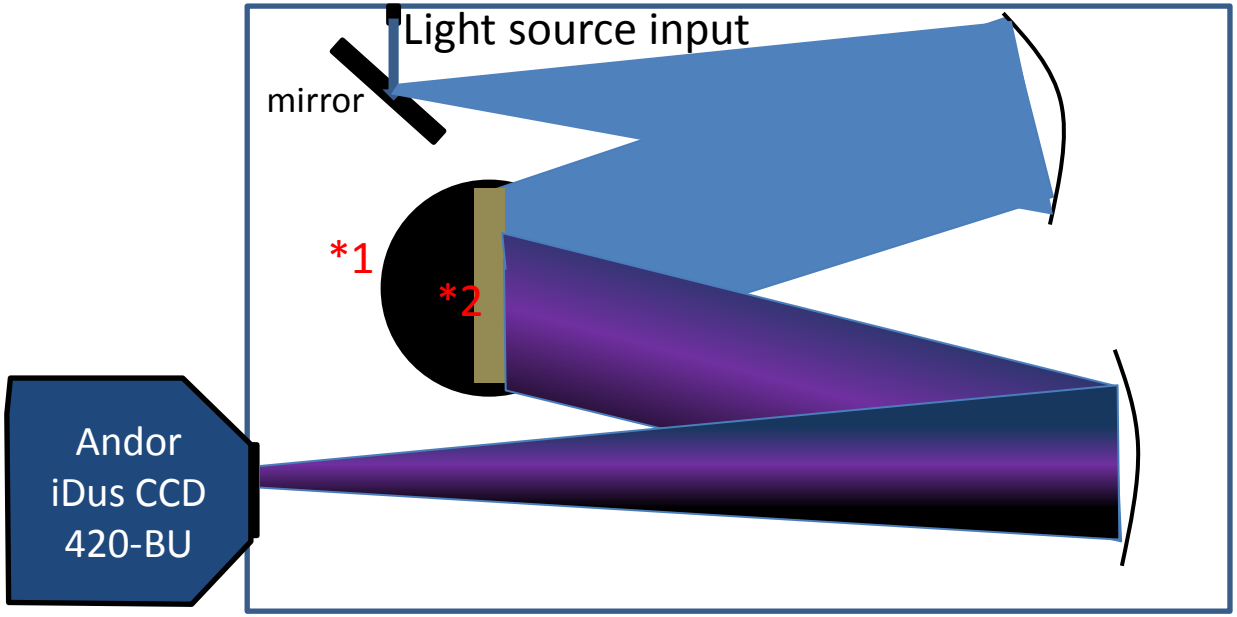
iDus UV-VIS Spectrometer

Specification

Basic Components of UV-VIS Spectrometer

- Andor iDus CCD 420-BU
- Newport plane Holographic reflection grating.*1
- PAT-001 rotational stepper motor. *2

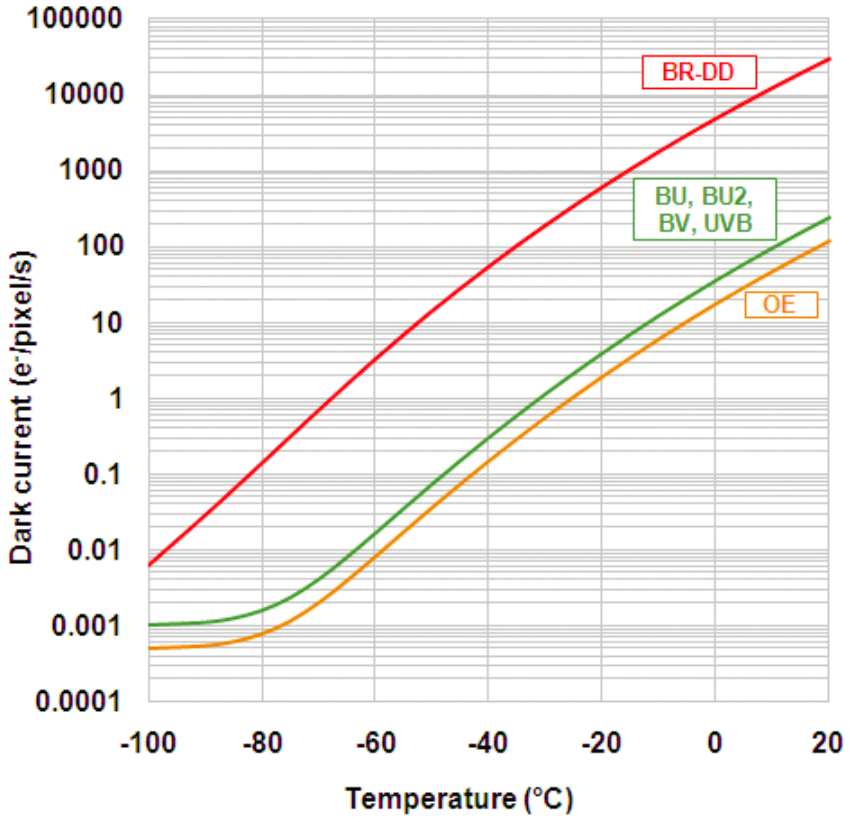


Specification of Andor iDus 420 BU CCD

Key Specifications

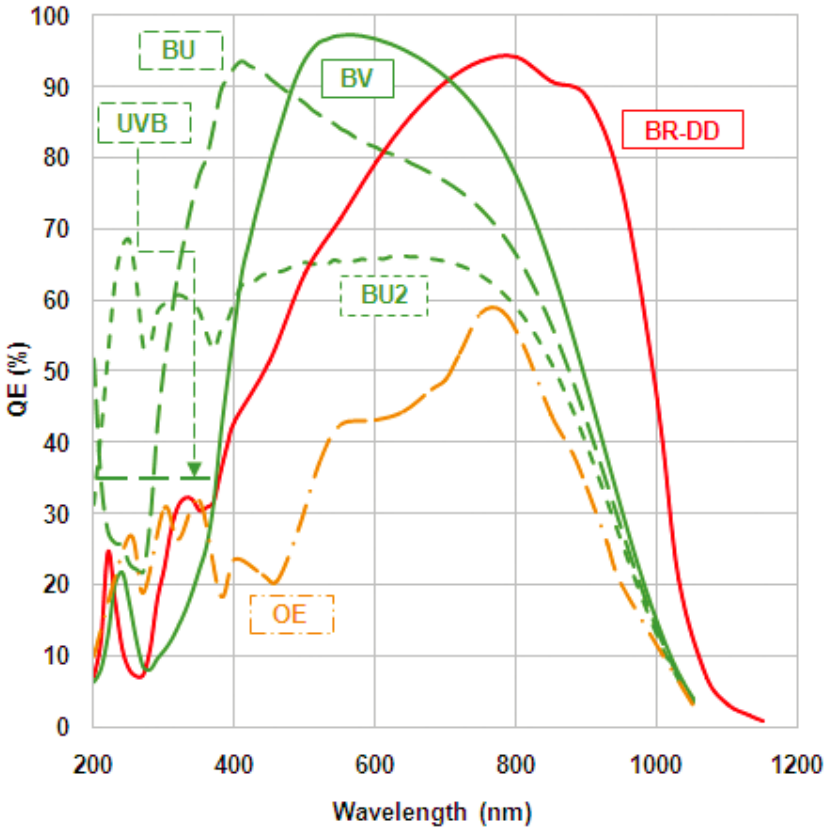
Model Number	DU420A series
Sensor option	BU:Back Illuminated CCD, UV enhanced, 350nm optimized
Active pixels	1024x255 pixels
Image area	26.6x6.6 mm
Maximum spectra per sec	88
Minimum temperature air cooled	-80˚C
Minimum temperature coolant chiller @10˚C	-100˚C

Dark Current

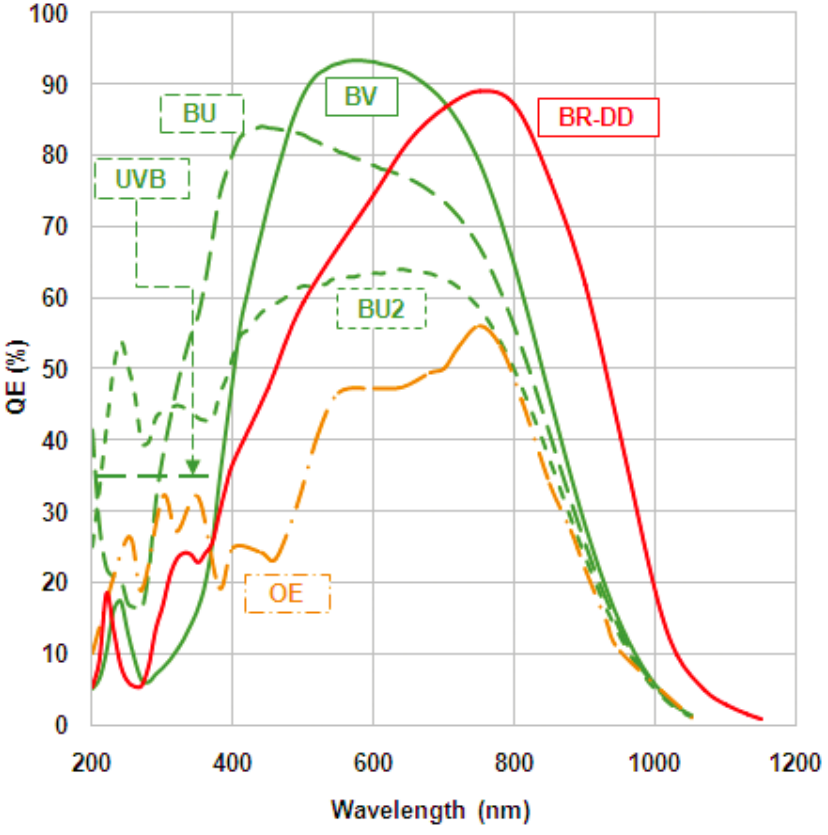


Quantum Efficiency Curves of Andor iDus 420 BU CCD

20°C

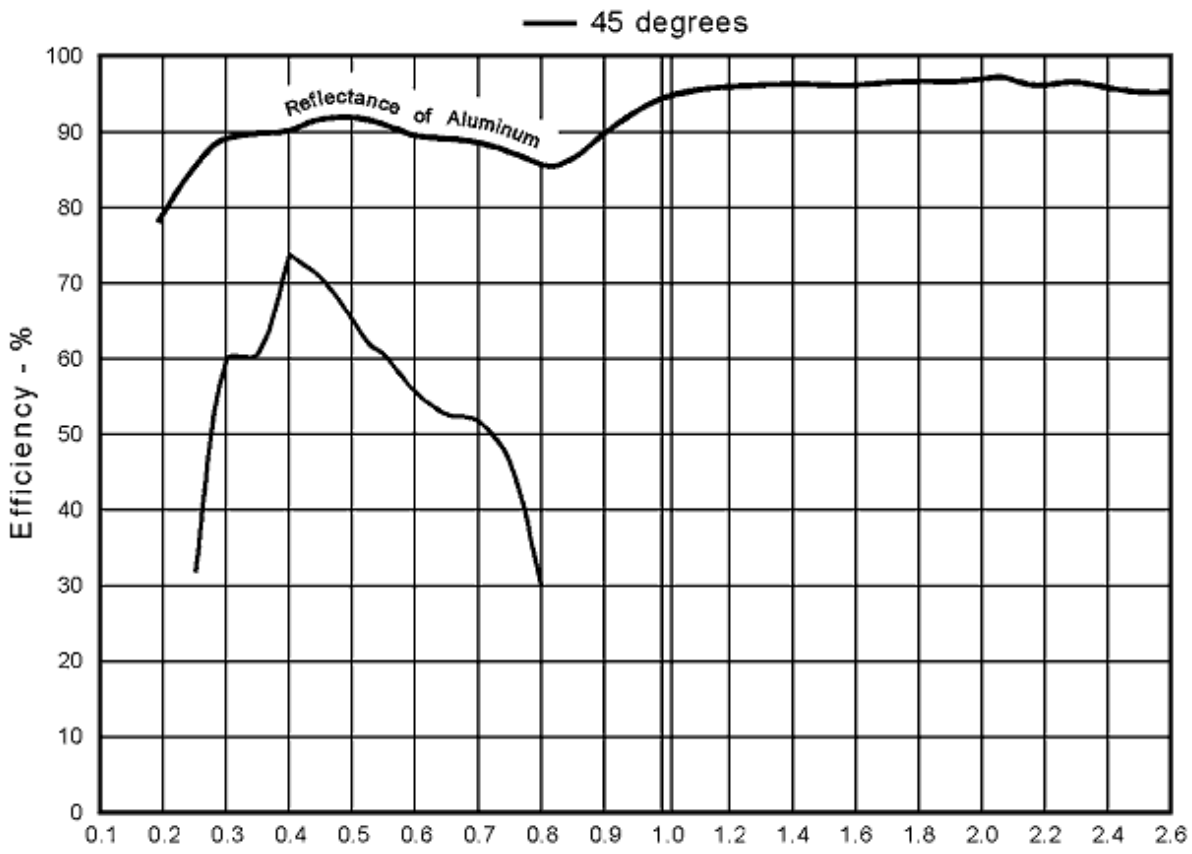


-100°C



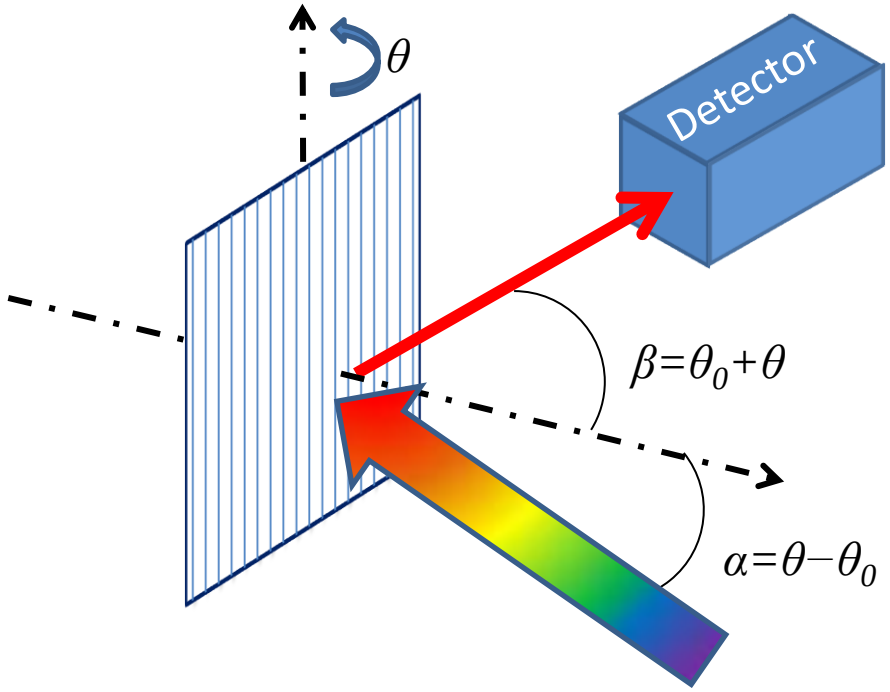
Newport Plane Holographic Reflection Grating

Catalog No.	20HG2400-400-1
Groove Frequency	2400 per mm
Dimensions	50x50x6mm
Blazed or Modulation	High modulation
Nominal Blazed Wavelength Tolarance	±25 µm
Coating	Aluminum
Spectral Region	250-600 nm
Max efficency	@ 400 nm



Calibration Protocal

Basic Grating Equations – for Center Wavelength



$$Gm\lambda = \sin\alpha + \sin\beta$$

G: Groove Density (Groove/nm) (eq.1)

m: Diffraction Order

$$\lambda = \frac{2}{G}\cos\theta_0 \sin\theta$$ (eq.2)

θ = angle rotated from $\alpha = \beta = \theta_0$

θ_0 = (Deviation Angle)入射光與出射光夾角的一半

= 同時也是Zero Order之角度

Center Wavelength Fitting

Pulse Number	Theoretical Position (nm)	Fitted Position (nm)	Difference (nm)
53495	0	0.033	-0.033
46343	253.652	253.617	0.035
44603	312.567	312.507	0.060
44585.5	313.17	313.091	0.079
43007	365.015	364.948	0.067
42992.5	365.484	365.417	0.067
42966.5	366.328	366.257	0.071
41753	404.656	404.923	-0.267
41664	407.783	407.716	0.067
40749	435.833	436.061	-0.228
38340	507.134	507.250	-0.116
36941	546.074	546.070	0.004
35770	576.96	577.005	-0.045
35693.5	579.066	578.975	0.091
33823	625.134	625.070	0.064

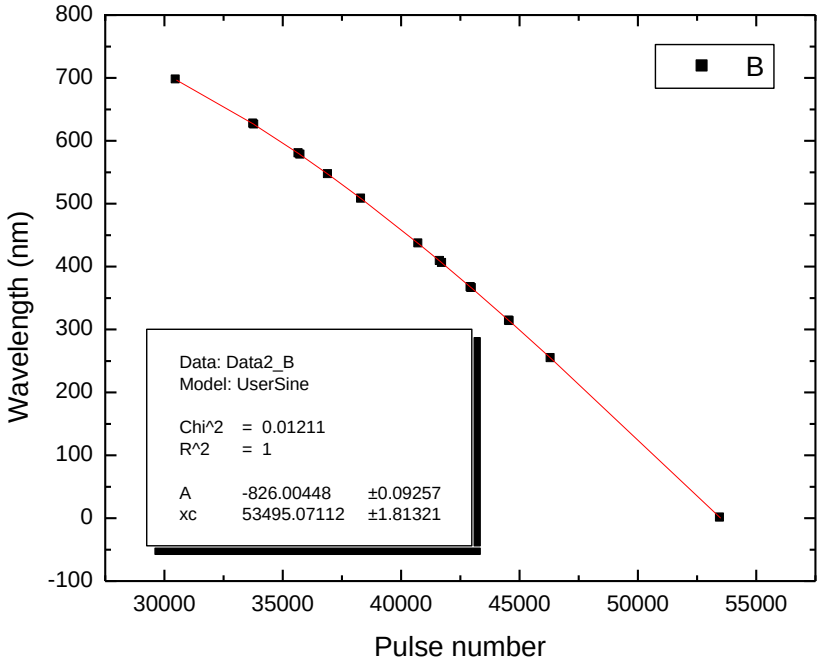
Pulse Number	Theoretical Position (nm)	Fitted Position (nm)	Difference (nm)
33773.5	626.31	626.234	0.076
33771	626.368	626.293	0.075
30502.5	696.5431	696.468	0.075
28649	730.03	730.059	-0.029
28599	730.968	730.900	0.068
28498	732.656	732.588	0.068
27378.5	750.3869	750.339	0.048
27306.5	751.4652	751.420	0.045
26652	760.3	760.904	-0.604
26467	763.5106	763.472	0.039
25794.5	772.498	772.388	0.110
22109	809.312	809.270	0.042
21959	810.3693	810.333	0.036
21789	811.5311	811.497	0.035
Standard Deviation (nm)			0.164

Fitting Process – I

•We transformed eq.2 into eq.3 to perform fitting in Origin

$$\lambda = A\sin\left(\frac{P - P_0}{72000} \times \pi\right) \quad \text{(eq.3)}$$

•We got –
A = -826.004 (nm)
P_0 = 53495.07112 (pulse)



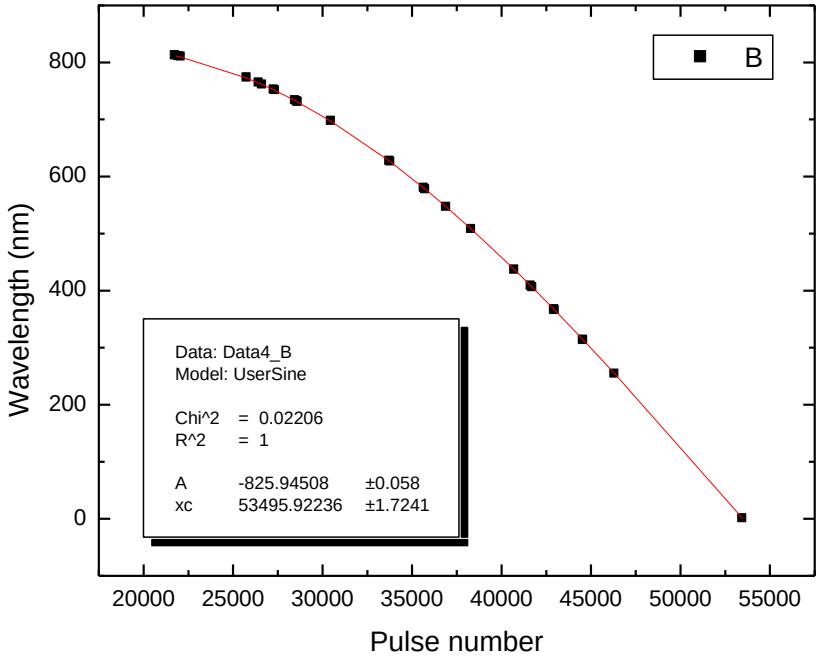
*首先鎖定較強的Peak位置365.016, 404.656...etc.
**由於所轉角度為負角度(順時鐘方向)，故有負號。
***Zero Order的pulse number為非整數的原是：由於Zero Order的Peak Position不容易確定(起初紀錄為最大值處)，故在Fitting時讓P_0也成為一個變數，誤差在1 pulse之內屬可以接受範圍，因此為非整數。

Fitting Process – II

•透過原先的Fitting將較弱的Peak位置補齊，同時確認並建立CAL-2000的Data Base

$$\lambda = A\sin\left(\frac{P - P_0}{72000} \times \pi\right) \quad \text{(eq.3)}$$

•We got –
A = -825.94508 (nm)
P_0 = 53495.92236 (pulse)



*事後讓Center Wavelength回到零點時，而第512個pixel落在整個Zero Order Peak的中心。以此確認Zero Order的Pulse Number為非整數的效果。

Equation for Fitting to Deviation Angle

•從eq.3我們利用Fitting得出 A = -825.94508, P_0 = 53495.92236

$$\lambda = \frac{2}{G}\cos\theta_0 \sin\theta \quad \text{(eq.2)} \Rightarrow \lambda = A\sin\left(\frac{P - P_0}{72000} \times \pi\right) \quad \text{(eq.3)}$$

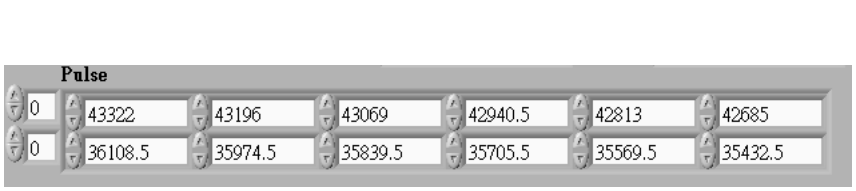
•由上我們得知，因此可以算出Deviation Angle θ_0。(即JY所述之Ebert Angle)

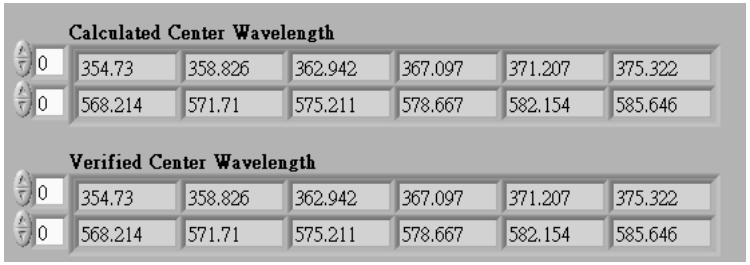
$$A = \frac{2}{G}\cos\theta_0 \quad \text{(eq.4)} \Rightarrow \theta_0 = 7.635^\circ$$

Dispersion Angle – I

•透過改變Center Wavelength，用以將365.016以及576.96這兩個Peak分別定於CCD上12、212、412、612、812以及1012 pixel的位置，並記錄每個位置對應到的Grating轉動的Pulse Number。

•在計算Dispersion以及Focal Length時之中心波長是由真實的Grating pulse position經由eq.2 or eq.3計算出來的結果。同時再以計算出之α、β值驗算中心波長的值、確保α、β以及程式正確。

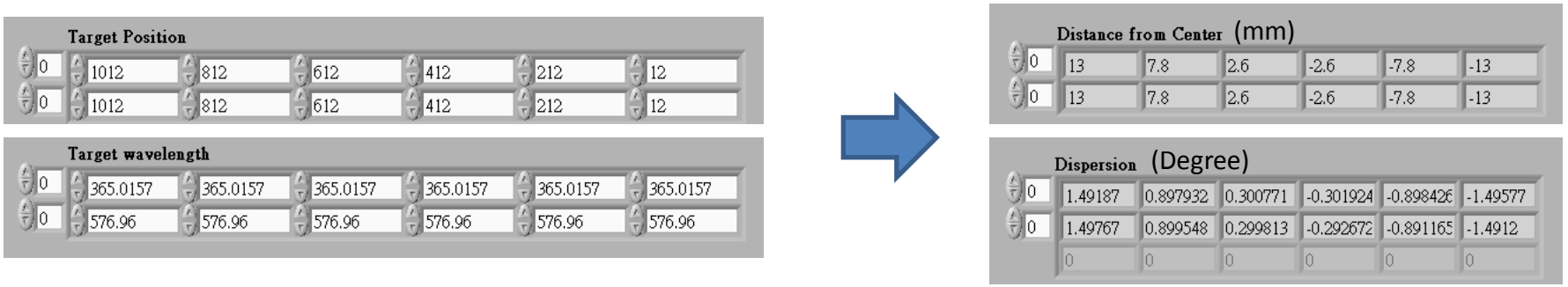




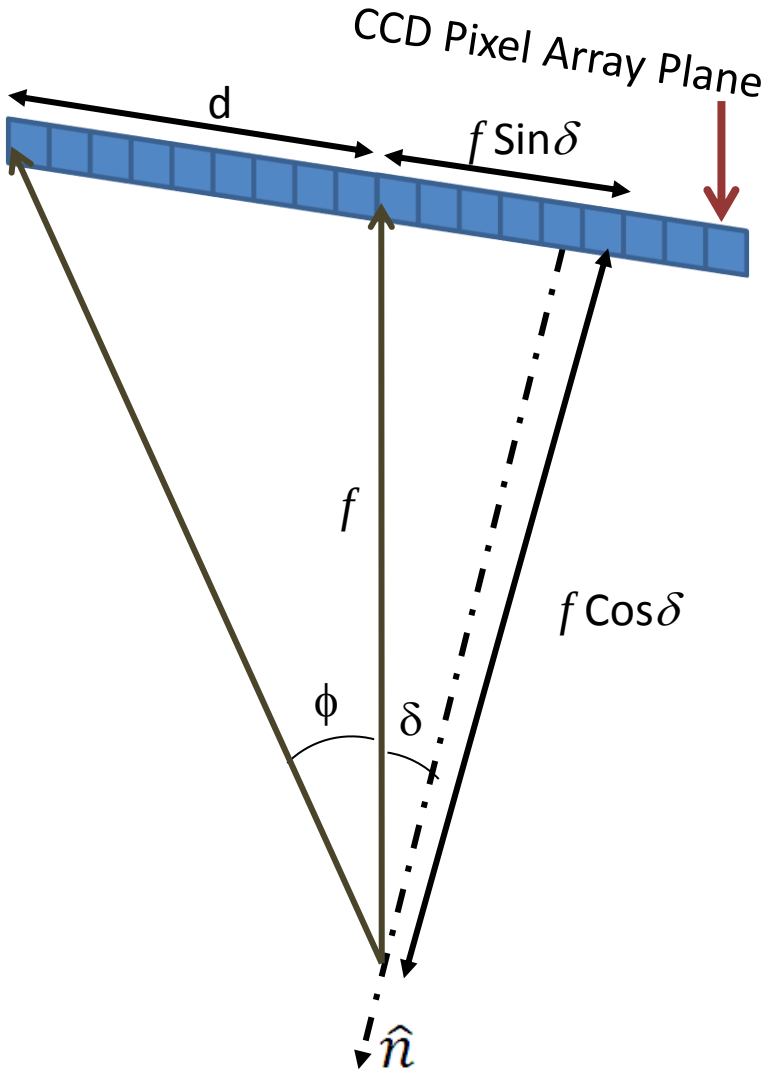
Dispersion Angle – II

- iDus每個Pixel之大小為26μm,故可計算Distance from Center Pixel
- 透過eq.1，我們可以回推估該pixel位置所對應之α、β值，而Dispersion Angle(ϕ_p)實為eq.5，其中β_c為中心波長對應的β值， β_p為某一pixel對應的β值

$$\emptyset_p = \beta_p - \beta_c \text{ (eq.5)}$$



Focus Length and Focal Plane Angle – Derived from Jobin Yvon Tutorial



•從左圖我們可以得到eq.6之關係

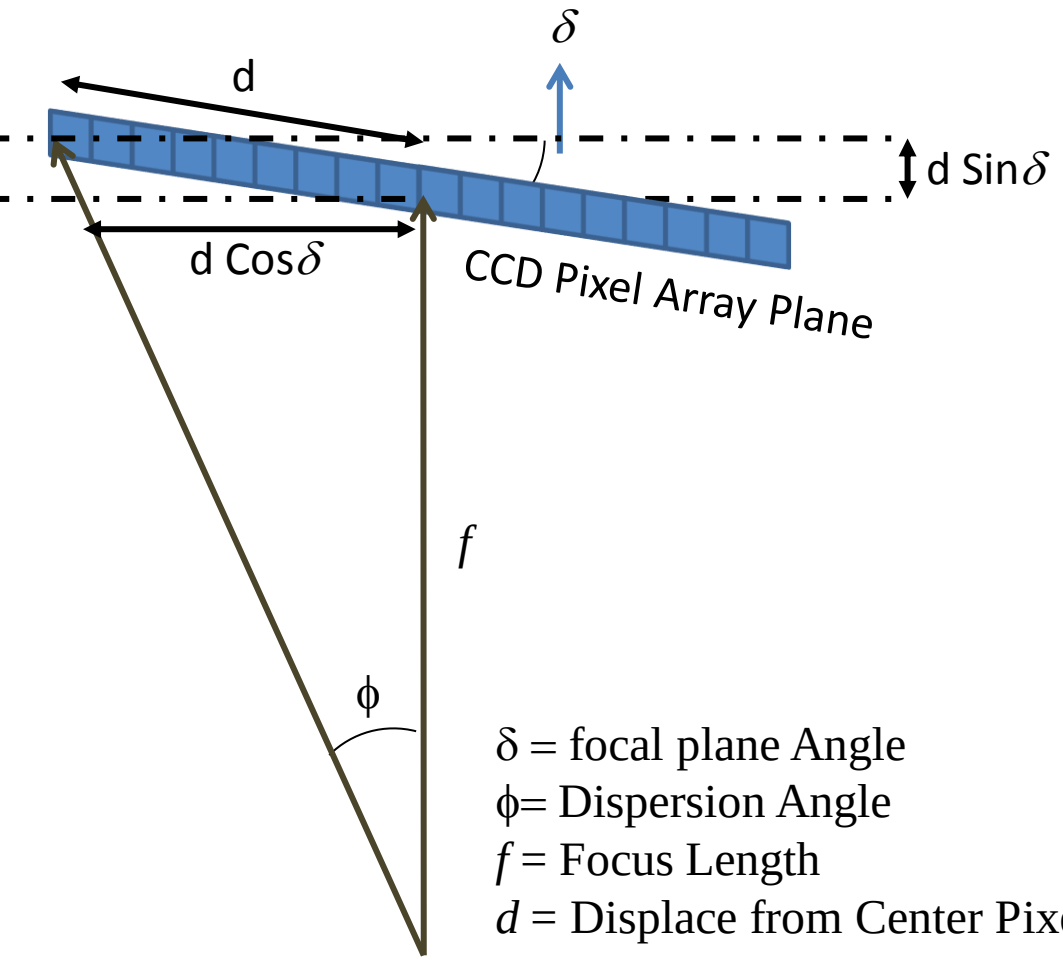
$$\tan(\emptyset + \delta) = \frac{d + f \sin\delta}{f \cos\delta} \quad \text{(eq.6)}$$

•因此，我們得到ϕ對f以及δ之關係，如eq.7，可做為後續fitting之用

$$\emptyset = \tan^{-1}\left(\frac{d + f \sin\delta}{f \cos\delta}\right) - \delta \quad \text{(eq.7)}$$

δ = focal plane Angle
ϕ= Dispersion Angle
f = Focus Length
d = Displace from Center Pixel

Focus Length and Focal Plane Angle – Our Lab



δ = focal plane Angle
ϕ= Dispersion Angle
f = Focus Length
d = Displace from Center Pixel

•從左圖我們可以得到eq.8之關係

$$\tan \emptyset = \frac{d \cos \delta}{f + d \sin \delta} \quad \text{(eq.8)}$$

•由此可計算Focus Length

$$f = \frac{d \cos \delta}{\tan \emptyset} - d \sin \delta \quad \text{(eq.9)}$$

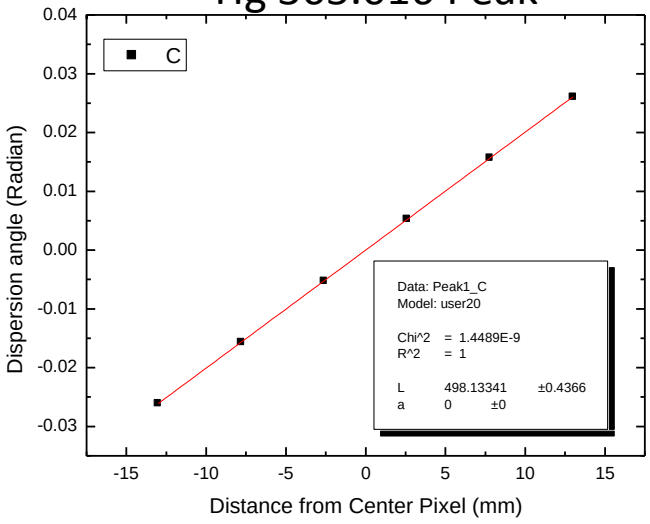
**相較之下，此看法得出之eq.8以及eq.9的形式較為簡單，方便用於直接計算focus length的值，若誤差很小時，則不需要fitting輔助。

Dispersion Angle to Focal Length

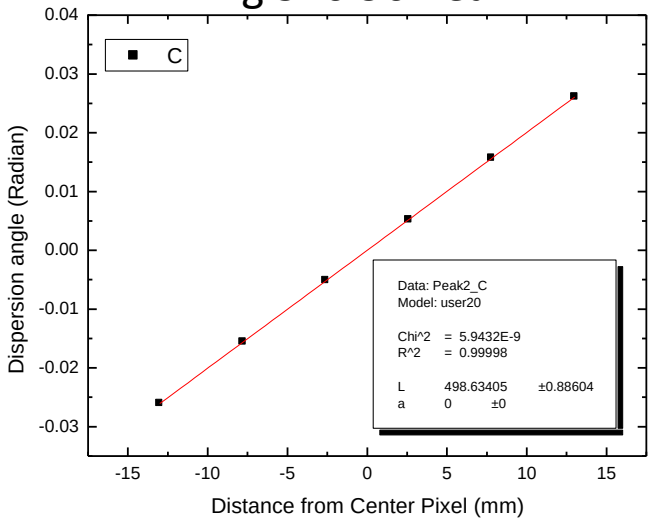
•上述二者所提出之方程式，為等價之方程式，因此用二者其中一項均可採用。先前不經徹底思考，因故採用eq.7。但後來覺得eq.8、eq.9的形式較簡單。

•透過程式搭配eq.1、eq.2得到的Dispersion Angle，加上離中心Pixel的距離，以eq.7做為fitting公式，我們得到：

Hg 365.016 Peak



Hg 576.96 Peak



•We got –

f_{365} = 498.133

f_{577} = 498.634

$\delta_{365} = \delta_{577} = 0$

*若以f_{577}之值取代f_{365}，則波長計算誤差約0.003nm

•由於小角度Dispersion為sin function的derivation，在β_c小時，造成的波長計算誤差較大，因此，設定f_{365}作為以下測試報告的Focal Length。

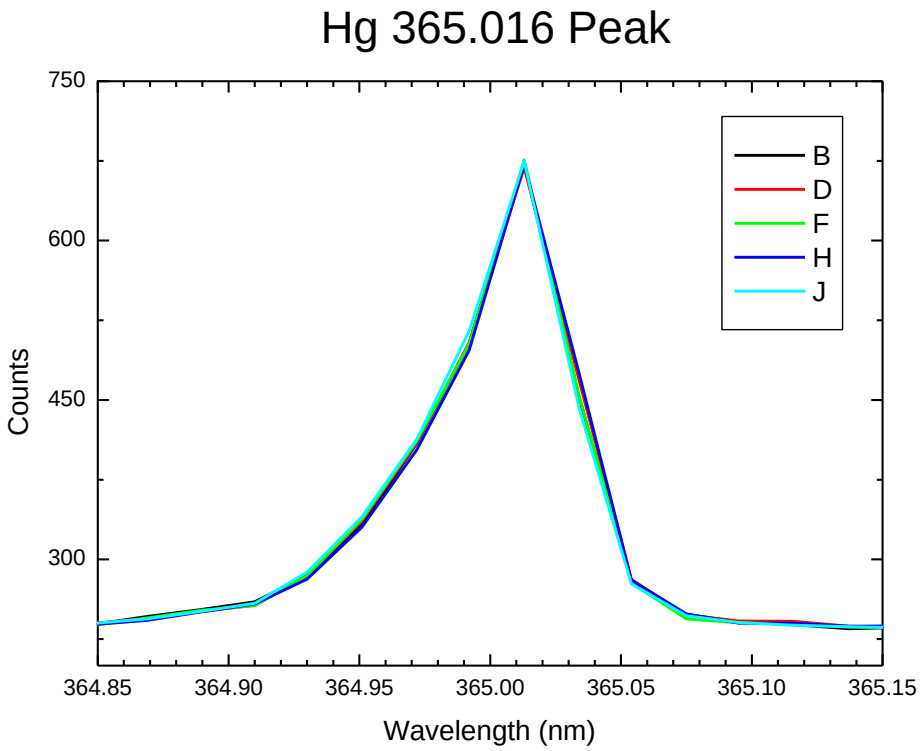
f = 498.133

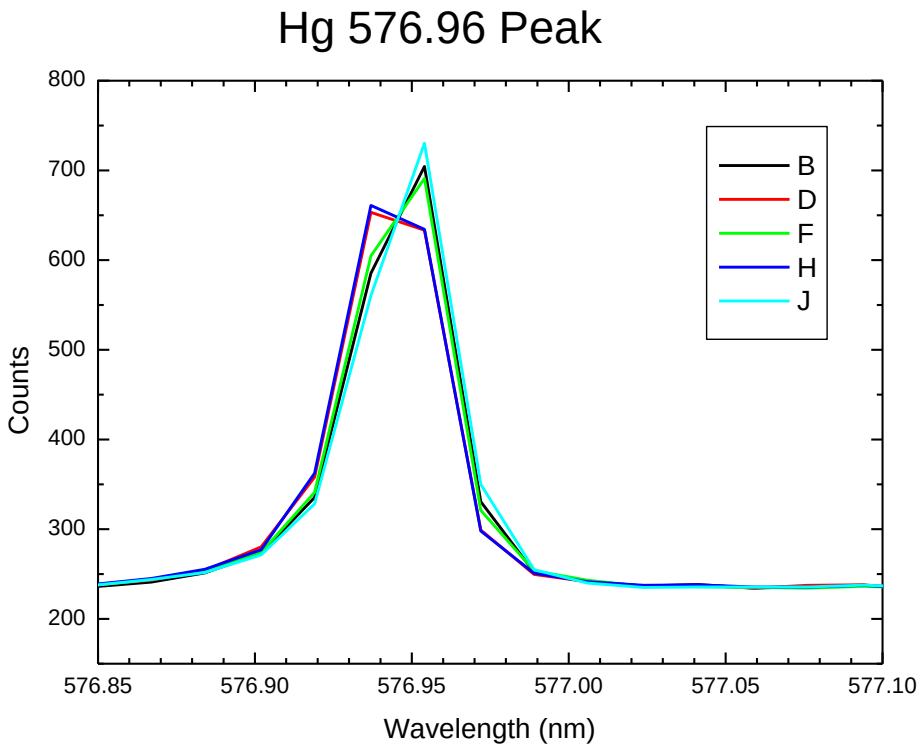
Test Report

Sample

- CAL-2000 Calibration Light Source with 8um fiber.
- Exposure : 100ms
- Average : 3 times

Repeatability



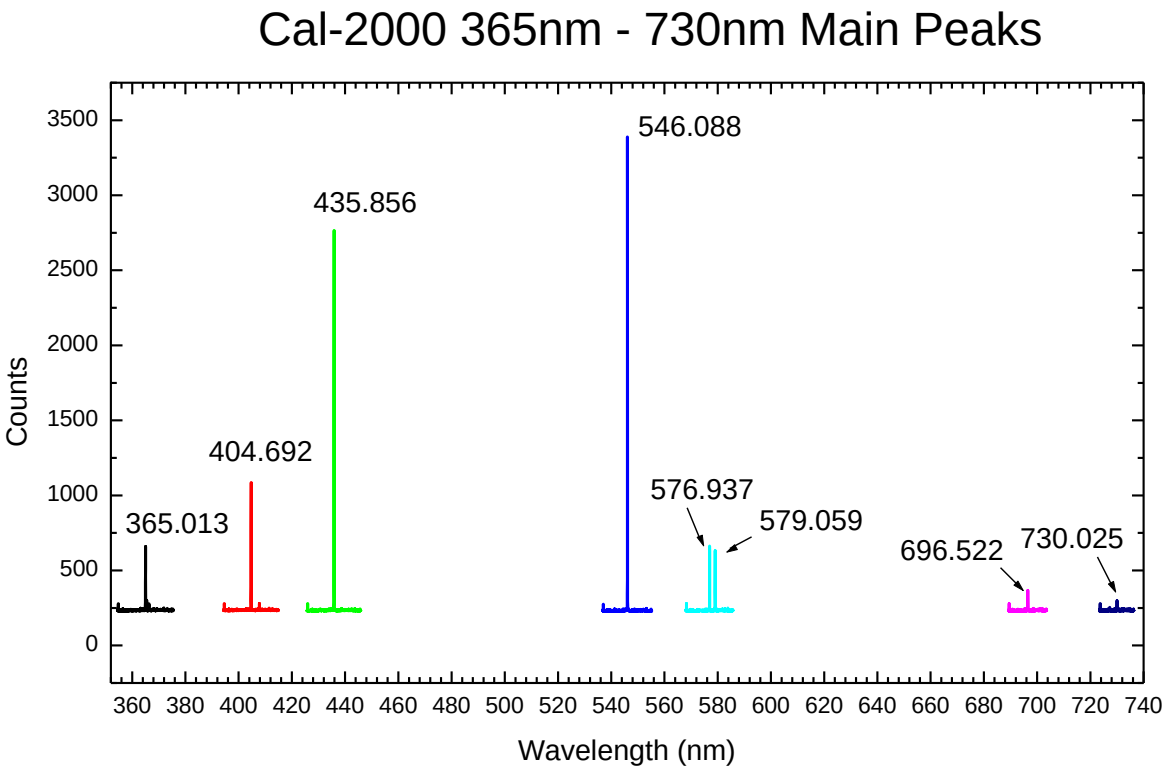


*中心波長為以下：

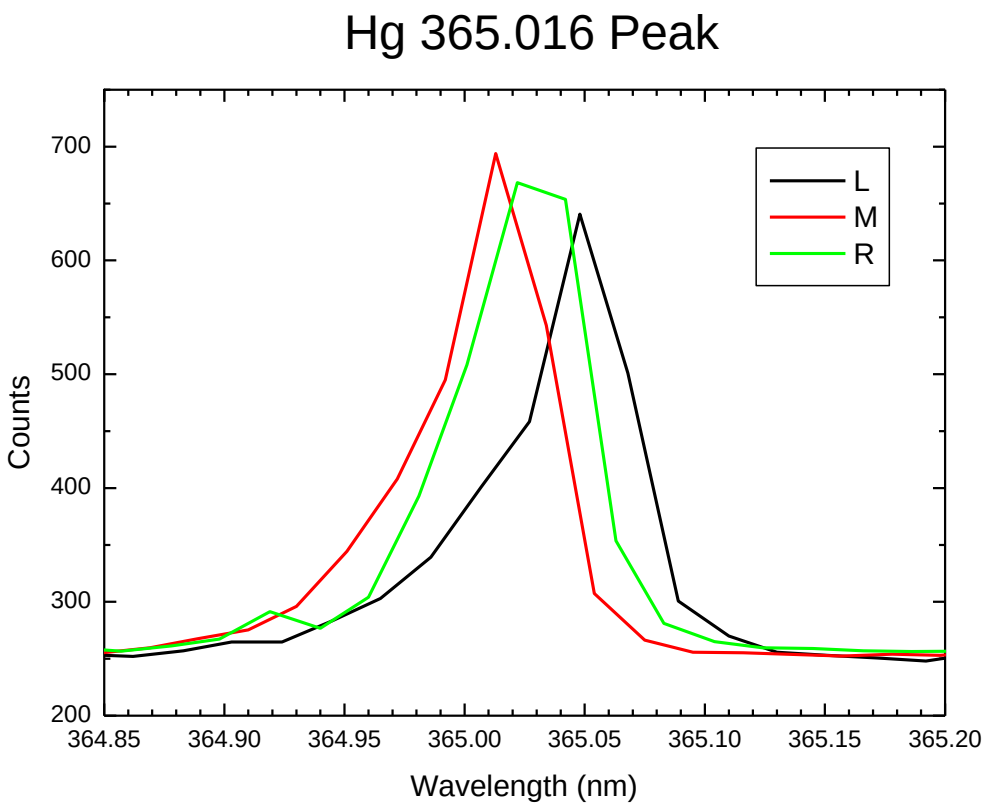
0 -> 365.016 -> 576.96 -> 700 -> 576.96 -> 365.016 -> 0 ->…

一直重複做出5組Data

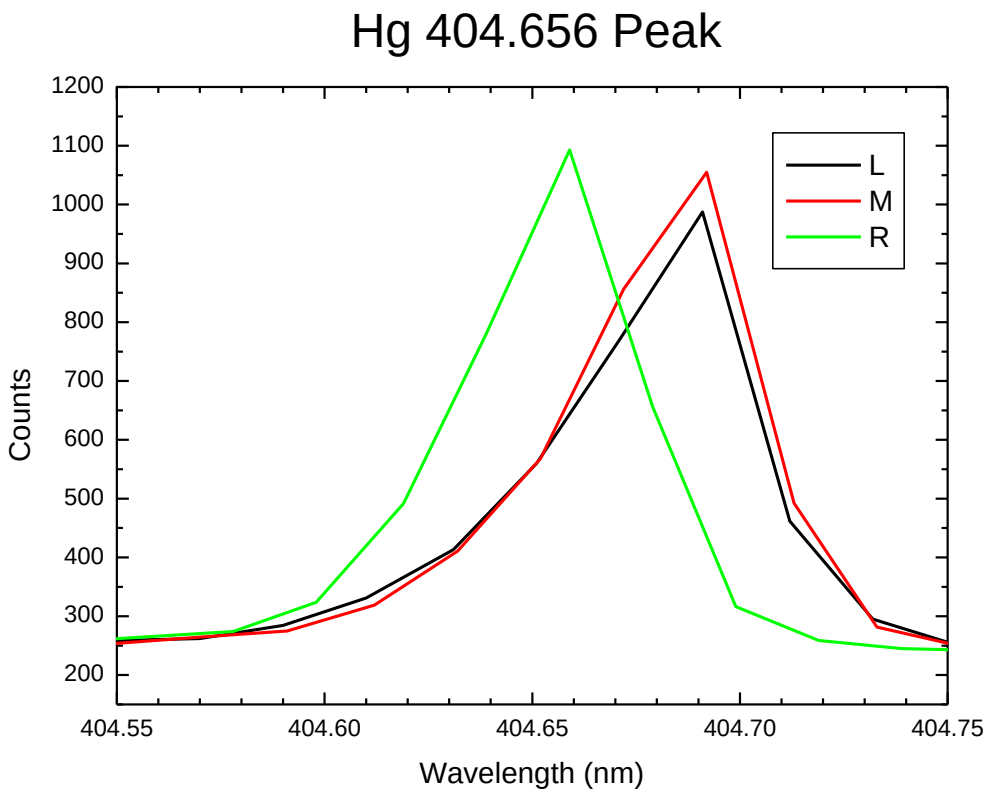
Linearity



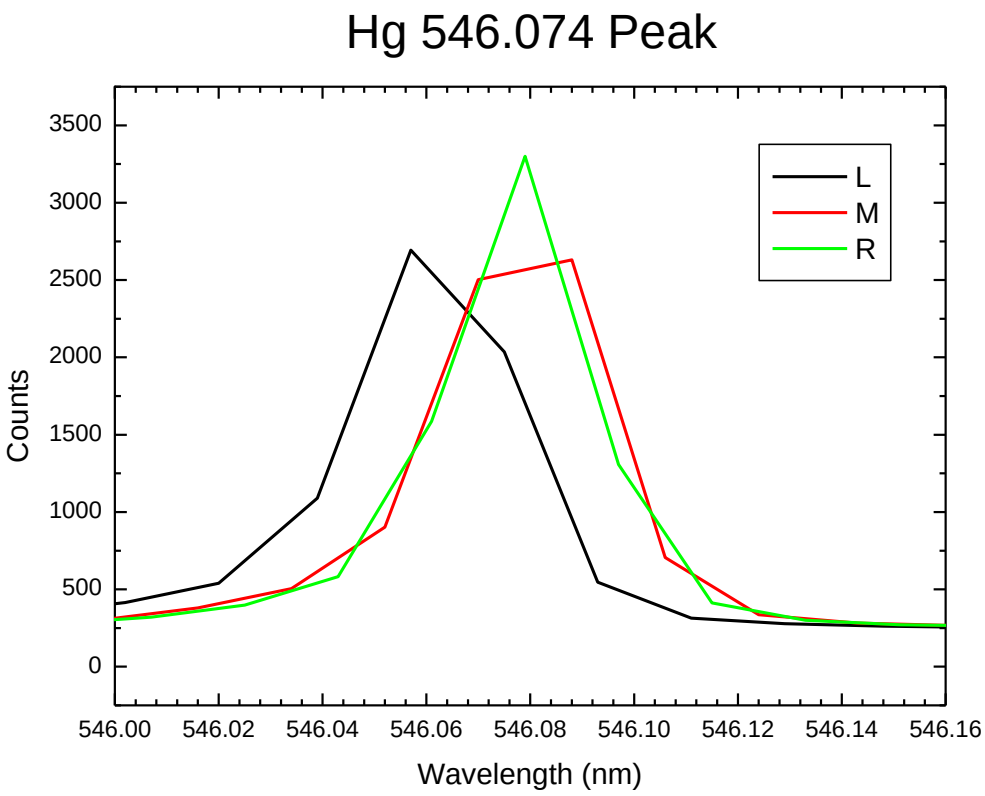
Reading	Theory	Difference
365.013	365.016	-0.003
404.692	404.66	0.028
435.856	435.833	0.023
546.088	546.074	0.014
576.937	576.96	-0.023
579.059	579.066	-0.007
696.522	696.543	-0.021
730.025	730.03	-0.005
Standard Deviation		0.019



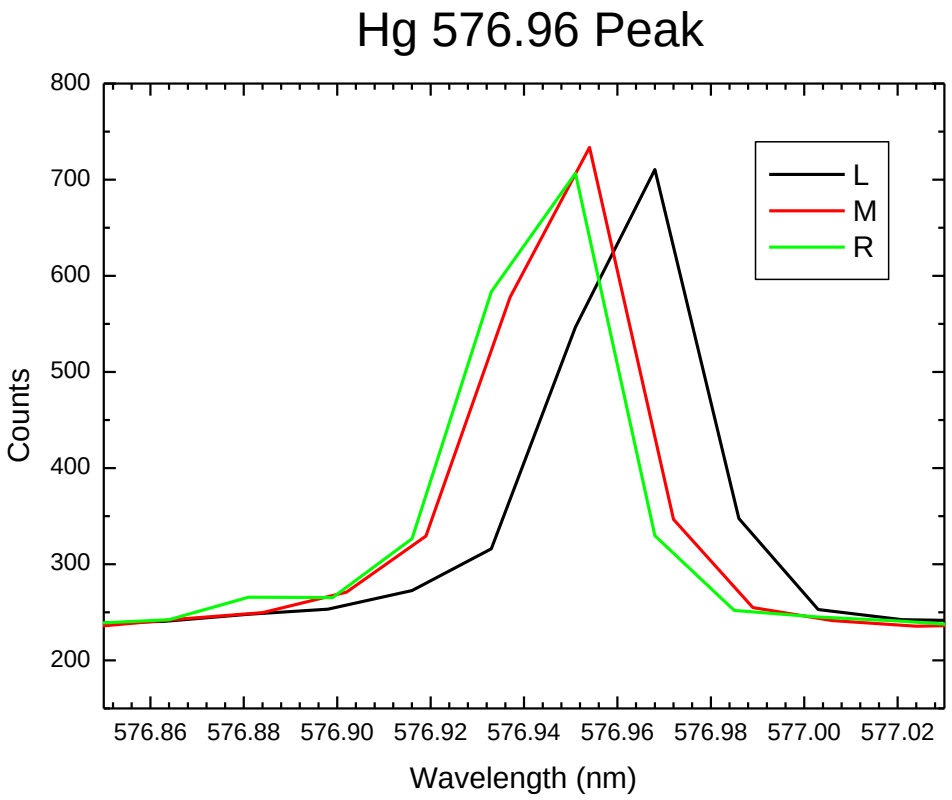
	Reading	Theory	Difference
L	365.048	365.016	0.032
M	365.013	365.016	-0.003
R	365.022	365.016	0.006
	Standard Deviation		0.018



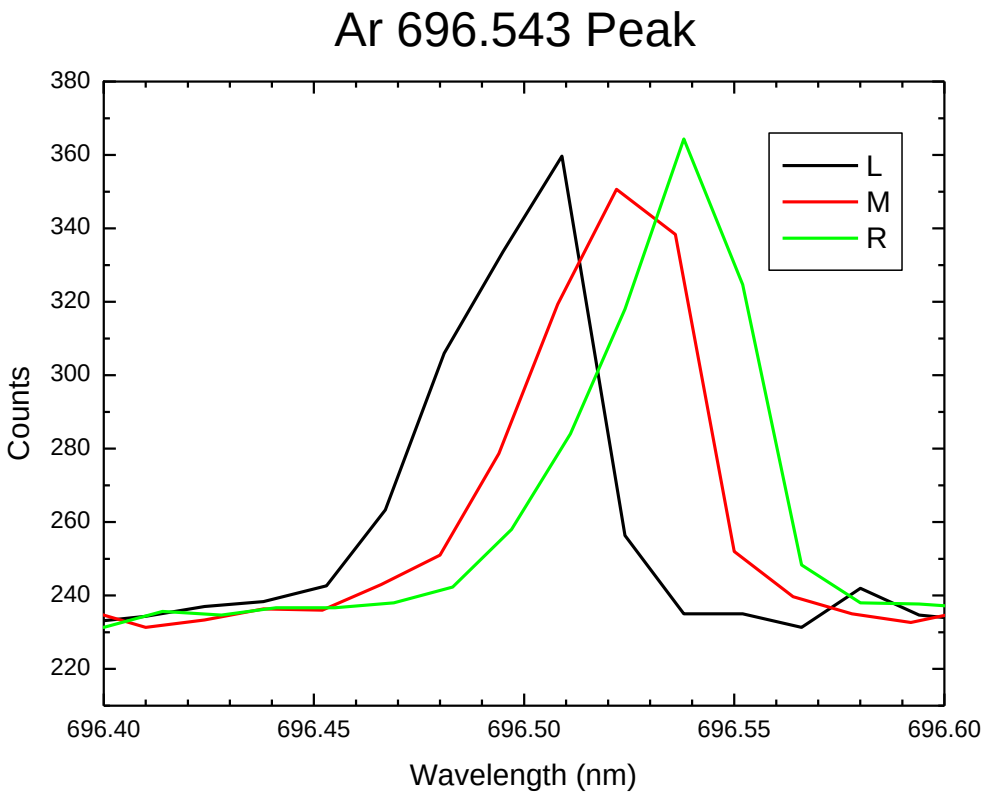
	Reading	Theory	Difference
L	404.691	404.656	0.035
M	404.692	404.656	0.036
R	404.659	404.656	0.003
	Standard Deviation		0.019



	Reading	Theory	Difference
L	546.057	546.074	-0.017
M	546.088	546.074	0.014
R	546.079	546.074	0.005
	Standard Deviation		0.016

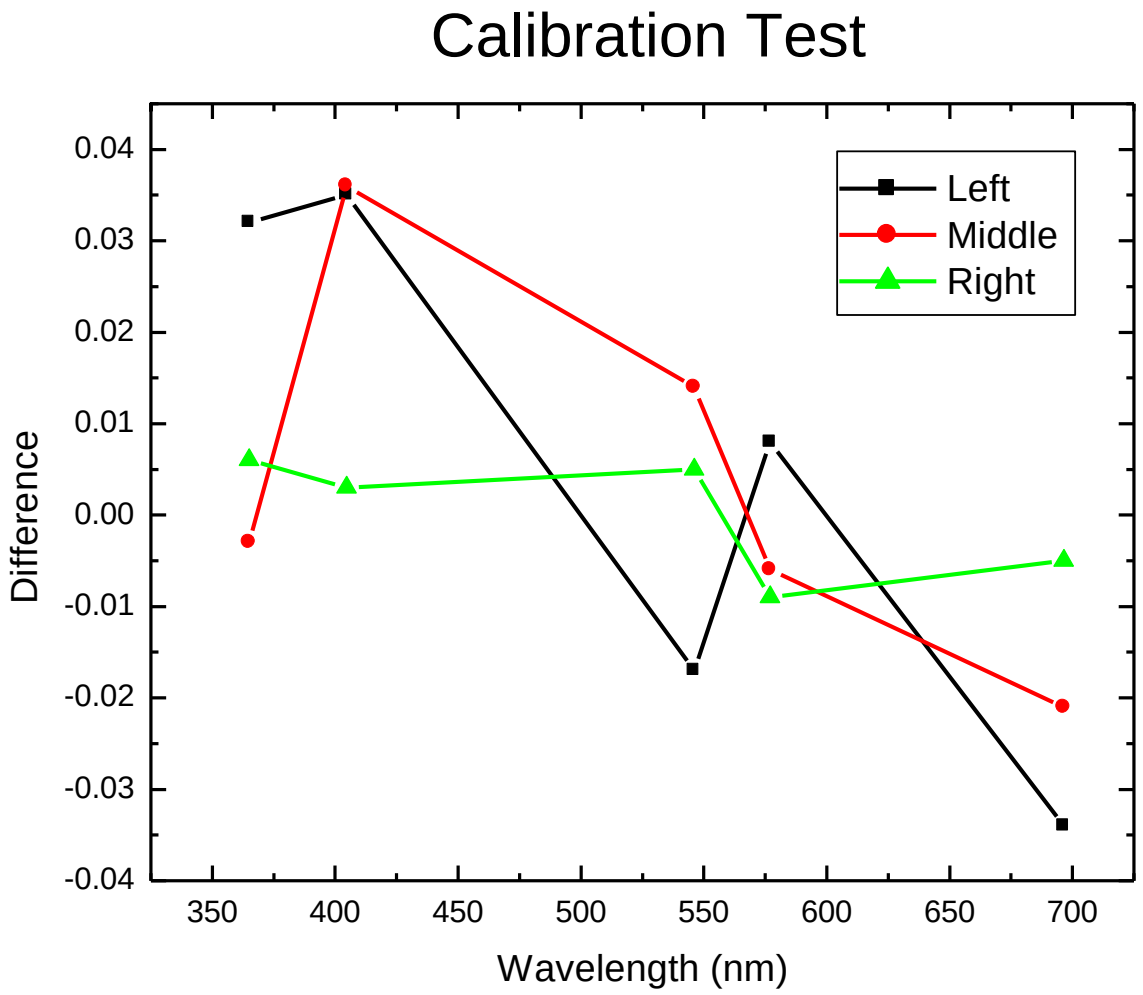


	Reading	Theory	Difference
L	576.968	576.96	0.008
M	576.954	576.96	-0.006
R	576.951	576.96	-0.009
	Standard Deviation		0.009



	Reading	Theory	Difference
L	696.509	696.543	-0.034
M	696.522	696.543	-0.021
R	696.538	696.543	-0.005
	Standard Deviation		0.014

Calibration Error v.s. Wavelength



Resolution

Peak Position (nm)	Left (nm)	Right (nm)	FWHM (nm)
365.016	364.982	365.041	0.059
404.656	404.657	404.707	0.05
546.074	546.043	546.081	0.038
576.96	576.93	576.965	0.035
696.543	696.499	696.544	0.045