applied to a forward voltage, the combination of injected minority and majority carriers releases excess energy as light, converting electrical energy directly into light energy.

$$E = hf = qU = 1.6 \times 10^{-19} C \times V_{Forward\ Voltage}$$

Color	Construction	Typical Forward Voltage (V)
Amber	AlInGaP	2.1
Blue	GaN	5.0
Green	GaP	2.2
Orange	GaAsP	2.0
Red	GaAsP	1.8
White	GaN	4.1
Yellow	AlInGaP	2.1

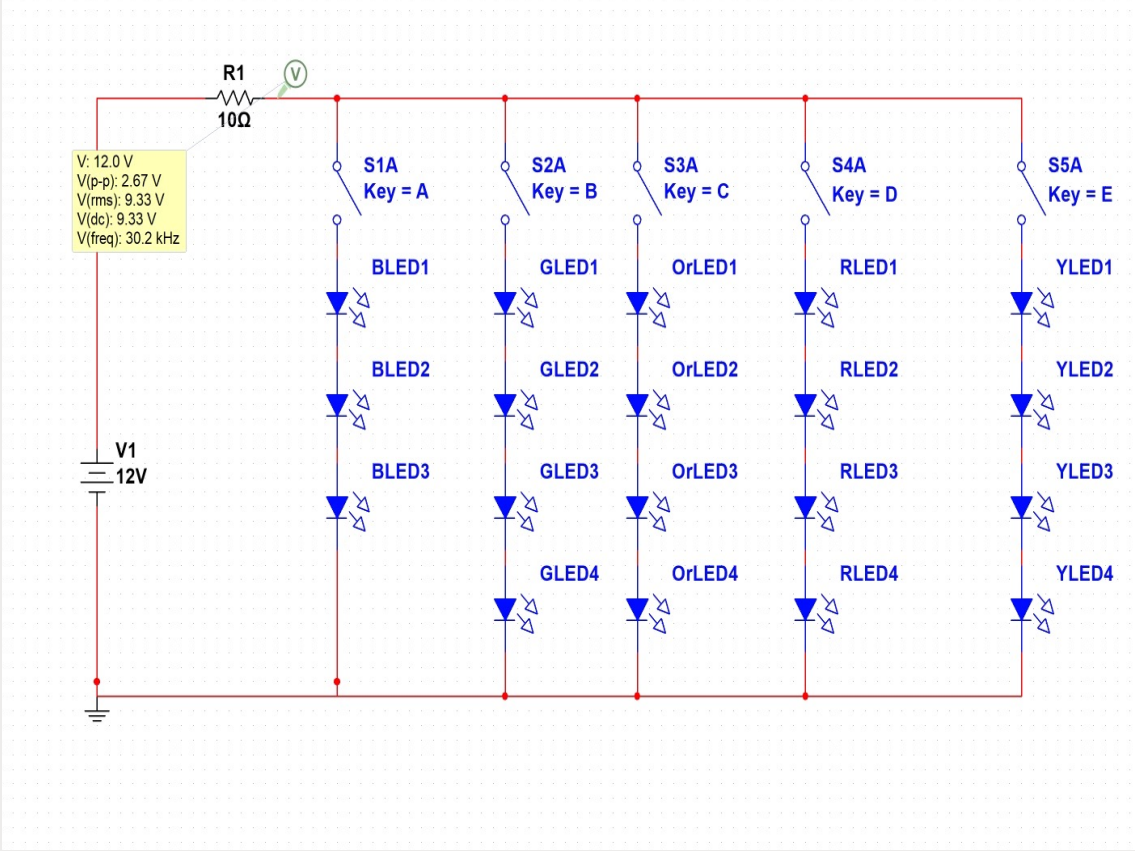
$$f = c/\lambda$$

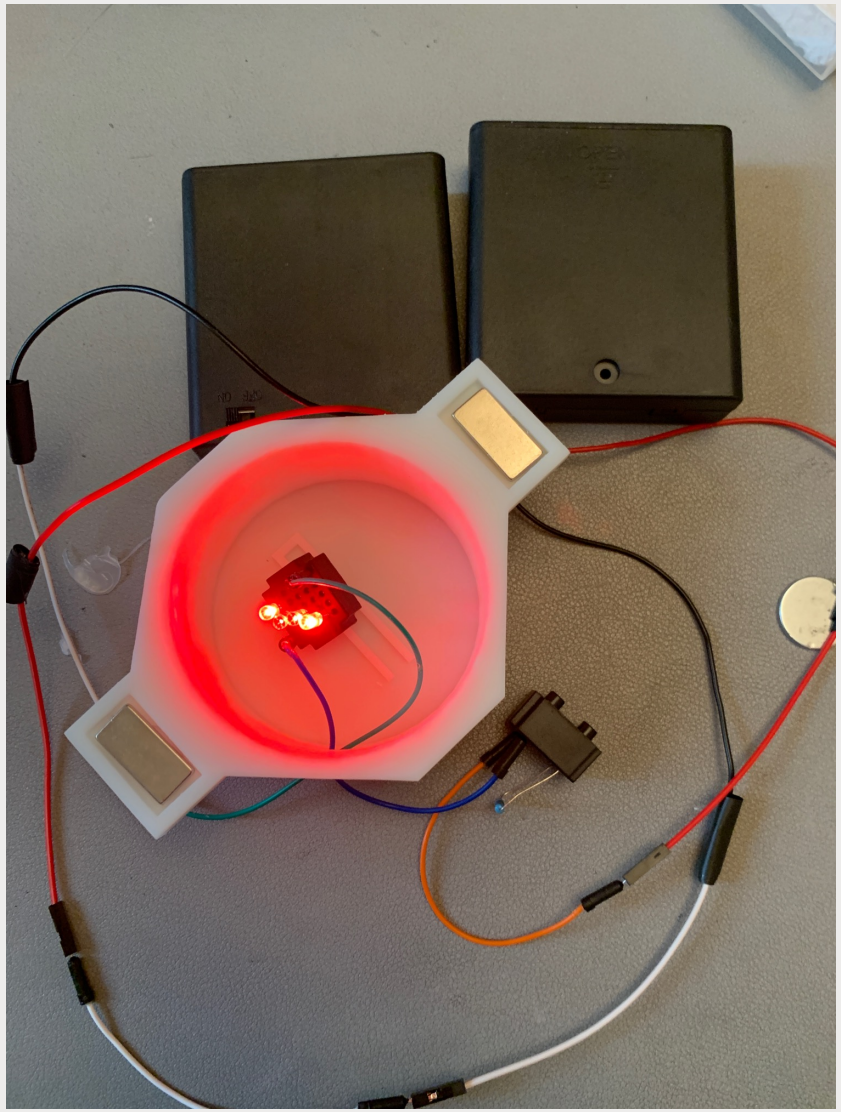
$$h = qf = qU\lambda/c$$

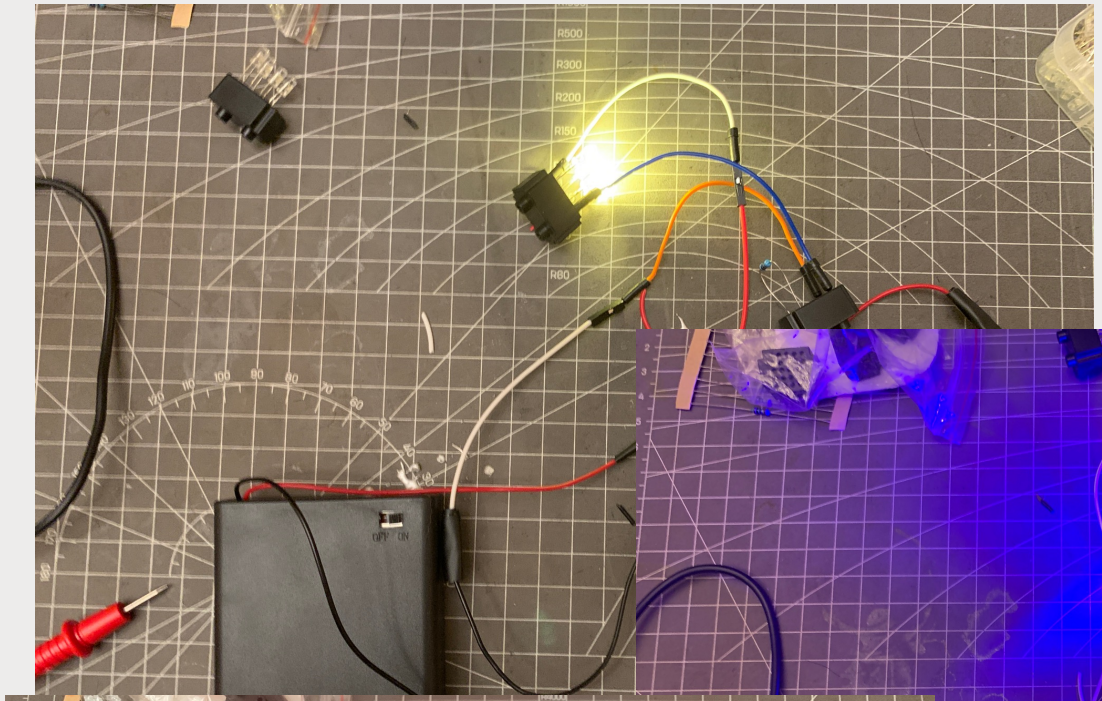
The forward Voltage of different Kinds of LED Bulb

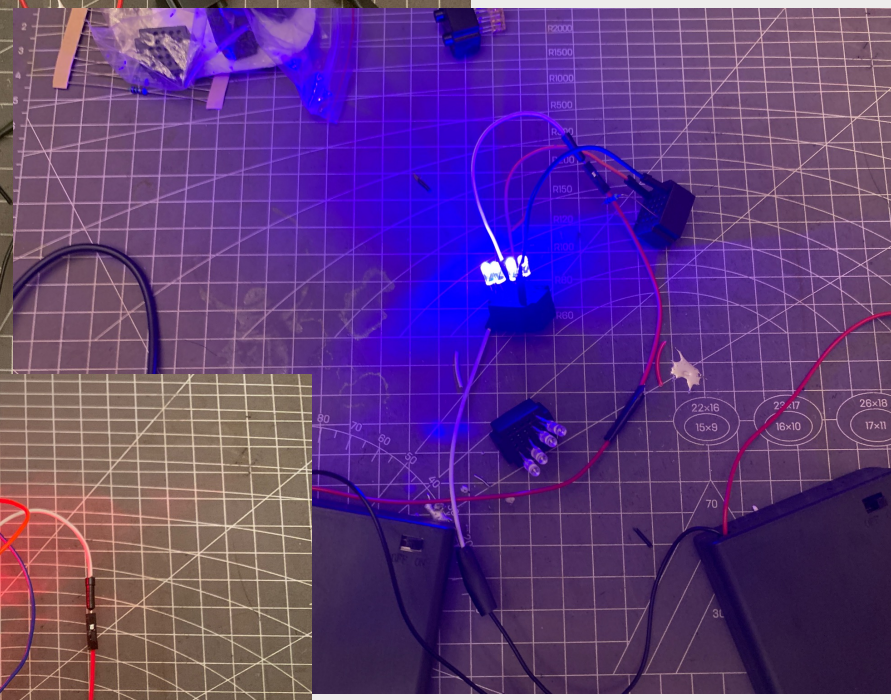
Experiment Methodology

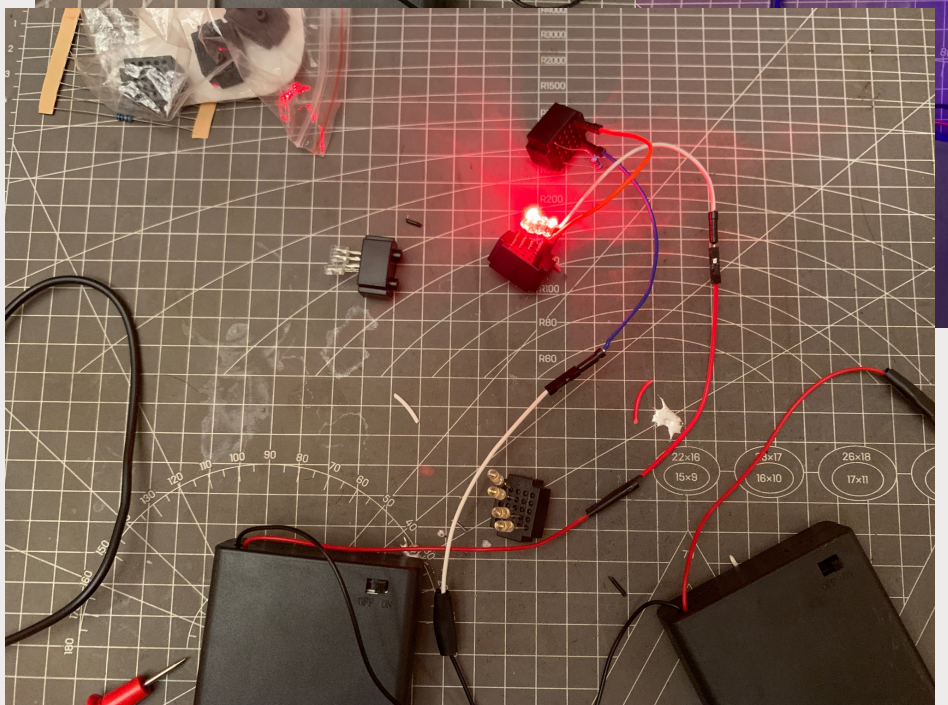
- In this part of the experiment, we will use multiple LEDs of the same type in series and measure their total potential to reduce the error due to.
- In this experiment, we use a multimeter as the measurement tool.
- The results in this part of the experiment will be used to calibrate the Spectrometer accurately.
- In order to save cost, here we use 8 household 1.5V batteries as the power supply, which constitute a 12V DC voltage
- On the right side is the circuit simulation in Multisim. You can see that when different switches are closed, different voltages can be obtained, which is the result of multiple LEDs chan'she

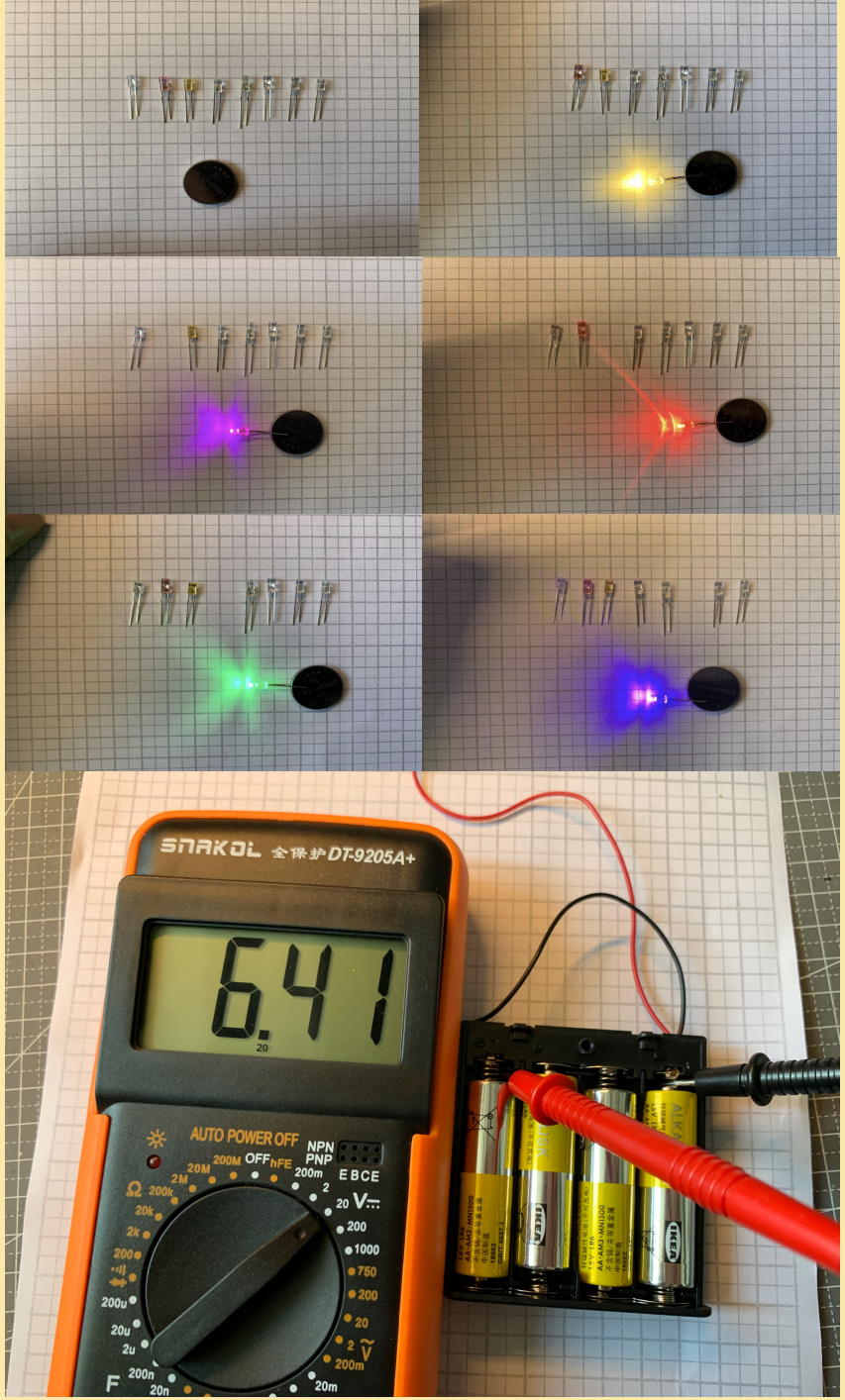












■ Material:

1. 8 kinds of the LED bulb
2. Resistor
3. Switch
4. Battery Case(about 12V)
5. 3D printed parts to construct the instrument

■ Experiment Analysis:

We will make a number of experiments to get the average value and make the error analysis. Detailed data analysis SOP shall be after experiement.

Application 2: Measure the Spectrum Absorption of Copper Sulfate Solution

- Background Information:
- In an experiment carried out by the Los Angeles City College, aimed at find out the relationship between concentration of the solution and the absorbance of solution, which draw out a colored solution's distribution of absorbance line is highly related to its color and the absorbance and concentration is of linear relationship.
- The experiment can be reduced by using spectrometer to determine the region of most significant absorbance happened and use two pair of data to calculate the maximum absorbance, and furthermore draw out the relationship between concentration and absorbance.

Hypothesis

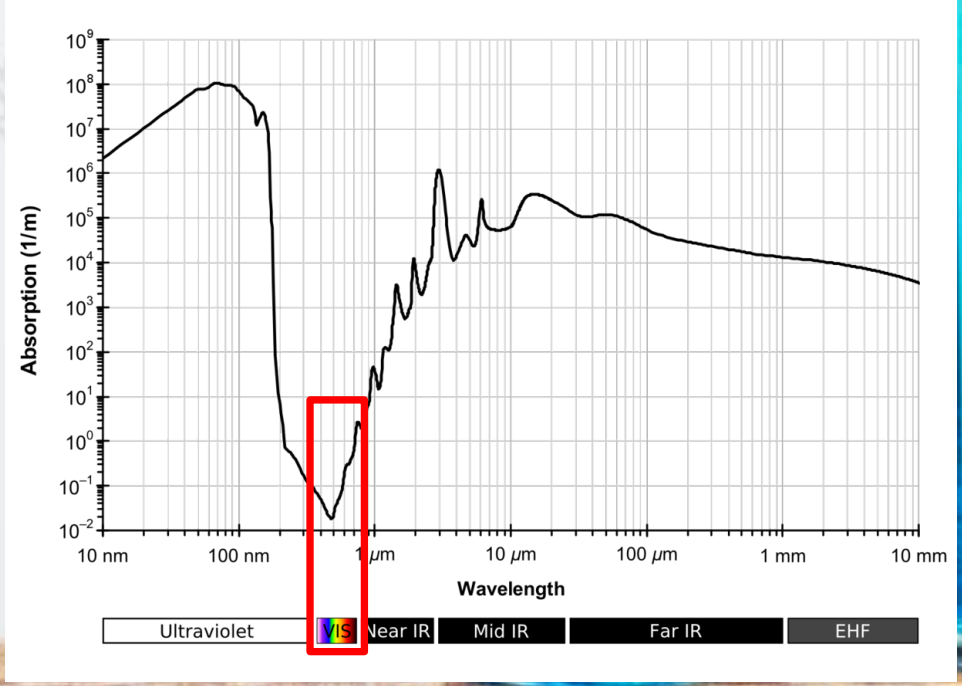
- The more concentrated the solution is, the more copper ions (we use $CuSO_4$ in this experiment) in a certain amount of solution, and the characteristic spectrum of the copper will be more significant, the absorbance will be higher.
- The characteristic spectrum of the ions inside the $CuSO_4$. solution is highly related to the color of this solution.
- The Spectrum of SO_4 ion is a simple add-on between the characteristic spectrum of sulfur and oxygen,

Application 2: Measure the Spectrum Absorption of Copper Sulfate Solution

- Background Information: Spectroscopy

In this experiment we will only focus on the visible light spectrum of the solution.

Reason: We use water as solvent.



Obviously, the water has it's absorbtion reaches bottom in the visisble light region

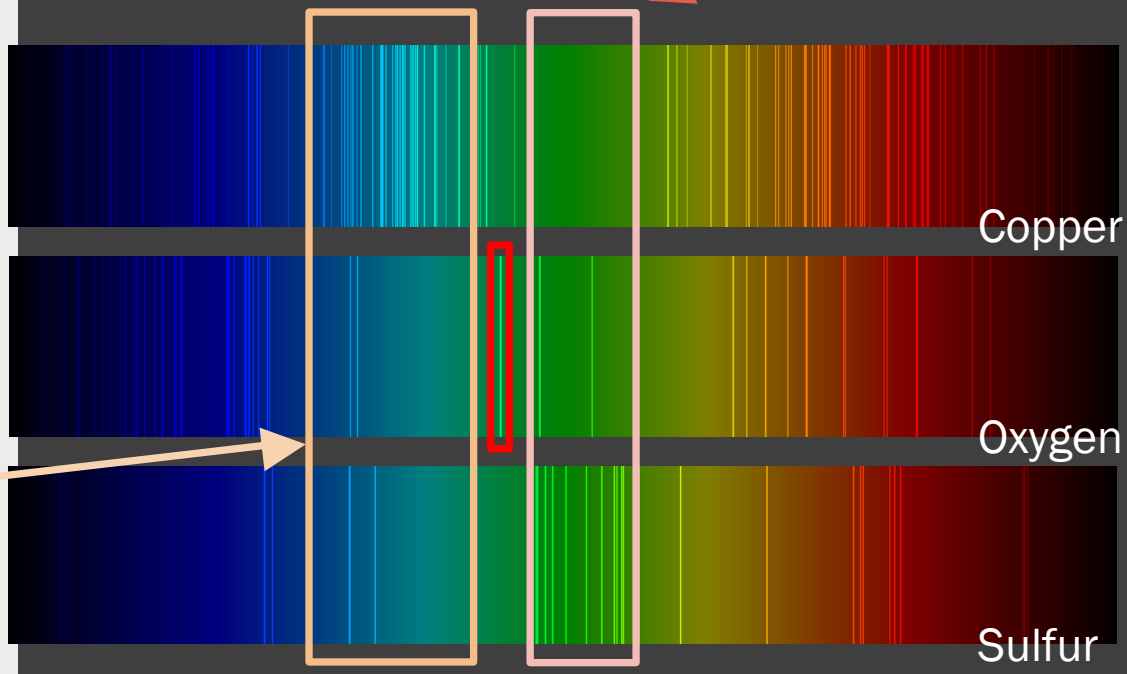
And consider the water we use is very thin (less than 1cm), such absorption will be least visible.

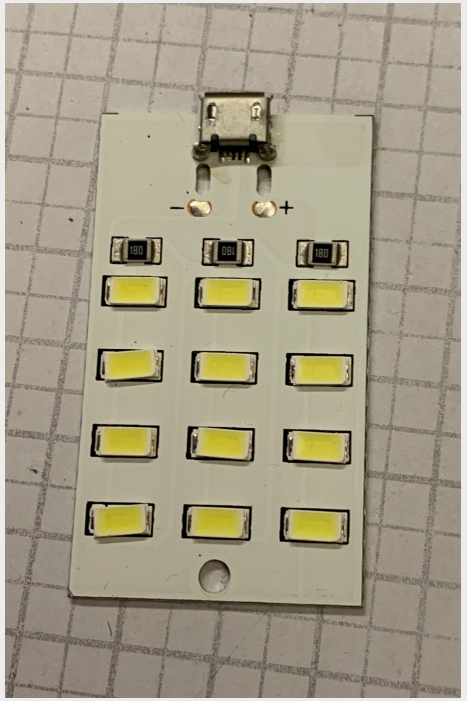
Spectrum

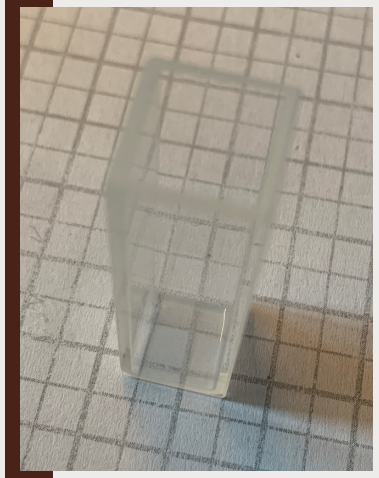
For it's hard to make the DIY spectrometer to have enough accuracy to record every absorption line, we focus on the most specific absorbance to verify our hypothesis

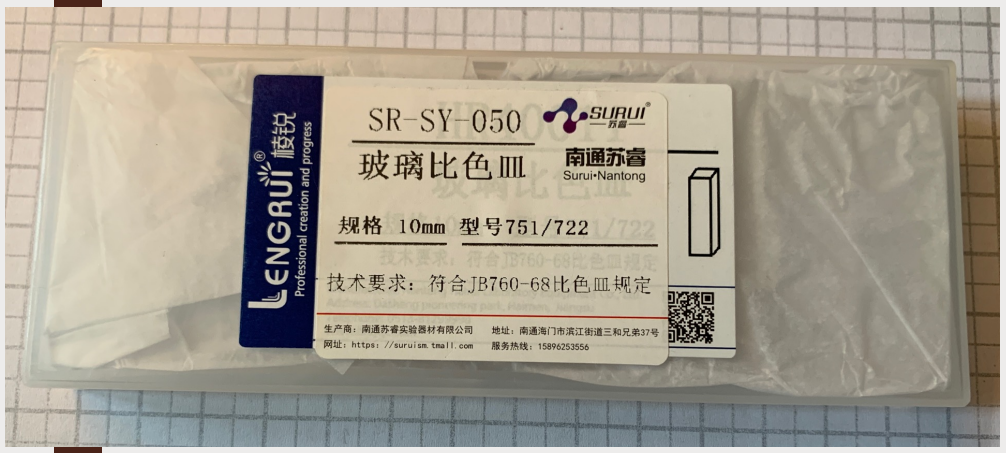
Here the copper shows most outstanding characteristic spectrum

Here the sulfur has obvious abosorbance, while almost no copper absorption









- Material:

1. The solution used: Deionized water, $CuSO_4$ solution (deionized water + $CuSO_4$ crystal)

2. Light Used: White light (produce the spectrum); 650nm red light source (optional), 500nm blue light (produce absorbance in certain wavelength, optional)

3. $CuSO_4$ concentration: 0.1Mol/L, 1Mol/L

4. Amount of solution need: 5mL/each experiment

Light/Solution	Deionized water	0.1mol/L $CuSO_4$	1mol/L $CuSO_4$
White light (LED)	Spectrum 1	Spectrum 2	Spectrum 3
675nm (Red) wavelength light (optional)	Absorbance 1	Absorbance 2	Absorbance 3
500nm (Blue) wavelength light (optional)	Absorbance 4	Absorbance 5	Absorbance 6

- Experiment Methodology:
- Experiment:

  i. Turn on the spectrometer we make, use white light with fixed intensity.

  ii.Insert the cuvette with deionized water into the spectrometer, assure that no fingerprint or dirt on the cuvette, if there is, wipe them off with light duty wipe.

  iii.Read and record the spectrum of the water.

  iv.Change another cuvette with 0.1mol/L solution, repeat the experiment, record the spectrum.

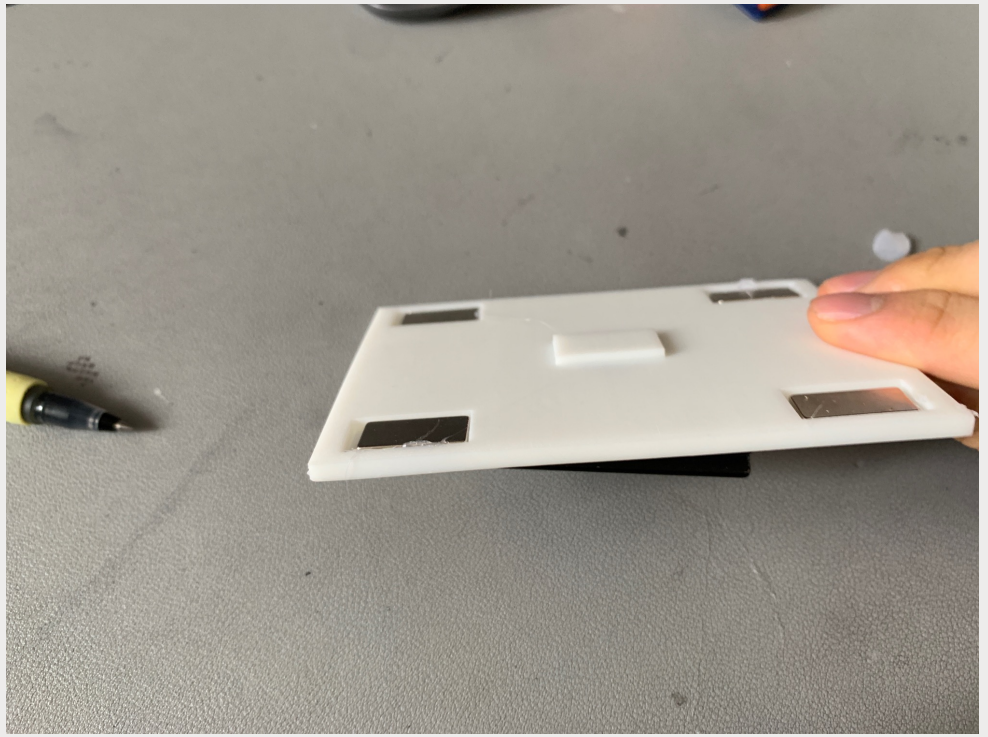
  v. Repeat the process using 1mol/L solution.

Optional step:

- Change the light source into 500nm light (blue), repeat the process, record the spectrum, mark the absorbance line.
- Change the light source into 650nm (red), repeat the process, record and mark the absorbance.
- Compare these absorbance spectrums, draw out the characteristic spectrum of the CuSO4 solution in these specific wavelengths.

More application

- Here we connect the spectrometer with the orangepi Development Boards
- and use the Camera base to hold it in a tripod
- Maybe can used in measuring the solar spectrum in the future



Thank you!

Reference:

1. leswright1977/PySpectrometer: Raspberry Pi Spectrometer (github.com)
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3. USING CDs AND DVDs AS DIFFRACTION GRATINGS | NNIN
4. https://www.theremino.com/wp-content/uploads/files/Theremino_Spectrometer_Technology_ENG.pdf
5. 利用发光二极管（LED）测定普朗克常数的实验设计 - 豆丁网 (docin.com)
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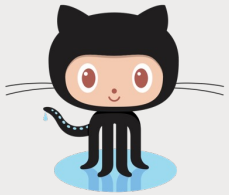

Any Technical Document relevant(Hardware Drawing, Circuit, Software) could be find in Github (MIT License): https://github.com/yimingio/Lab_IV_Spectrometer