09:00~10:10	實驗講解、DEMO	
10:20~11:10	研究簡介：臭氧洞成因	
11:20~12:10	實驗實作 ＋實驗室參觀	分兩組

實驗實作

光的偏振： LCD screen Exp + photodetector Exp

氣體放電與平均自由徑：放電球 EXP + 低真空放電 EXP

CD光柵光譜儀

氧氣液化與磁性

光的偏振

§光是電磁波，具有來回震盪的電場與磁場。

§光是橫波。若光束的行進方向為Z，則(在均勻介質中)其電場振動方向須與Z垂直，可能為X或Y方向，或任何X與Y的組合方向。**磁場呢?**

§電場振動的方向稱為光的偏振(polarization)。**磁場呢?**

§電場的來回震盪會引發物質中帶電粒子的振動；帶電粒子的振動會引發電磁波。例如

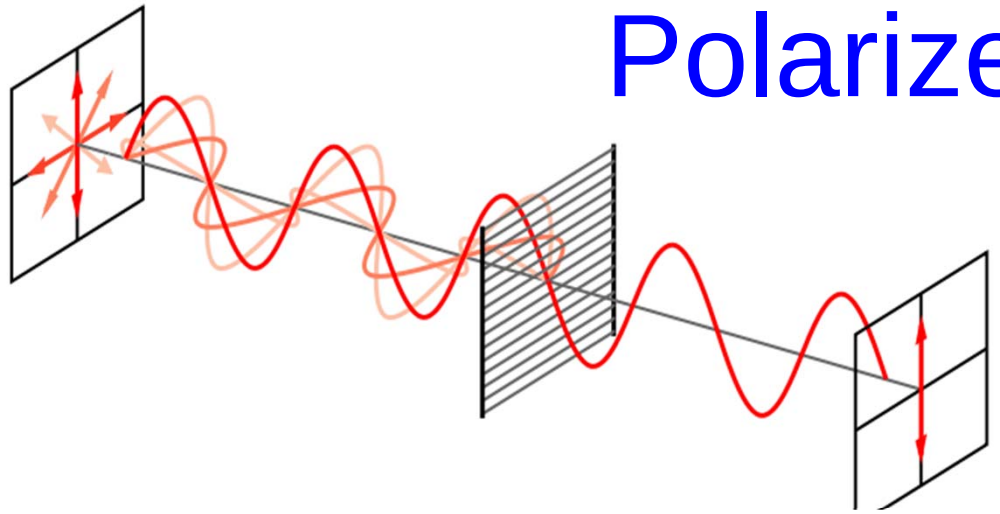
Wiki說：「當微粒的半徑足夠小（小於0.1λ），散射光線的強度與入射光線波長的四次方成反比，因此對於較短波長的散射程度要遠遠大於較大波長。這種散射規律是由英國物理學家瑞利勳爵（Lord Rayleigh）於1900年發現的，因此被稱作瑞利散射。」

Such that the sky is blue. 偏振方向=?

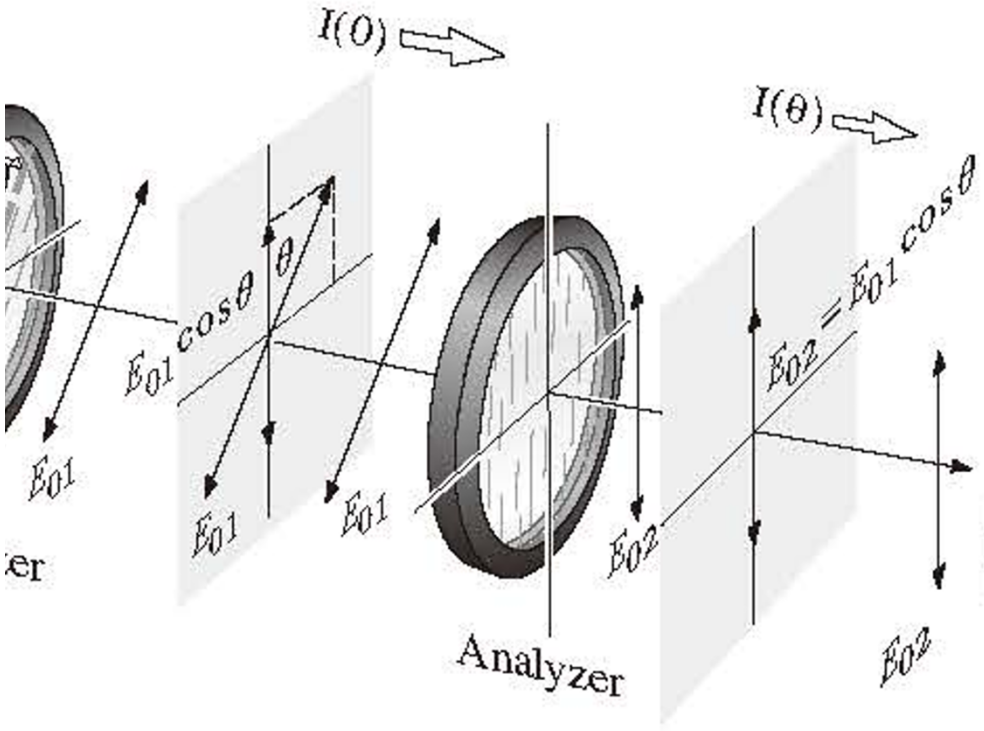
§Polarizer 偏振片：僅一個偏振方向的光可以穿透(另一個偏振方向的光呢? 能量去哪裡了?)

§透過偏振片看液晶螢幕及透明膠帶：神奇！
原理有些複雜，基本上是，雙折射介質(膠帶)能造成偏振方向的旋轉。

Polarizer



Allows only light polarized in certain direction to pass



$$E_{02} = E_{01}\cos\theta$$

$$I \propto \left|\vec{E}\right|^2$$

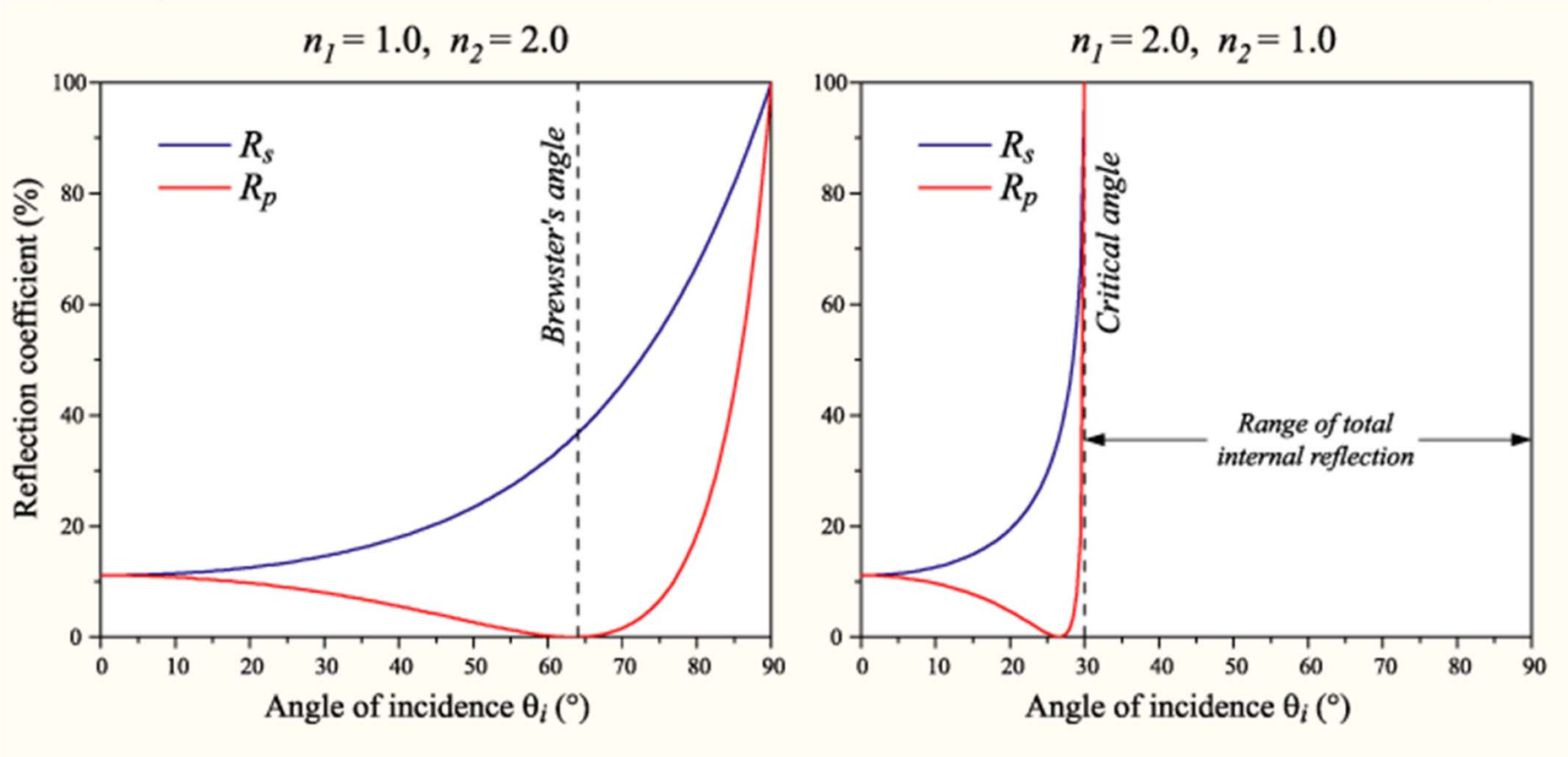
$$I(\theta) = I(0)\cos^2\theta$$

(Malus's law)

§透過偏振片看藍天：神奇！(原理有些簡單，記得光是橫波)

§某方向的偏振光在某角度附近，布儒斯特角（Brewster angle），的反射率很低。

原理有些複雜，先做觀察。



http://physics.stackexchange.com/questions/

Glow discharge & mean free path

氣體是絕緣體；

A glow discharge is a plasma (導電).

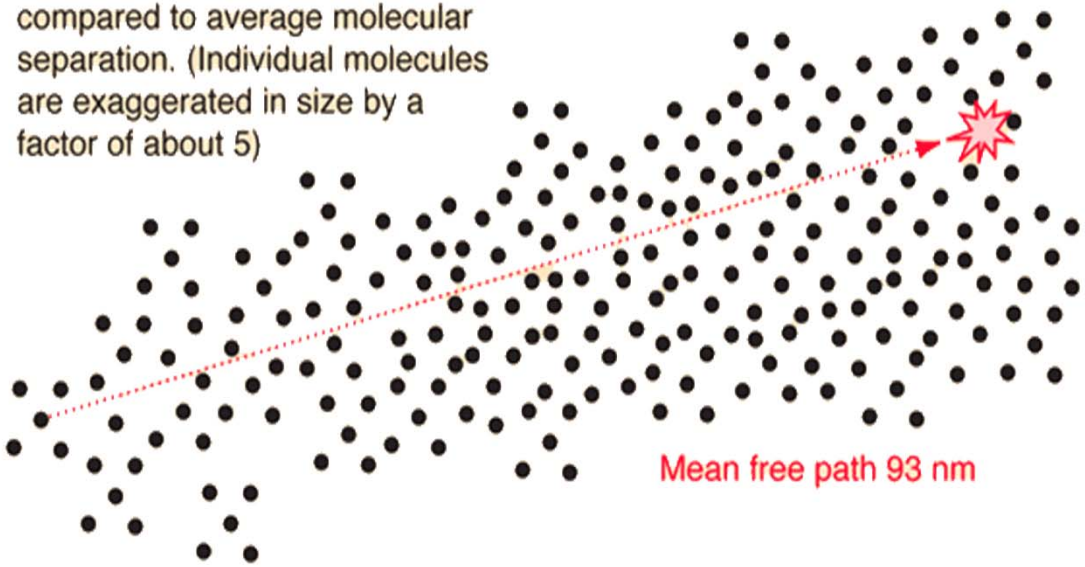
例：日光燈、省電燈泡、氖氣燈、、、

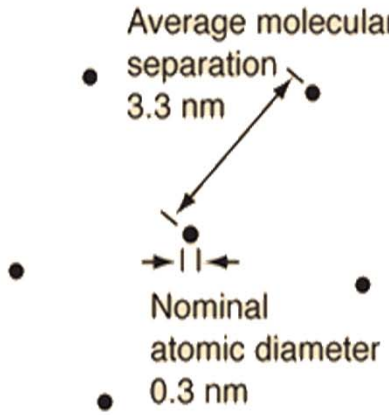
Wiki: The mean free path is the average distance traveled by a moving particle between successive impacts (collisions).

Model of an ideal gas at STP (760 mmHg pressure, 0C)

The mean free path is 310 times the nominal atomic diameter and 28 times the average molecular separation.

Perspective of mean free path compared to average molecular separation. (Individual molecules are exaggerated in size by a factor of about 5)





Perspective of molecular size compared to average molecular separation.

The average molecular separation is about 10x the atomic diameter.

TABLE I. Mean Free Path

Gas	Mean Free Path in millimeters*	
	For Molecule	For Electron In Gas
H_2	0.90	5.1
He	1.41	8.0
Ne	1.00	5.66
A	0.51	2.88
Kr	0.39	2.2
Xe	0.26	1.47
Hg	0.35 (100 μ, 82 C) 3.5 (10 μ, 47 C) 35.0 (1 μ, 18 C)	1.98 19.8 198.0

*Note: At 0 C and 100 microns (μ) pressure except as indicated

100 μ = 0.1 Torr

$$\lambda \propto 1/P$$

H H Wittenberg
Electron Tube Design, RCA Electron Tube Division, 1962, pages 792 - 817.

http://hyperphysics.phy-astr.gsu.edu/hbase/Kinetic/menfre.html

Potential energy change (ΔU) of a charged particle (q) between two collisions (mean free path = λ) in electric field (E)

$$\Delta U = q\vec{E}\cdot\vec{\lambda} \qquad \lambda \propto 1/P$$

下樓梯 small λ

跳樓 big λ

on earth *Vs*. on moon.

Using ΔU, a molecule (M) can be excited (M*) or ionized (M^+). Photon may be emitted from M*.

$M + e^- + (\sim 16\ \text{eV}) \rightarrow M^+ + 2\ e^-$:

# of charged particles: 1 → 3

$M + e^- + (\sim 9\ \text{eV}) \rightarrow M^* + e^-$; $M^* \rightarrow M + h\nu$

For the cylindrical electrodes,

E is higher at smaller radius (R), thus

$\Delta U = E\,\lambda$ is larger at smaller R.

$$E(R) \propto R^{-n}\,,\ n = ?\ \ 1?\ \text{or}\ 2?$$

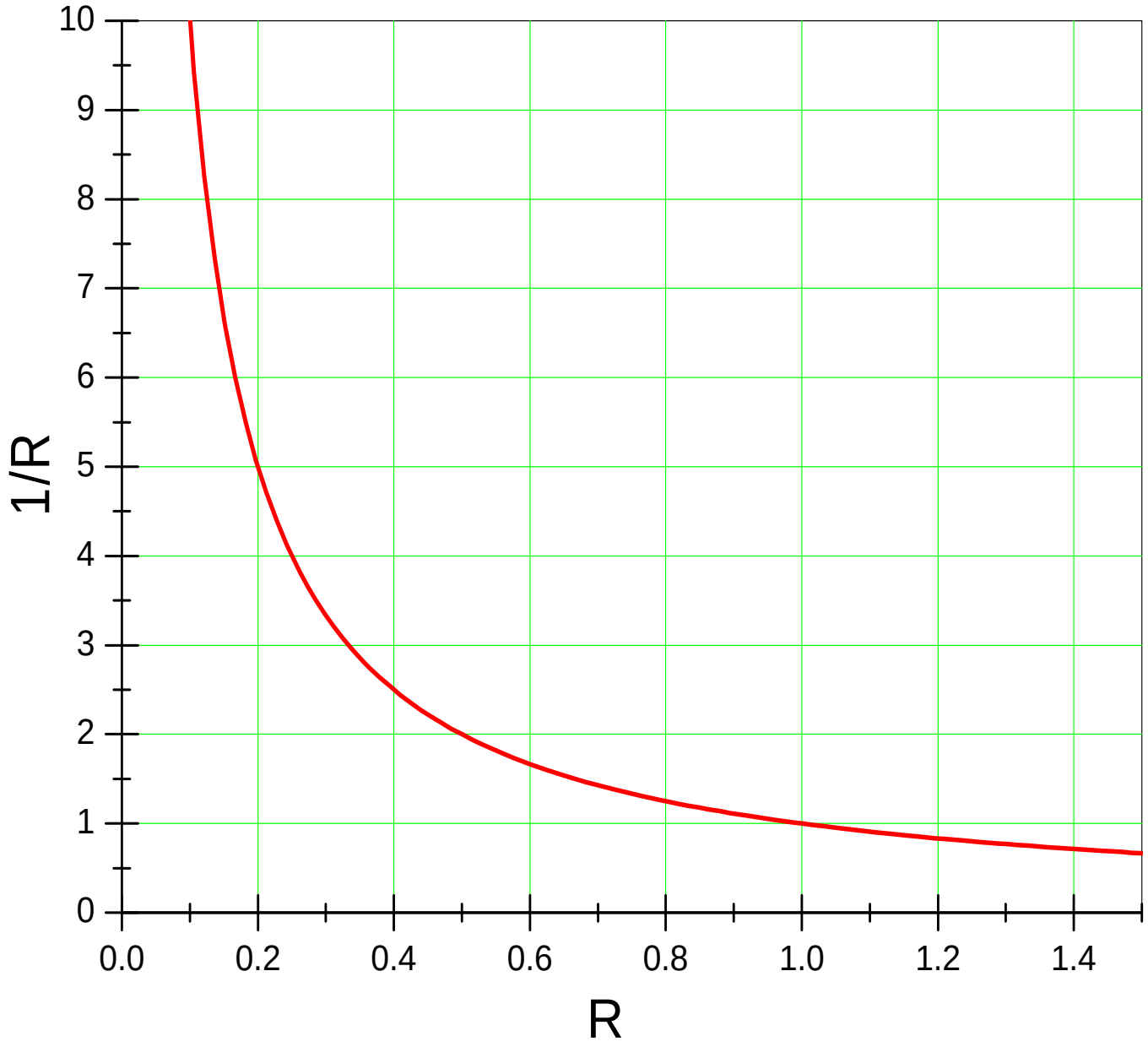
For exciting M to M*,

ΔU must be larger than a threshold value (ΔU_{min}),

$\Delta U = E(R)\,\lambda\ > \Delta U_{\text{min}}$; R has a limit value R_{lim}.

R_{lim} is smaller at smaller λ (higher P)

$\lambda \propto 1/P$


10
9
8
7
6
5
4
3
2
1
0
1/R
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
R

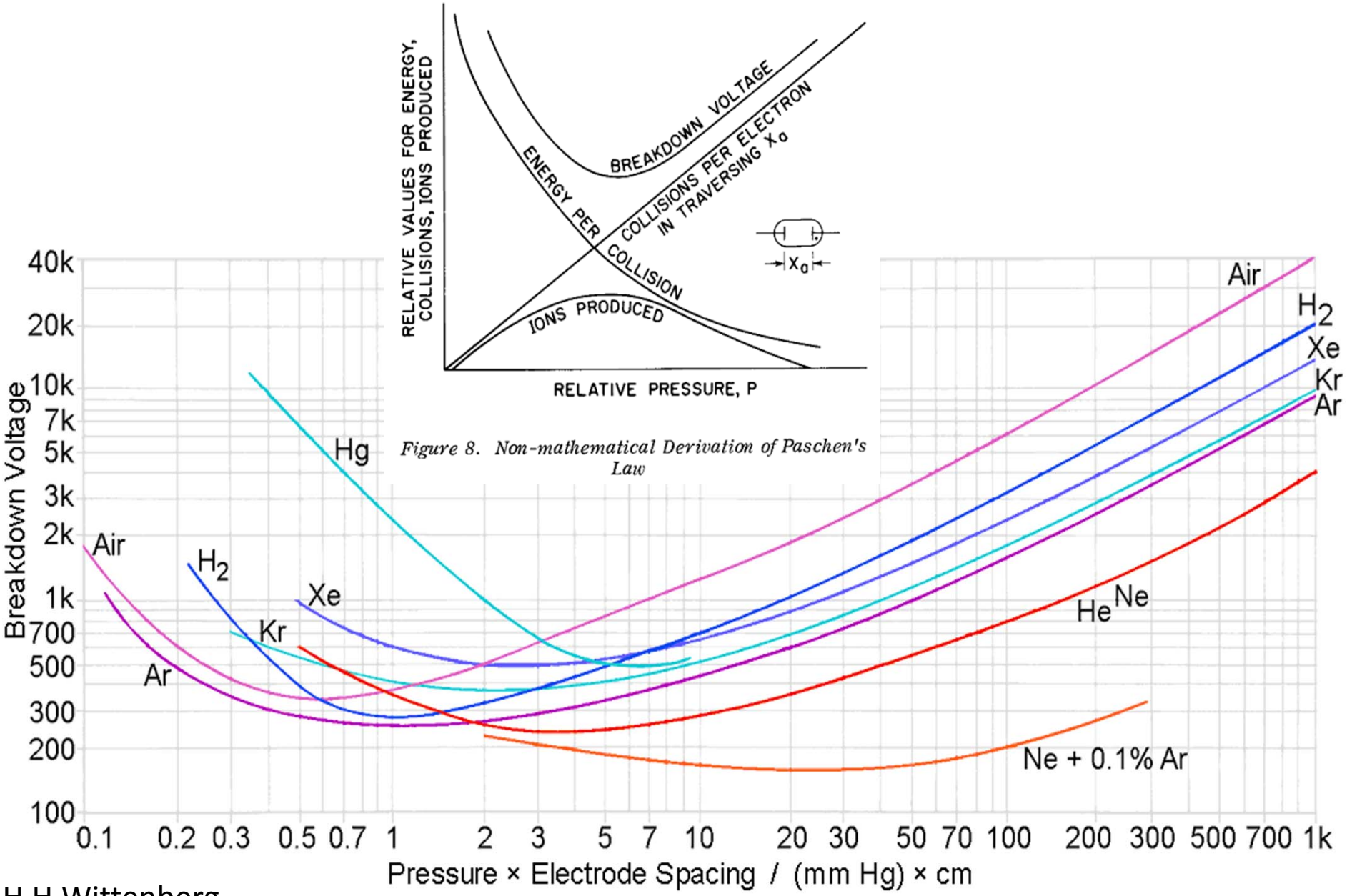
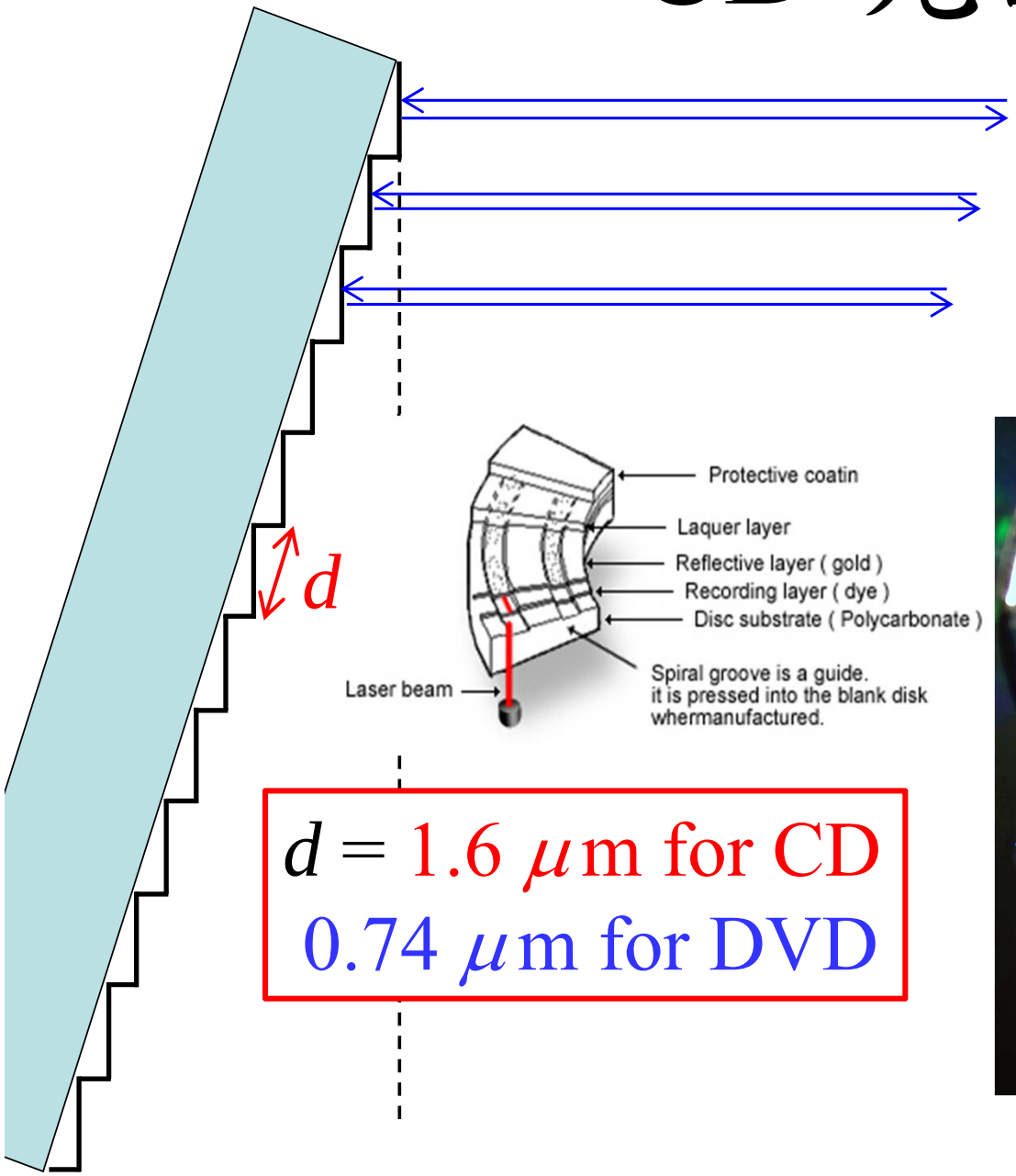


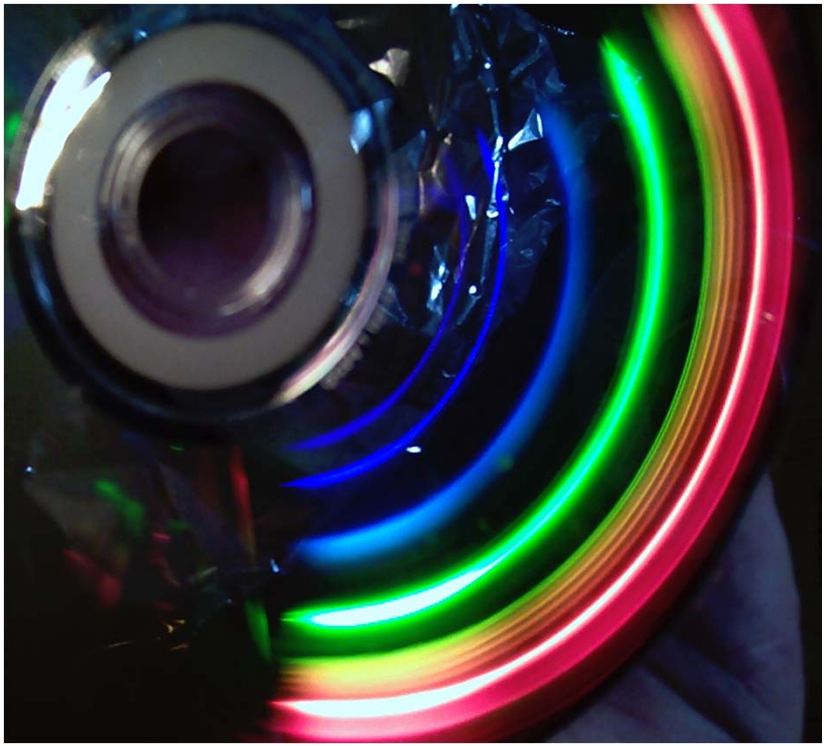
Figure 8. Non-mathematical Derivation of Paschen's Law

H H Wittenberg
Electron Tube Design, RCA Electron Tube Division, 1962, pages 792 - 817.
http://g3ynh.info/disch_tube/intro.html

CD 光譜儀



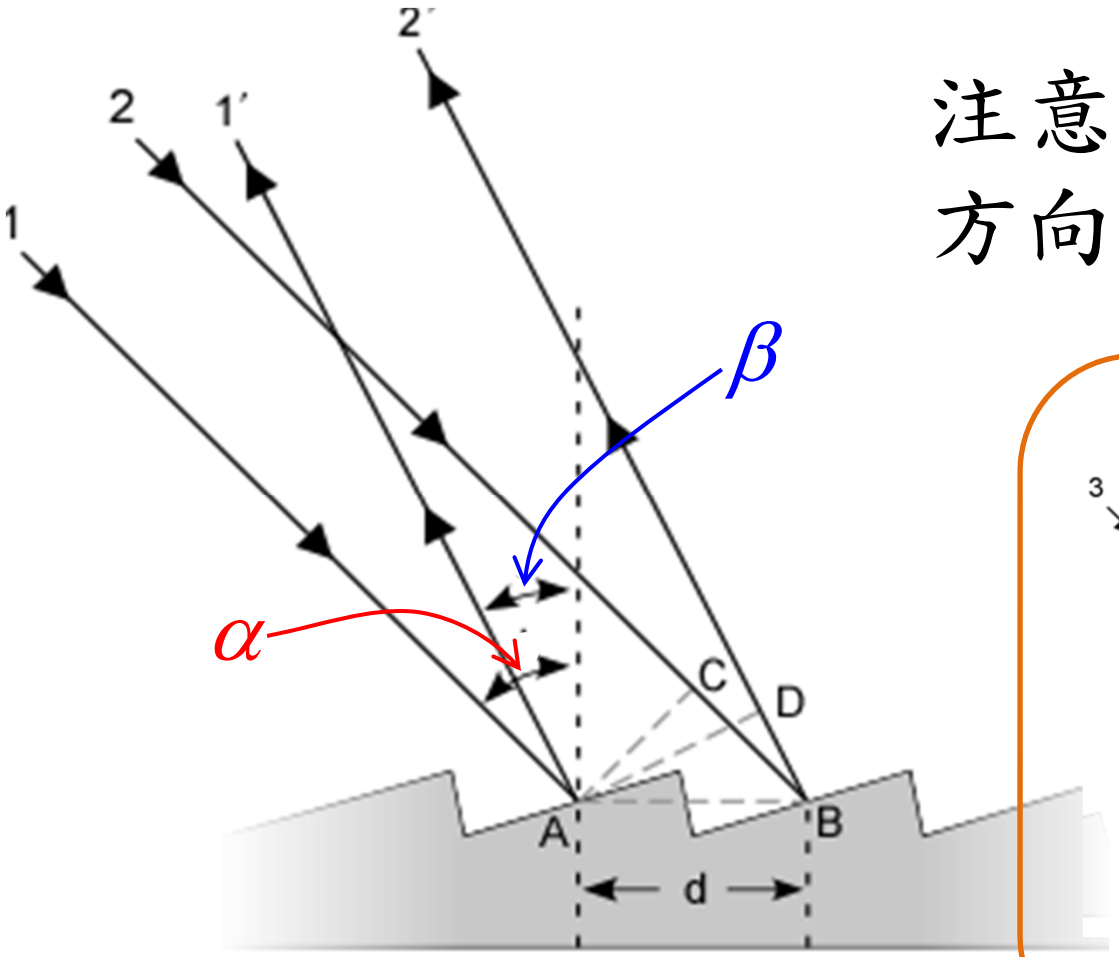
光柵之週期性結構，
造成週期性的光程差；
數千道等光程差的光
造成的建設性干涉



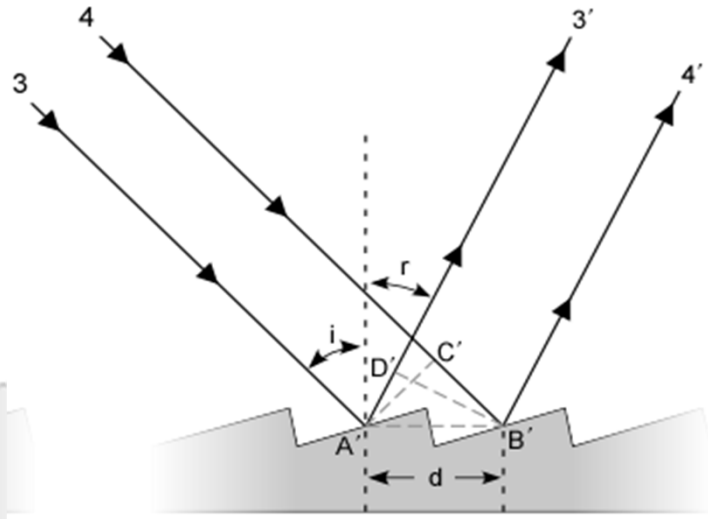
d = 1.6 μm for CD
0.74 μm for DVD

小台階的反射要遵守反射定律嗎？

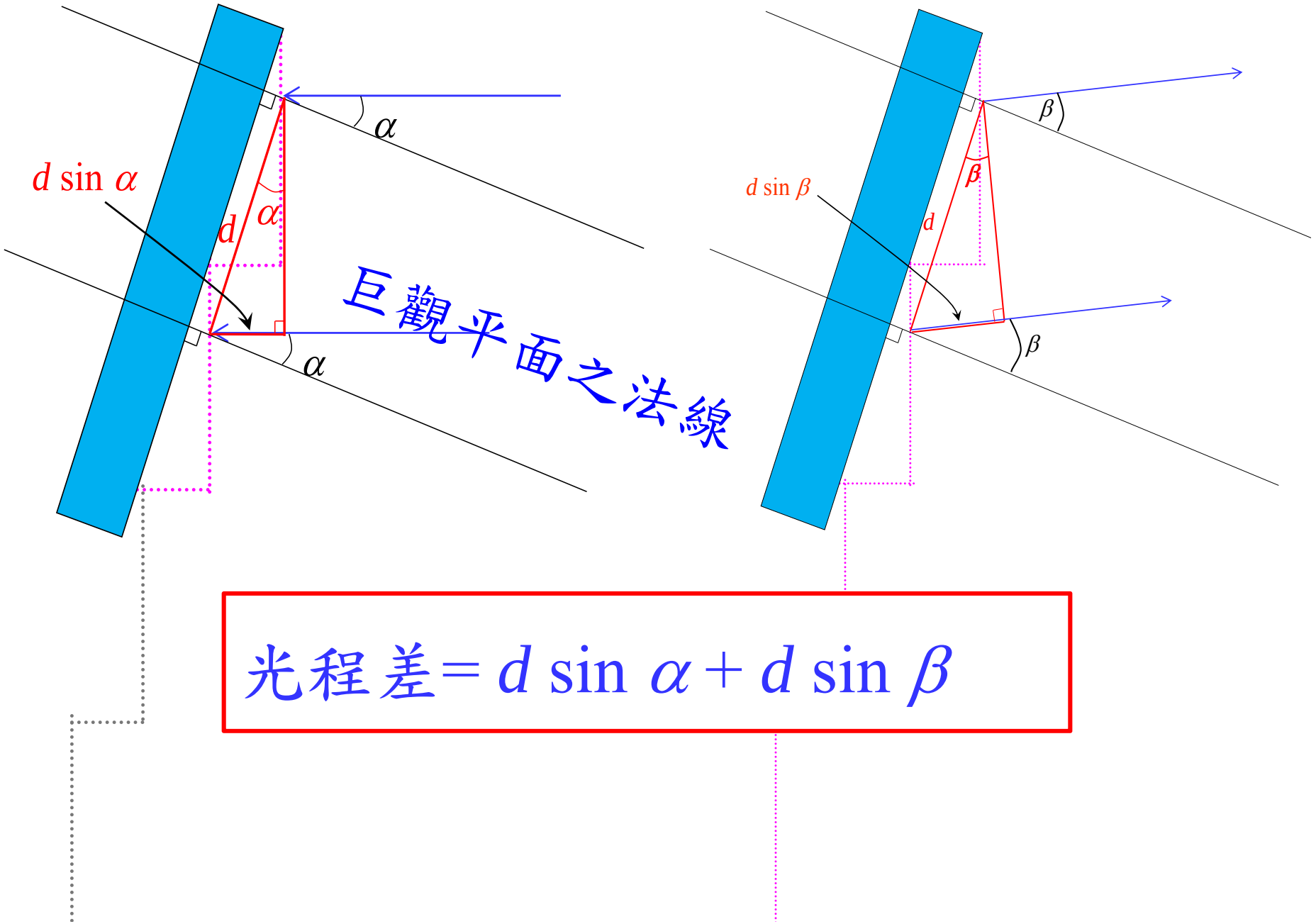
If Yes, Why? *if No, Why?*



注意α β角度之方向(+/−)定義



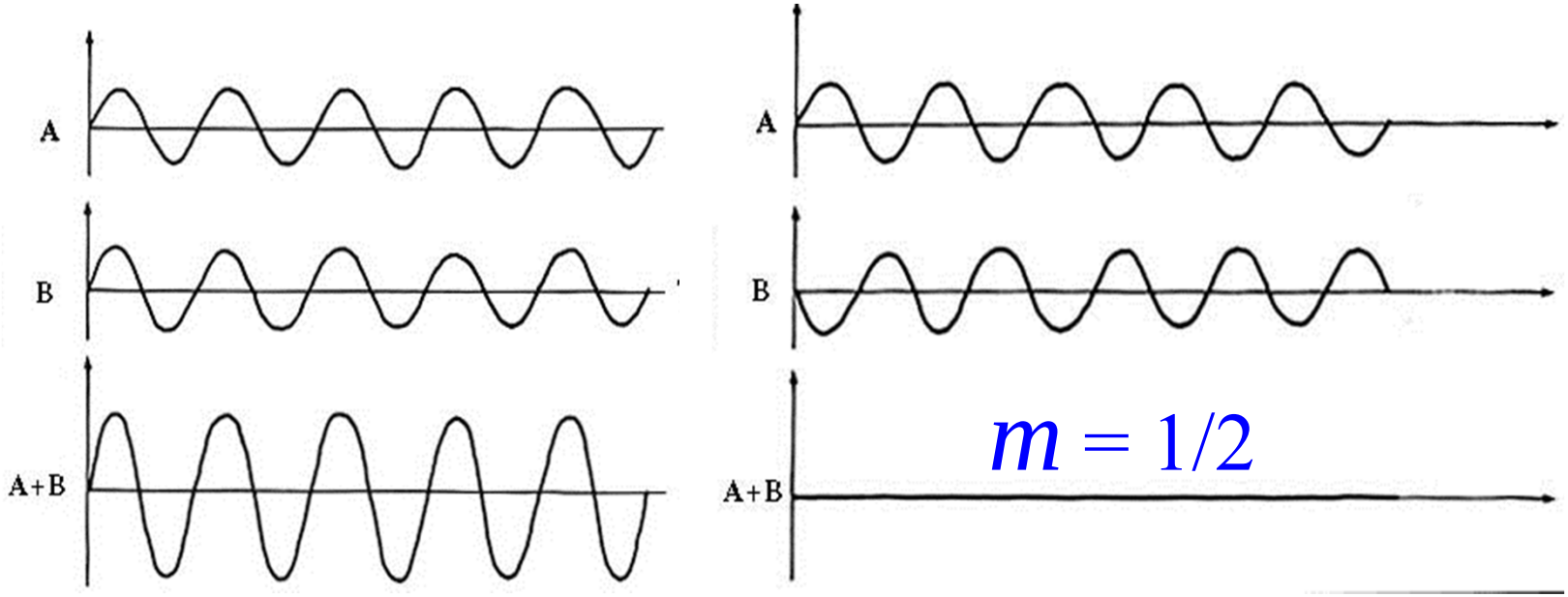
不同的定義



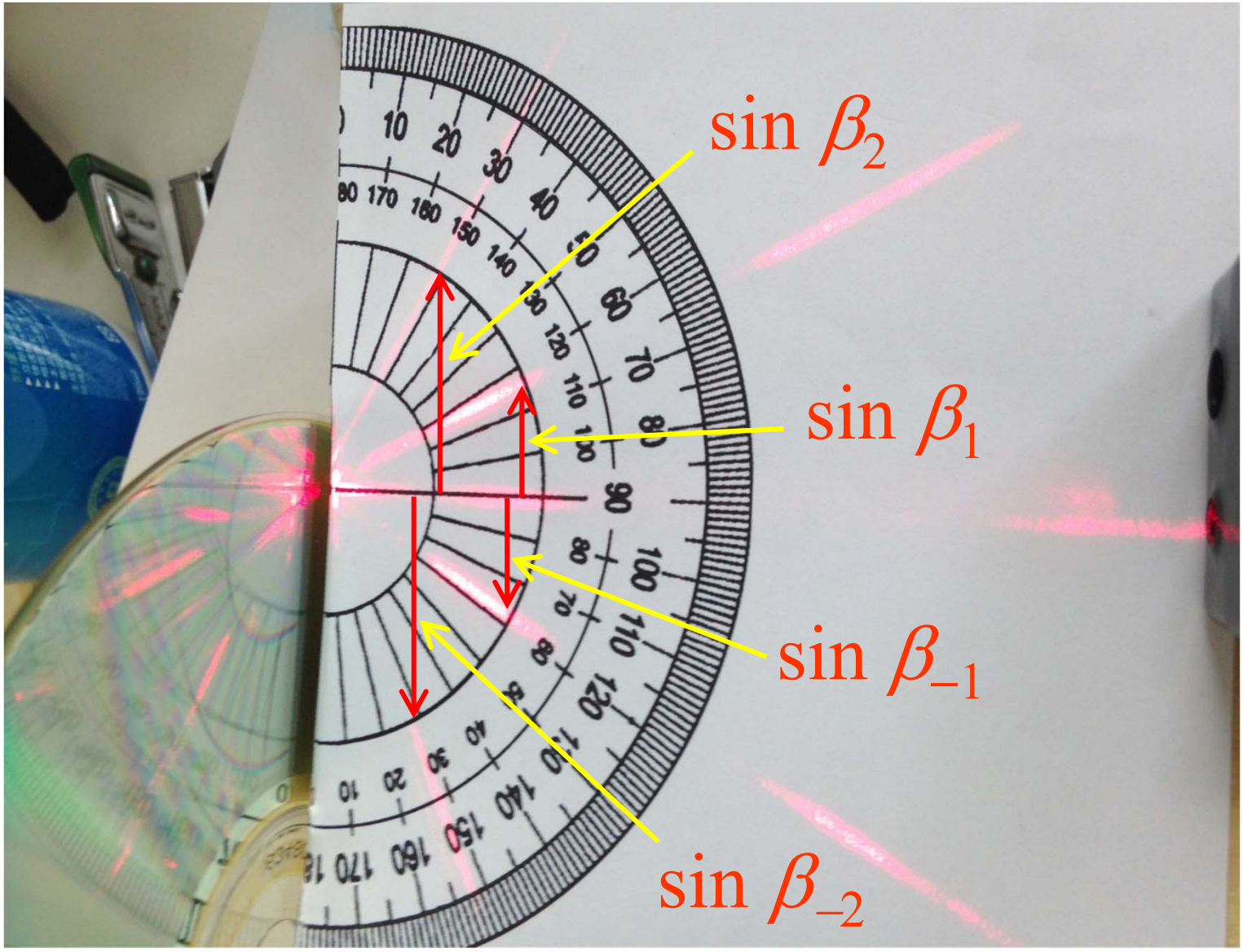
光程差 $= d \sin \alpha + d \sin \beta$

建設性干涉條件 $d\sin\alpha + d\sin\beta = m\lambda$

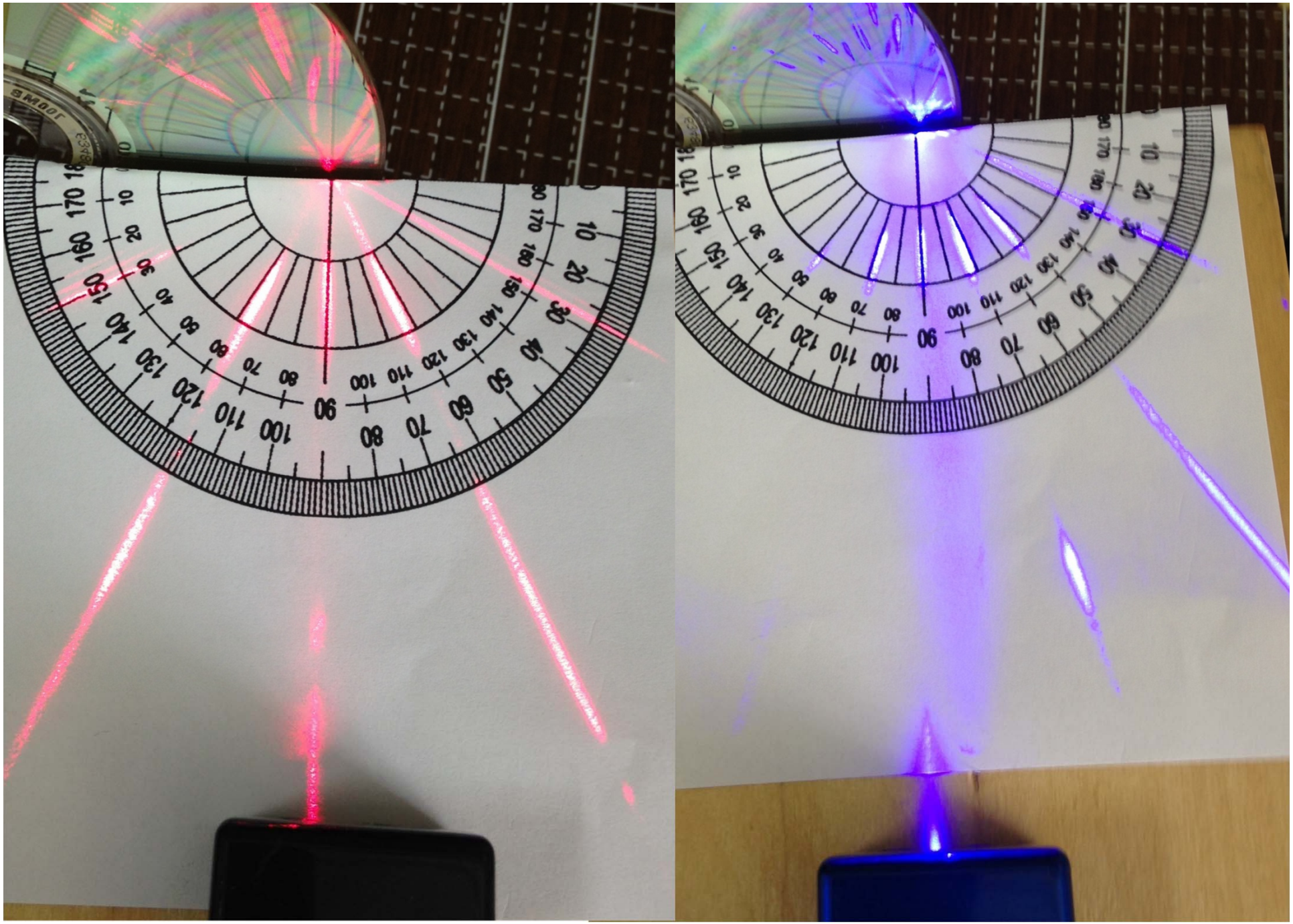
$m = 0,\ 1,\ 2,\ 3, \ldots$ m 可以是負整數嗎？



For $m = 0, \sin\alpha + \sin\beta = 0,\ \beta = -\alpha$ 符合巨觀之反射定律



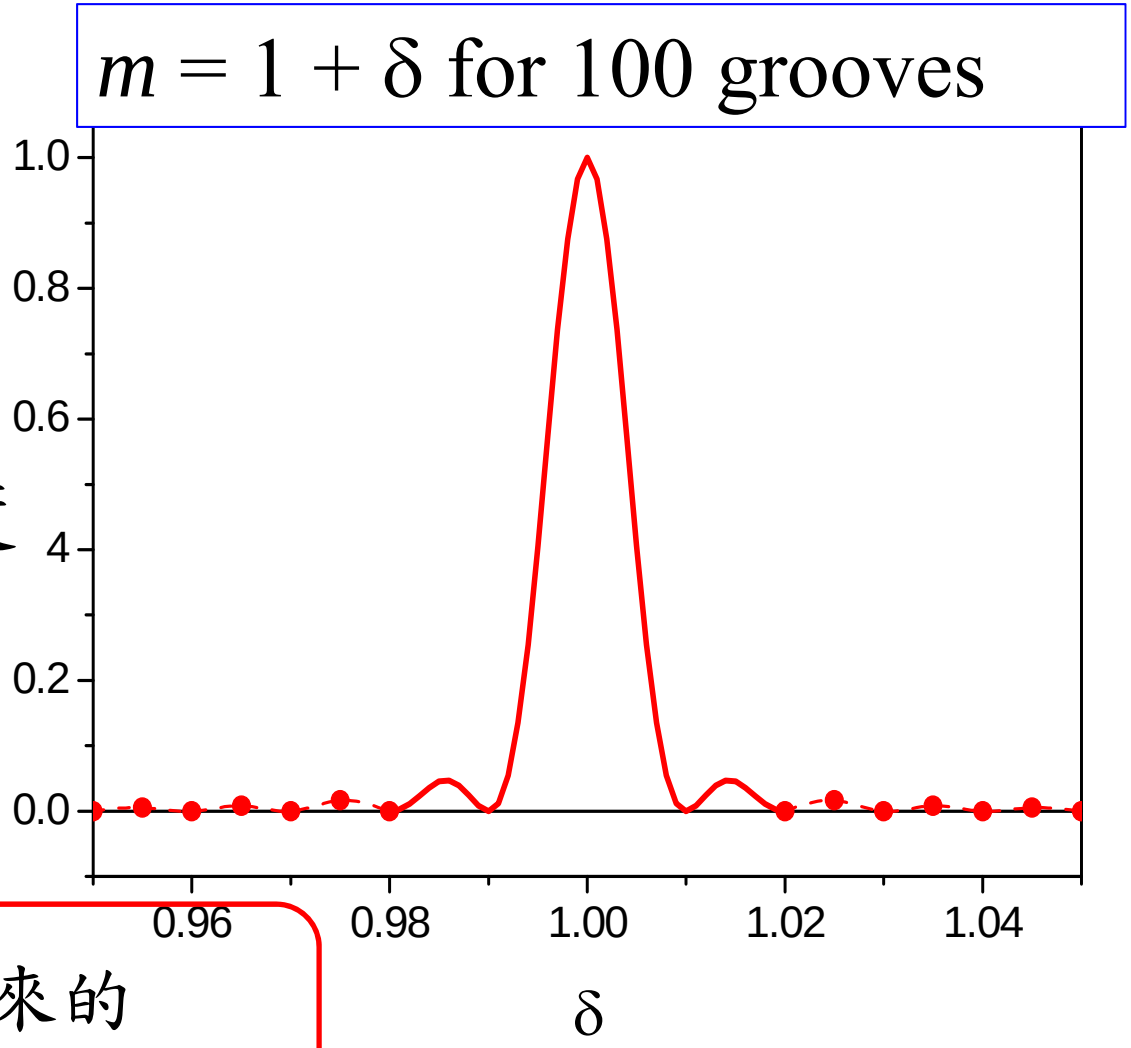
Use a laser pointer to show various m.



m 不是剛剛好整數時，會怎樣？

不是建設
就是破壞嗎？

能量正比於
振幅之平方

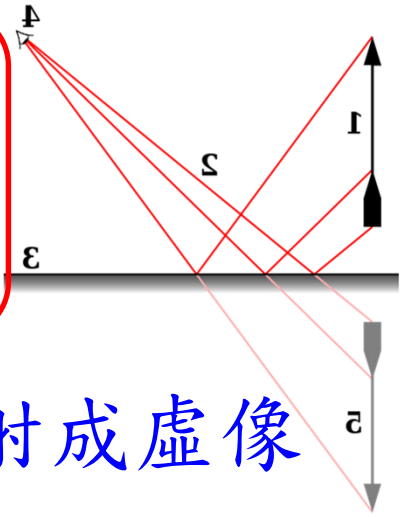


挑戰：

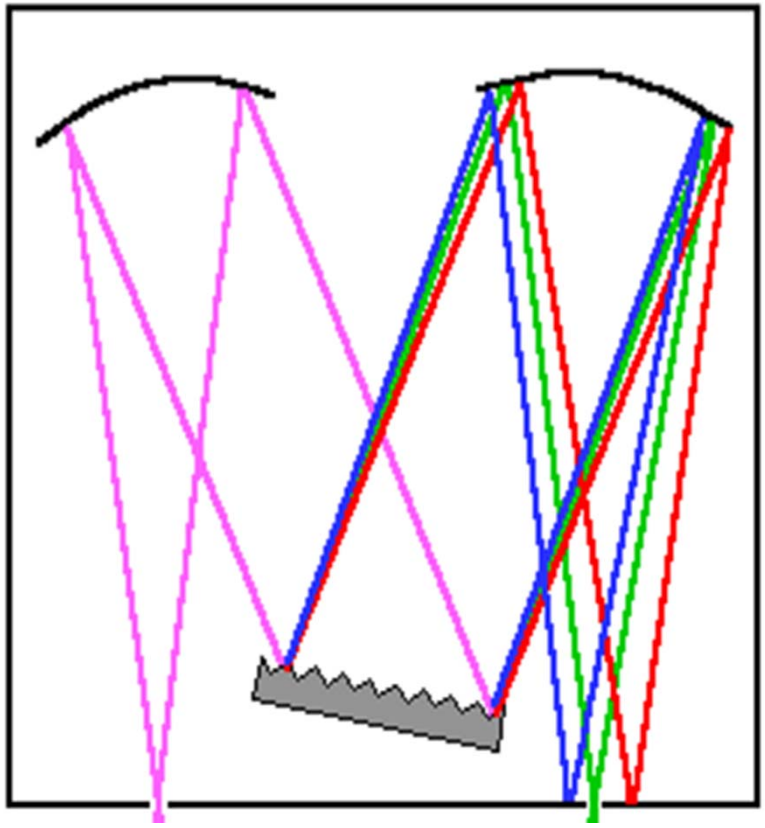
右圖是用EXCEL算出來的
你能做出50 grooves 的結果嗎？

挑戰：

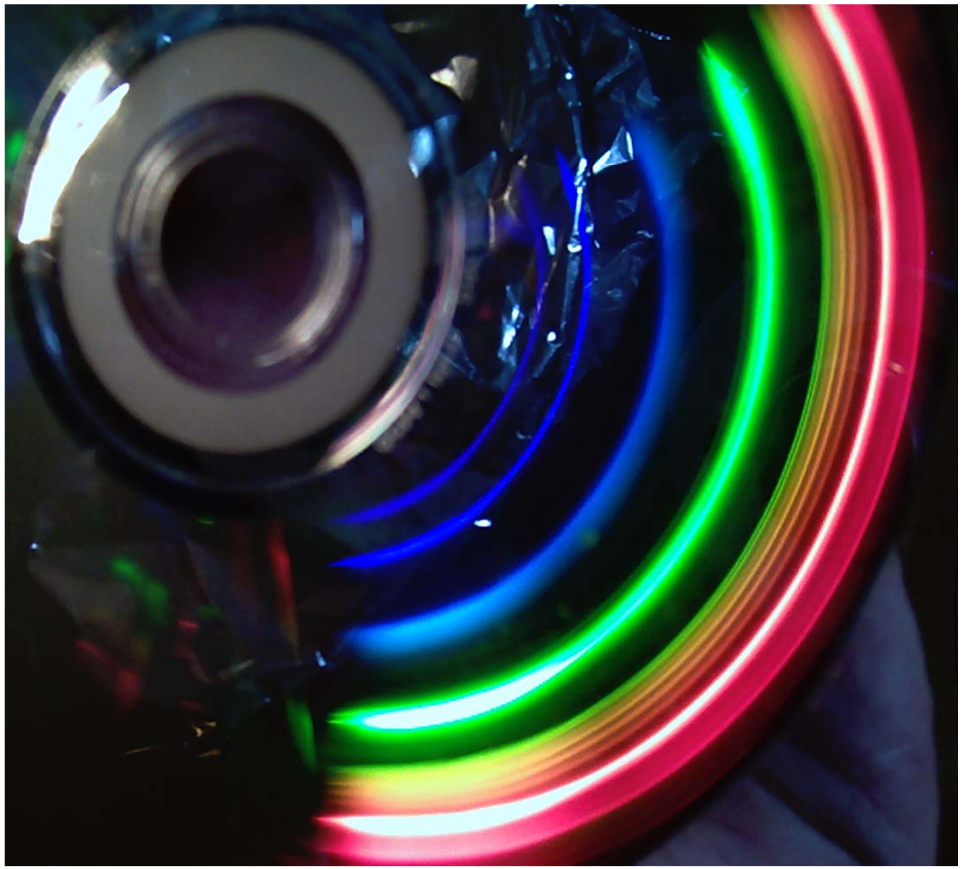
拍下類似照片、記錄距離等條件，你能求出 α β 角度並驗證 $d\sin\alpha + d\sin\beta = m\lambda$ 嗎?



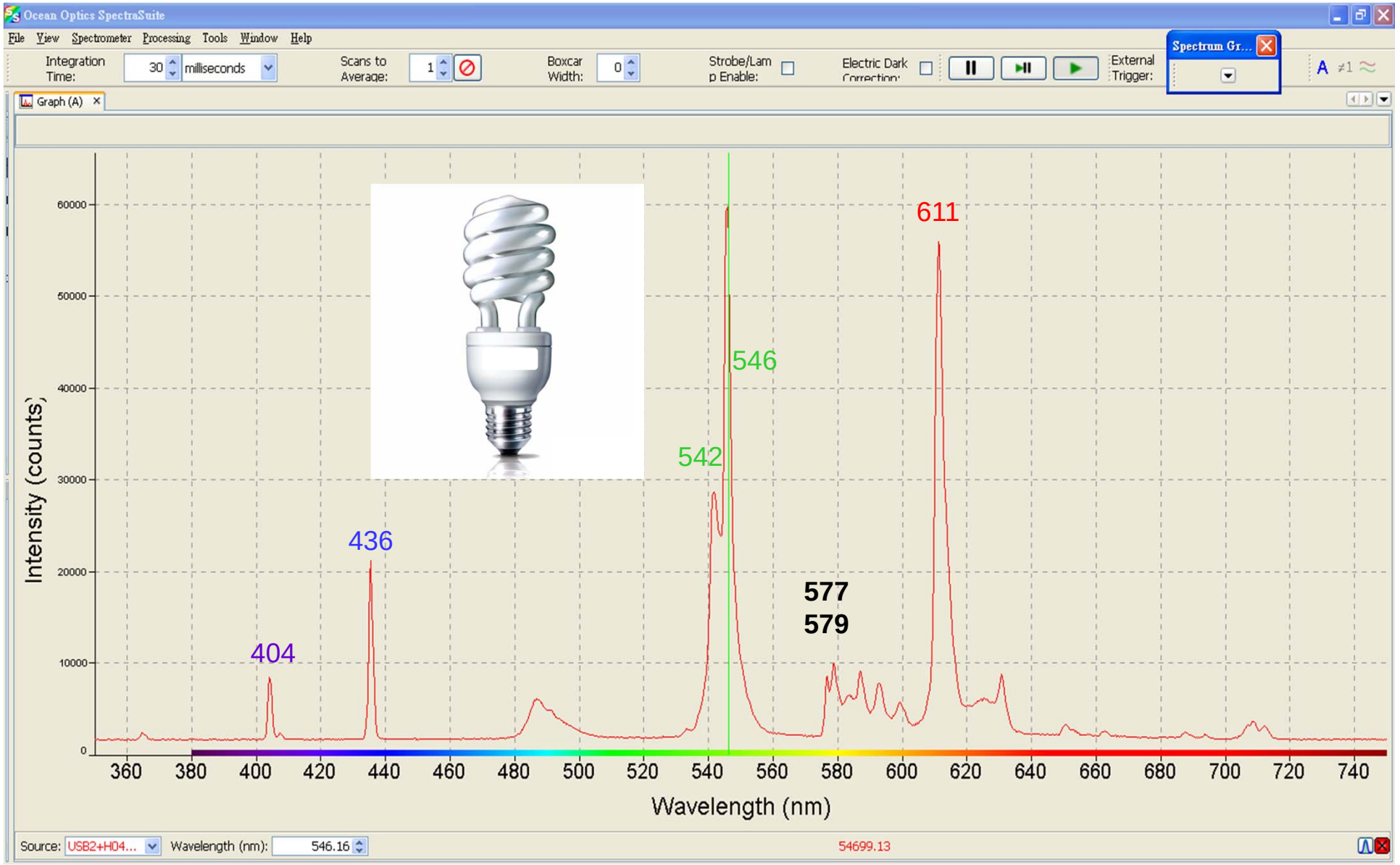
鏡面反射成虛像



光柵分光儀之結構



參考譜線波長(光源：省電燈泡)



Ocean Optics USB2000+UV-VIS-ES

氧氣的液化、磁性

Key Ideas:

氣球碰液氮時，哪邊先縮小？

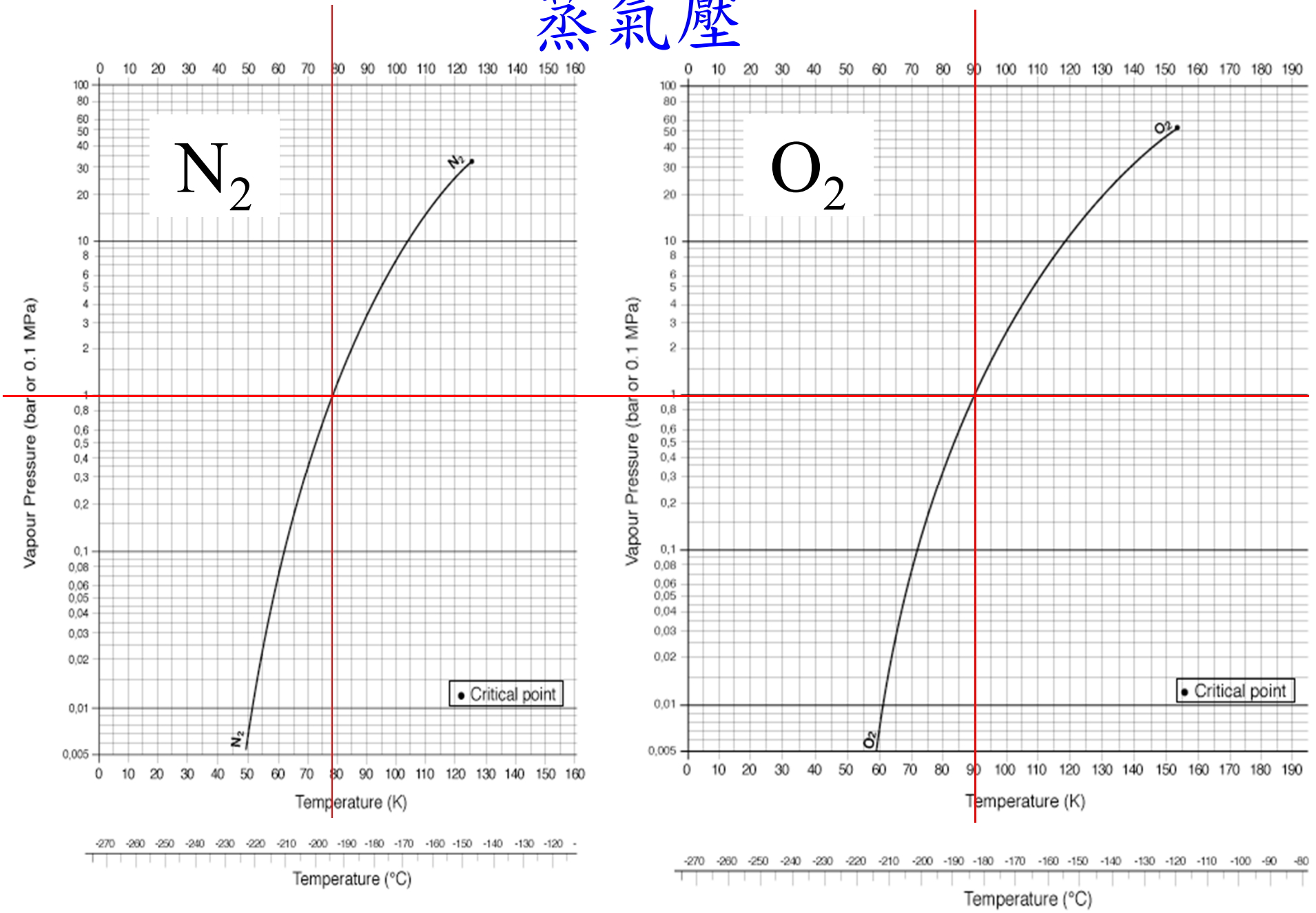
氧氣的沸點；氧氣有磁性；

注意：

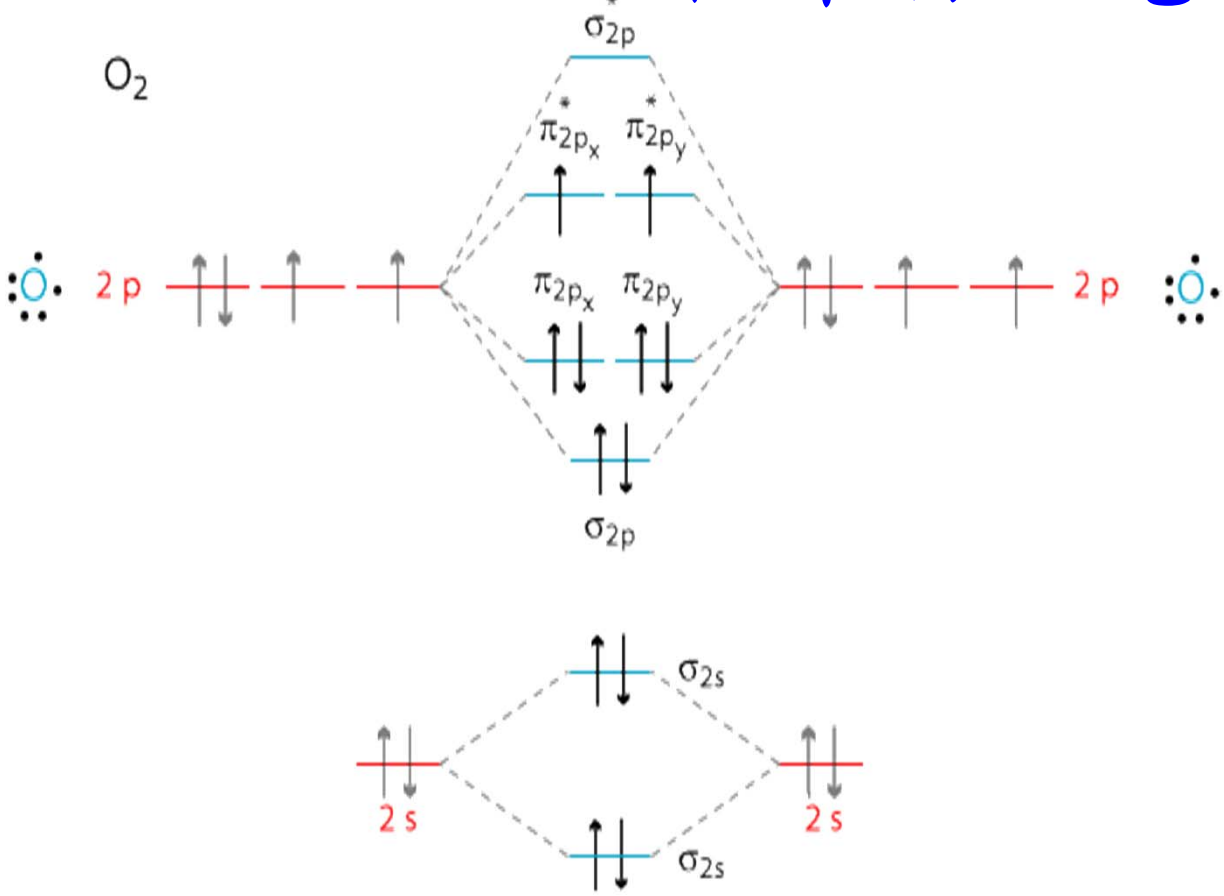
液氮可用手短時間碰觸，但禁止潑人！

強力磁鐵嚴禁靠近鐵製品(會無法分開)，
不用時要放在專用盒內

蒸氣壓


N_2
O_2
Vapour Pressure (bar or 0.1 MPa)
Temperature (K)
Temperature (°C)
• Critical point
N_2
O_2

Molecular Orbital 磁性來自於電子的自旋



Electron Configuration: $(\sigma_{2s})^2\ (\sigma_{2s}^*)^2\ (\sigma_{2p})^2\ (\pi_{2p})^4\ (\pi_{2p}^*)^2$

Bond Order $= \frac{1}{2}(2 - 2 + 2 + 4 - 2) = 2$ Double Bond

Other fun parts:

橡皮筋@ *Low T*

氣球天燈

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