Meeting Notes 1

2020年9月23日 20:00

Meeting Method: Zoom (online video calling), **Date:** 09/23/2020, **Time:** 11:00 GMT (19:00 Beijing Time)

Items for discussion (noted by student before supervisory meeting):

1	Details of the project
2	Time schedule for the submission

Record of discussion of supervisory meeting:

1	The project is to build an optical spectrometer based on a USB camera that can measure the light spectrum at different wavelength and showing the frequency spectrum.
2	The time schedule can be found on Moodle.

Action list (to be attempted or completed by student by the next supervisory meeting):

1	Do some brief research about the spectrometer, its principle and its basic structure.

Time schedule:

Project Component	**Weight**	**Deadline**	**Submission Method**	**Responsible**
Project Specifications & Preliminary Report and 1st logbook		Friday, 30th Oct 2020 23:59 CST	Moodle	Student
Project Specifications & Preliminary Report (Grading) - Resources request approval	5%	Friday, 20th Nov 2020	Moodle/Blackboard + MS Forms	Supervisor
Interim (Mid Project report) and 2nd logbook + Risk Assessments + Ethics		Monday, 04th Jan 2021 23:59 CST	Moodle	Student
Interim (Mid Project report) (Grading)	5%	Friday, 22nd Jan 2021	Moodle/Blackboard + MS Forms	Supervisor
Final Report and 3rd logbook		Friday, 23rd April 2021 23:59 CST	Hardcopy handover and softcopy through Moodle	Student
Student Performance Evaluation	10%	Friday, 23rd April 2021	Moodle/Blackboard + MS Forms	Supervisor
FYP software codes, prototyping/equipment		Friday, 23rd April 2021 23:59 CST	Software codes, hardware and equipment submission and storage	Student & GC-UESTC
Final Report (Grading)	50%	Friday, 14th May 2021	Moodle/Blackboard + MS Forms	Final Report Panel
PowerPoint slides for oral presentations		Friday, 07th May 2021 12:00 CST	Moodle	Student
Oral presentations	30%	Monday, 10th- Friday, 14th May 2021	Panel presentations + MS Forms	Oral Presentation Panel

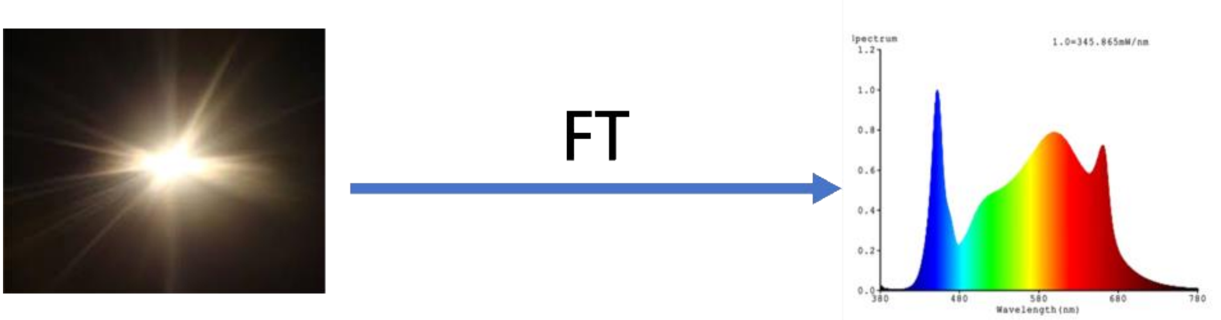
来自 <https://moodle.gla.ac.uk/course/view.php?id=21109>

Brief Research 1

2020年10月26日　　22:00

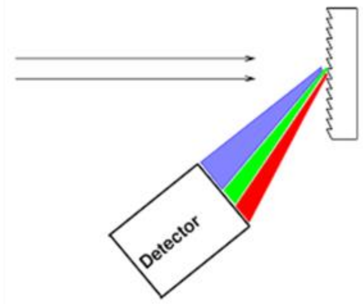
Date: 10/26/2020, **Time:** 13:00 GMT (21:00 Beijing Time)
I have made some search online and got better understanding about the project.

The basic idea of the Optical spectroscopy is actually doing fourier transform on the incoming light signal, transformating it in to frequency domian.

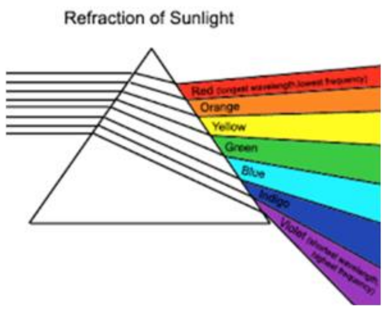


However the visual light's frequency is around several Tera Hertz and it is impossible for a typical electronic device to sample on this high frequency. So we want to use some optical instrument to separate the wide-band light signal into many narrow-band so that we can estimate the power spectrum on each frequency.

To achieve this, we usually use two instrument: diffraction grating and prism and in this project I am request to use the diffraction grating.

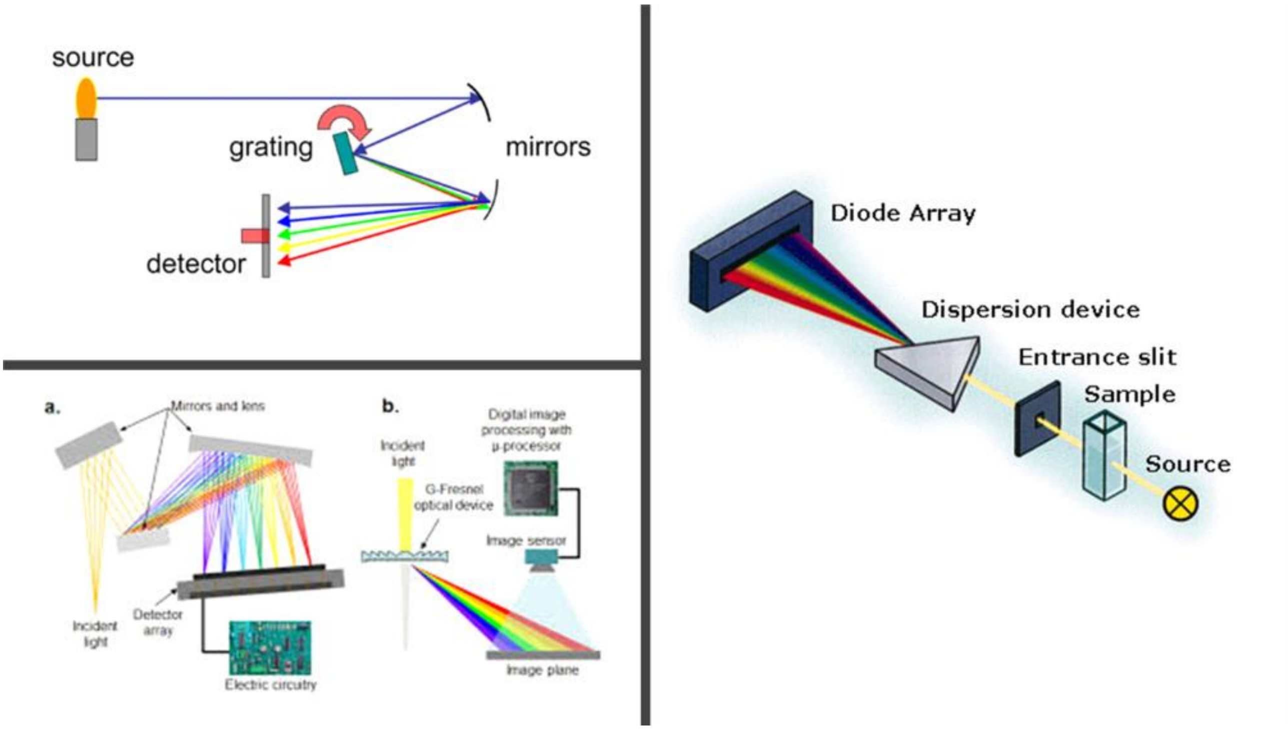


Diffraction Grating



Prism

Then I did some search online, and found some basic design structure below:


source
grating
mirrors
detector
a.
Mirrors and lens
Incident light
Detector array
Electric circuitry
b.
Incident light
Digital image processing with µ-processor
G-Fresnel optical device
Image sensor
Image plane
Diode Array
Dispersion device
Entrance slit
Sample
Source

Meeting Notes 2

2020年10月28日 20:00

Meeting Method: Zoom (online video calling), **Date:** 10/27/2020, **Time:** 14:00 GMT (22:00 Beijing Time)

Items for discussion (noted by student before supervisory meeting)**:**

1	Show my brief research about the project to the supervisor.
2	Ask about the tangible tasks, targets, outcomes and other detials which will be written in the preliminary report.

Record of discussion of supervisory meeting:

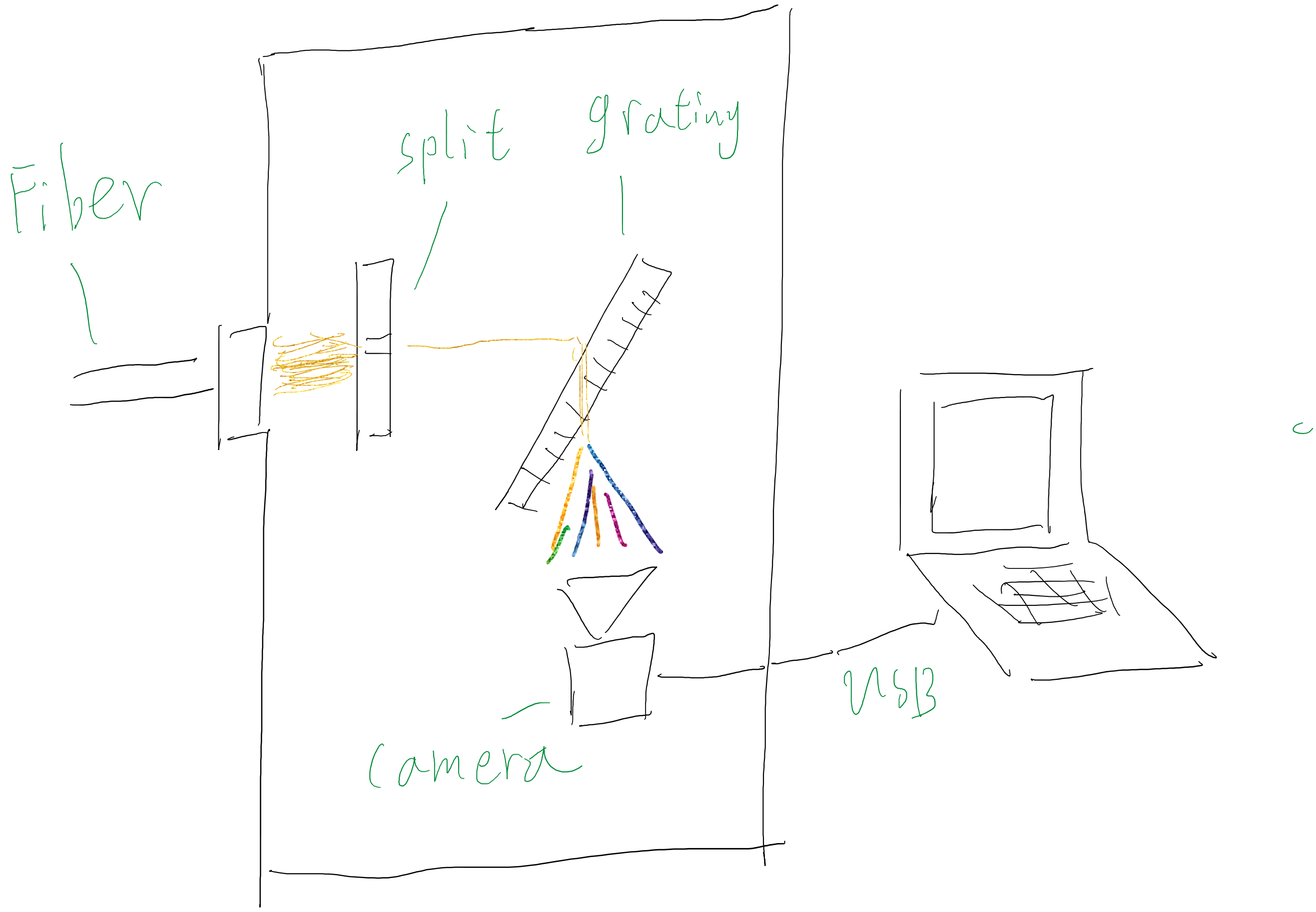
1	The supervisor confirm my brief research.
2	The main tasks are: 1. Design and choose the diffraction grating 2. Design and choose a CCD camera 3. Build the software for data processing 4. Build a graphical user interface The measurable outcomes are: 1. A fully functional spectrometer with a USB interface. 2. A software with GUI to show the light spectrum.

Action list (to be attempted or completed by student by the next supervisory meeting)**:**

1	Finish the resources list and Risk Assessment Form

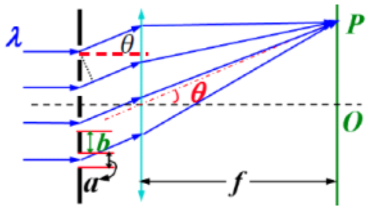
Design Draft 1

2020年12月23日 4:53



Calculation of two equations

2020年12月29日 2:05



$$\Delta\varphi_p = \frac{2\pi}{\lambda} d\sin\theta$$

Phase different for maximum

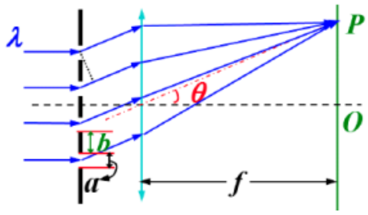
$$\boxed{d\sin\theta = \pm k\lambda \quad (k = 0,1,2,\cdots)}$$

$$\boxed{\Delta\varphi_p = \pm 2k\pi \quad (k = 0,1,2,\ldots)}$$

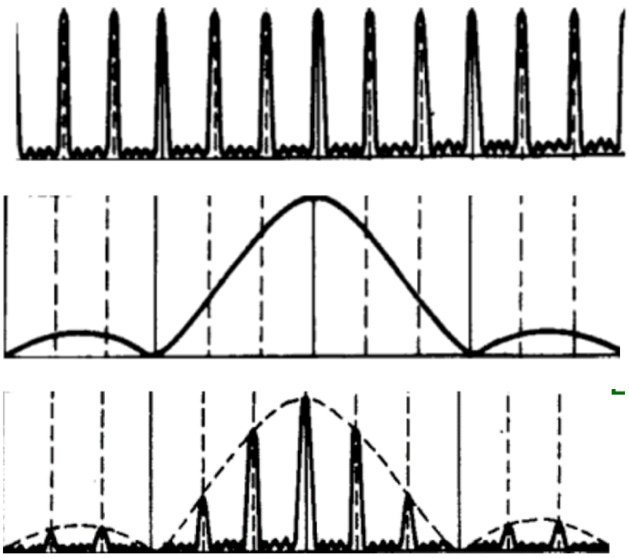
$$\boxed{\Delta\varphi_p = \frac{\pm 2k'\pi}{N}}$$

: $d\cdot\sin\theta = \dfrac{\pm k'}{N}\lambda$

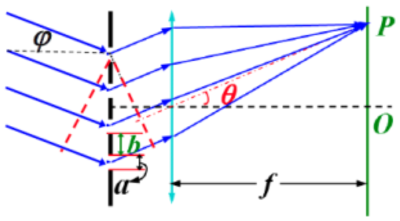
Phase different for minimum



$$\boxed{\Delta\varphi_p = \frac{2\pi}{\lambda} d\sin\theta}$$



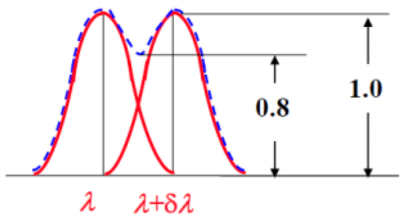
the effect of the diffraction can be explained as the result of multi-split interference modulated by single-split diffraction.



$$\boxed{d(\sin\theta + \sin\varphi) = k\lambda \quad (k = 0,\pm1,\pm2\ldots)}$$

When the incident light has angle with the grating

$$\boxed{R \equiv \frac{\lambda}{\delta\lambda}}$$



Resolution definition

$$d\sin\theta = \pm k\lambda$$

$$d\cdot\sin\theta = \frac{\pm k'}{N}\lambda$$

$$\sin\theta = \frac{k'}{Nd}(\lambda + \delta\lambda)$$

$$\sin\theta = \frac{k'}{Nd}(\lambda + \delta\lambda)$$

$$\frac{k}{d}\cdot\lambda = \frac{Nk-1}{Nd}\cdot(\lambda + \delta\lambda)$$

$$Nk\lambda = (Nk-1)(\lambda + \delta\lambda) \quad \Rightarrow 0 = Nk\delta\lambda - \lambda - \delta\lambda$$

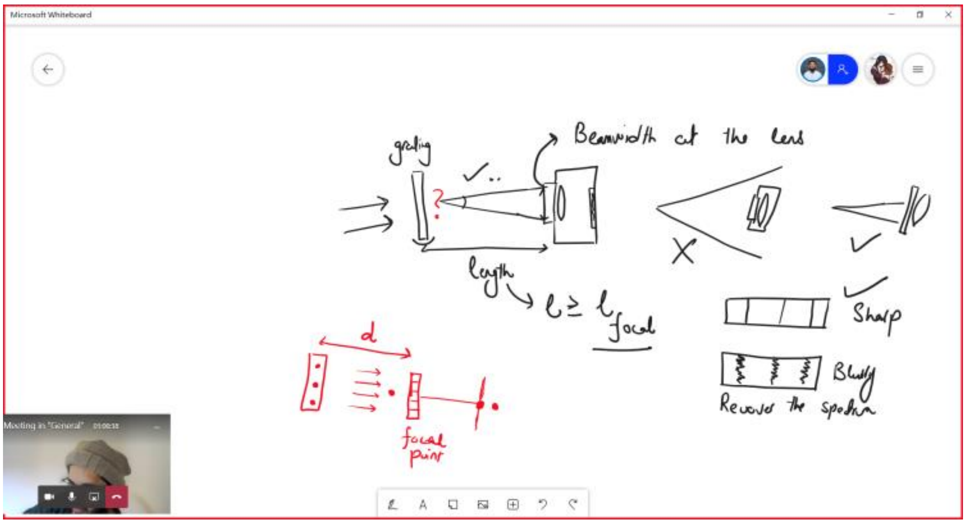
$$\Rightarrow \lambda = \delta\lambda(Nk-1)$$

$$R = \frac{\lambda}{\delta\lambda} = Nk - 1 \approx Nk, (k \neq 0) \qquad (N >> 1)$$

$$\boxed{R \approx Nk}$$

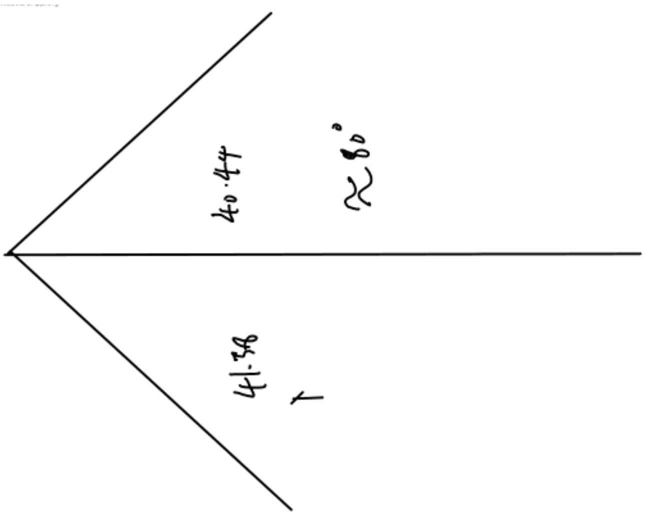
Meeting Note 3

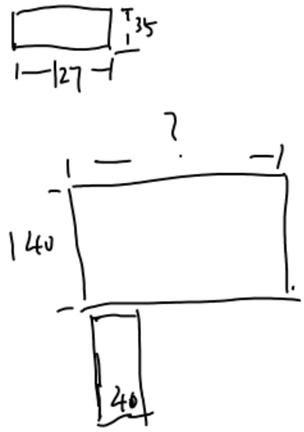
2021年3月5日 22:07

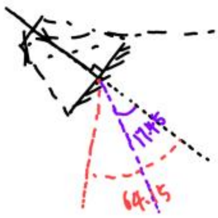


Design Draft 2

2021年3月18日 22:04

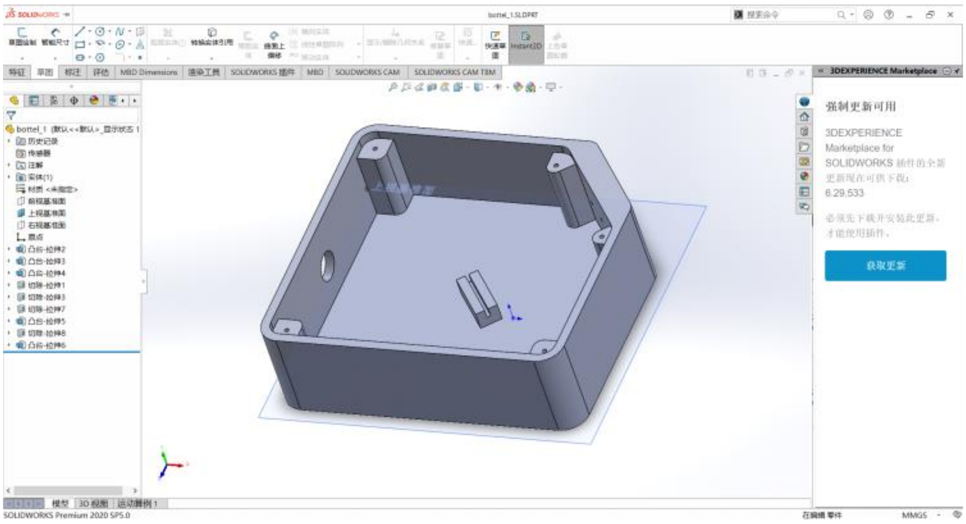






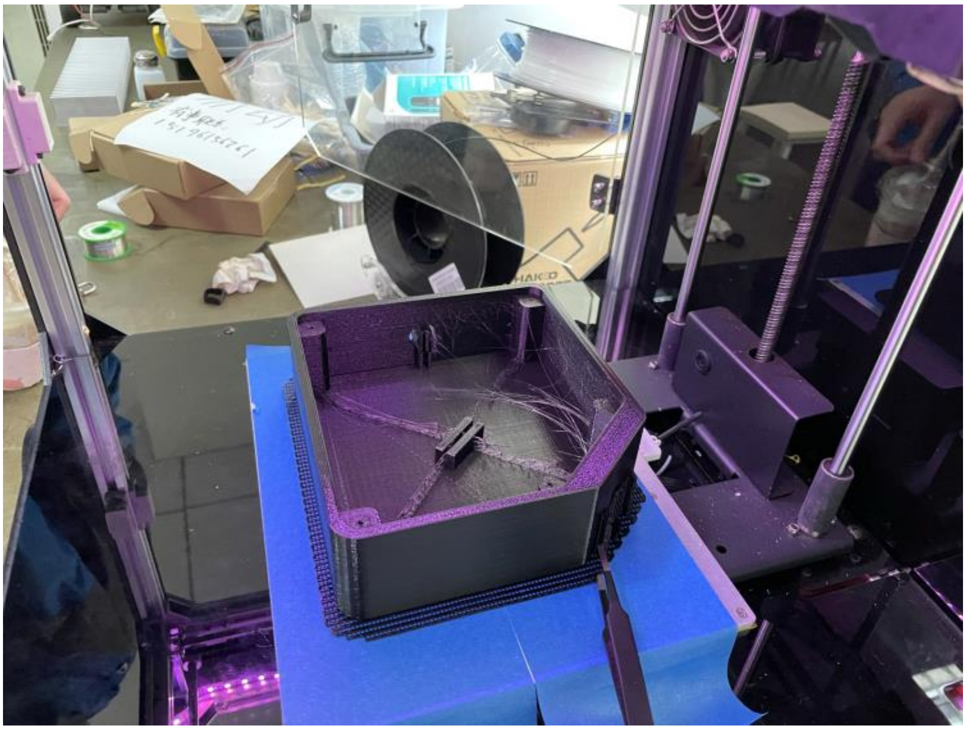
3D Modeling 1

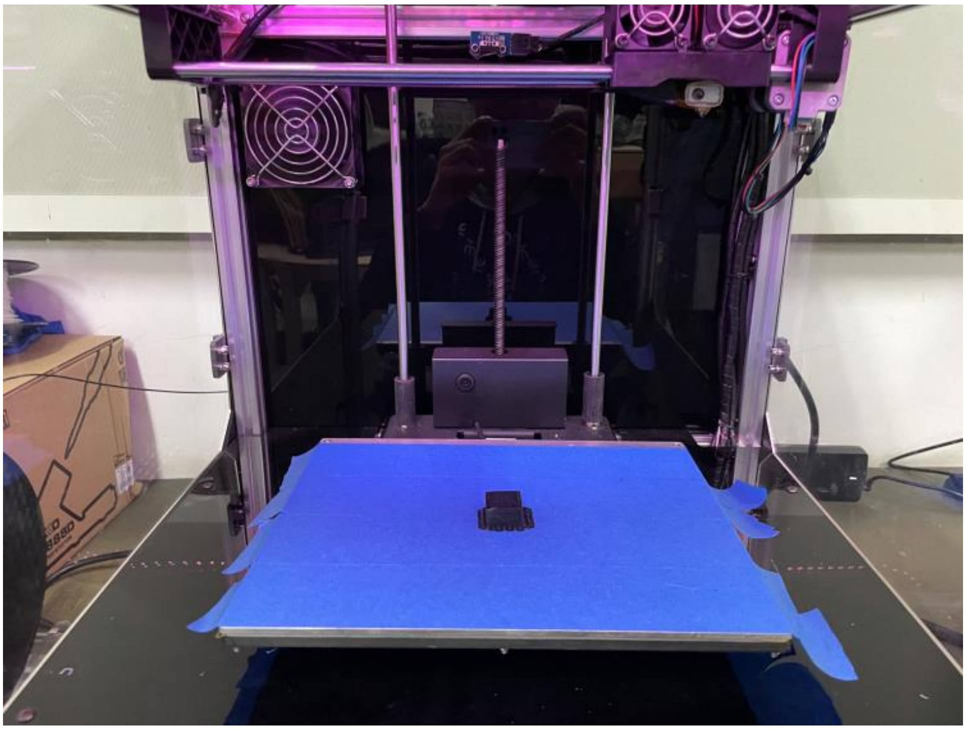
2021年3月22日 22:16



3D Printing 1

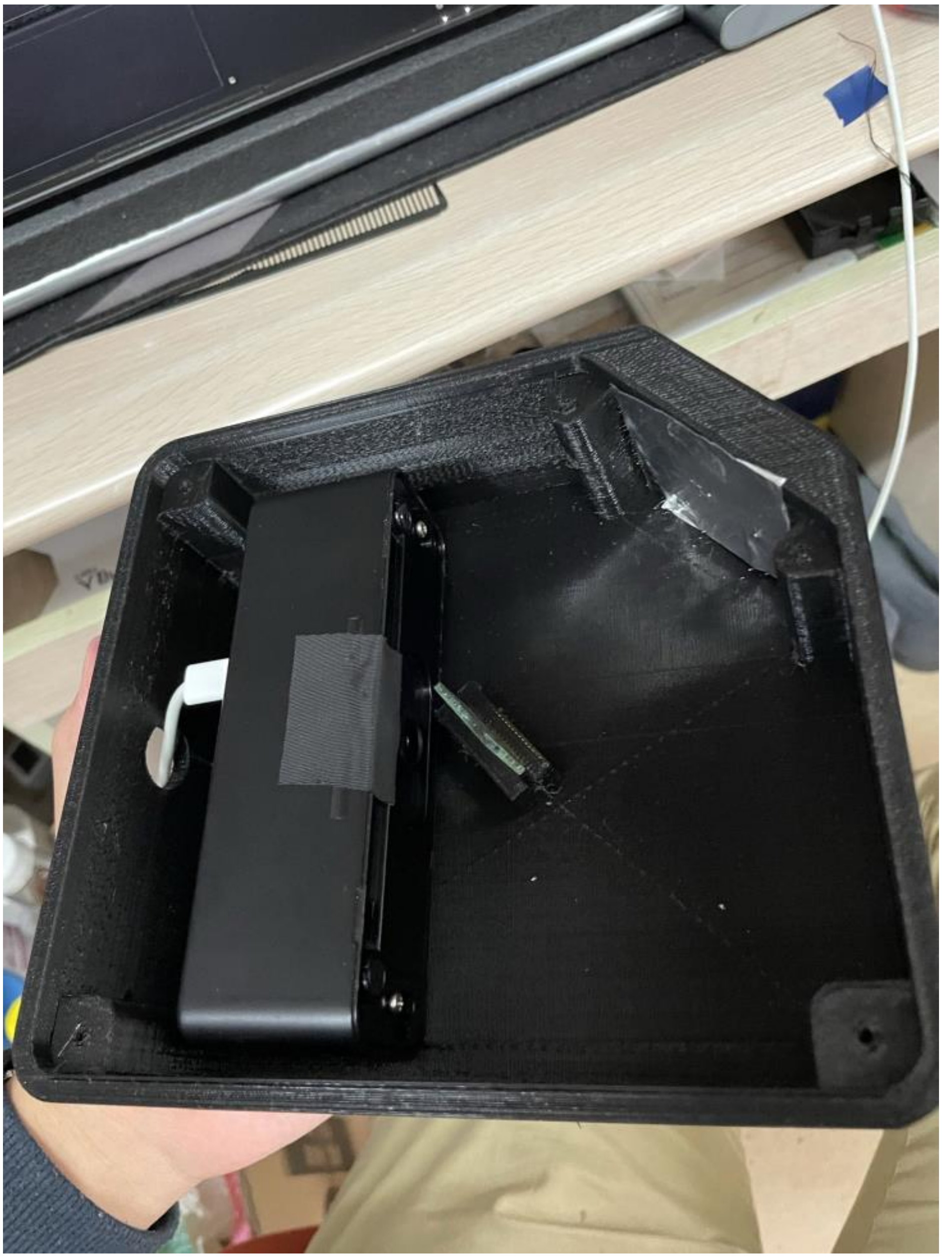
2021年3月23日 22:06

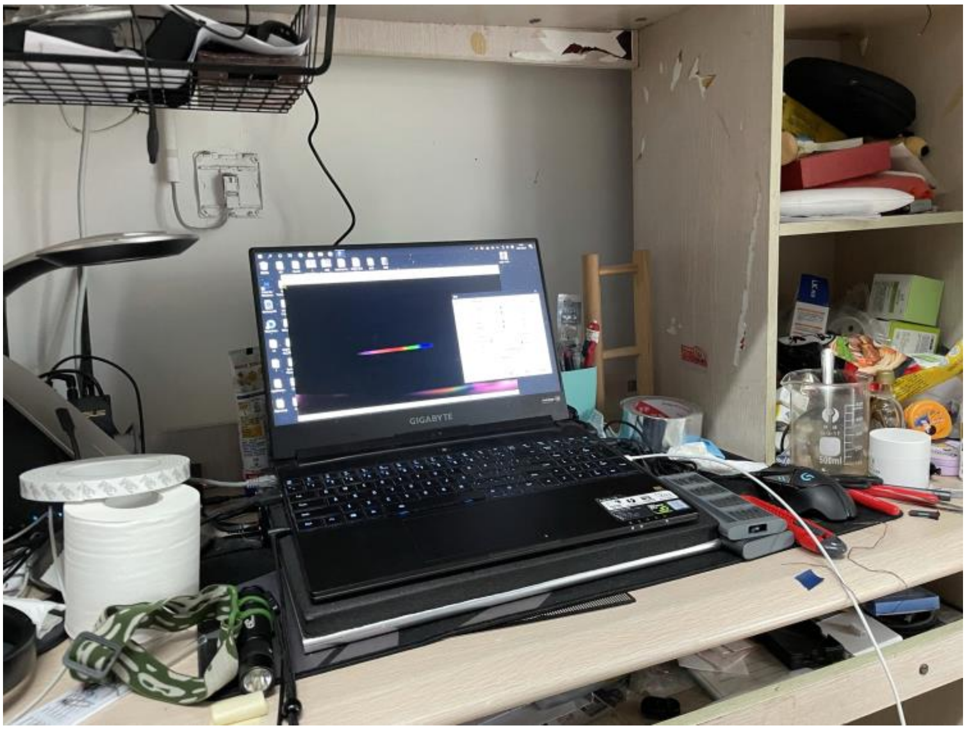




Result test 1

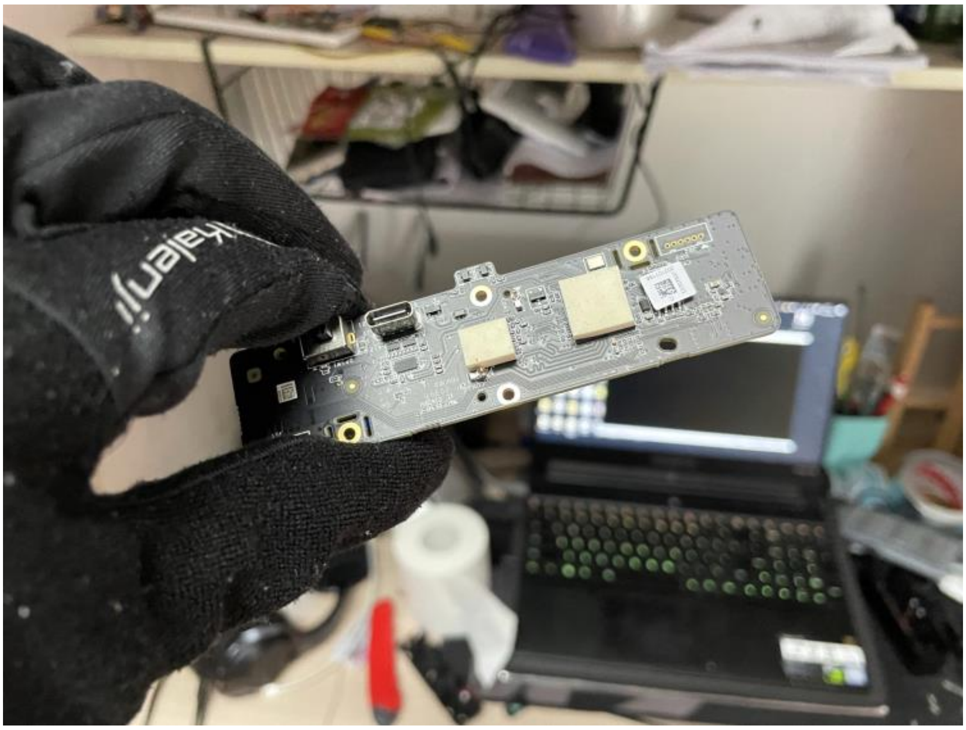
2021年3月24日 22:09





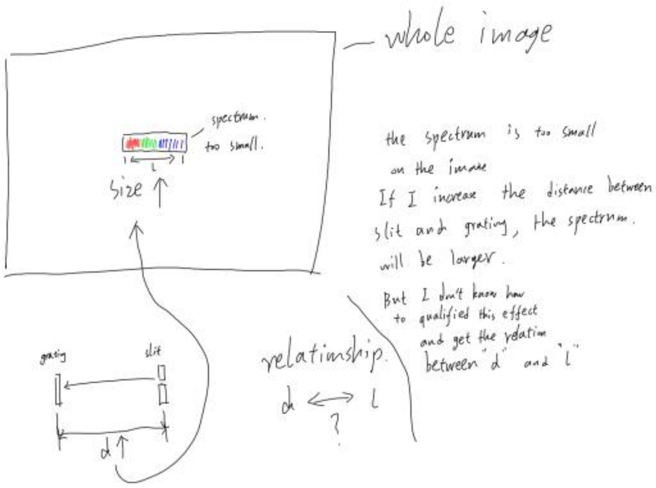
Modify Camera Lens

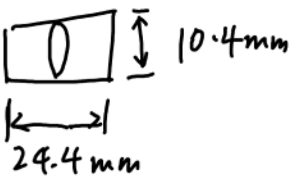
2021年3月24日 22:10



Design Draft 3

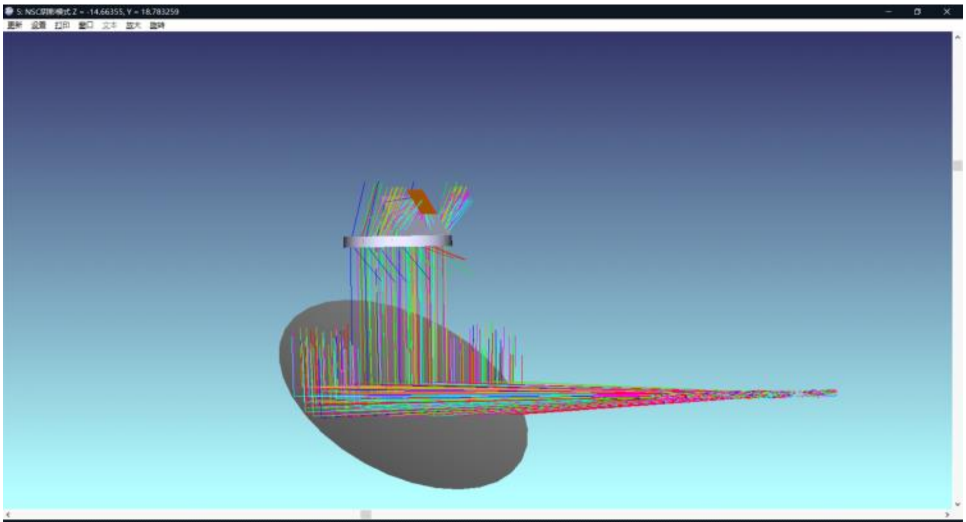
2021年3月28日 22:12

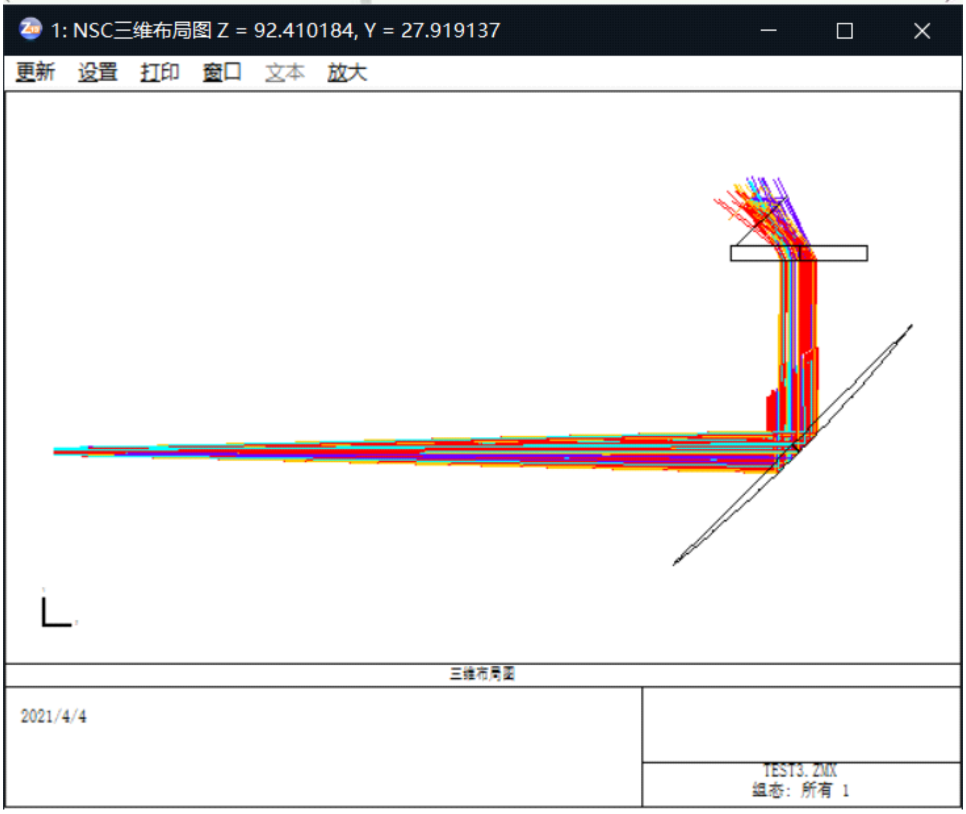


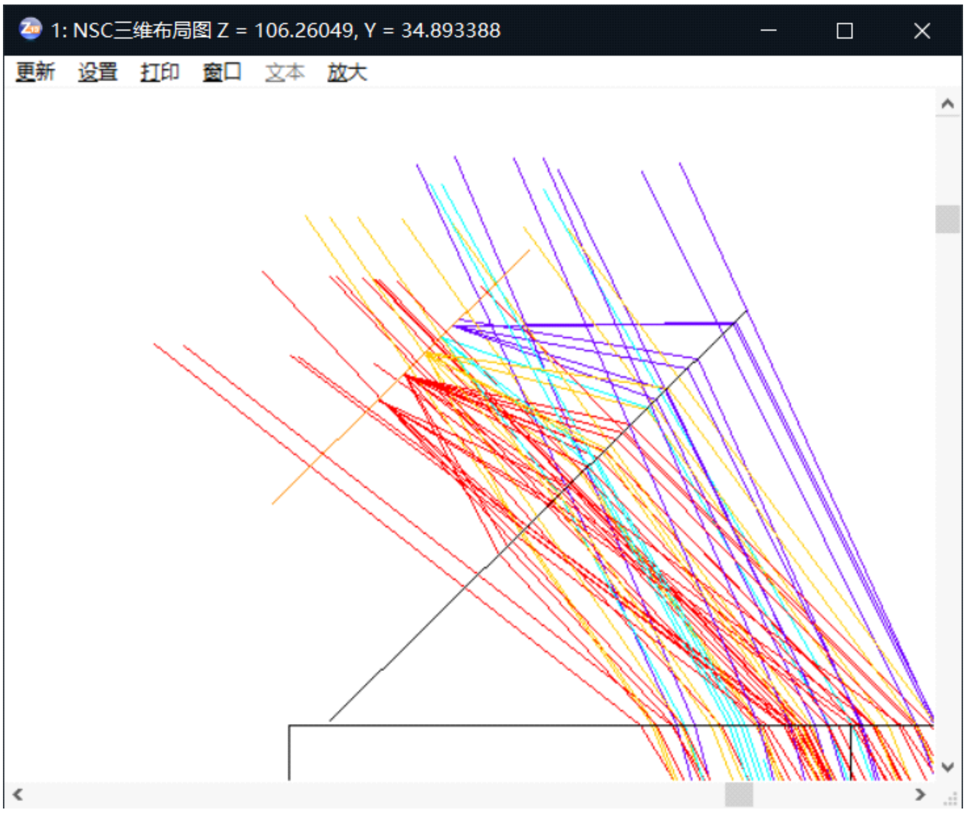


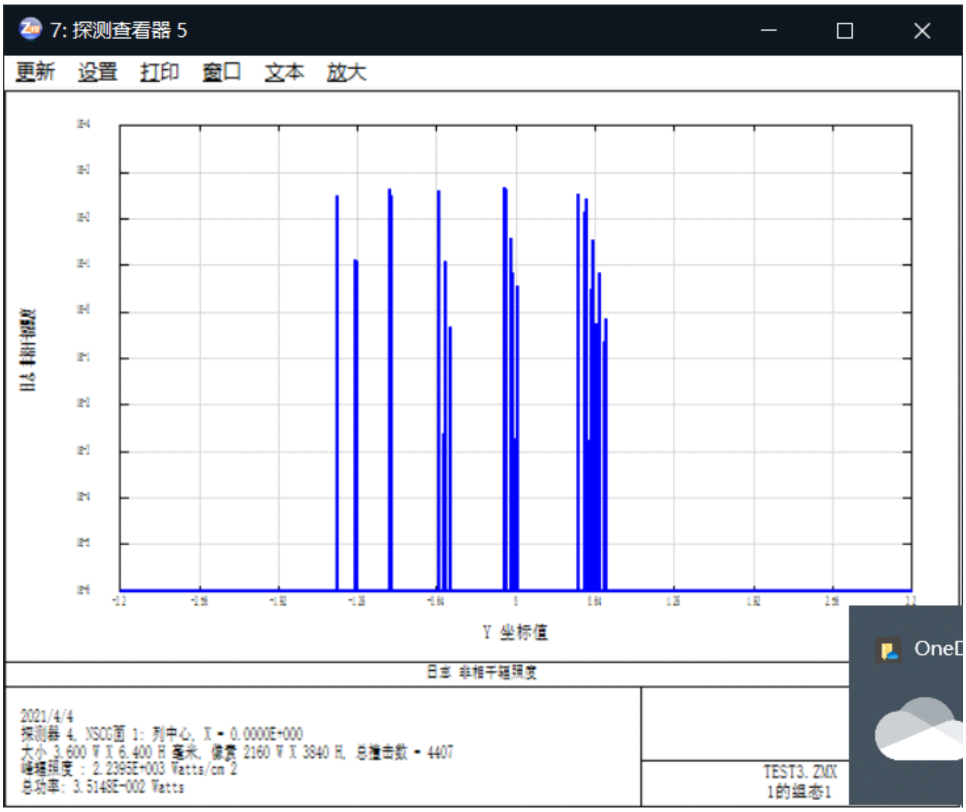
Zemax simulation result 1

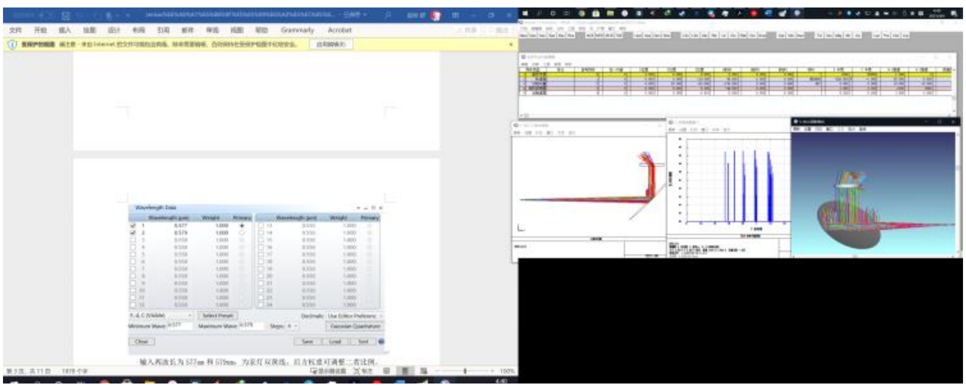
2021年4月4日 22:02

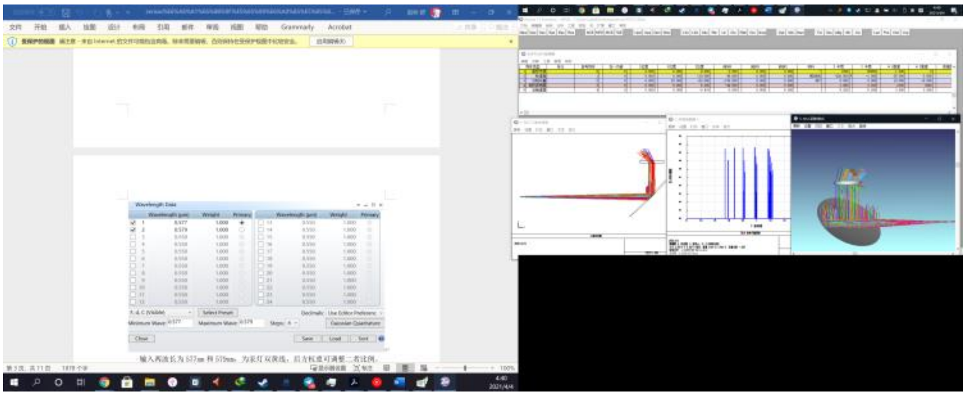


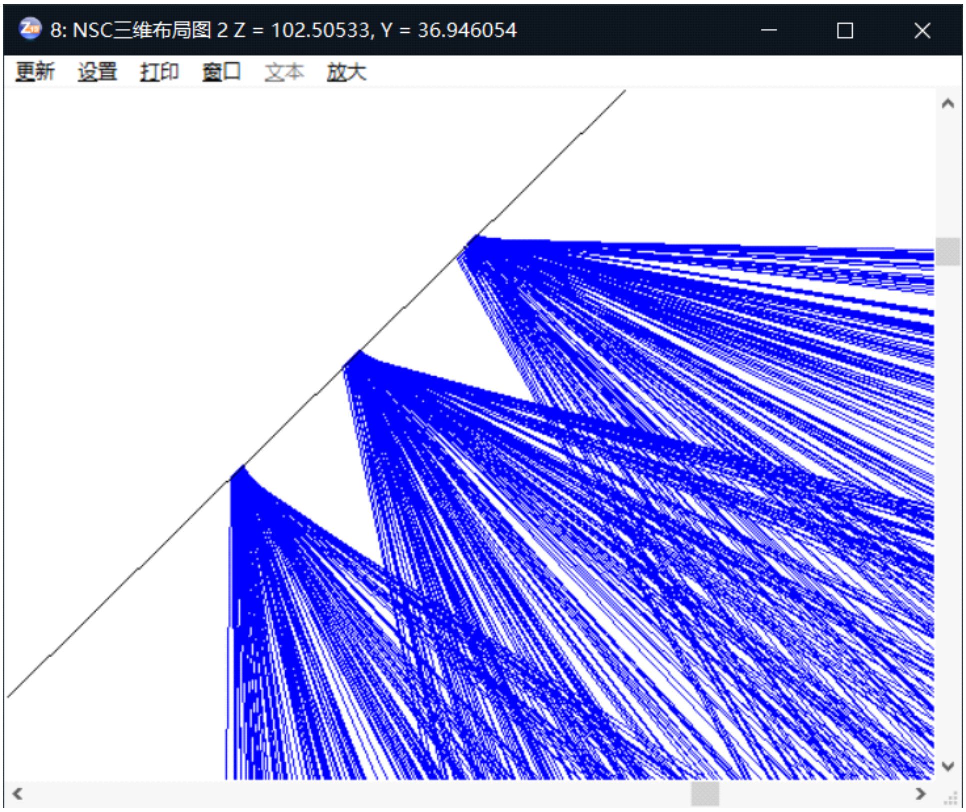


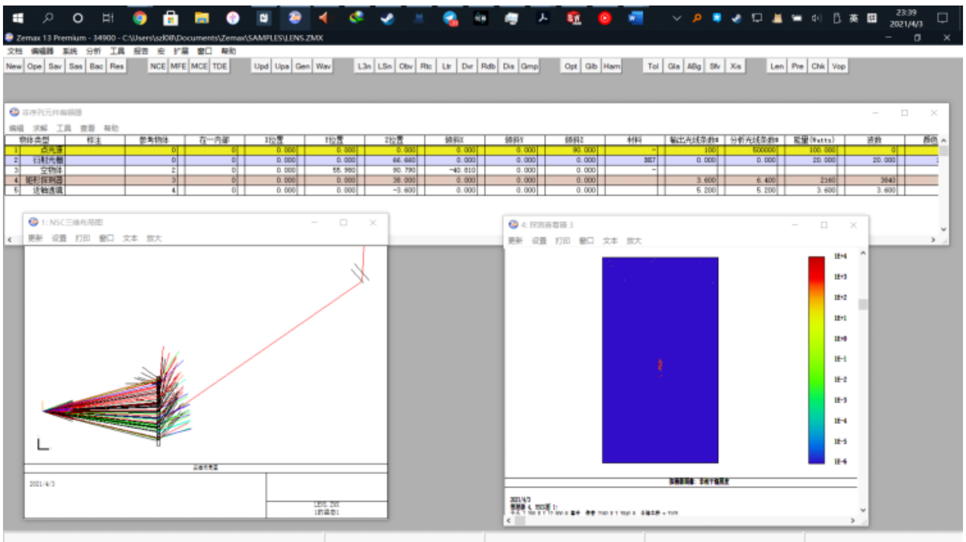

1: NSC三维布局图 Z = 106.26049, Y = 34.893388
更新 设置 打印 窗口 文本 放大

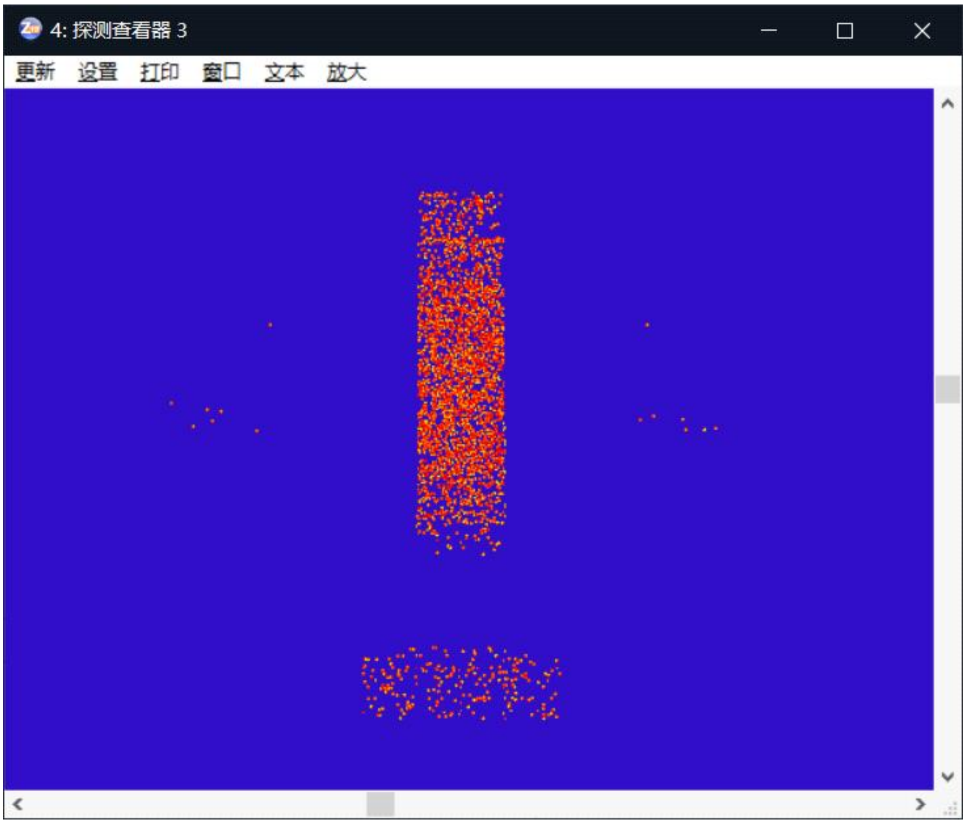

7: 探测查看器 5
更新 设置 打印 窗口 文本 放大
Y 坐标值
2021/4/4
探测器 4, NSC面 1: 列中心, X = 0.0000E+000
大小 3.600 W X 6.400 H 毫米, 像素 2160 W X 3840 H, 总撞击数 = 4407
峰辐照度 : 2.2395E+003 Watts/cm 2
总功率: 3.5148E-002 Watts
TEST3.ZMX
1的组态1





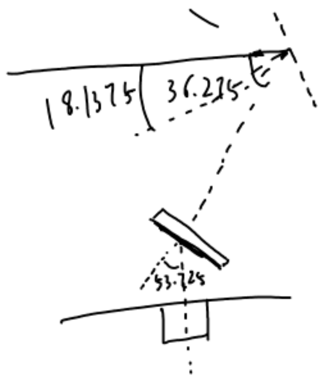

8: NSC三维布局图 2 Z = 102.50533, Y = 36.946054
更新 设置 打印 窗口 文本 放大

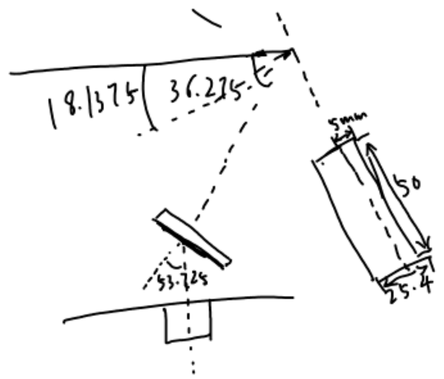



4: 探测查看器 3
更新 设置 打印 窗口 文本 放大

Design Draft 4

2021年4月15日 22:13





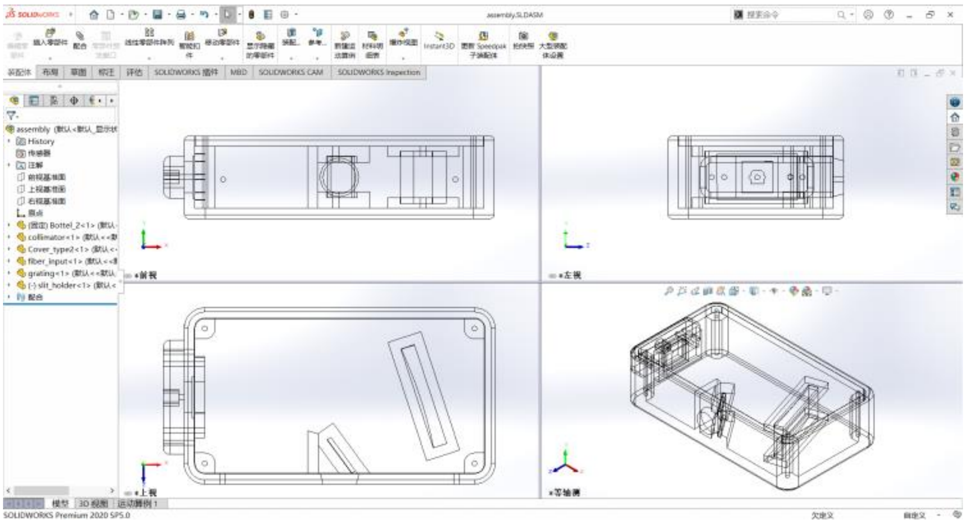
$$\lambda = c + \alpha \sin\left(\frac{(x - c_p)\cdot p_w}{F} - \theta\right)$$

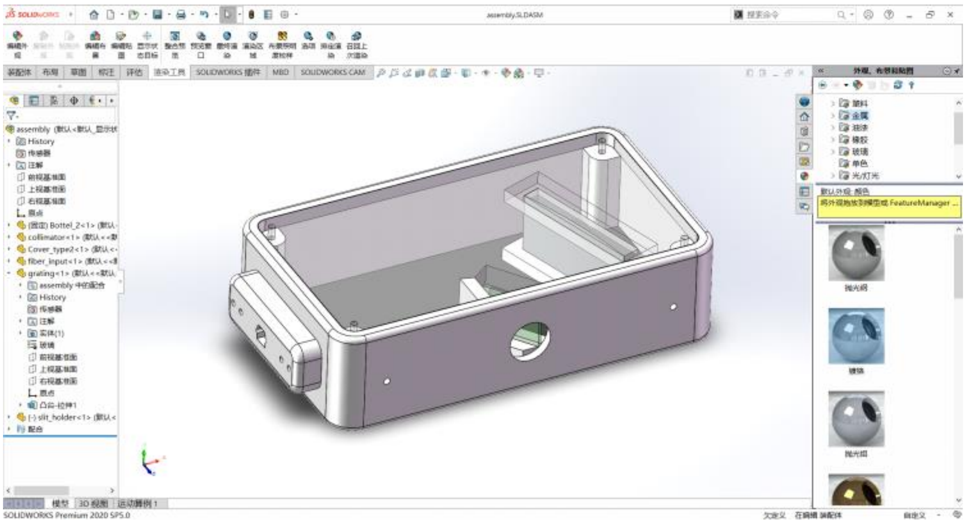
$$\underline{\arcsin\left(\frac{\lambda}{\alpha}\right)} = \frac{(x - c_p)p_w}{F} - \theta$$

$$\frac{(\downarrow + \theta)\cdot F}{p_w} + c_p = x.$$

3D Modeling 2

2021年4月17日　　22:17

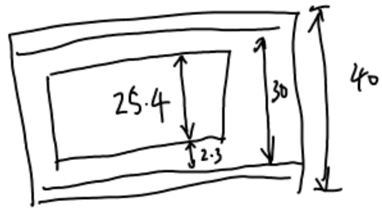


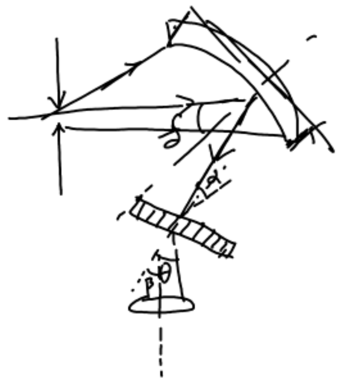


$$W_{slit} = \frac{G \cdot \Delta\lambda L_C}{\cos(\alpha)}$$

$$\frac{\cos(\alpha)}{M\cos\beta} L_F = L_C$$

$$\cos\alpha = \frac{L_C}{L_F}\cos\beta \cdot M$$





$$d\cdot(\sin\alpha + \sin\theta) = k\lambda$$

$$\frac{dx}{d\beta} = \underline{\text{focal length}}$$

$$x = \int \frac{dx}{d\beta}\, d\beta = \int_0^\beta F\, d\beta = \beta \cdot F$$

$$\frac{d\cdot(\sin\alpha + \sin\theta)}{k} = \lambda$$

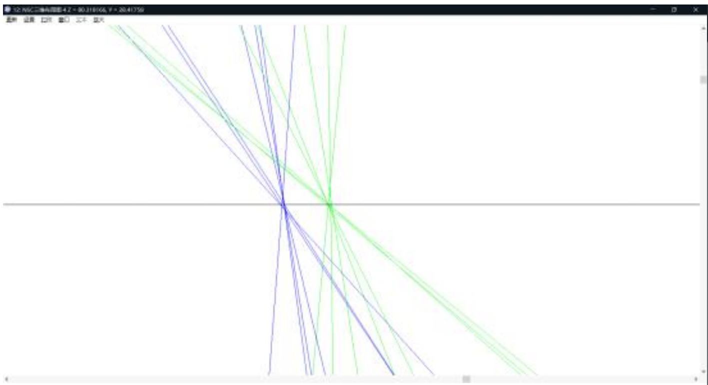
$$\Delta x = \beta \cdot F_{L_2} \qquad \frac{\Delta x}{F} - \varphi$$

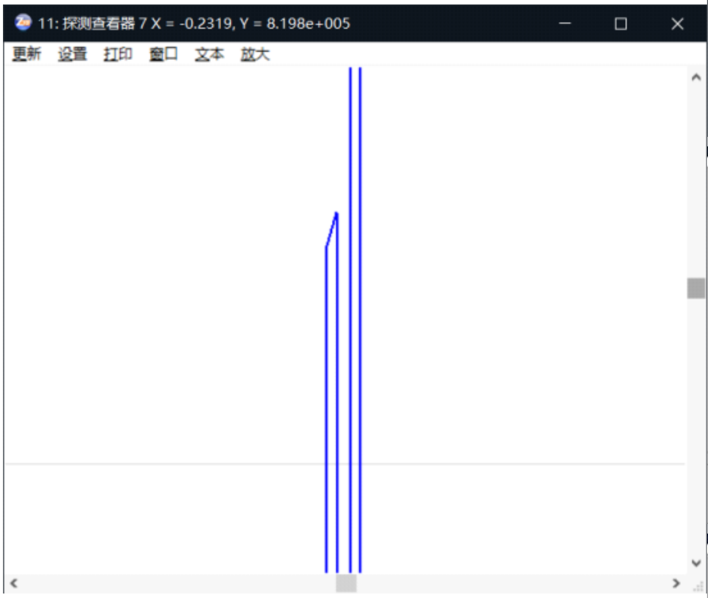
$$\beta = \theta + \varphi$$

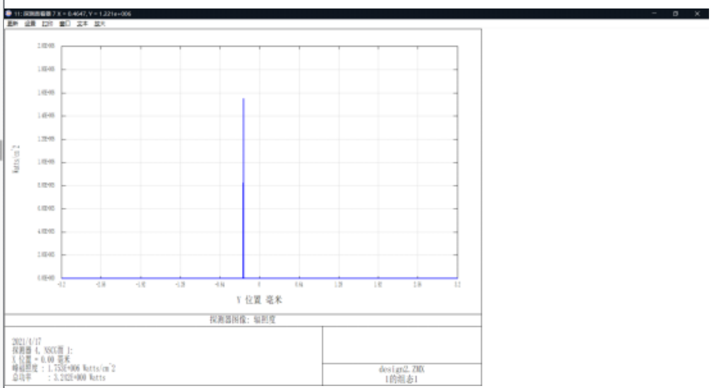
$$\lambda = \frac{d\left[\sin\alpha + \sin\left(\frac{\Delta x}{F} - \varphi\right)\right]}{k}$$

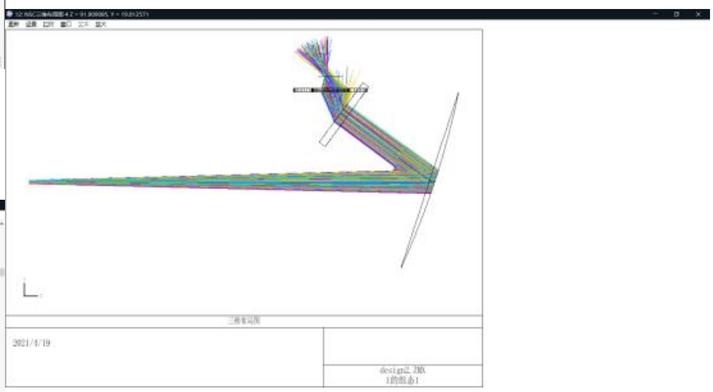
Zemax Simulation Result 2

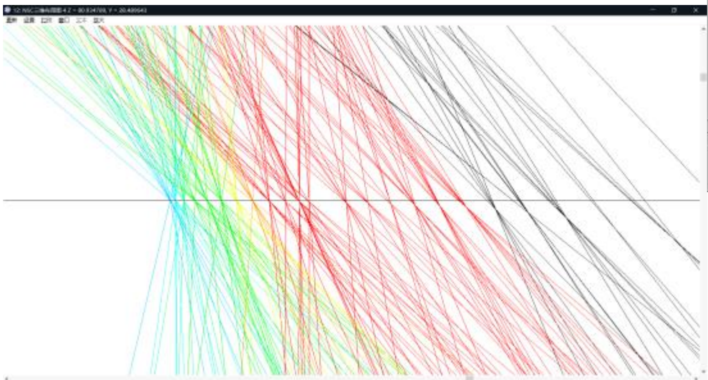
2021年4月19日 22:18

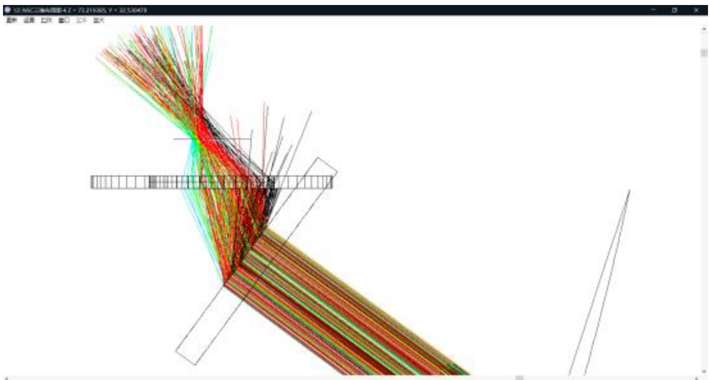


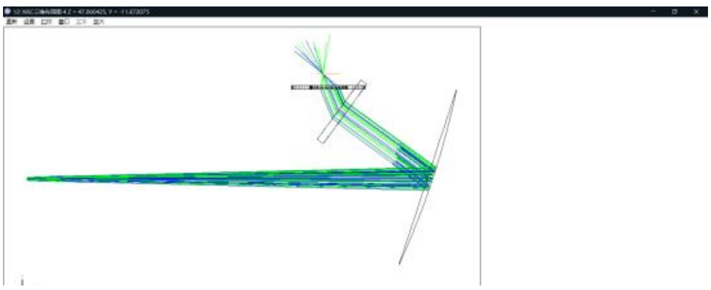


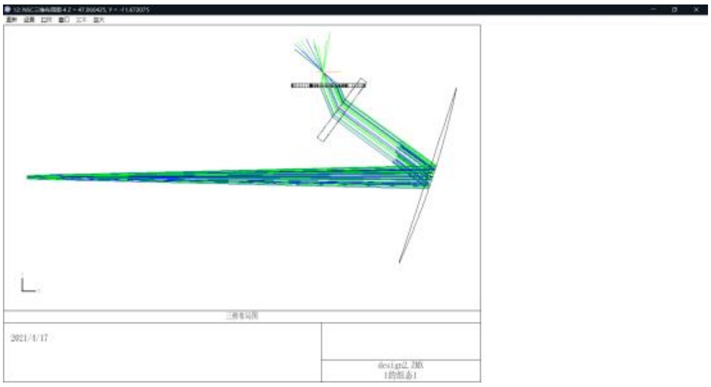











2021/4/17
design2.ZMX
1的组态1

3D Printing 2

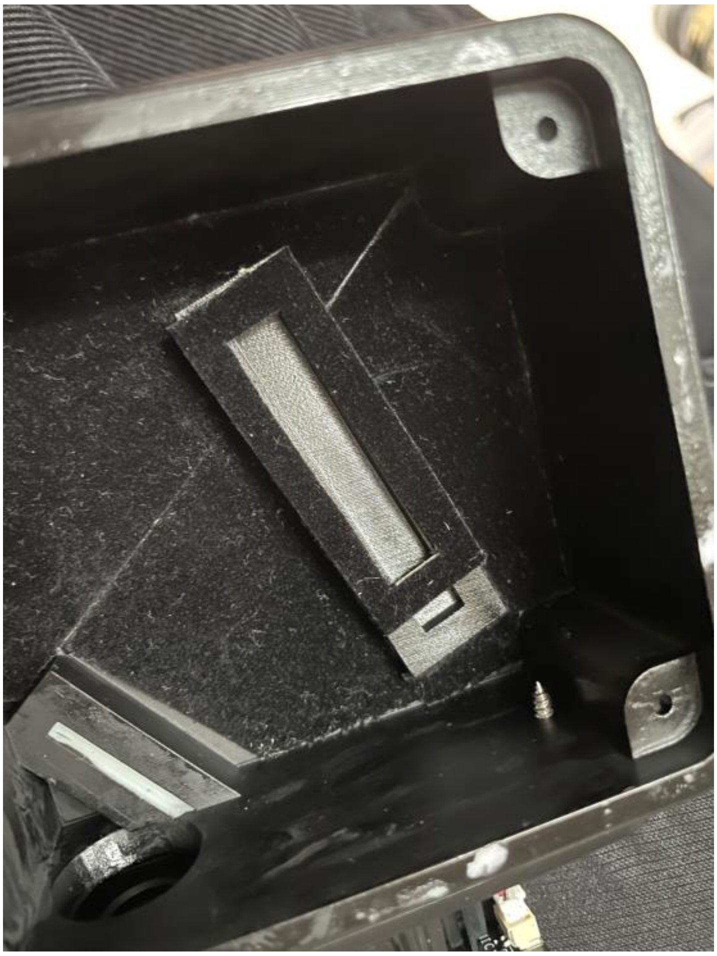
2021年4月20日 22:26

Assembling

2021年4月20日 22:29

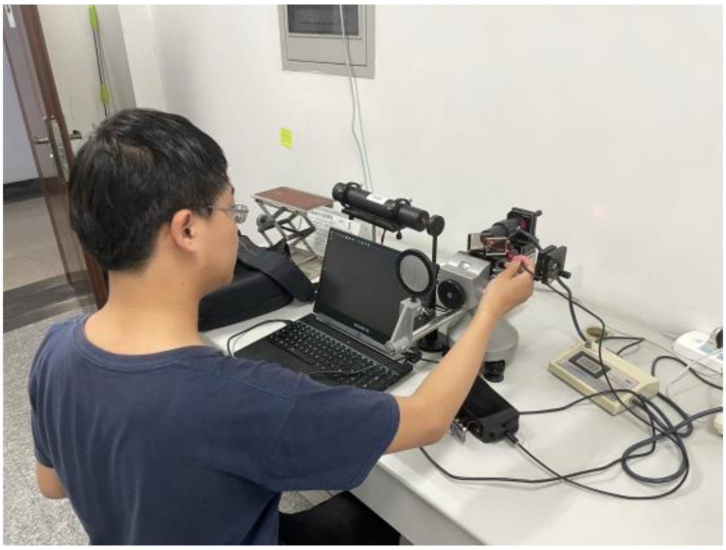


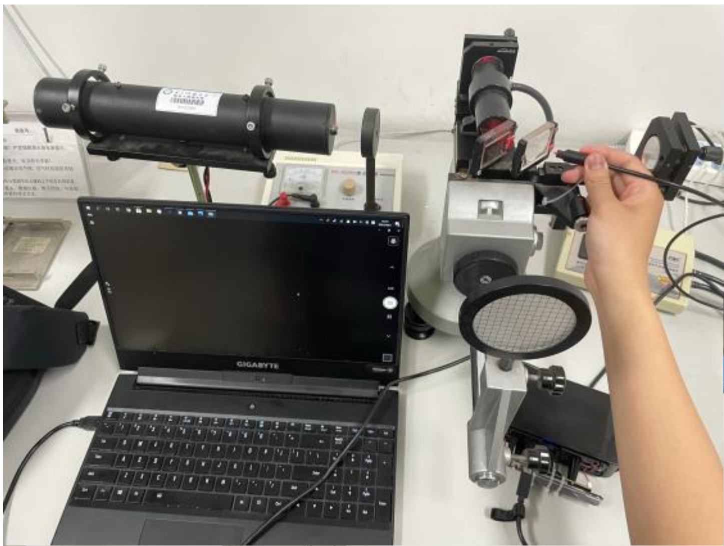
伊利

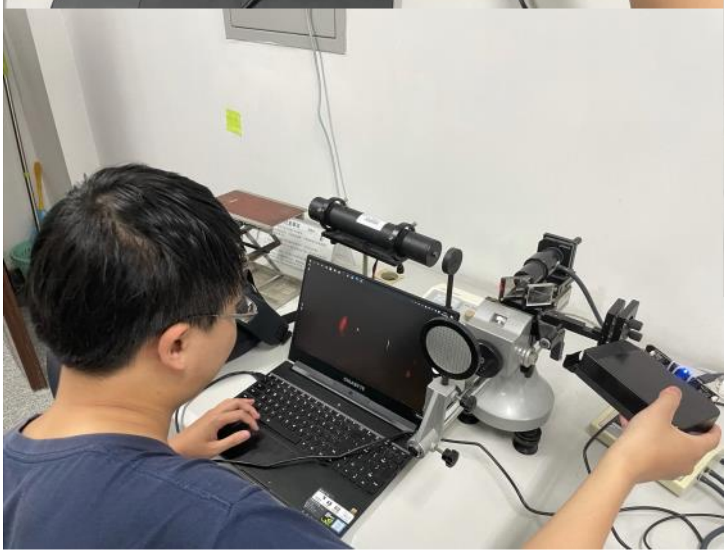


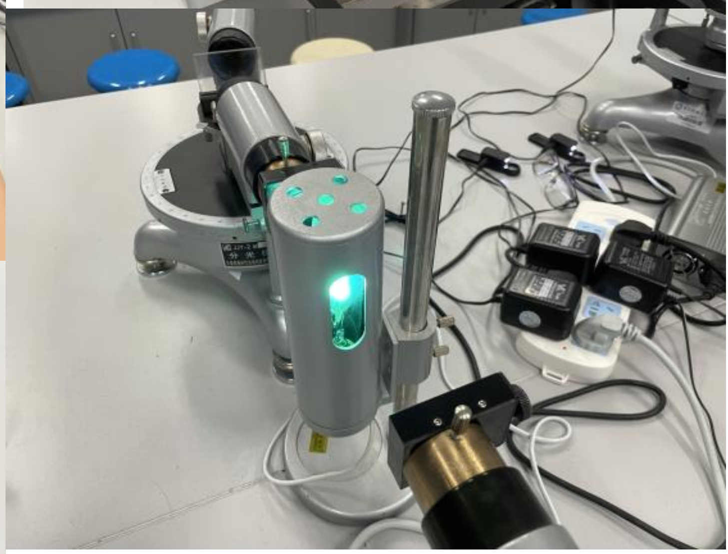
Data capturing

2021年4月22日 22:31



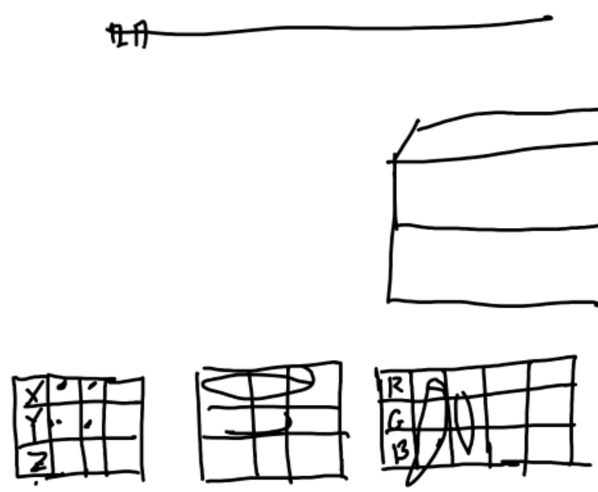






Design Draft 6

2021年4月22日 22:32



$$\lambda = d * \left[\sin\alpha + \sin\left(\frac{|PP-1920| \times \frac{6.4}{3840}}{F} - \varphi\right)\right]$$

$d \approx 1000$

$\alpha \approx 0$

$F \approx 3.6$

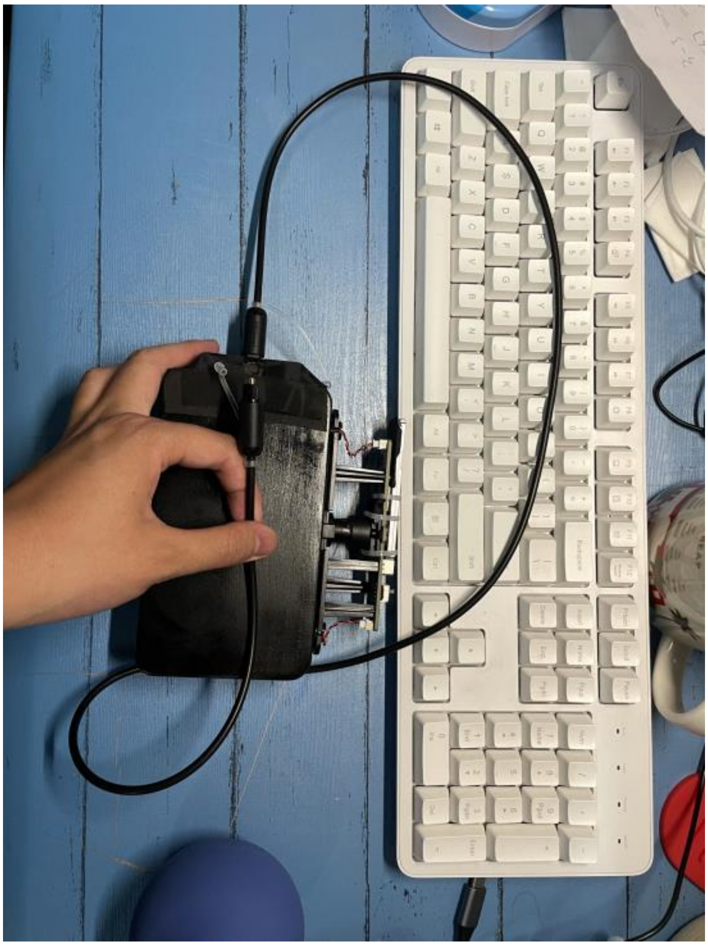
$\varphi \approx 0.9376$

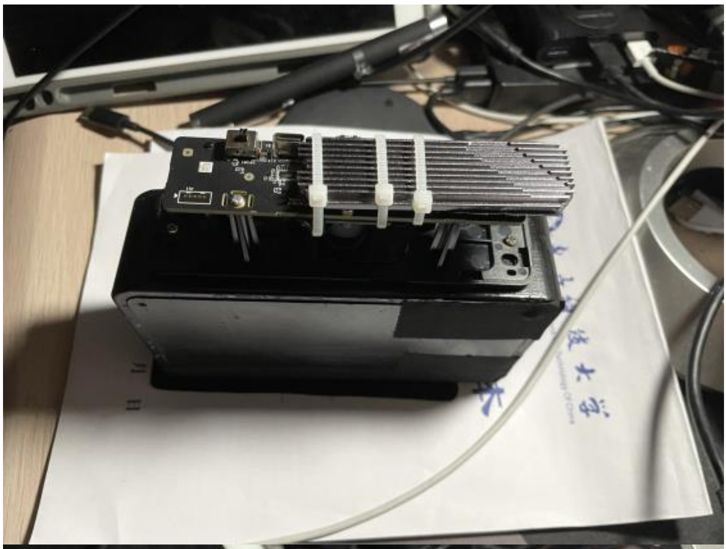
未知

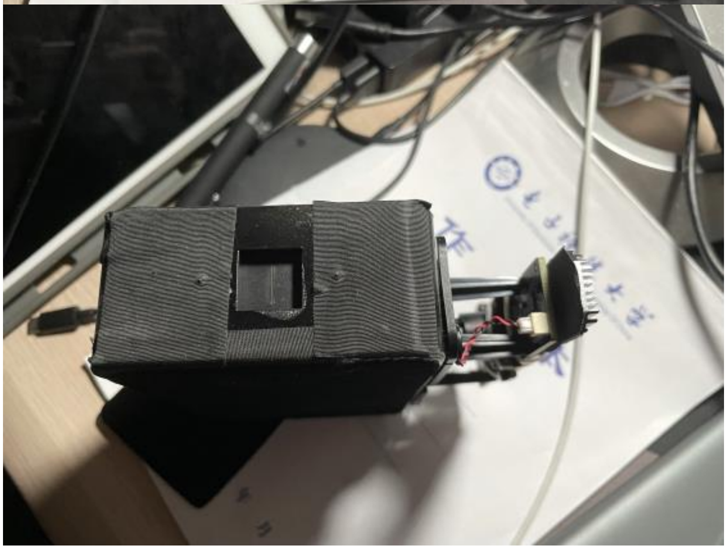
λ	PP
532	827
632.8	1179
650	1289
808	1919

Finished Product

2021年4月23日 22:32







Code

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```matlab
%this code is for estimation algorithm for linear callibration
L=[532 632.8 808 532];
b=L/1000;
PP=[827 1179 1919 827];
k=abs(PP-1920)*6.4/3840;
a=0:0.1:3;
a=a*pi/180;
q=zeros(3,31);
for i=1:3
   for j=1:31
      q(i,j)=(k(i)*asin(b(i+1)-sin(a(j)))-k(i+1)*(asin(b(i)-sin(a(j)))))/(asin(b(i+1)-sin(a(j)))-
asin(b(i)-sin(a(j))));
   end
end
Variance=zeros(1,31);
for j=1:31
   Variance(j)=var(q(:,j));
end
[min_value,min_position]=min(Variance);
q_estimation=q(:,min_position);
q_mean=sum(q_estimation)/3;
F=zeros(1,3);
for i=1:3
    F(i)=(q_mean-k(i))/asin(b(i)-sin(a(min_position)));
end
F_mean=mean(F);
phi=q_mean/F_mean;

   %% caculating effective indeicent angle
   d = 1000;
   theta_1 = 0:0.001:pi / 2;
   lambda_1 = 300;
   lambda_2 = 1000;
   lambda_3 = 635;
   theta_2 = asin(sin(theta_1) - (lambda_1) / d);
   theta_3 = asin(sin(theta_1) - (lambda_2) / d);
   theta_4 = theta_2 - theta_3;
   figure(1);
   plot(theta_1, theta_4, 'LineWidth', 2);
   xlabel("Incident Angle (rad)");
   ylabel("Diffraction Angle Difference (rad)")

      % verification of linear callibration
      C = 0;
      d = 1e-6;
      center = 1920;
      pixel_w = 6.4/3840;
      focal_l = 3.6;
      angle_1 = 53.725/180 * pi;
      x = 0:3839;
      angle_2 = (x - center) * pixel_w / focal_l + angle_1;
      lambda = C + d * sin((x - center) * pixel_w / focal_l + angle_1);
      plot(x, lambda);
```

```python
import cv2
import numpy as np
from matplotlib import pyplot as plt


def linear(u):
    if u < 0.04045:
        gamma = 25 * u / 323
    else:
        gamma = pow(((200 * u + 11) / 211), (12 / 5))
    return gamma


cap = cv2.VideoCapture(2)
while (1):
    # get a frame
    ret, frame = cap.read()
    # show a frame
    cv2.imshow("capture", frame)
    if cv2.waitKey(1) & 0xFF == ord('q'):
        break
cap.release()
img = frame
col, row, a = img.shape
col2 = col // 2
img2 = img.astype(float)[col2, :, :]
for x in range(row):
    for y in range(a):
        img2[x, y] = linear(img2[x, y] / 255)
convert_XYZ = np.array([[0.4124, 0.3576, 0.1805], [0.2126, 0.7152, 0.0722
],
                        [0.0193, 0.1192, 0.9505]])
XYZ = np.dot(convert_XYZ, np.fliplr(img2).T)
sensor_w = 6.4
F_L2 = 4.784575119803315
phi = 0.942087992419107
alpha = 0
d = 1000
k = 1
pixel_w = sensor_w / row
x = np.arange(0, row)
x_1 = np.flipud(
    (np.sin((x - (row / 2)) * pixel_w / F_L2 + phi) + np.sin(alpha)) * d
/ k)
print(XYZ)
Y = XYZ[1, :]
B = img[col2, :, 0] / 255
G = img[col2, :, 1] / 255
R = img[col2, :, 2] / 255
""" plt.plot(x_1, B, color='blue', label='blue')
plt.plot(x_1, G, color='green', label='green')
plt.plot(x_1, R, color='red', label='red') """
plt.plot(x_1, Y, color='black', label='luma')
plt.show()
```

```matlab
%calculate linear distance
C = 0;
d = 1e-6;
center = 1920;
pixel_w = 6.4/3840;
focal_l = 3.6;
lambda1 = 300e-9;
lambda2 = 1000e-9;
theta = 0:0.0001:(pi / 2);
x1 = (asin(lambda1 / d) + theta) * focal_l / pixel_w + center;
x2 = (asin(lambda2 / d) + theta) * focal_l / pixel_w + center;
dx = x2 - x1;
plot(theta, dx);
```

Result

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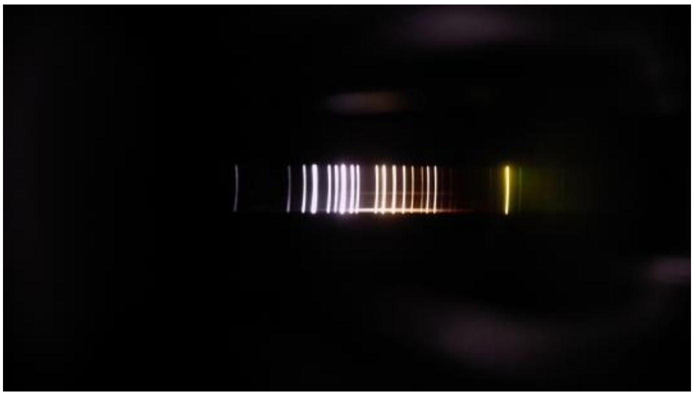
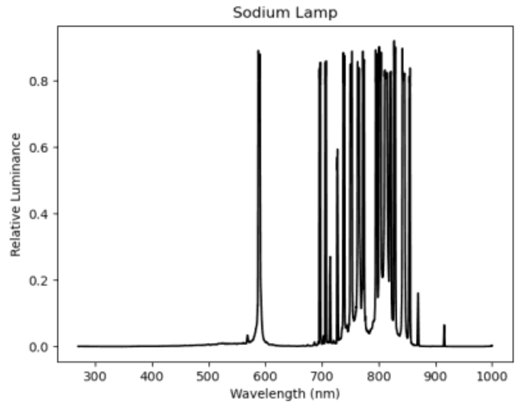
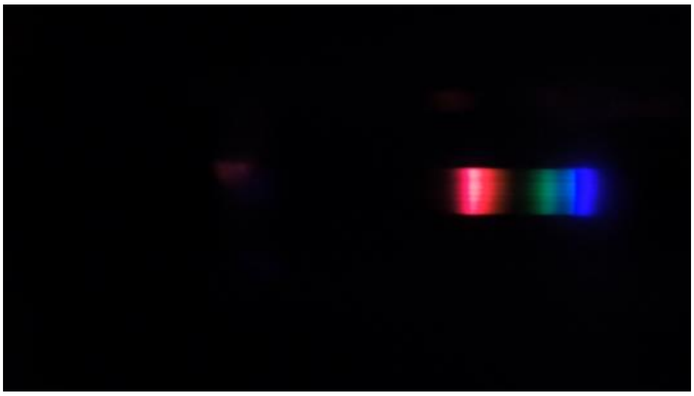
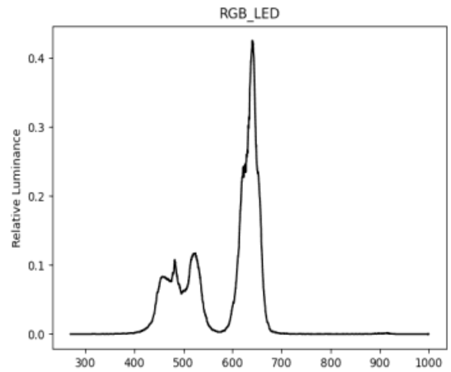
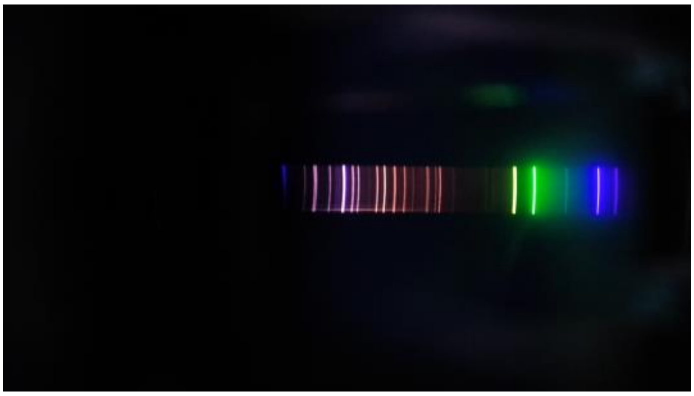
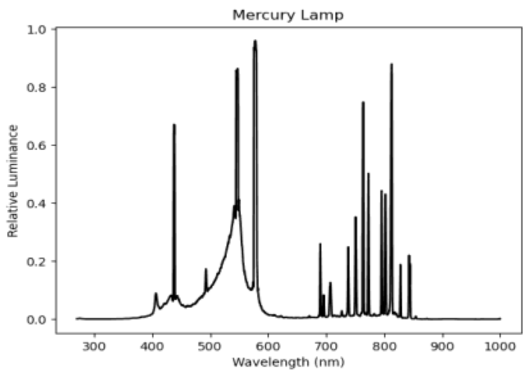


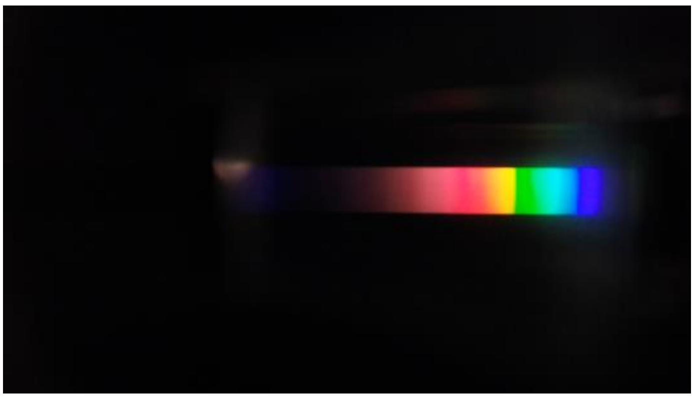


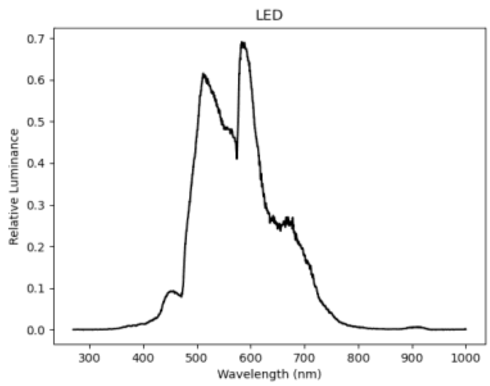


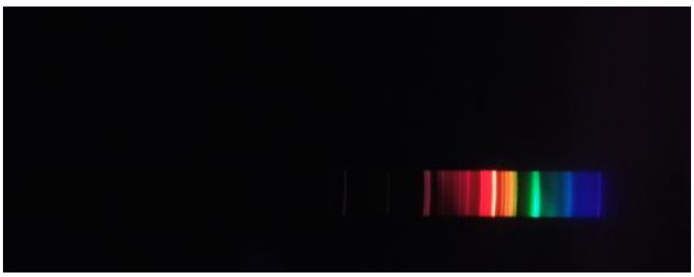


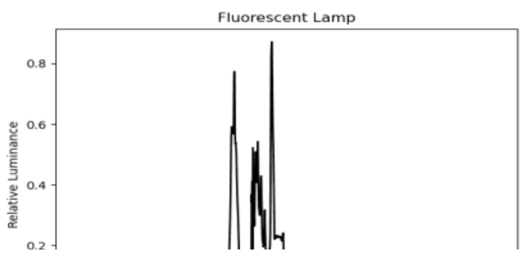


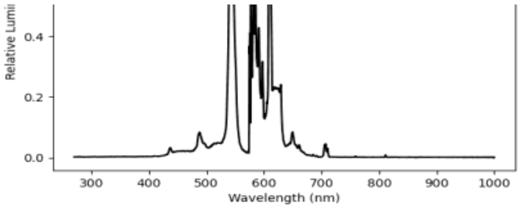


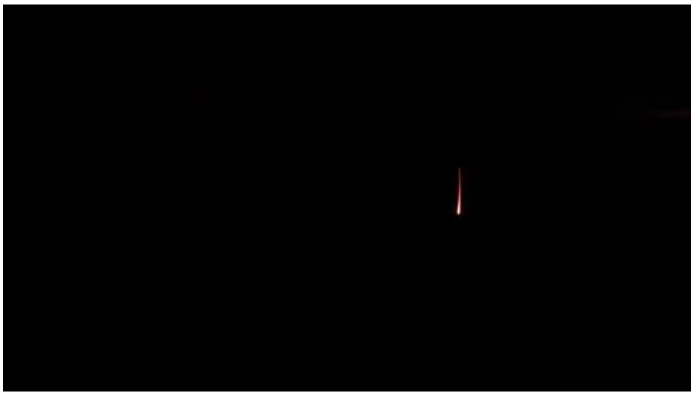


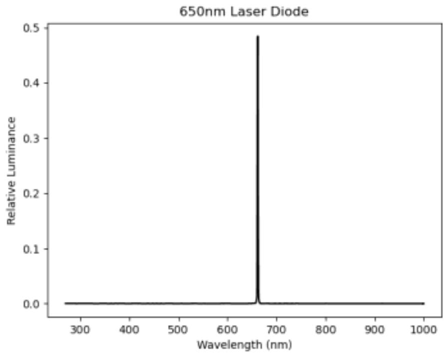


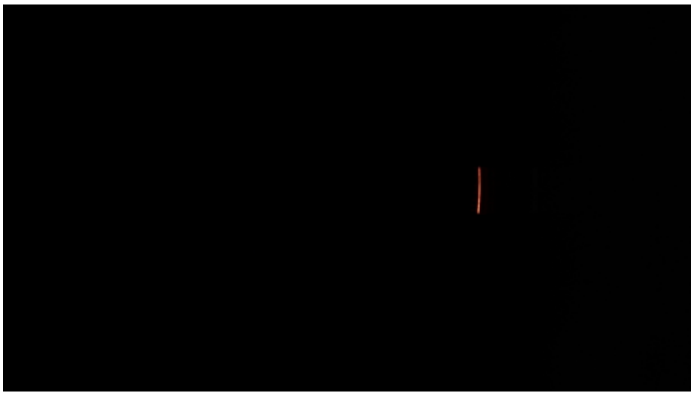


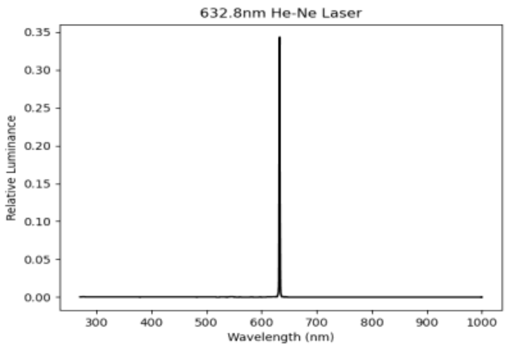


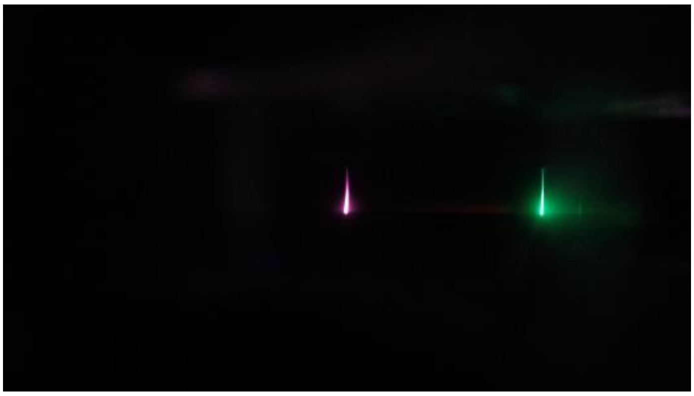

Relative Lumi
Wavelength (nm)

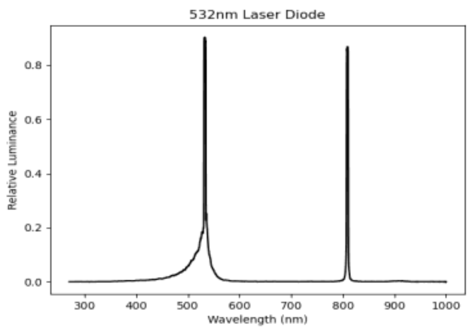


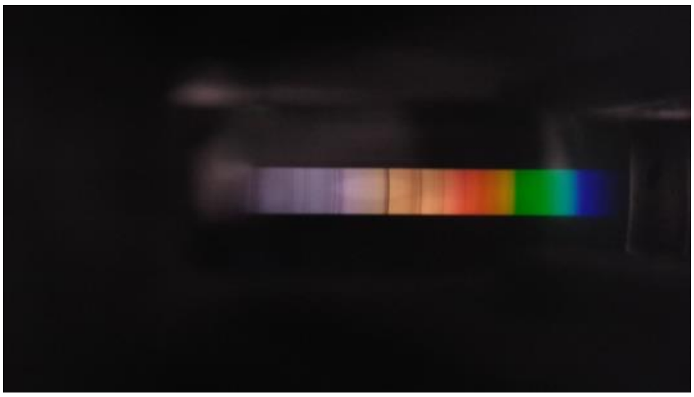

650nm Laser Diode
Relative Luminance
Wavelength (nm)

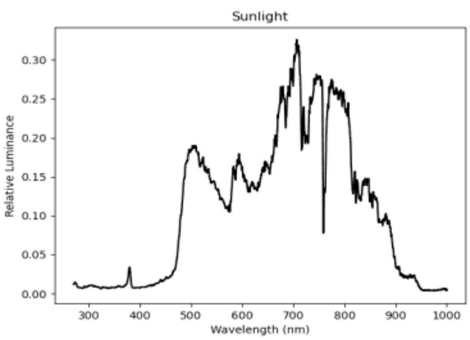



632.8nm He-Ne Laser
Relative Luminance
Wavelength (nm)




532nm Laser Diode
Relative Luminance
Wavelength (nm)




Sunlight
Relative Luminance
Wavelength (nm)