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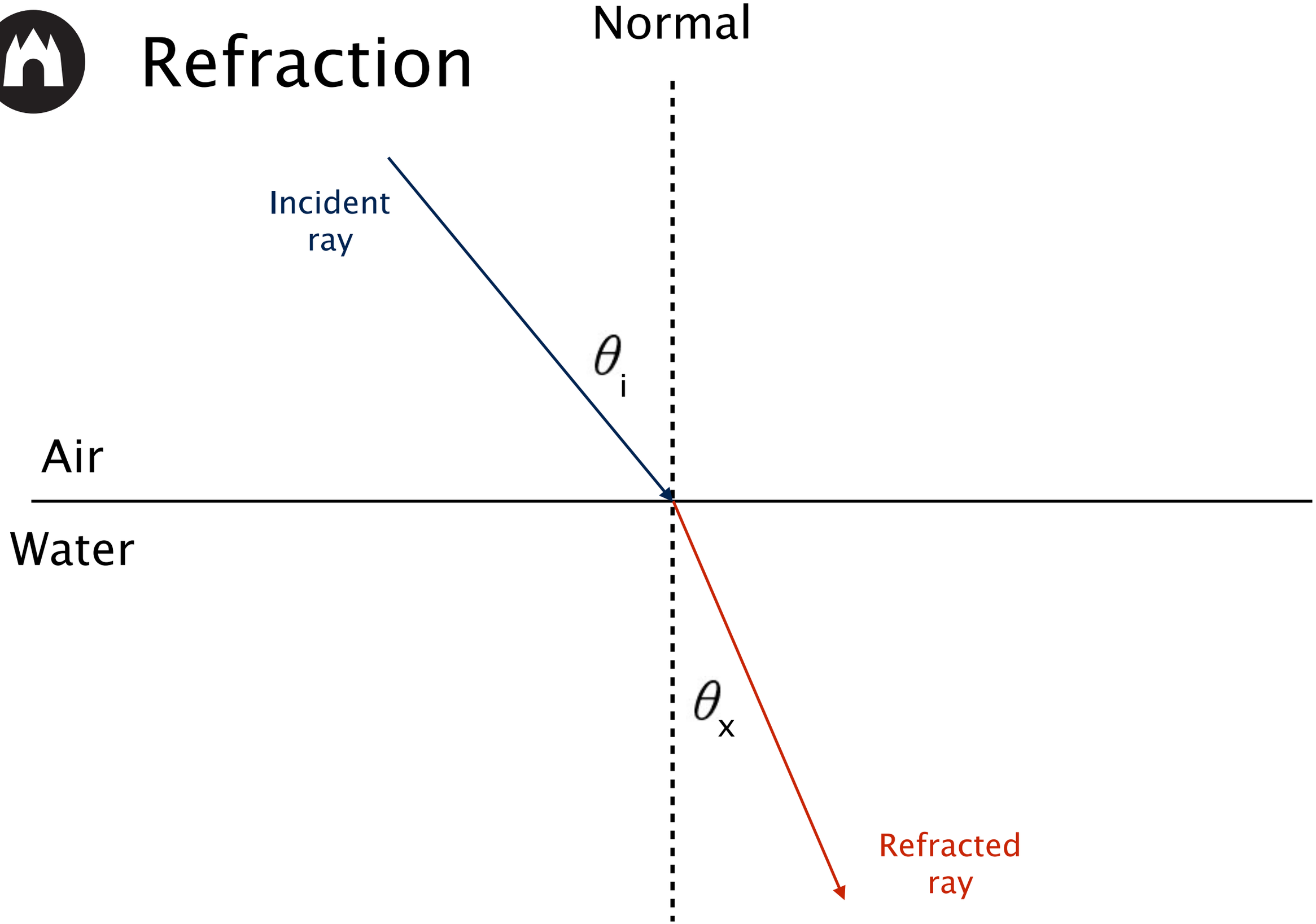
BioHack Academy
Spectrometer Design

Tibicos - kefir

Refraction



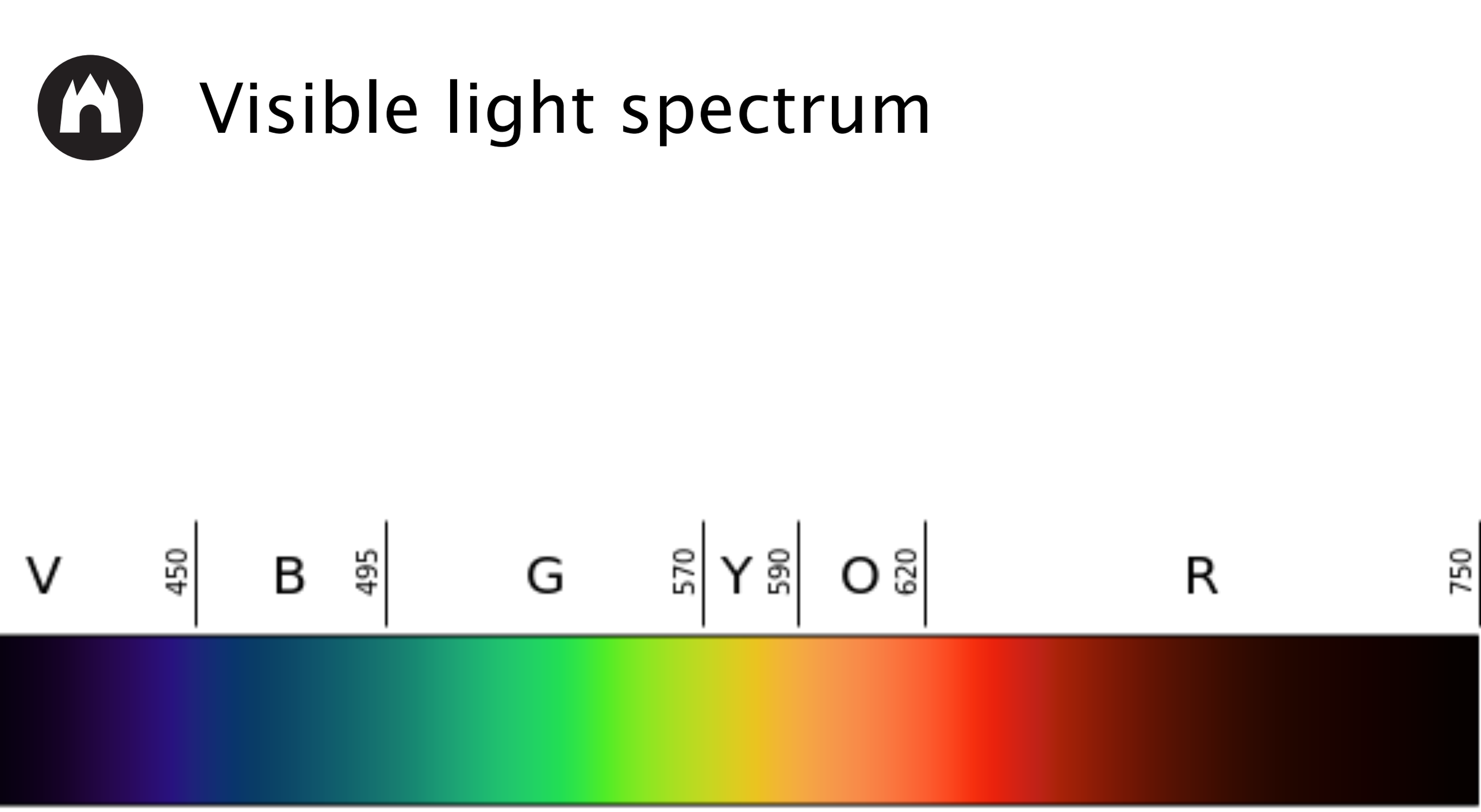
θ_i Angle of incidence

θ_x Angle of refraction

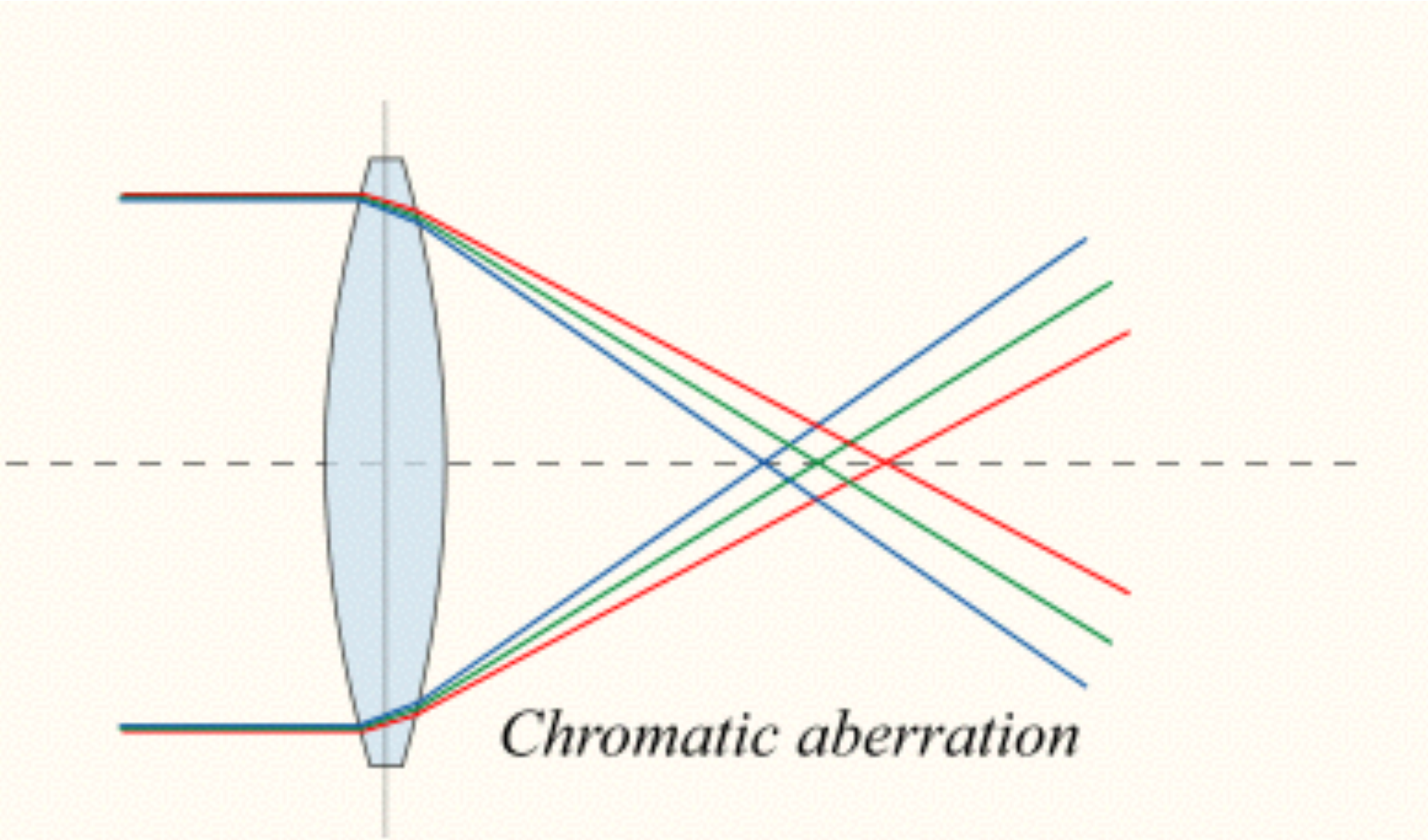
Snell's Law

$$\sin(\theta_i) = n_{material} \times \sin(\theta_x)$$

Visible light spectrum

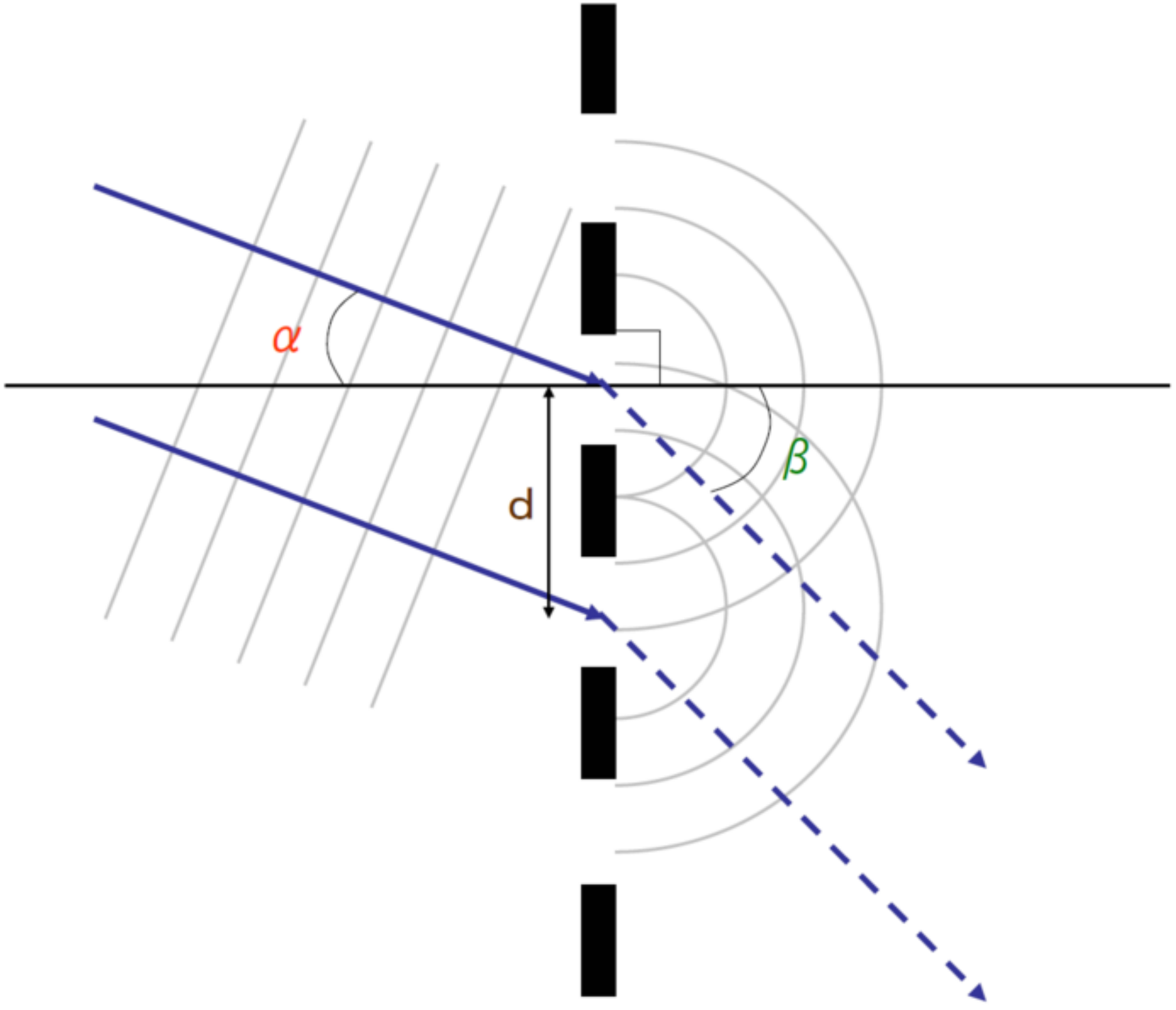


Chromatic aberration

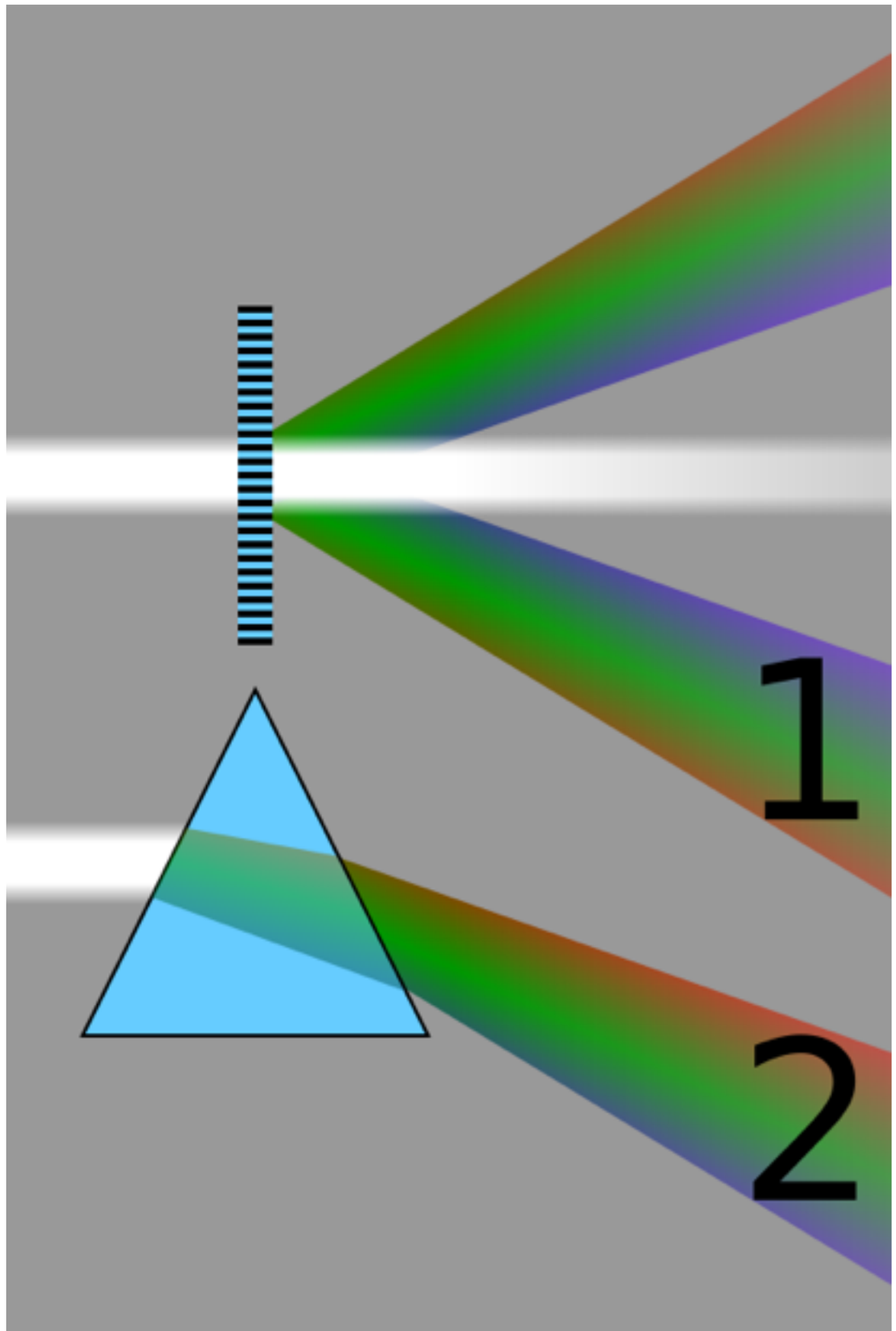


Grating diffraction

Diffraction grating principle



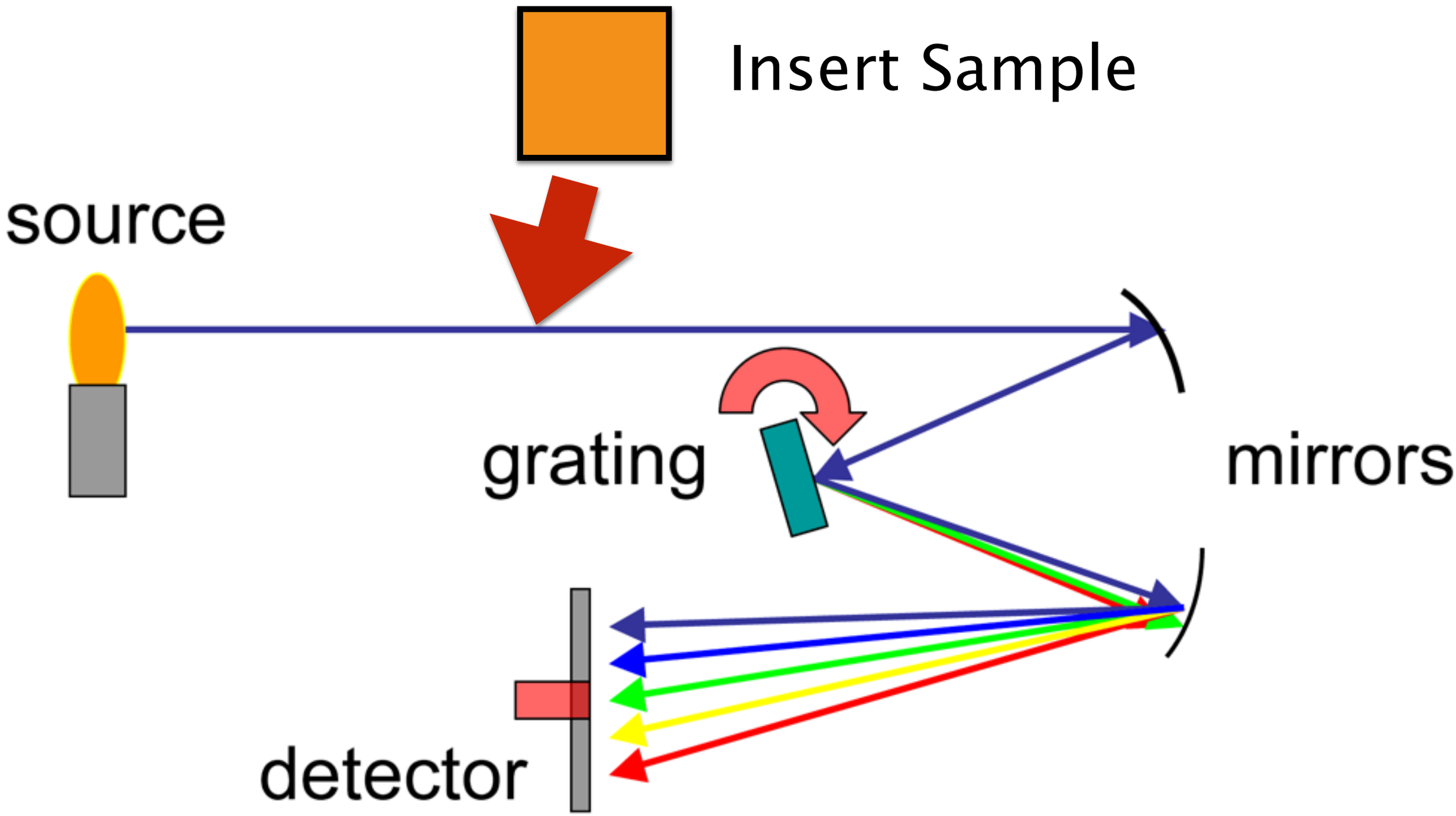
Just like a prism



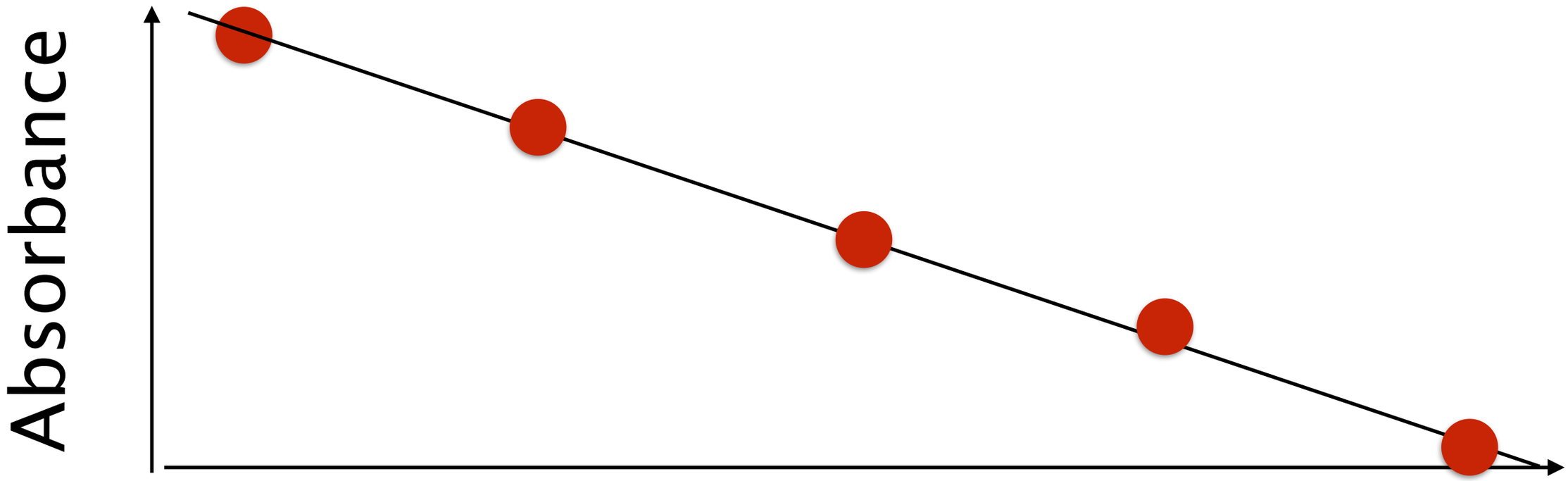
Industry standard

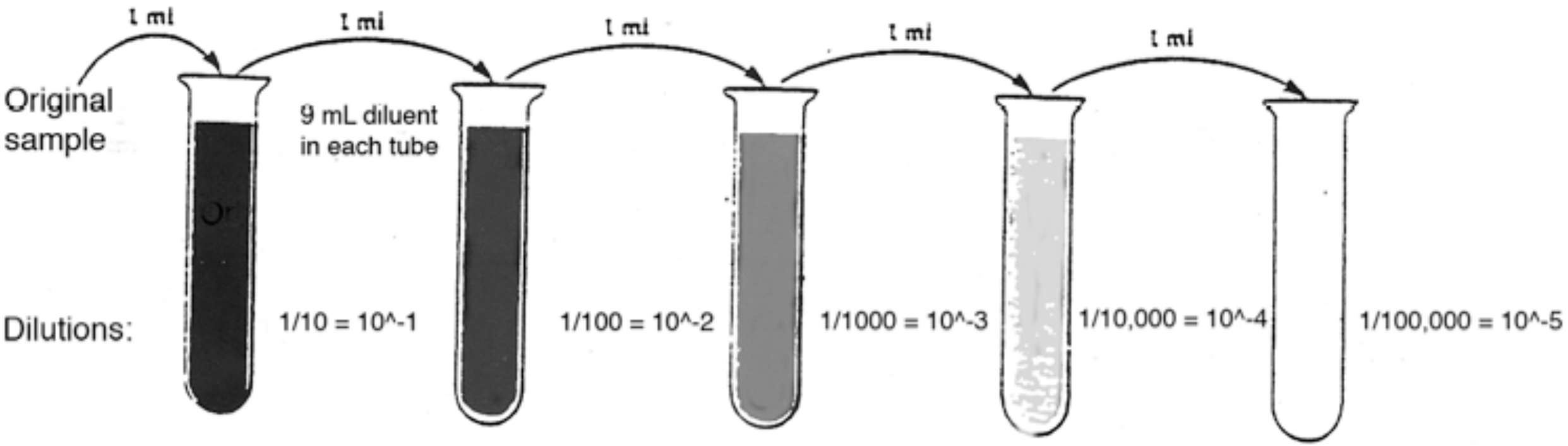
BME Lab & Science

Inside

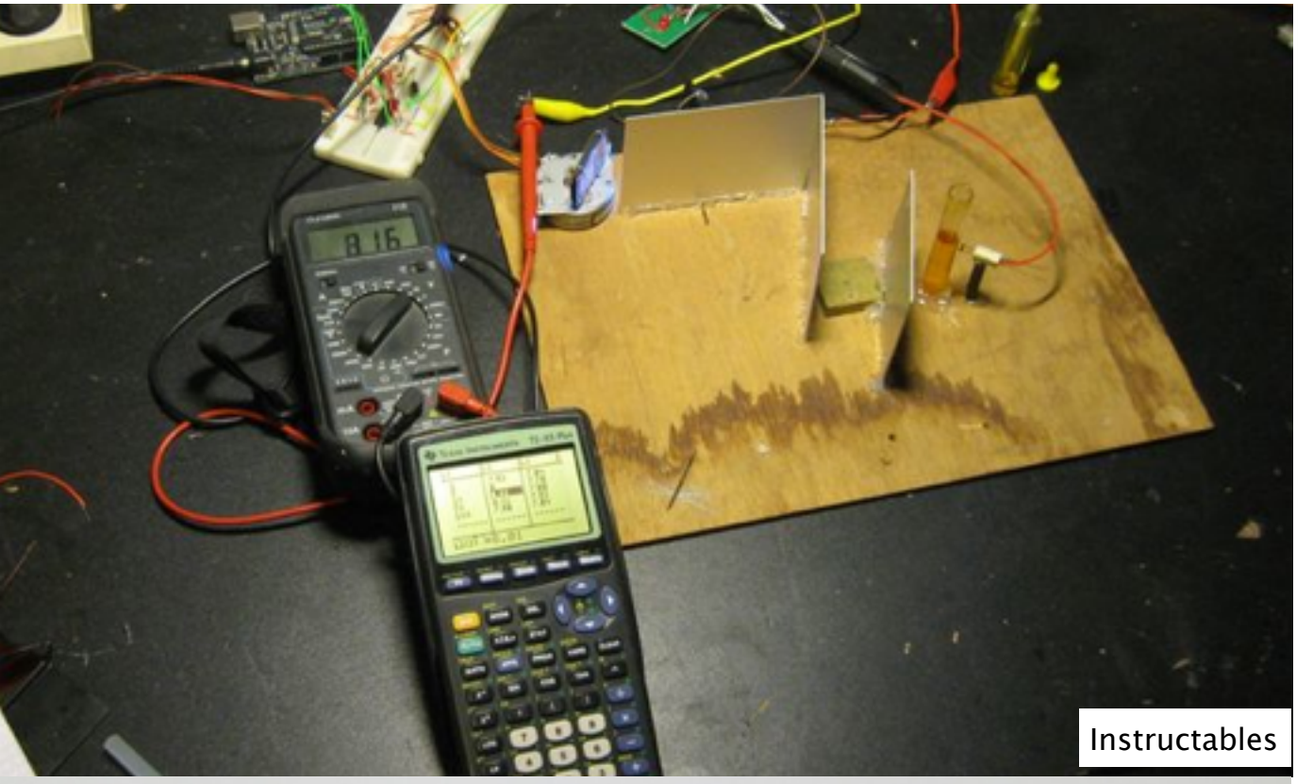


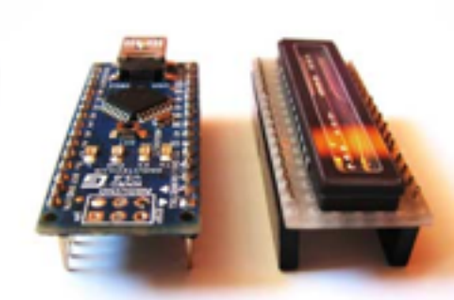
Dilution series

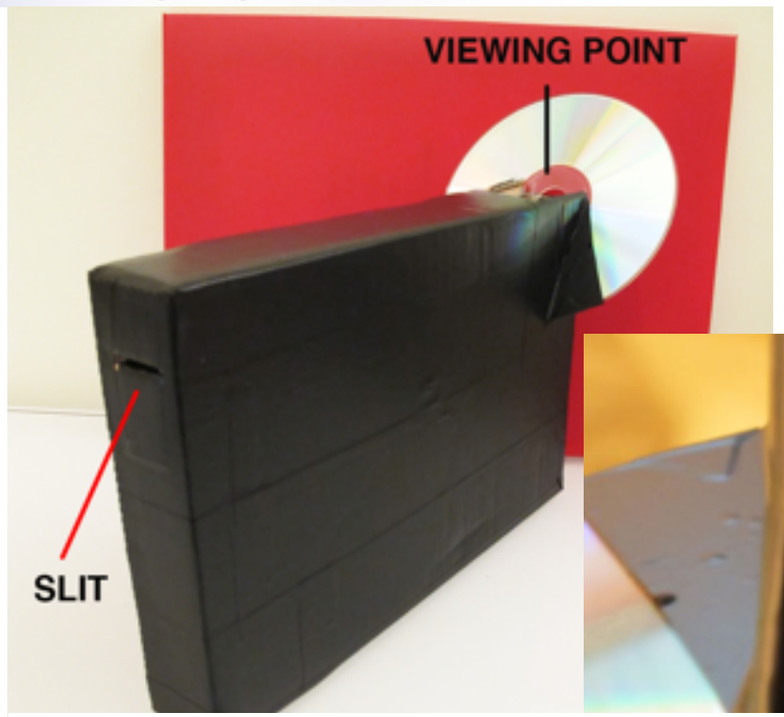




Previous hacks







http://www.cs.cmu.edu/~zhuxj/astro/html/spectrometer.html

Content

- Webcam spectrometer
- CCD Array spectrometer

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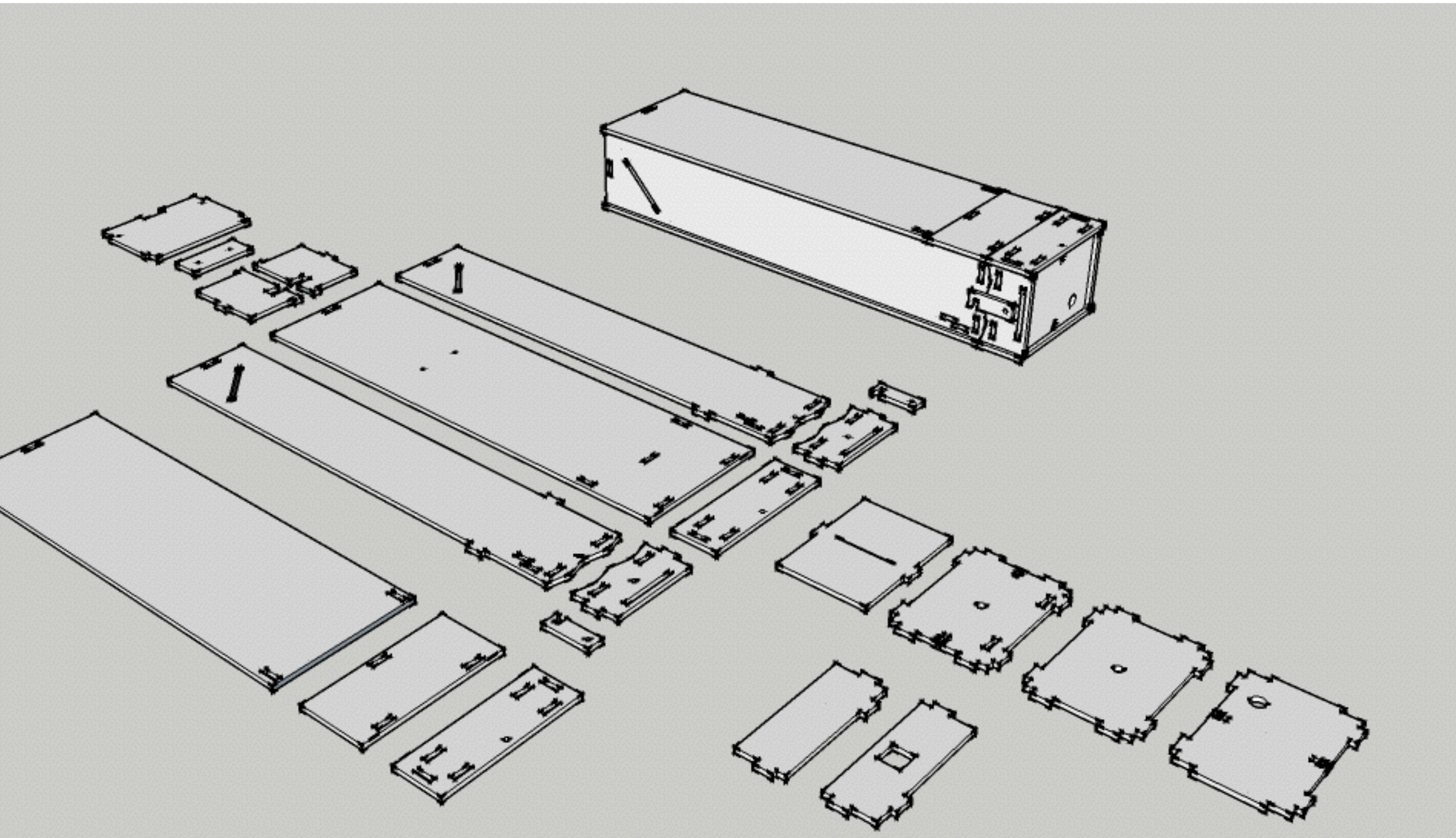
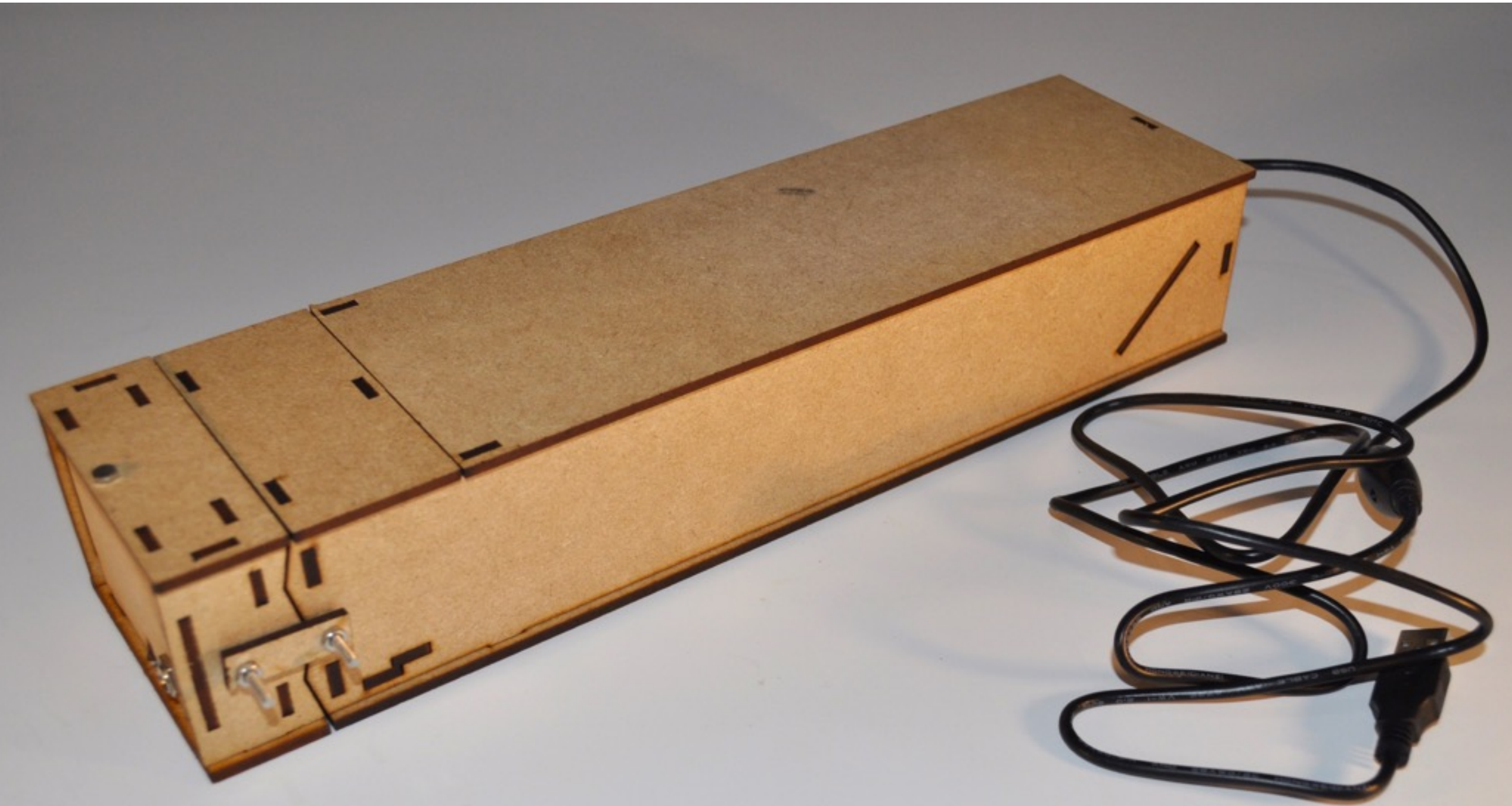
Webcam Spectrometer

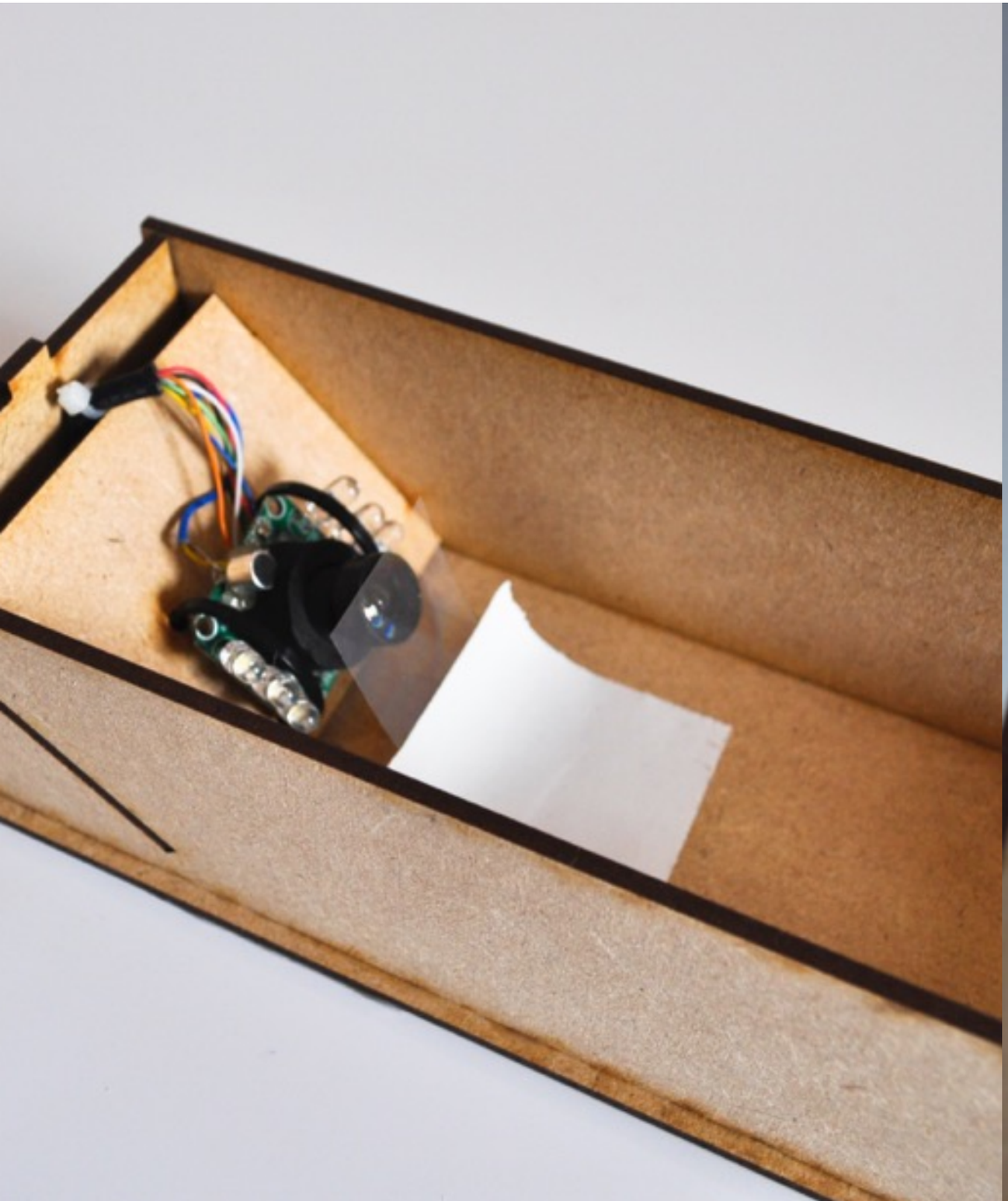
BioHack Academy design

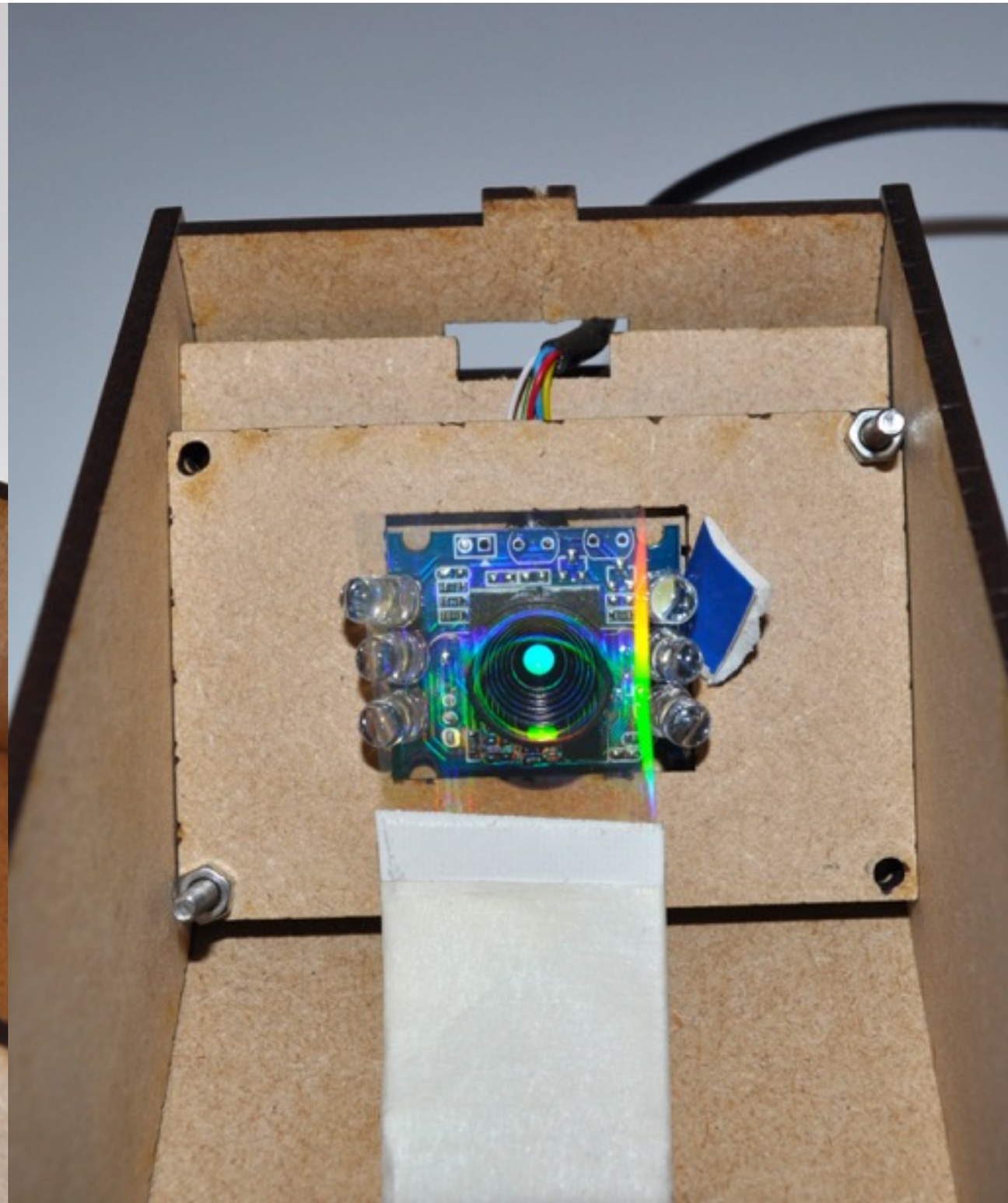


BioHack Academy design



BioHack Academy design



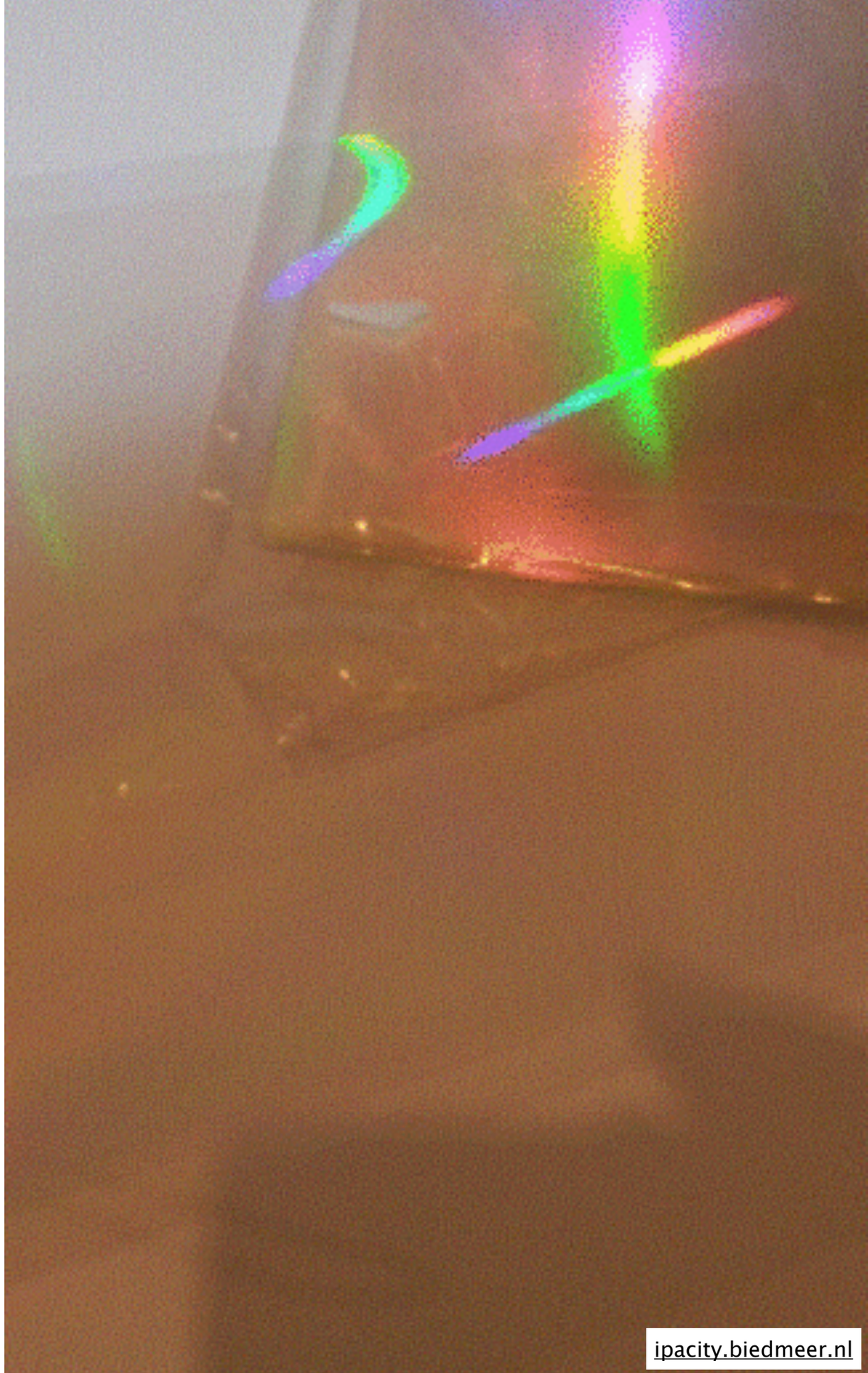


Bill of Materials

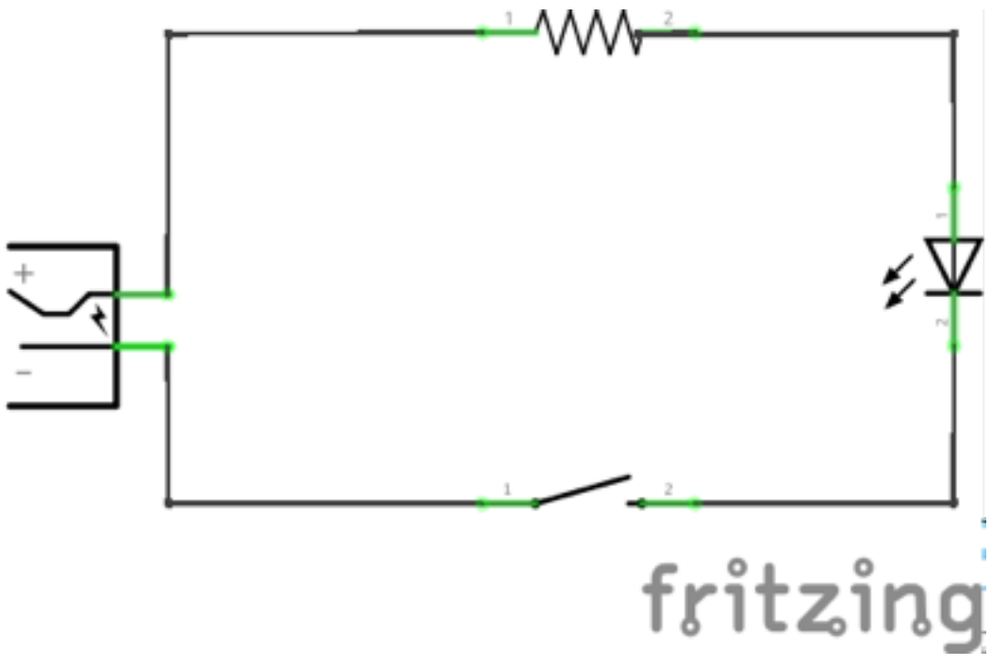
#	Amount	Description
1	1	Webcam
2	1	3mm MDF
3	1	White LED
4	1	220 Ohm resistor
5	1	7.5 W power supply
6	1	Jack Adapter
7	1	4.7 GB DVD-R (track pitch 0.74 microns) or 1,000 lines/mm grating

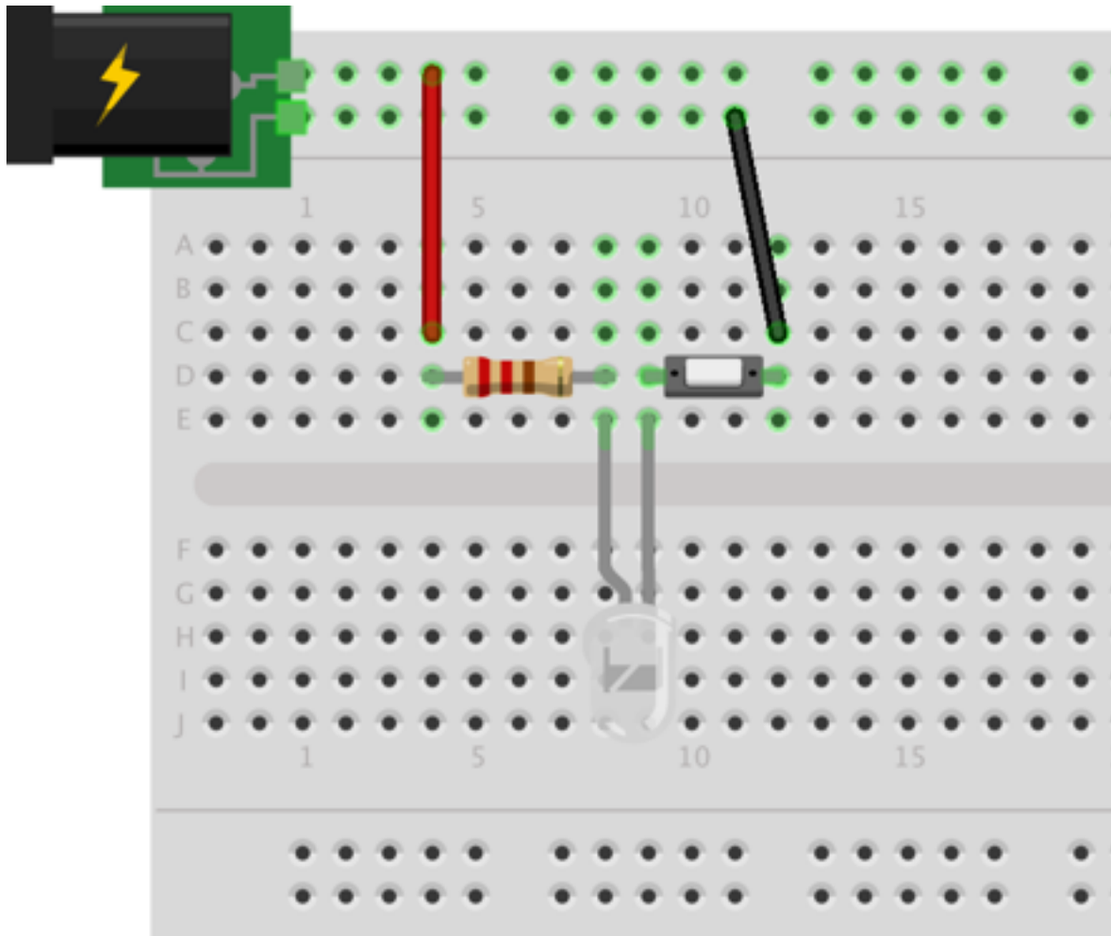
Foil

- Angle 45 degrees
  - Grating foil
    - 1000 lines per mm
  - DVD-R 4.7 GB:
    - Track pitch of 0.74 microns
    - 1351 lines per mm
  - DVD-R 3.95 GB:
    - Track pitch of 0.8 microns
    - 1250 lines per mm
- CD:
  - track pitch 1.6 microns
  - 625 lines per mm



LED Wiring



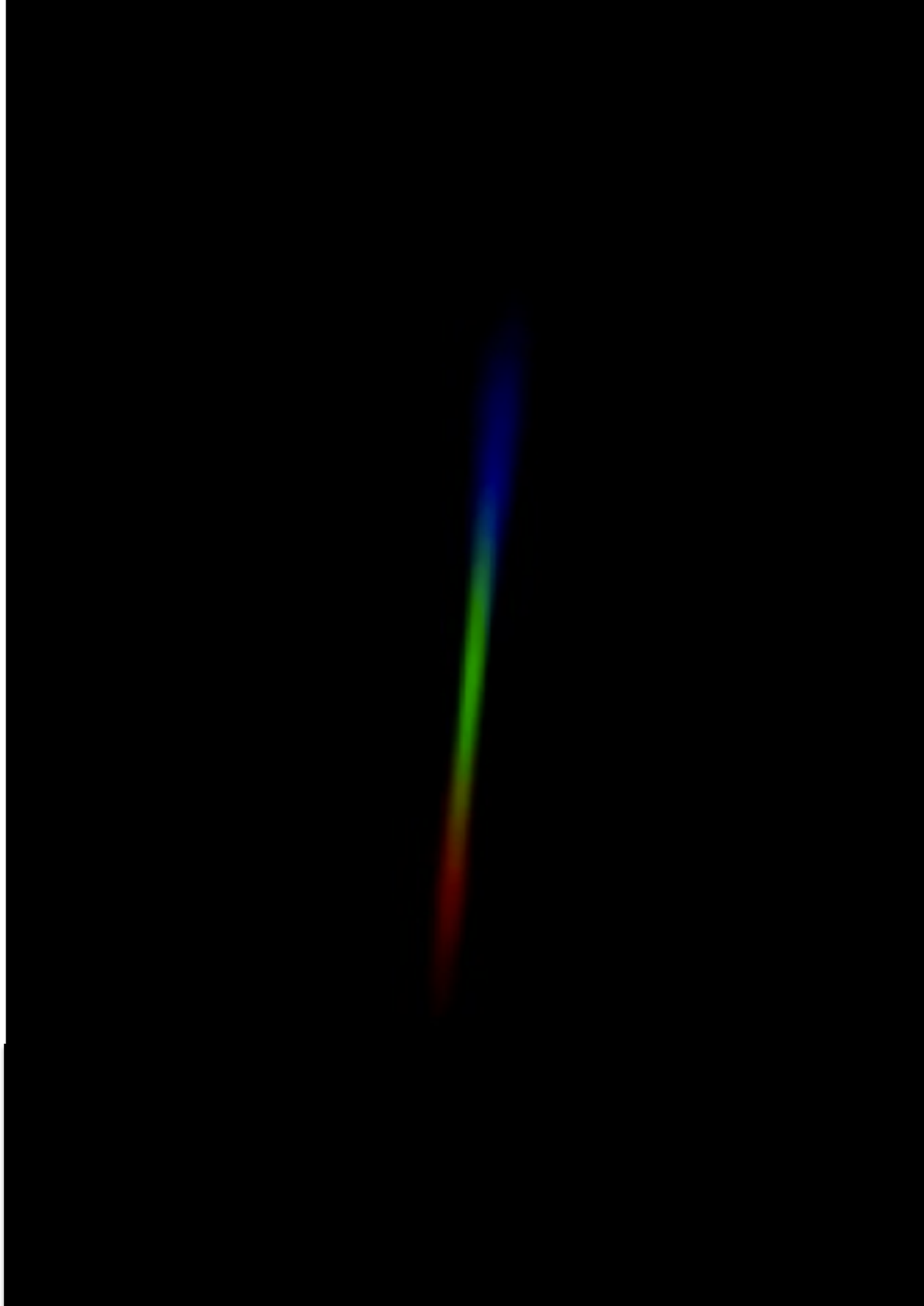


Slit

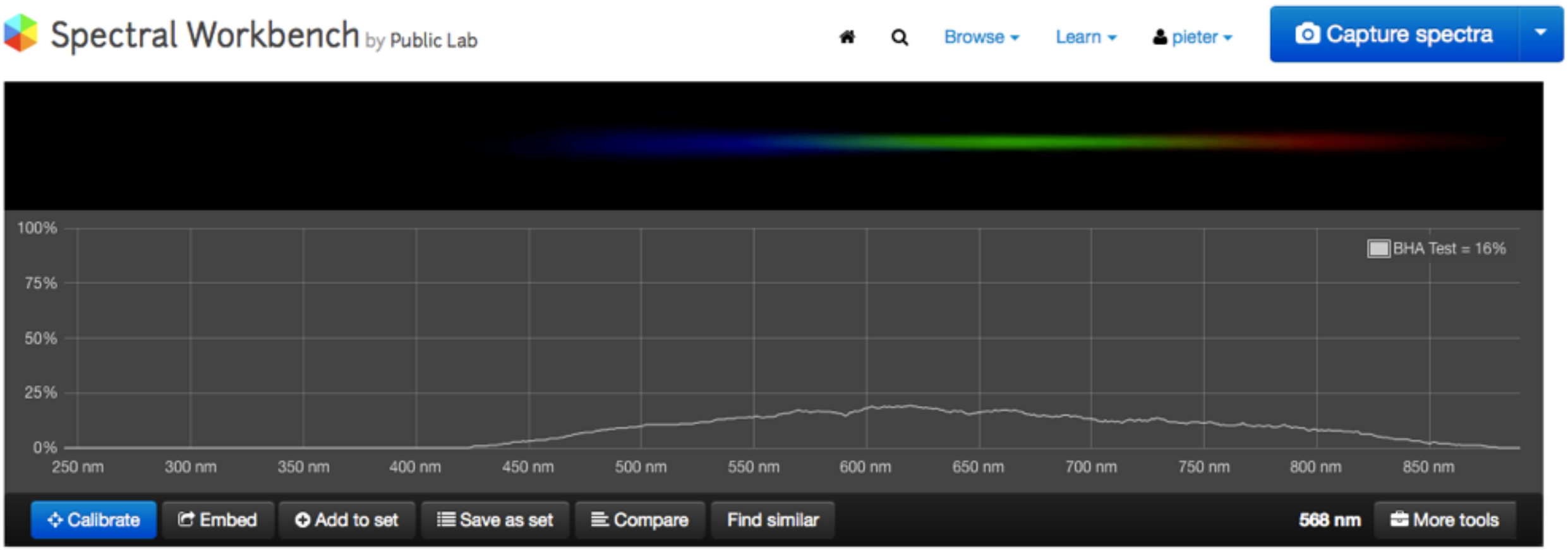
- Slit size: 1mm
- Lower is better resolution, but less sensitive
- Distance to slit: 22 cm
  - Focus webcam on this distance

Spectrum

- Day light



Spectral Workbench analysis



BHA Test

uploaded by pieter | March 31, 2015 07:26

Tags: upload x device:custom x

soil, sunlight

JSON CSV CSV (raw) XML

Notes

Like 0 Tweet 0 0 likes Edit Delete

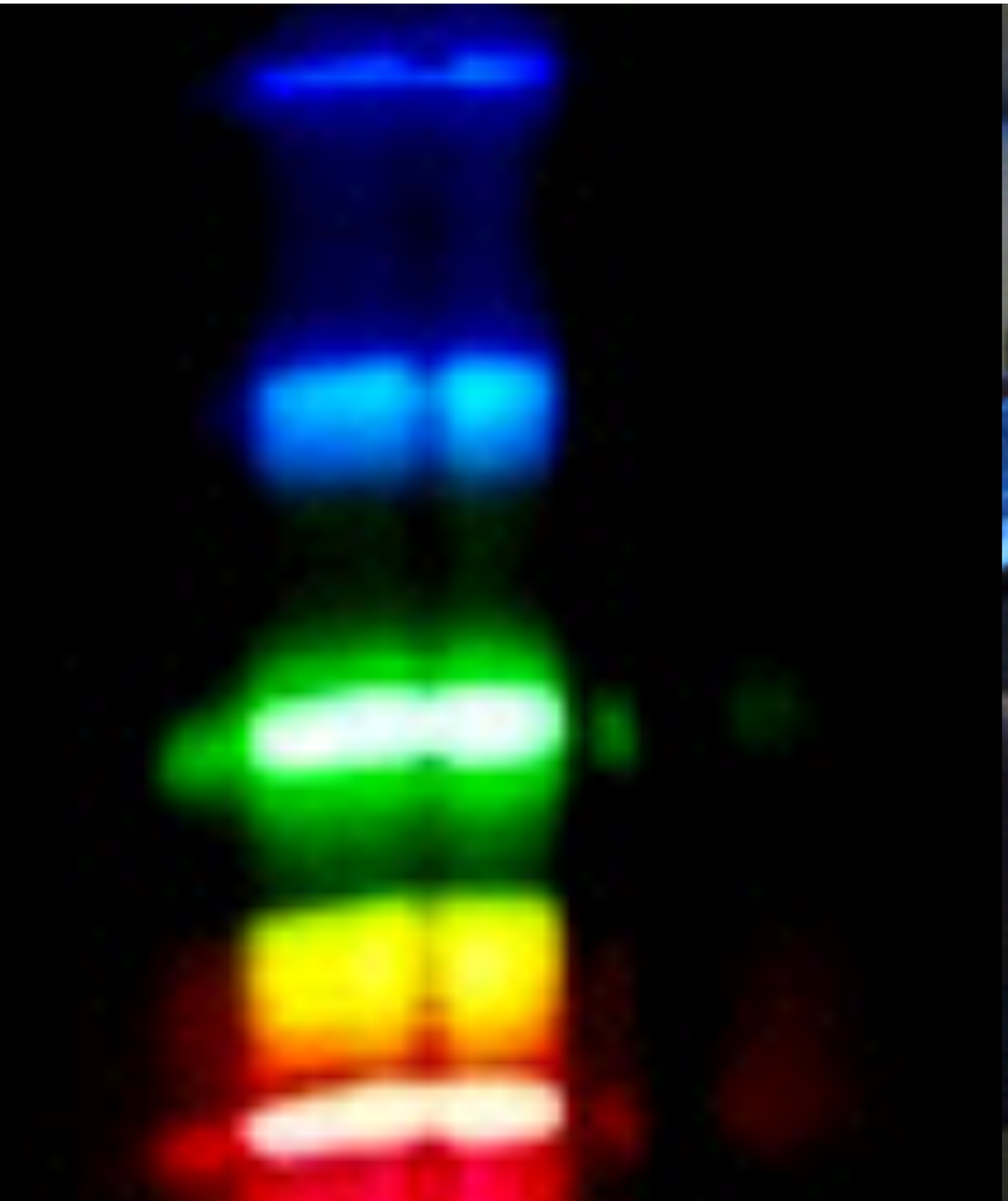
-- (Cloned calibration from cal3) -- (Cloned calibration from BHA Test)

Comments (0)

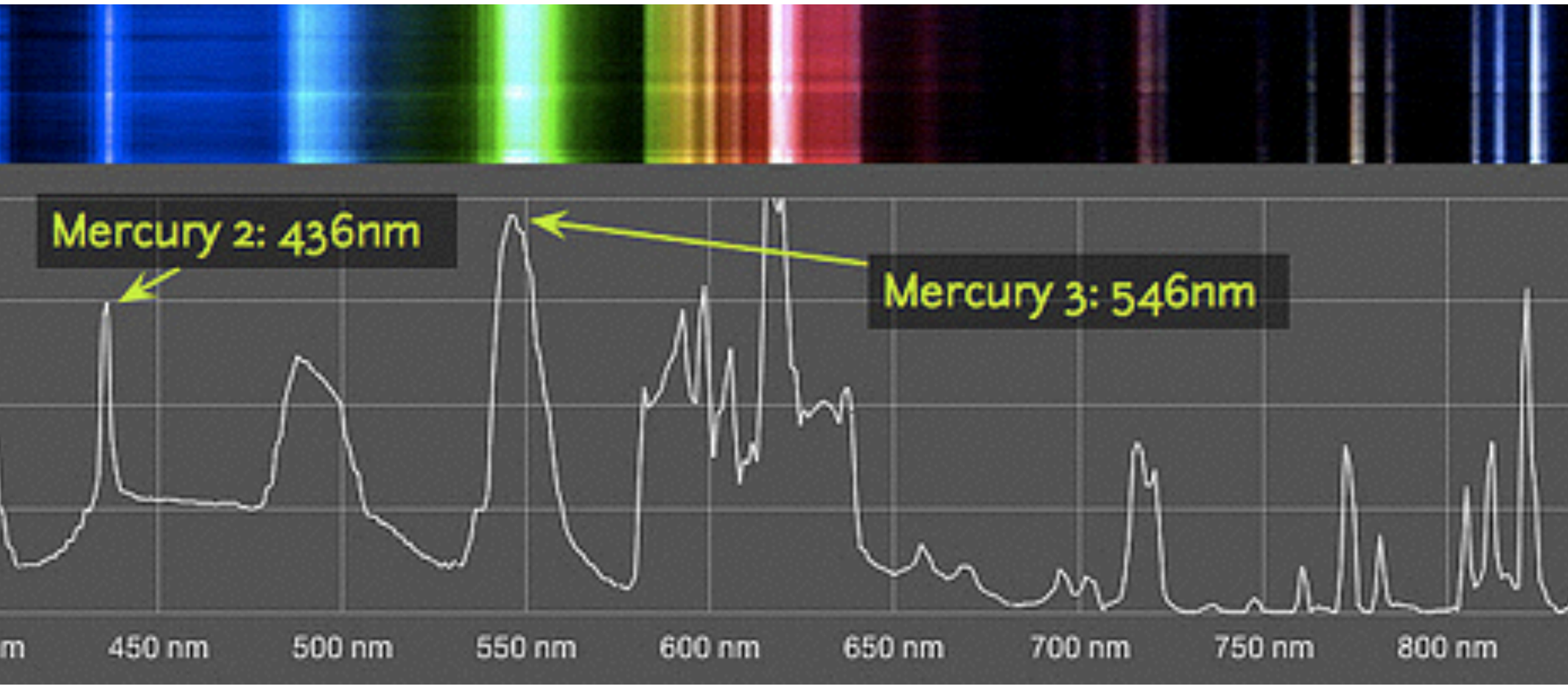
No comments

Post a comment

Calibration



Calibration



http://publiclab.org/wiki/spectral-workbench-calibration

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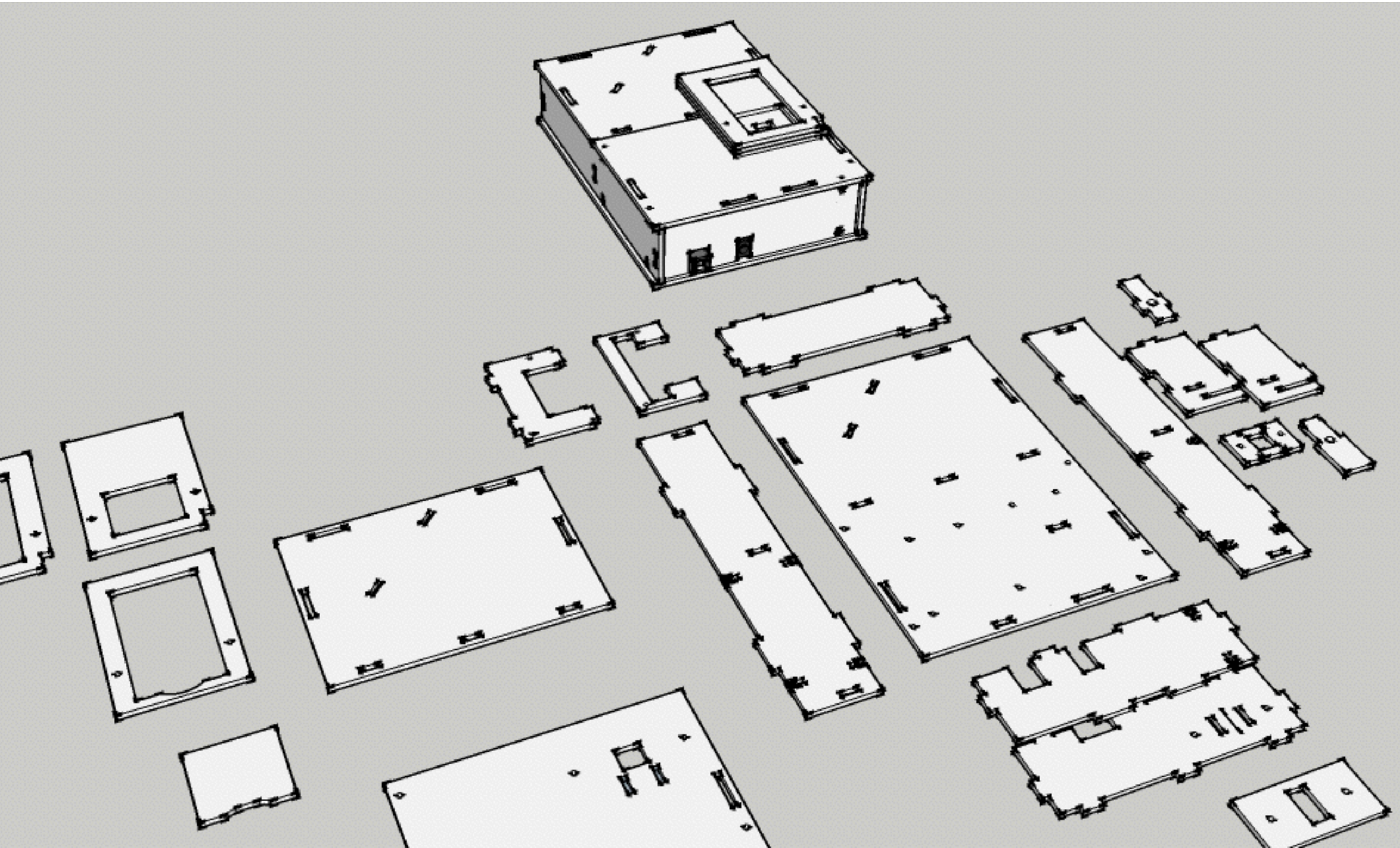
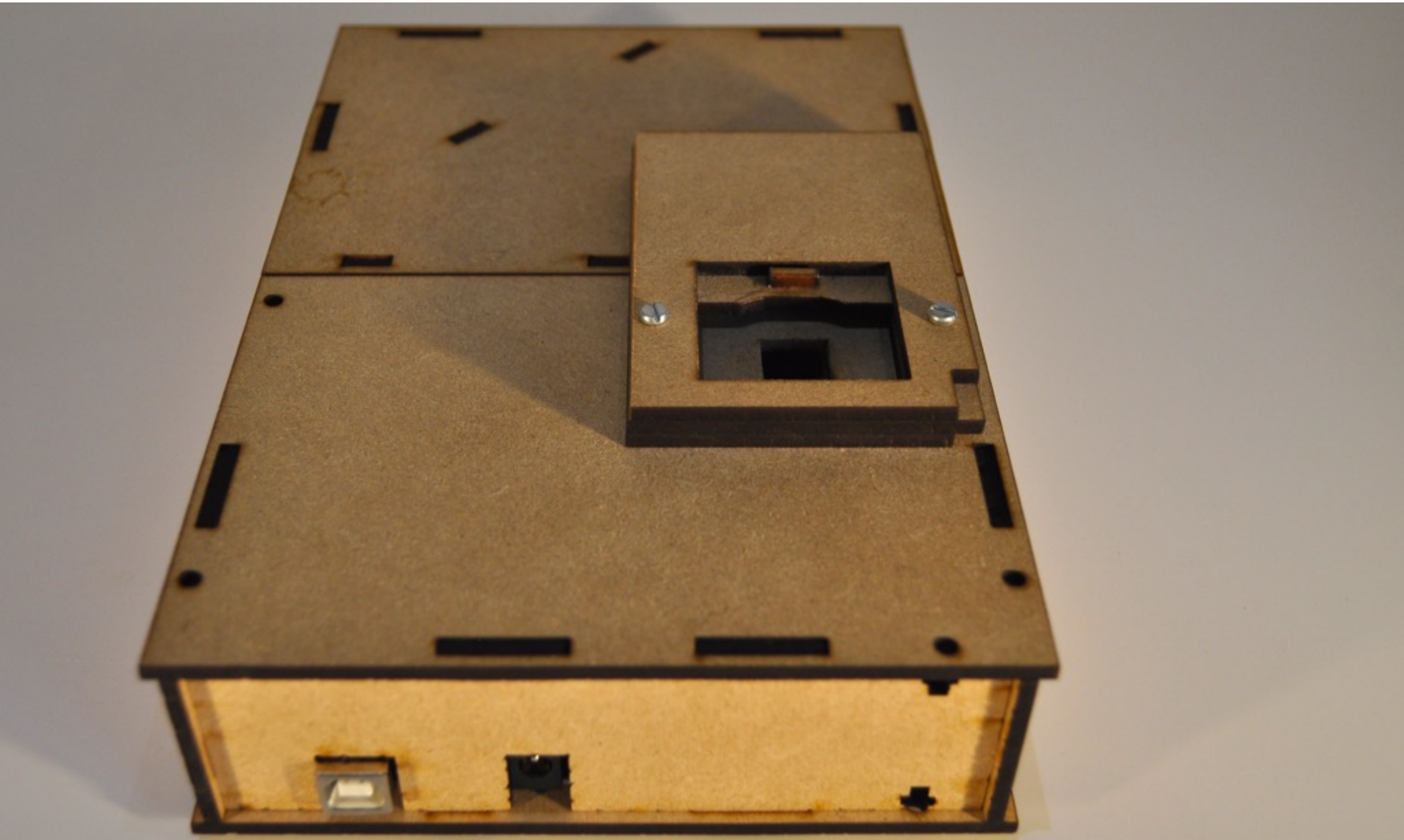
CCD Array Spectrometer

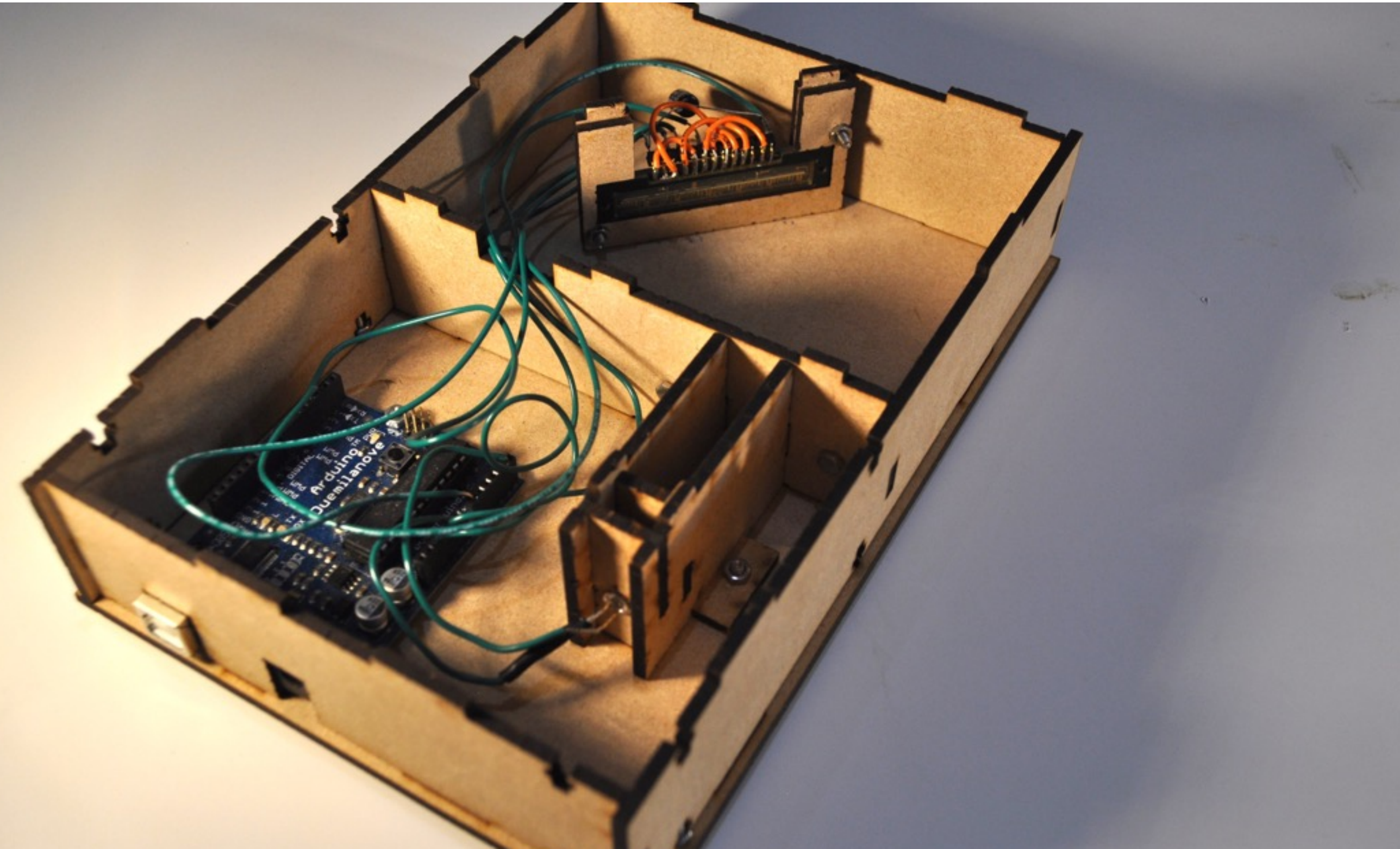
BioHack Academy design



BioHack Academy design

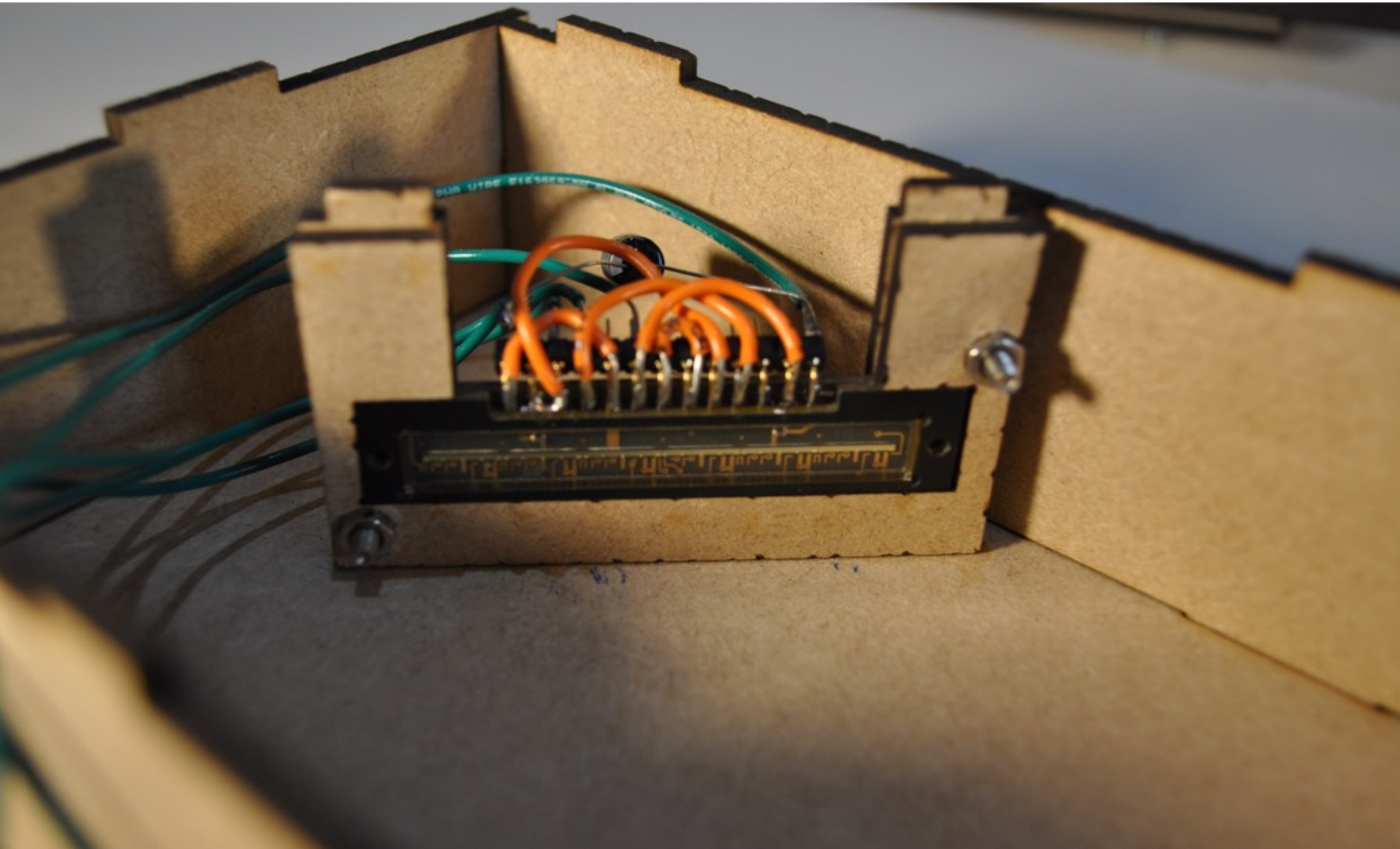


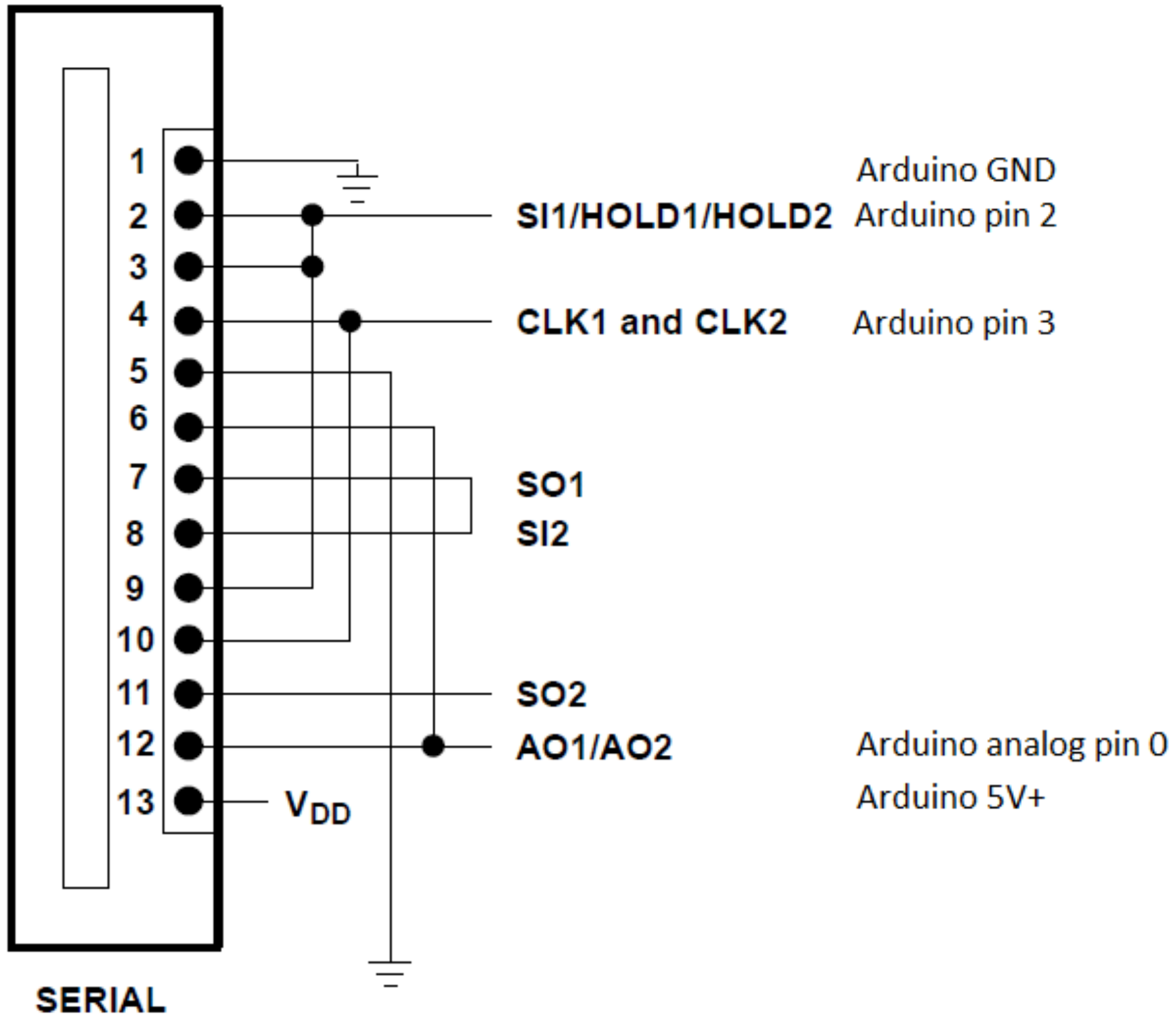
BioHack Academy design



Bill of Materials

#	Amount	Description
1	1	White LED
2	1	TSL1406R Photo diode array
3	1	1,000 lines/mm grating
4	1	220 ohm resistor
5	1	Power switch
5	1	7.5 W power supply
6	1	Jack Adapter




1
2
3
4
5
6
7
8
9
10
11
12
13
SERIAL
Arduino GND
SI1/HOLD1/HOLD2
Arduino pin 2
CLK1 and CLK2
Arduino pin 3
SO1
SI2
SO2
AO1/AO2
Arduino analog pin 0
VDD
Arduino 5V+

CCD array

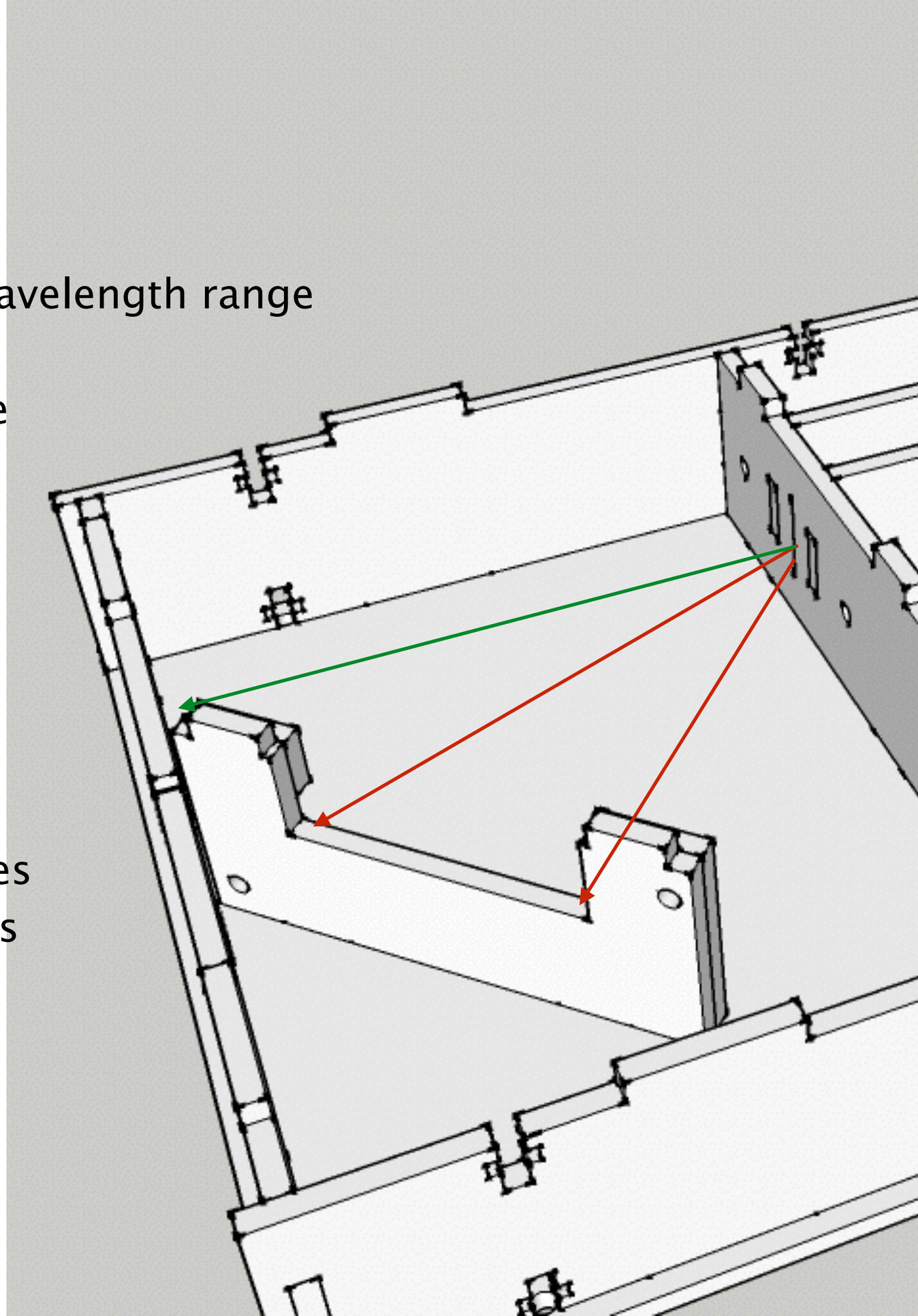
- 400 nm to 900 nm target wavelength range

- d = grating 0.001 mm / line
- lambda = wavelength
- phi = diffraction angle
- m = order of diffraction = 1

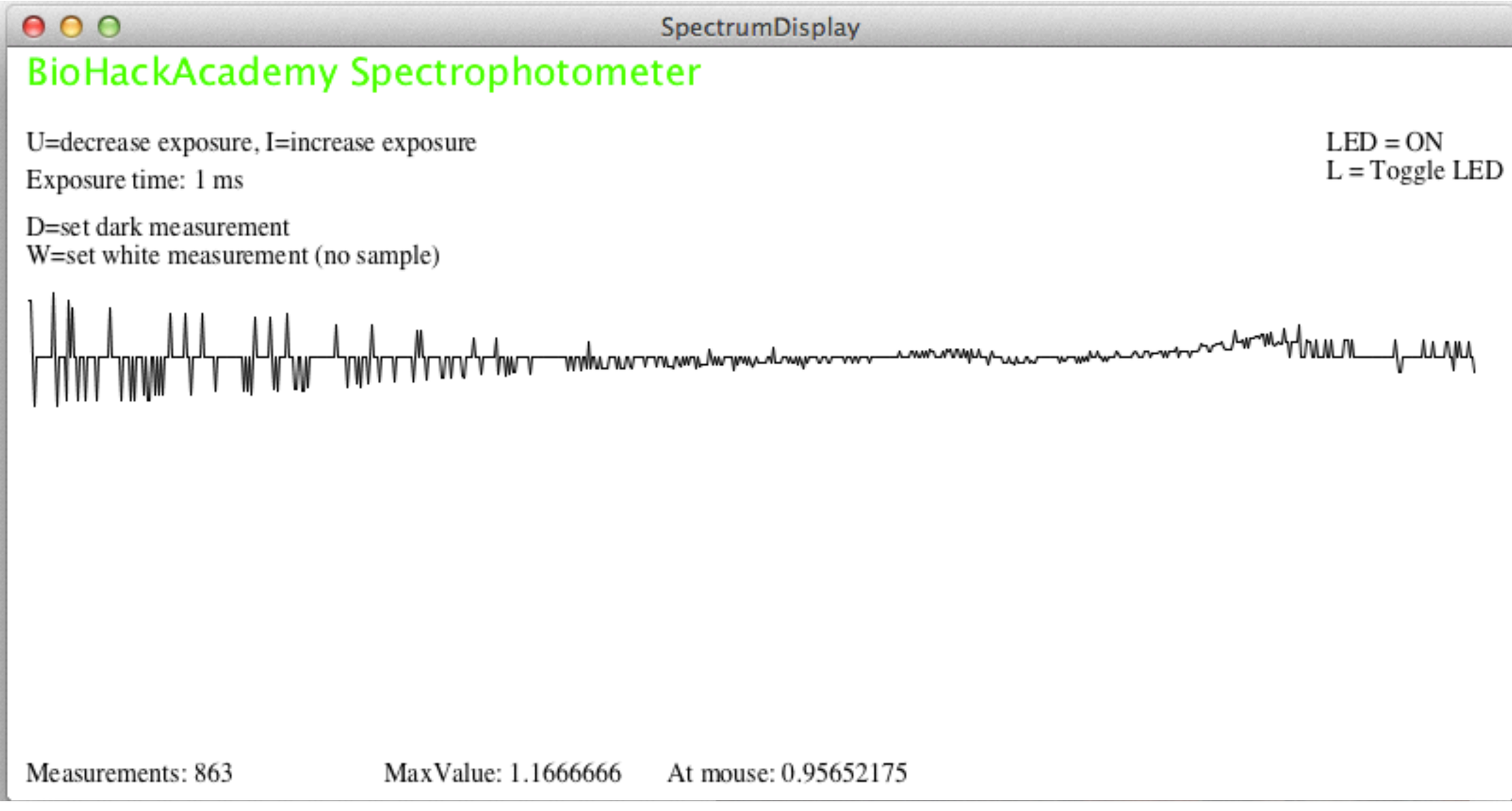
$$d \times \sin(\theta) = m \times \lambda$$

$$\theta = \sin^{-1}(\frac{m \times \lambda}{d})$$

- 400 nm: phi = 23.58 degrees
- 900 nm phi = 64.16 degrees



Processing Software - SpectrumDisplay



Source Code – setup

```
import processing.serial.*;

Serial port;      // The serial port
int exposureTime = 1; // 1 ms
float updateSpeed = 2000; // 1000 ms

int lastSpectrumUpdate=0;

boolean ledState=true;
PFont defaultFont;
PFont titleFont;

String buffer;

int SpectrumSize = 768;
float[] rawSpectrumData, correctedSpectrumData;
float[] darkReadout, whiteReadout;
int spectrumValueIndex=0;
int spectraCount=0;
```

```
void setup() {
  size(800, 400);
  // create a font with the third font available to the system:
  defaultFont = createFont(PFont.list()[0], 14);
  titleFont = createFont(PFont.list()[4], 20);
  textFont(defaultFont);

  // List all the available serial ports:
  printArray(Serial.list());

  String portName = Serial.list()[0];
  port = new Serial(this, portName, 57600);

  correctedSpectrumData = new float[SpectrumSize];
  rawSpectrumData = new float[SpectrumSize];
  darkReadout = new float[SpectrumSize];
  whiteReadout = new float[SpectrumSize];
  for(int i=0;i<SpectrumSize;i++)
    whiteReadout[i]=1.0f;

  lastSpectrumUpdate=millis();

  ledState=true;
  port.write("led 1\n");
}
```

Source Code – spectrum

```
void readSpectrum() {
  println("Updating spectrum");
  port.write("read\n");
}

void drawSpectrum() {
  int xstart=10, ystart=height-30;

  float maxVal=0.0f;
  for (int i=0;i<correctedSpectrumData.length;i++)
    maxVal = max(correctedSpectrumData[i],maxVal);

  float yscale = (height - 160)/maxVal;
  for (int i=1;i<correctedSpectrumData.length;i++) {
    line(i+xstart, ystart - correctedSpectrumData[i-1] * yscale,
        i+xstart+1, ystart - correctedSpectrumData[i] * yscale);
  }

  int indexAtMousePos = max(0, min(SpectrumSize-1, mouseX - xstart));
  text("At mouse: " + correctedSpectrumData[indexAtMousePos], 350, 39
  text("MaxValue: " + maxVal, 200, 390);
}

/*
Compute correctedSpectrumData based on rawSpectrumData, whiteReadout
*/
void computeSpectrum() {
  for (int i=0;i<SpectrumSize;i++) {
    correctedSpectrumData[i] = (rawSpectrumData[i] - darkReadout[i])
  }
}
```

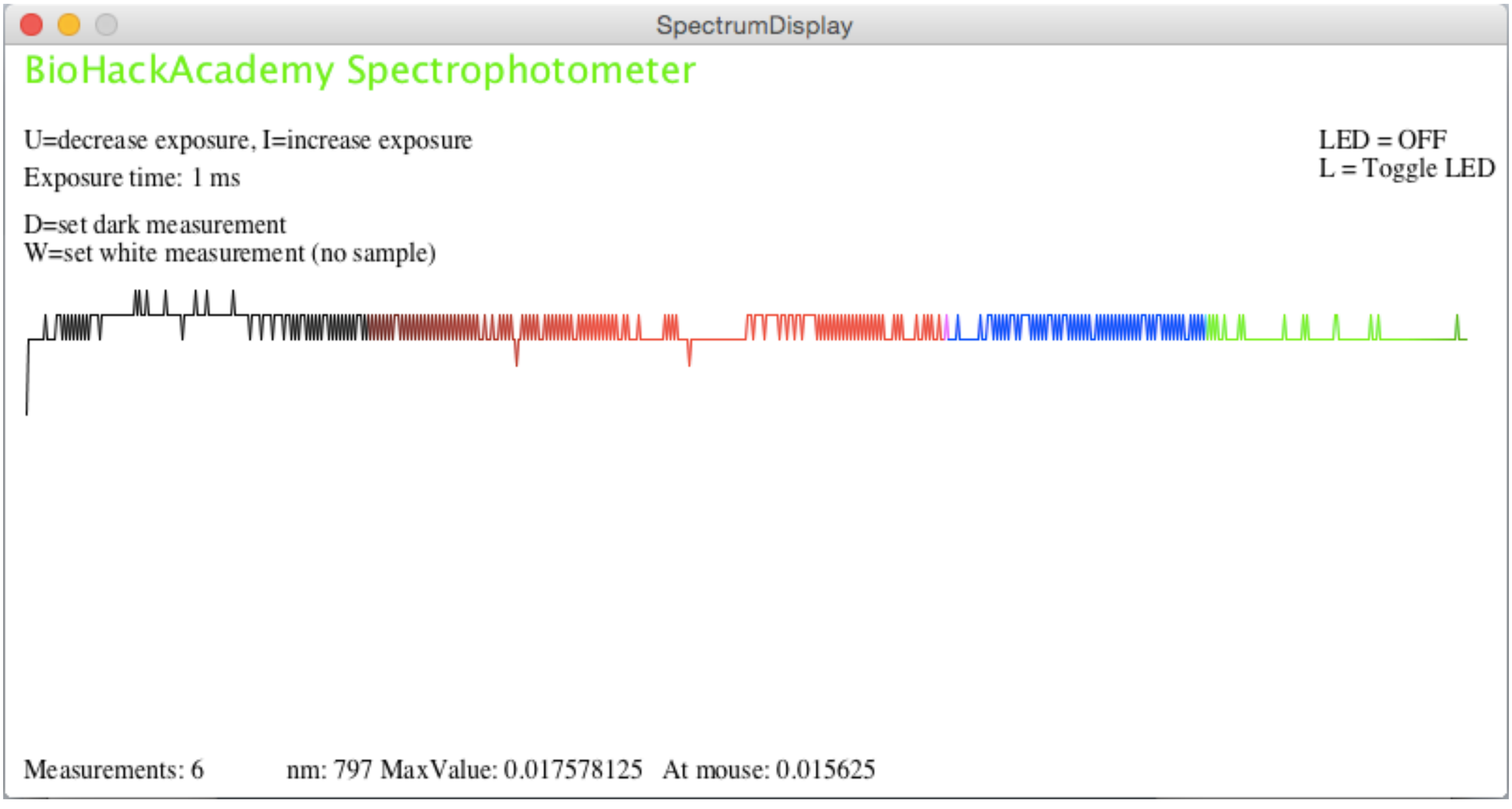
```
void draw() {
  int time = millis();

  if (lastSpectrumUpdate + updateSpeed < time) {
    lastSpectrumUpdate=time;
    readSpectrum();
  }

  background(255);
  text("U=decrease exposure, I=increase exposure", 10, 55);
  text("Exposure time: " + exposureTime + " ms", 10, 75);
  text("D=set dark measurement", 10, 100);
  text("W=set white measurement (no sample)", 10, 115);

  text("Measurements: " + spectraCount, 10, 390);

  text("LED = " + ( ledState ? "ON" : "OFF" ), 700, 55);
  text("L = Toggle LED", 700, 70);

  textFont(titleFont);
  fill(0, 255, 0);
  text("BioHackAcademy Spectrophotometer", 10, 20);
  textFont(defaultFont);
  fill(0);

  drawSpectrum();
}
```

Source Code – interaction

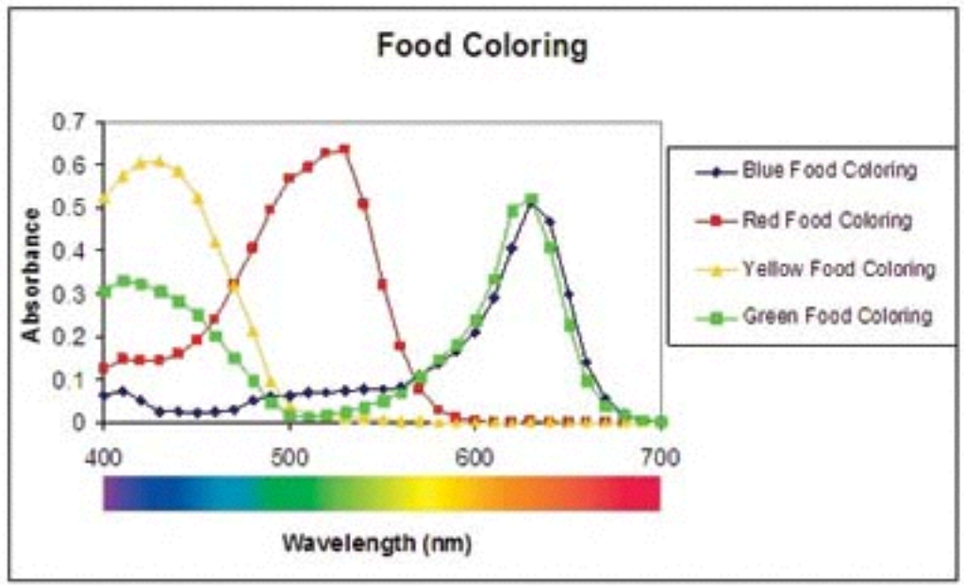
```
void serialEvent(Serial port) {
  while (port.available () >0) {
    char c = port.readChar();
    if (c == '\n' && buffer.length() > 0) {
      char first=buffer.charAt(0);
      if (first >= '0' && first <= '9') {
        int value = Integer.parseInt(buffer.trim());//substring(0,bu
        rawSpectrumData[spectrumValueIndex++] = value/1024.0f;
        if (spectrumValueIndex==SpectrumSize) {
          computeSpectrum();
          spectrumValueIndex=0;
          spectraCount ++;
        }
      } else if(buffer=="start") {
        spectrumValueIndex=0; // align again
      }
      buffer="";
    } else {
      buffer+=c;
    }
  }
}
```

```
void keyPressed() {
  if (key >= 'A' && key <= 'Z')
    key += 'a'-'A'; // make lowercase

  if (key == 'i' || key == 'u') {
    if (key == 'i') exposureTime += 3;
    else exposureTime -= 3;
    exposureTime = max(exposureTime,1);

    port.write("exp " + max(1, (int)exposureTime) + "\n");
  }

  if (key == 'l') {
    ledState=!ledState;
    port.write("led " + ( ledState ? "1" : "0" )+ "\n");
  }

  if (key == ' ') {
    readSpectrum();
  }

  if (key == 'd') {
    for (int i=0;i<SpectrumSize;i++)
      darkReadout[i] = rawSpectrumData[i];
  }

  if (key == 'w') {
    for (int i=0;i<SpectrumSize;i++)
      whiteReadout[i] = rawSpectrumData[i];
  }
}
```

Processing Software - Empty



Red food dye

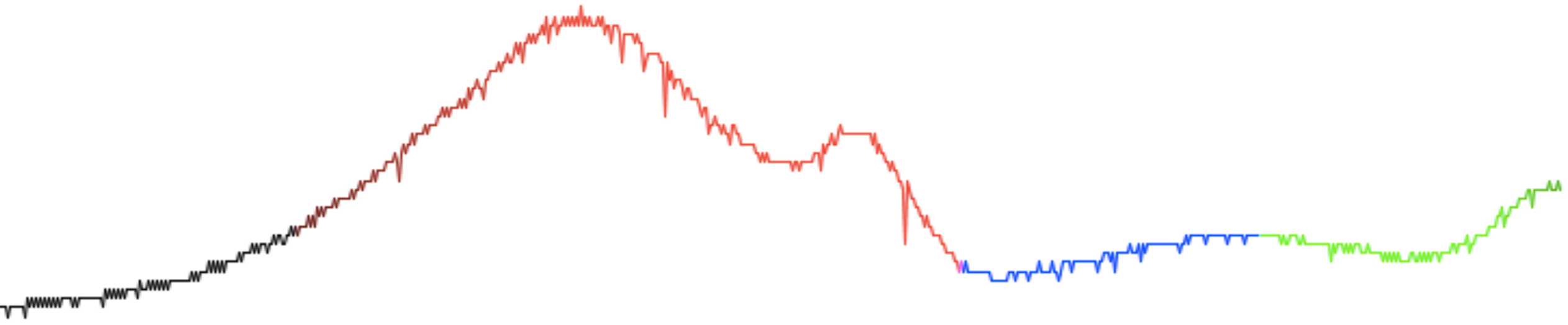


ackAcademy Spectrophotometer

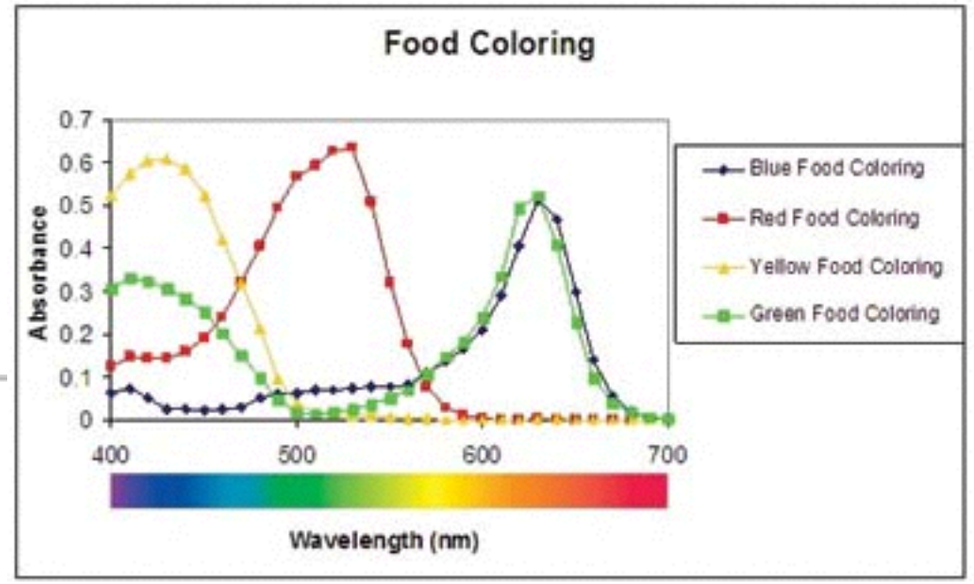
ease exposure, I=increase exposure
e time: 1 ms

ark measurement
white measurement (no sample)

L = Toggle LED



Green food dye

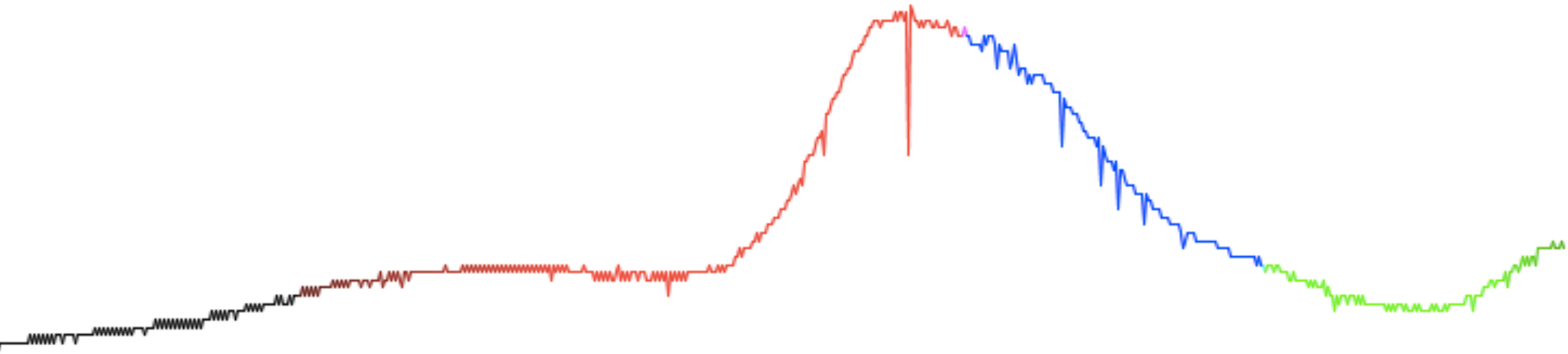


ackAcademy Spectrophotometer

ease exposure, I=increase exposure
re time: 1 ms

ark measurement
white measurement (no sample)

L = Toggle LED



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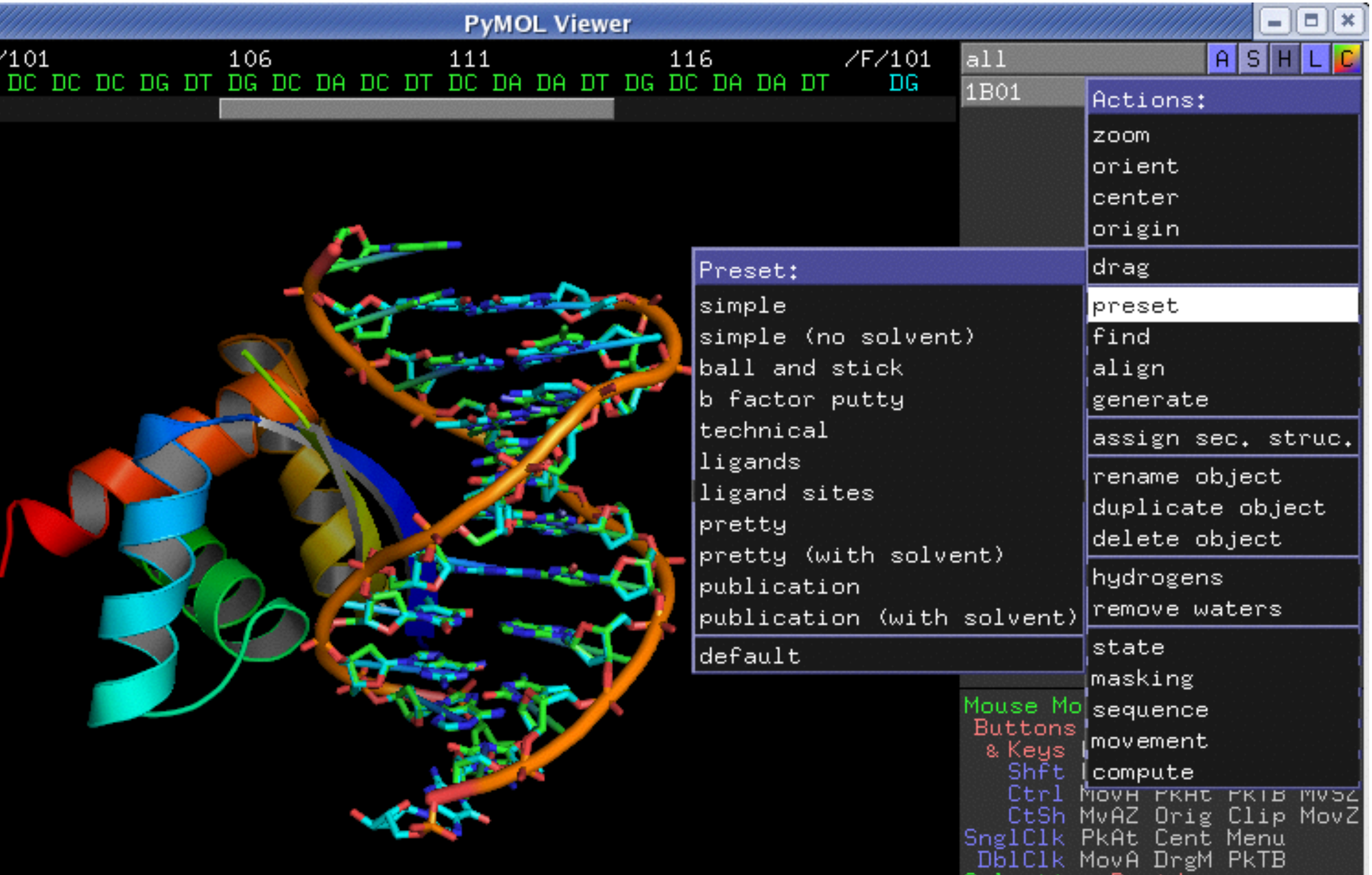
Coming up

Practical – Iodine Clock Reaction

Bio informatics practical



Graduation Show

- Tuesday November 17th

- Program:
  - 18:30 Doors Open
  - 19:00 Graduation Show Starts
  - 21:30 Handing out certificates and drinks
  - 22:30 End

- 8 presentations
  - Andreia, Clara, Erwin, Ilva, Manon, Margot, Tim, Yasemin
  - 5 minutes presentation, 5 minute questions