Experiment 3: Concave Grating Spectrometer

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In [1]:
```
# import necessary libraries
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from scipy.stats import linregress
```

In [2]:
```
# set default params for matplotlib :
plt.rcParams['font.size'] = 14
plt.rcParams['lines.linewidth'] = 2
plt.rcParams["figure.figsize"] = (8,5)
```

In [3]:
```
# read all the data form the excel file :
data_dict = {f'Linear-Order-{i+1}' : pd.read_excel('data.xlsx' , sheet_na
data_dict.update( {f'Angular-Order-{i-1}' : pd.read_excel('data.xlsx' , s
data_dict['Sodium'] = pd.read_excel('data.xlsx' , sheet_name=-1)
```

In [4]:
```
# list to store interpolated results :
sodium_wavelenght = np.array([])
```

In [5]:
```
# define function to plot the clabration curves and get the iterpolated v
# the given data set

def calibrate_interpolate(x,y,order:int,linear:bool=False,p=None):
    '''
        param x: independet variable of the data.
        param y: give data points of the function.
        param p: list of points to intepolate on.
        returns : interpolated values of y(p).
    '''

    if( type(x) == list ):
        x = np.array( x )
    if( type(y) == list ):
        y = np.array( y )
    if linear :
        if( type(p) == list ):
            p = np.array(p)

    # get the linear interpolated results :
    if linear :
        q = np.interp( p , x , y )
```

```
    # get the slope post linear regression :
    regress = linregress( x , y )

    # plot the curves :
    plt.plot( x , y , linewidth = 3 )
    plt.scatter( x , y , linewidths=2 , label = 'Recorded Data Point')
    if linear :
        plt.scatter( p , q  , color = 'r' , marker = '|' , s = 160 , labe
        plt.xlabel(r'Linear Distance from the Slit $X$ ($cm$)')
        plt.title(fr'$X$ vs $\lambda$ Calibration Curve of Hg for Order {
    else :
        plt.xlabel(r'Angular Distance from the Slit $\theta$ ($\degree$)'
        plt.title(fr'$\theta$ vs $\lambda$ Calibration Curve of Hg for Or
    plt.ylabel(r'Wavelength $\lambda$ ($nm$)')
    plt.grid()
    plt.legend()
    plt.show()

    # return the slope of the regression line
    if linear :
        return q , regress[0]
    else :
        return regress[0]
```

In [6]:

```
print('--------Reading for the Sodium Lamp--------')
sodium_data = data_dict['Sodium']
sodium_data
```

```
--------Reading for the Sodium Lamp--------
```

Out[6]:

	Linear Distance (cm)	Color	Order
0	13.94	Yellow(1)	1
1	13.98	Yellow(2)	1
2	29.23	Yellow(1)	2
3	29.25	Yellow(2)	2

In [7]:

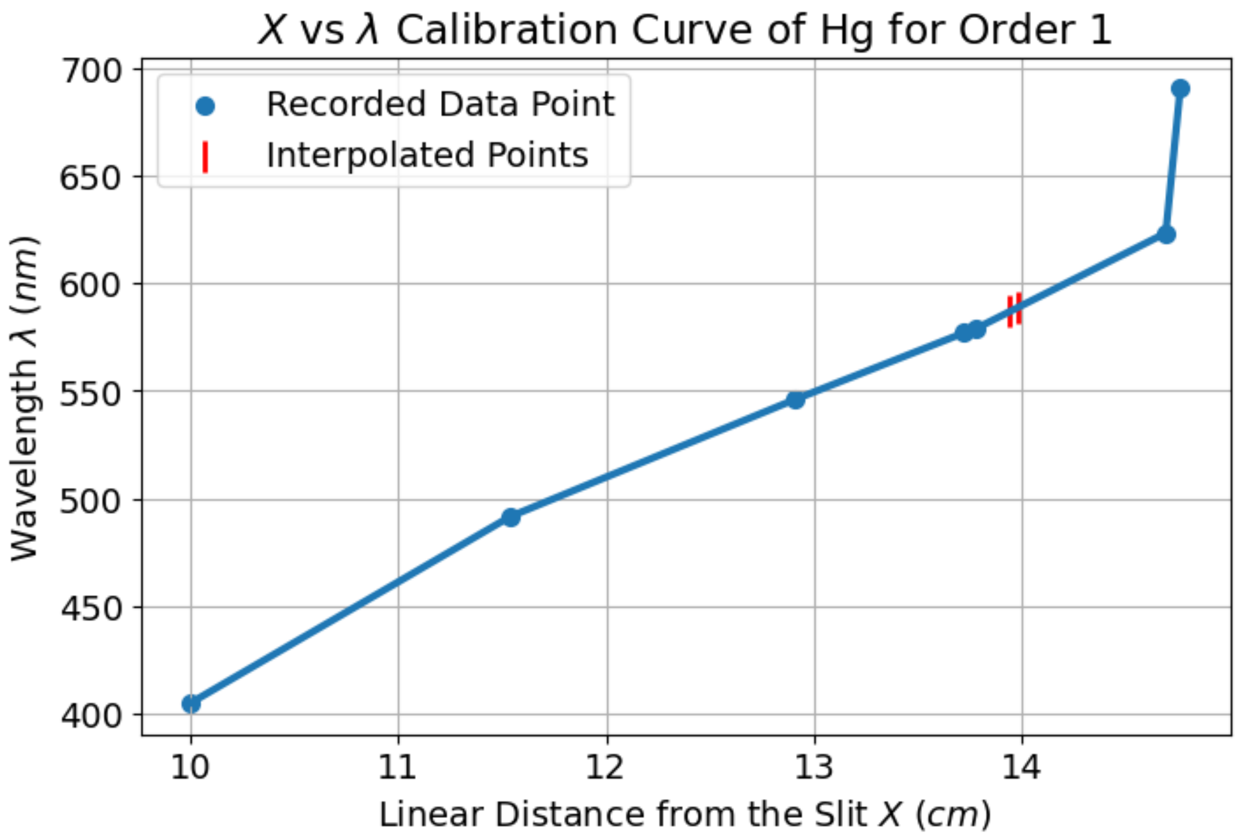
```
print('--------Linear Readings for Order 1 Bands of Hg--------')
display( data_dict['Linear-Order-1'] )

p  = sodium_data['Linear Distance (cm) '].to_numpy()[:2]
q , slope_order1 = calibrate_interpolate(
    x = data_dict['Linear-Order-1']['Linear Distance (cm) '].to_numpy() ,
    y = data_dict['Linear-Order-1']['Wavelength (nm)'].to_numpy(), order
    linear= True , p = p
)

sodium_wavelenght = np.append( sodium_wavelenght , q )
q
```

```
--------Linear Readings for Order 1 Bands of Hg--------
```

	Linear Distance (cm)	Color	Wavelength (nm)
0	10.00	Violet[Deep]	404.7
1	11.54	Blue/Green	491.6
2	12.91	Green	546.1
3	13.72	Yellow-Orange(1)	577.0
4	13.78	Yellow-Orange(2)	579.1
5	14.69	Red(1)	623.4
6	14.76	Red(2)	690.8




```
Out[7]:  array([586.88901099, 588.83626374])
```

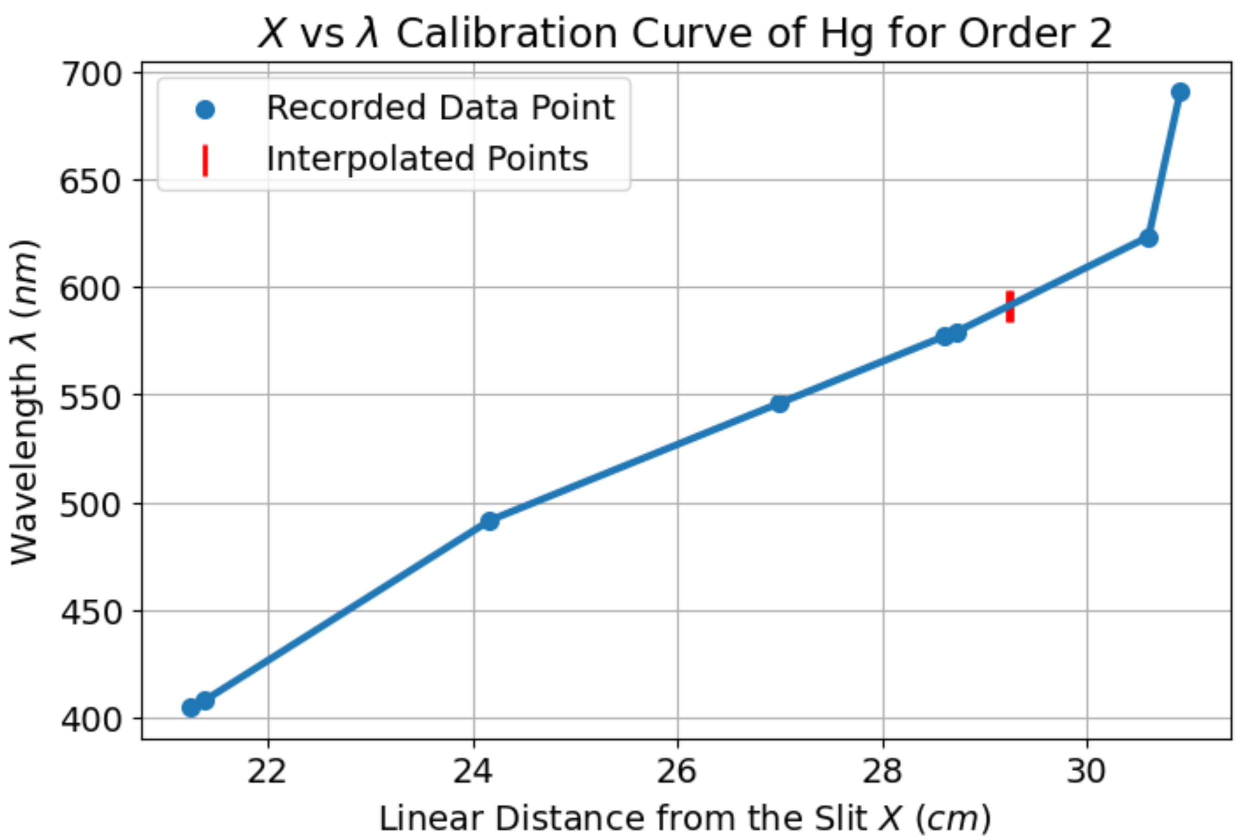
```
In [8]:
print('--------Linear Readings for Order 2 Bands of Hg--------')
display( data_dict['Linear-Order-2'] )

p  = sodium_data['Linear Distance (cm) '].to_numpy()[2:]
q , slope_order2 = calibrate_interpolate(
    x = data_dict['Linear-Order-2']['Linear Distance (cm) '].to_numpy() ,
    y = data_dict['Linear-Order-2']['Wavelength (nm)'].to_numpy(), order
    linear = True , p = p
)

sodium_wavelenght = np.append( sodium_wavelenght , q )
q
```

```
--------Linear Readings for Order 2 Bands of Hg--------
```

	Linear Distance (cm)	Color	Wavelength (nm)
0	21.24	Violet[Deep]	404.7
1	21.38	Violet	407.8
2	24.17	Blue/Green	491.6
3	27.00	Green	546.1
4	28.60	Yellow-Orange(1)	577.0
5	28.72	Yellow-Orange(2)	579.1
6	30.60	Red(1)	623.4
7	30.91	Red(2)	690.8



Out[8]: `array([591.11755319, 591.58882979])`

since $(\mathrm{d}\lambda/\mathrm{d}x)_{\mathrm{order}n} \propto 1/n$ we expect :

$$\zeta = \frac{(\mathrm{d}\lambda/\mathrm{d}x)_{\mathrm{order1}}}{(\mathrm{d}\lambda/\mathrm{d}x)_{\mathrm{order2}}} = \frac{2}{1}$$

In [9]:
```
slope_order1/slope_order2
```

Out[9]: `2.011690000313097`

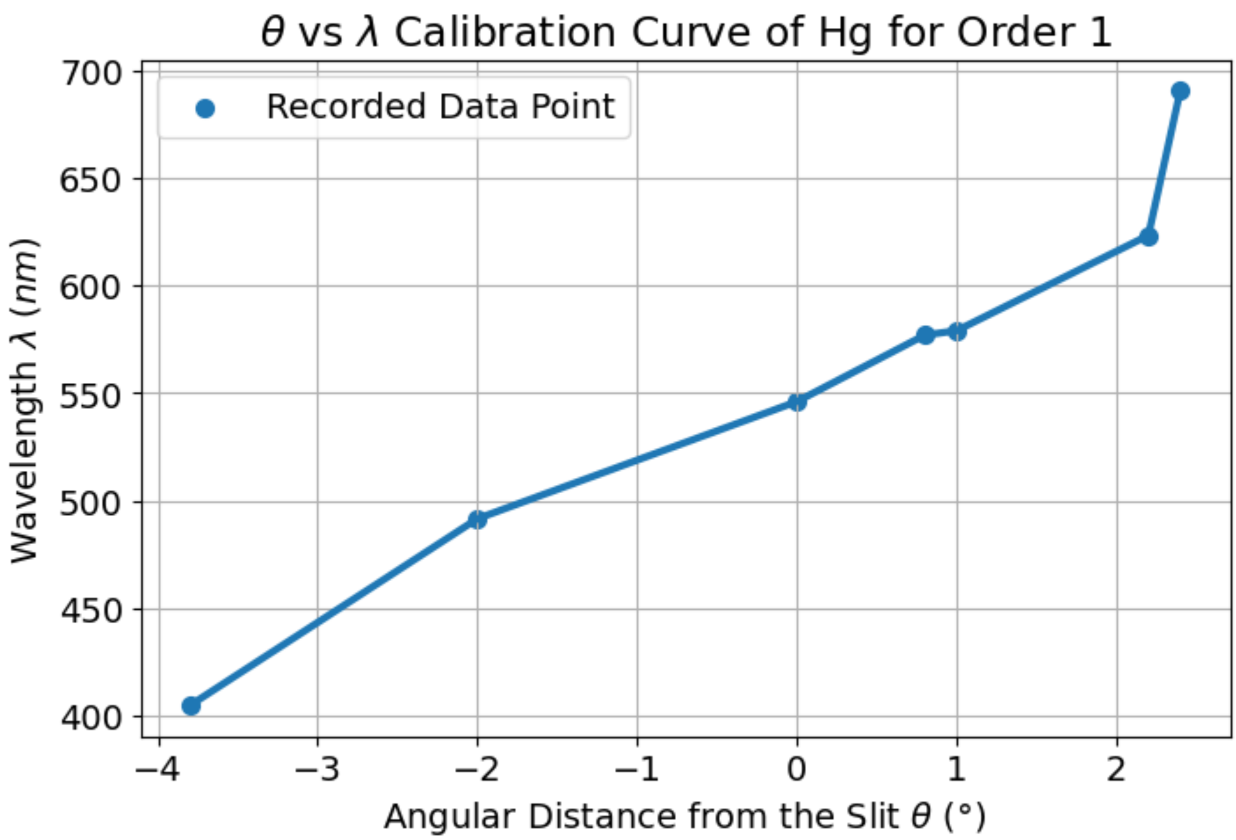
we get $\zeta = 2.011690000313097$ which is highly accurate

In [10]:
```
print('--------Angular Readings for Order 1 Bands of Hg--------')
display(data_dict['Angular-Order-1'])
```

```
slope_order1 = calibrate_interpolate(
    x = -data_dict['Angular-Order-1']['Angular Distance (*)'].to_numpy()
    y = data_dict['Angular-Order-1']['Wavelength (nm)'].to_numpy(), order
)
```

```
--------Angular Readings for Order 1 Bands of Hg--------
```

	Angular Distance (*)	Color	Wavelength (nm)
0	3.8	Violet[Deep]	404.7
1	2.0	Blue/Green	491.6
2	0.0	Green	546.1
3	-0.8	Yellow-Orange(1)	577.0
4	-1.0	Yellow-Orange(2)	579.1
5	-2.2	Red(1)	623.4
6	-2.4	Red(2)	690.8

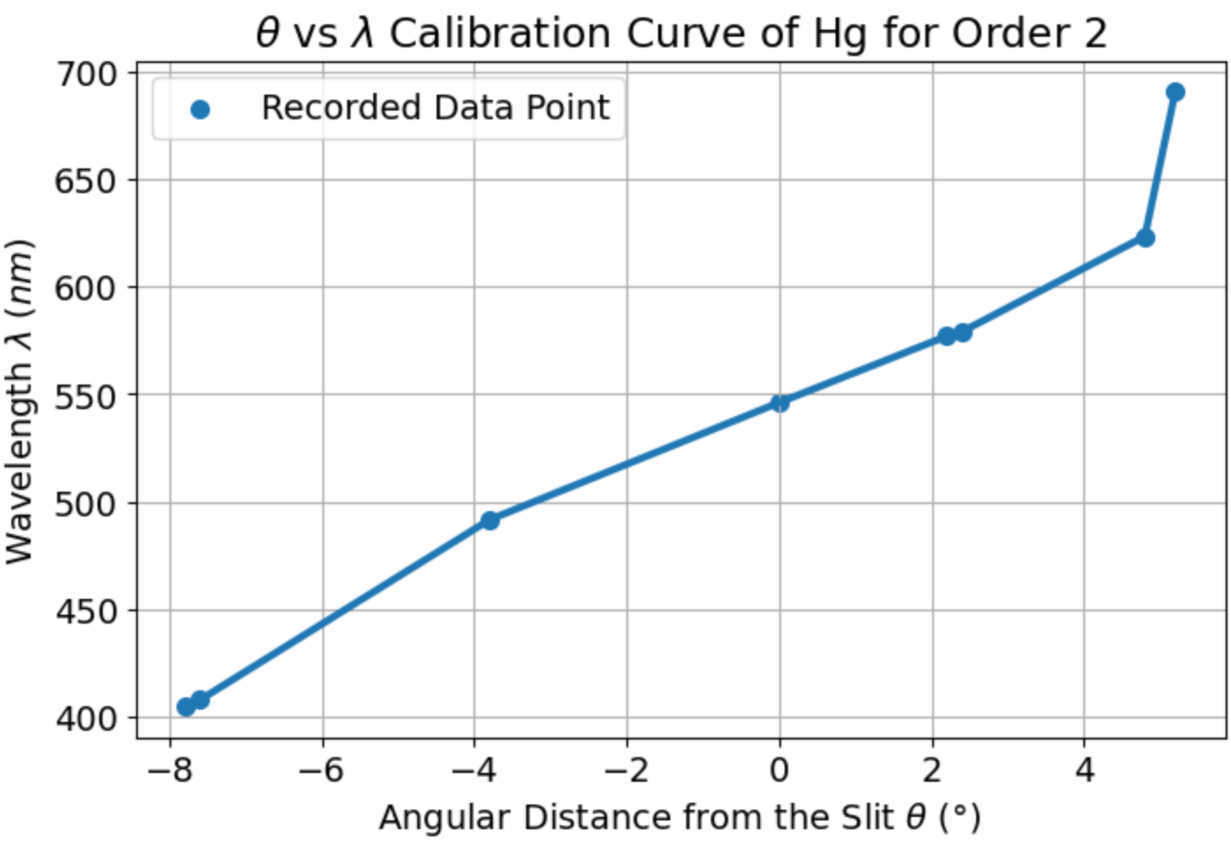


In [11]:
```
print('--------Angular Readings for Order 2 Bands of Hg--------')
display(data_dict['Angular-Order-2'])

slope_order2 = calibrate_interpolate(
    x = -data_dict['Angular-Order-2']['Angular Distance (*)'].to_numpy()
    y = data_dict['Angular-Order-2']['Wavelength (nm)'].to_numpy(), order
)
```

```
--------Angular Readings for Order 2 Bands of Hg--------
```

	Angular Distance (*)	Color	Wavelength (nm)
0	7.8	Violet[Deep]	404.7
1	7.6	Violet	407.8
2	3.8	Blue/Green	491.6
3	0.0	Green	546.1
4	-2.2	Yellow-Orange(1)	577.0
5	-2.4	Yellow-Orange(2)	579.1
6	-4.8	Red(1)	623.4
7	-5.2	Red(2)	690.8



here too $(\mathrm{d}\lambda/\mathrm{d}\theta)_{\text{order n}} \propto 1/n$ we expect :

$$\zeta = \frac{(\mathrm{d}\lambda/\mathrm{d}\theta)_{\text{order1}}}{(\mathrm{d}\lambda/\mathrm{d}\theta)_{\text{order2}}} = \frac{2}{1}$$

In [12]:
```
slope_order1/slope_order2
```

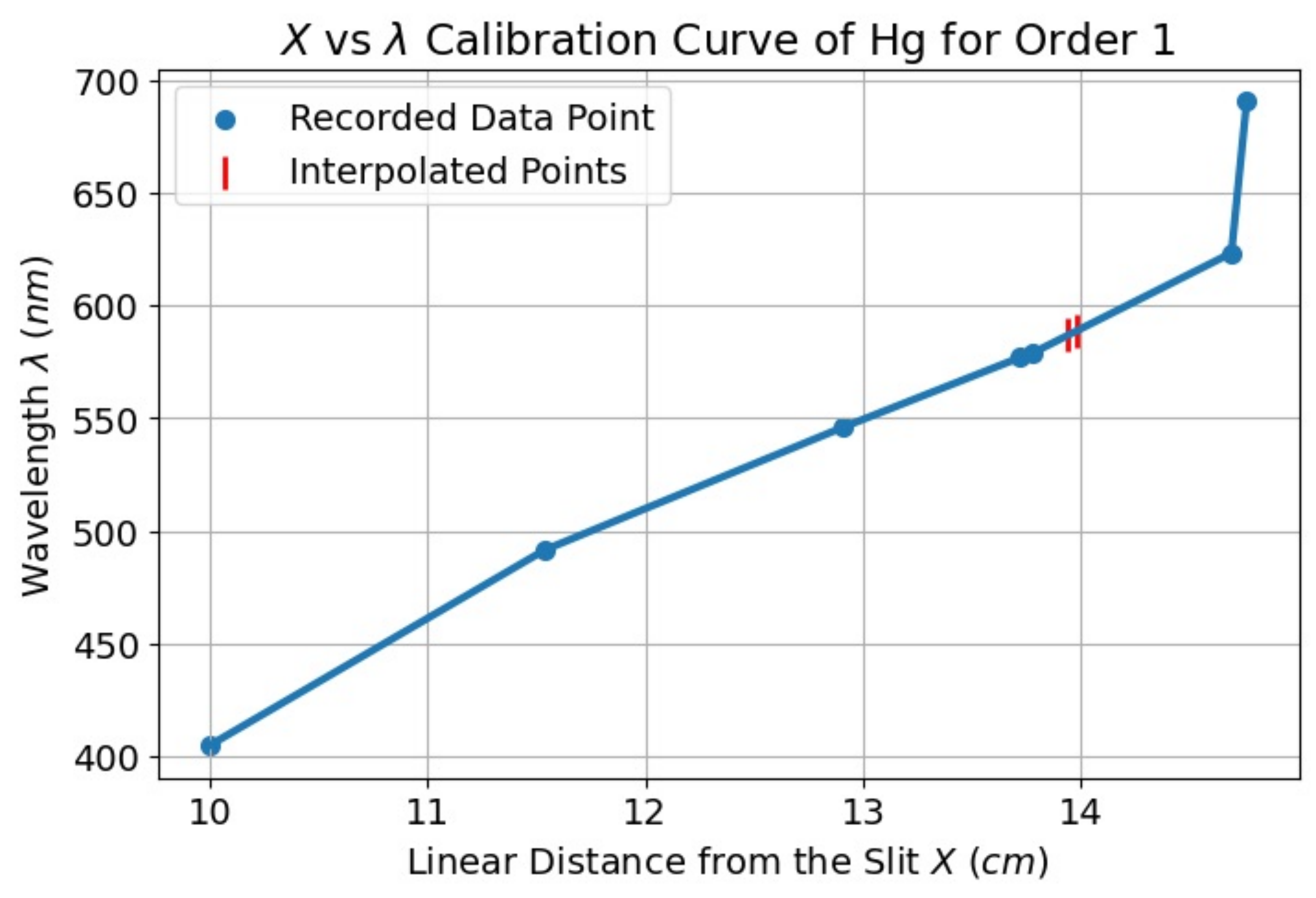
Out[12]:
```
2.100839791337052
```

we get $\zeta = 0.7409141340876566$ which also is very accurate !

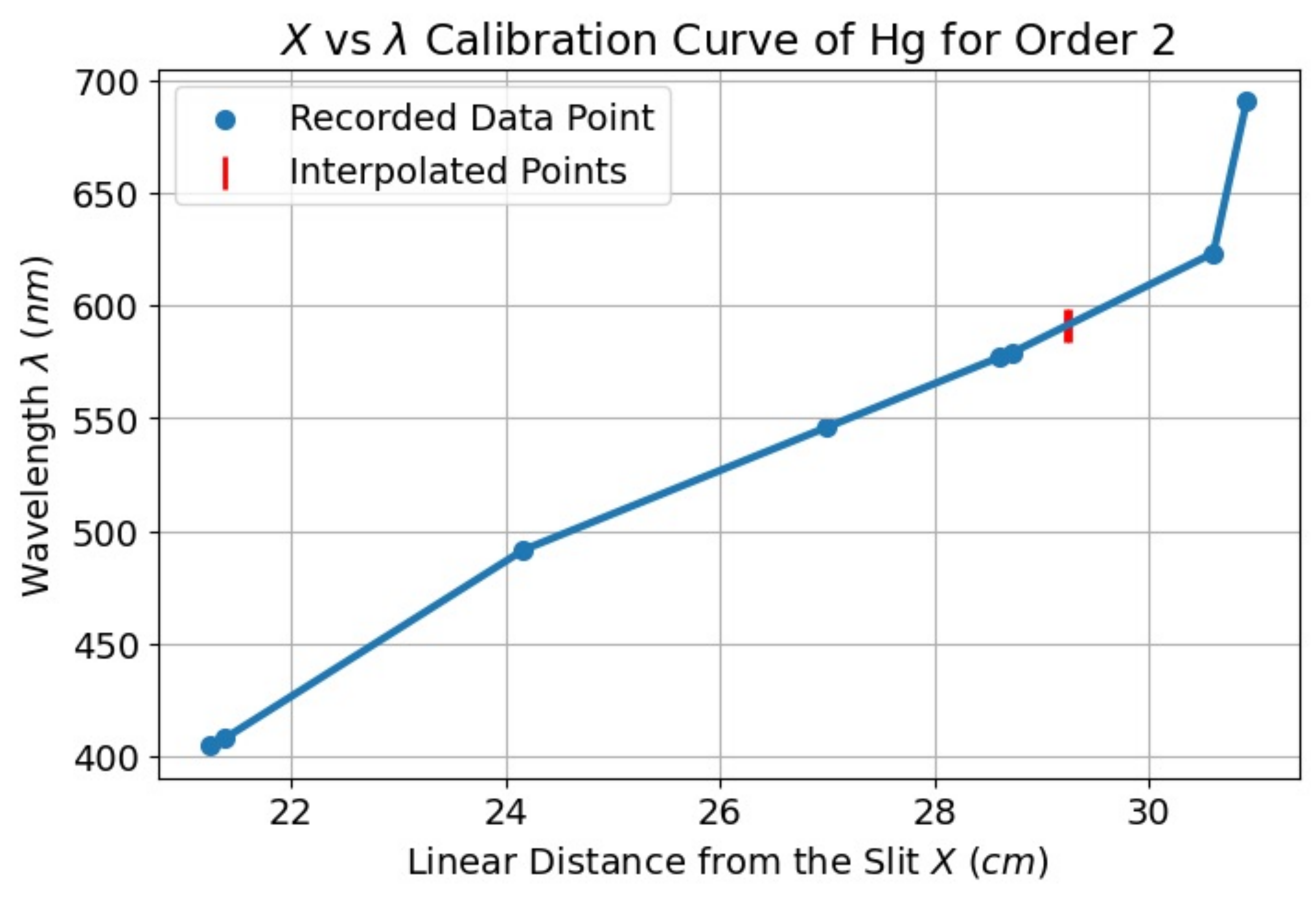
In [13]:
```
sodium_data['Calculated Wavelenght (nm)'] = sodium_wavelenght
sodium_data
```

Out[13]:

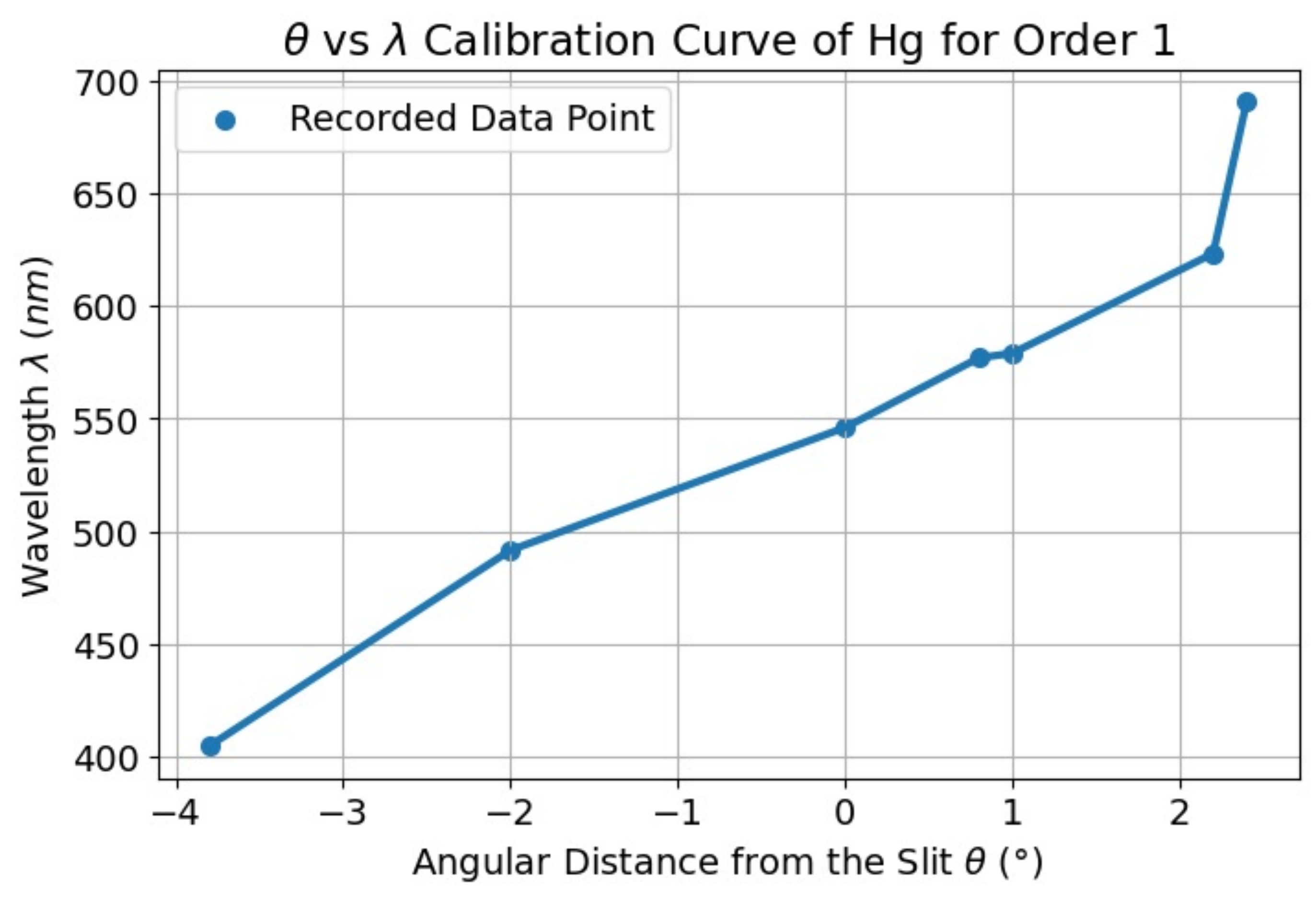
	Linear Distance (cm)	Color	Order	Calculated Wavelenght (nm)
0	13.94	Yellow(1)	1	586.889011
1	13.98	Yellow(2)	1	588.836264
2	29.23	Yellow(1)	2	591.117553
3	29.25	Yellow(2)	2	591.588830



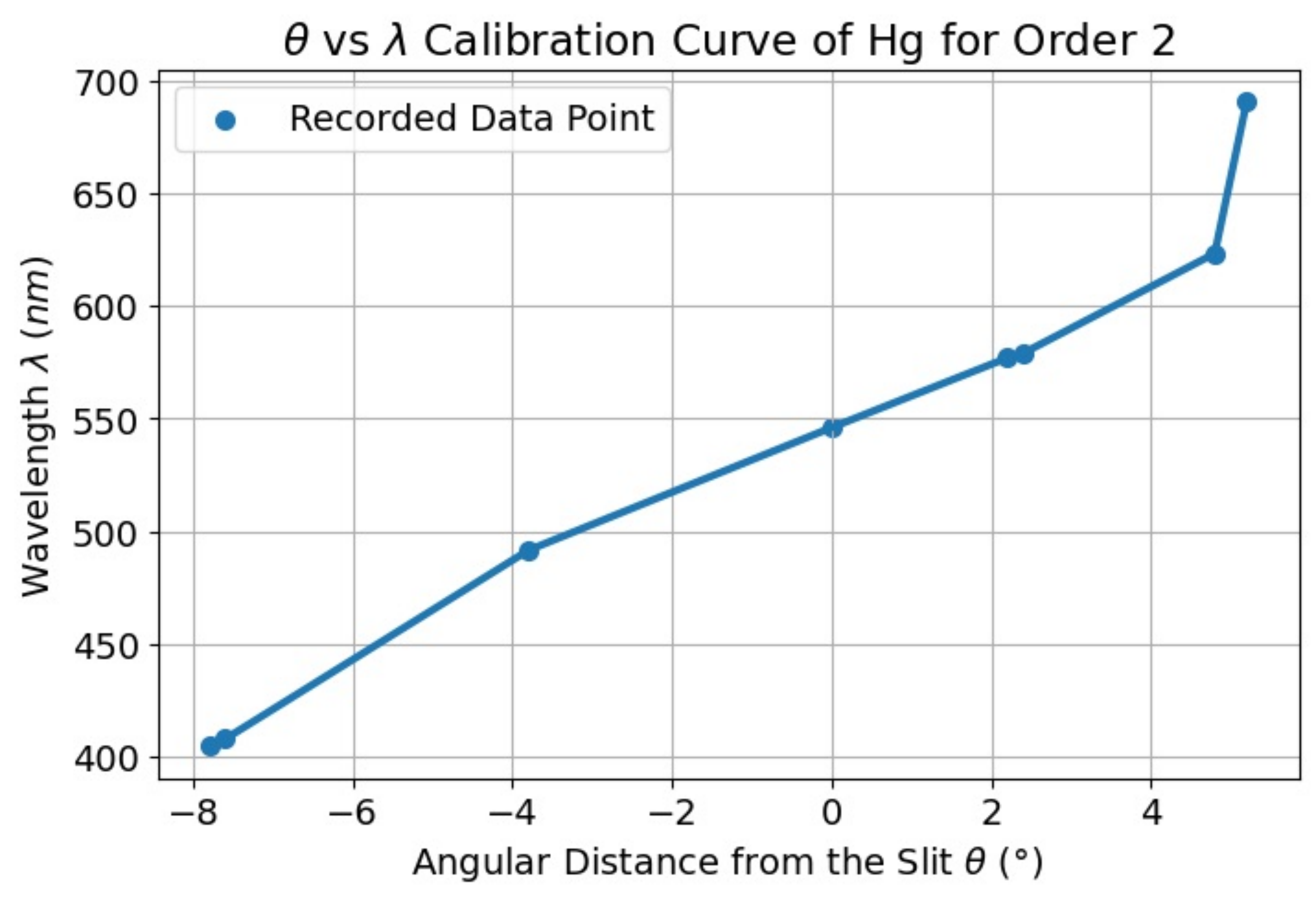
X vs λ Calibration Curve of Hg for Order 1
Recorded Data Point
Interpolated Points
Wavelength λ (nm)
Linear Distance from the Slit X (cm)
700
650
600
550
500
450
400
10
11
12
13
14



X vs λ Calibration Curve of Hg for Order 2
Recorded Data Point
Interpolated Points
700
650
600
550
500
450
400
22
24
26
28
30
Wavelength λ (nm)
Linear Distance from the Slit X (cm)



θ vs λ Calibration Curve of Hg for Order 1
Recorded Data Point
Wavelength λ (nm)
Angular Distance from the Slit θ (°)
700
650
600
550
500
450
400
−4
−3
−2
−1
0
1
2


θ vs λ Calibration Curve of Hg for Order 2
Recorded Data Point
Wavelength λ (nm)
Angular Distance from the Slit θ (°)
700
650
600
550
500
450
400
−8
−6
−4
−2
0
2
4