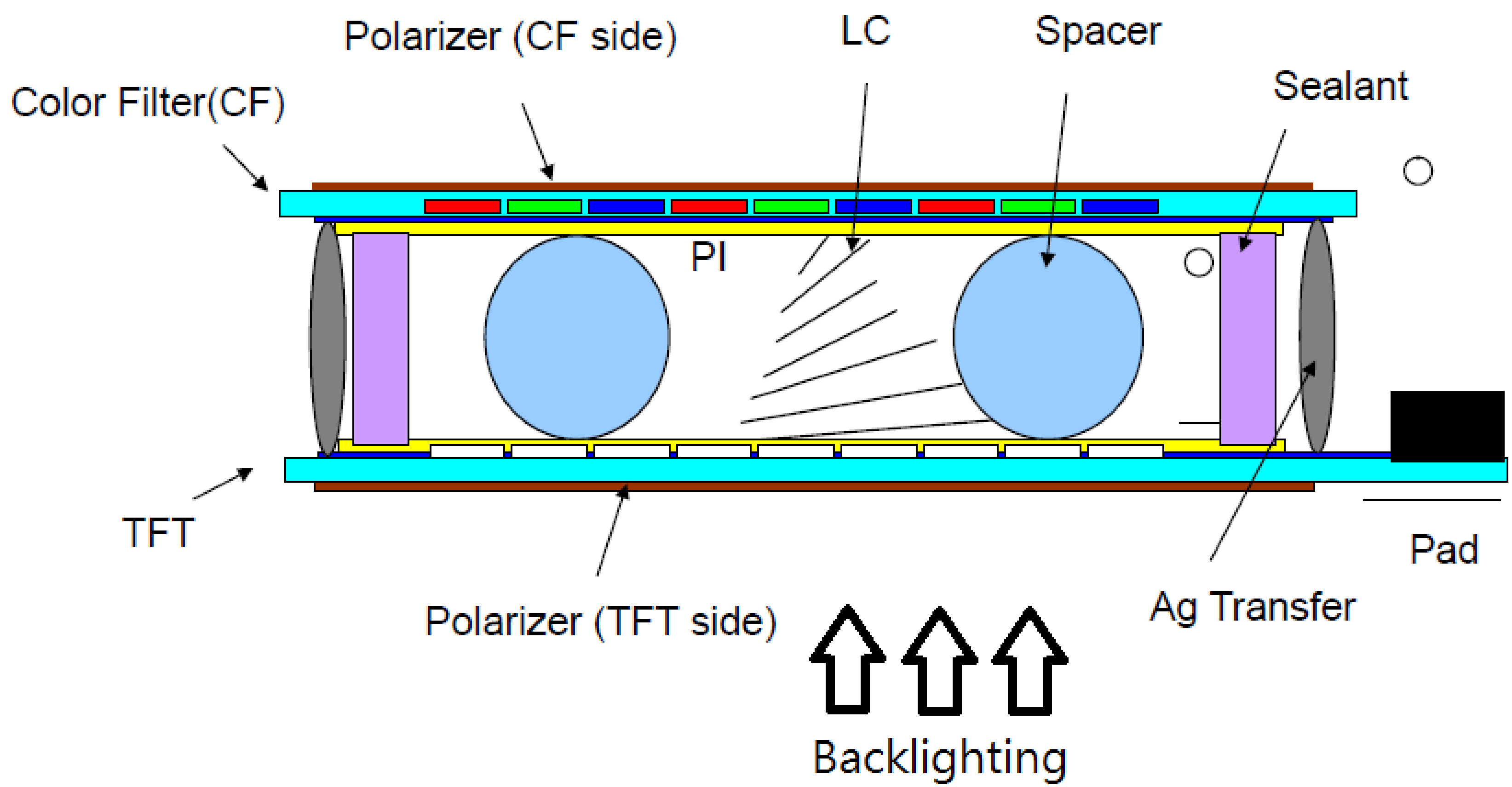
實驗六. 液晶與偏振實驗

助教：陳薇琛

r08941038@ntu.edu.tw
電二館 351A

Display Applications

Cross-section of LCD panel



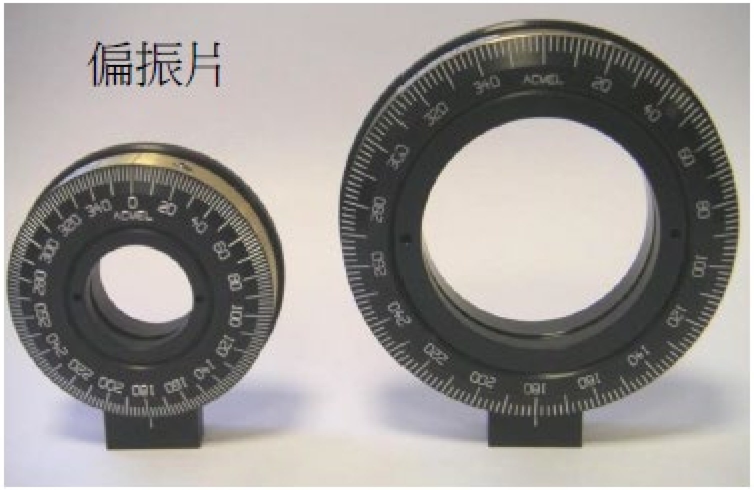
實驗項目（目的及步驟）

實驗目的

- 了解液晶顯示器的操作原理
- 認識何為偏振光

實驗步驟

- 認識 線性偏振片 (Polarizer)
- 認識 λ/2 與 λ/4 plate (波片) 特性
- TN（Twisted Nematic)液晶層與電壓的關係



$$\nabla \times \vec{E} = -\mu \frac{\partial \vec{H}}{\partial t}$$

Differential Form	Integral Form	Significance
$\nabla \times \mathbf{E} = -\dfrac{\partial \mathbf{B}}{\partial t}$	$\oint_C \mathbf{E} \cdot d\boldsymbol{\ell} = -\dfrac{d\Phi}{dt}$	Faraday's law
$\nabla \times \mathbf{H} = \mathbf{J} + \dfrac{\partial \mathbf{D}}{\partial t}$	$\oint_C \mathbf{H} \cdot d\boldsymbol{\ell} = I + \int_S \dfrac{\partial \mathbf{D}}{\partial t} \cdot d\mathbf{s}$	Ampère's circuital law
$\nabla \cdot \mathbf{D} = \rho$	$\oint_S \mathbf{D} \cdot d\mathbf{s} = Q$	Gauss's law
$\nabla \cdot \mathbf{B} = 0$	$\oint_S \mathbf{B} \cdot d\mathbf{s} = 0$	No isolated magnetic charge

- **Plane EM waves in a simple, nonconducting and source-free region**

$$\nabla \times \vec{E} = -\mu \frac{\partial \vec{H}}{\partial t} \qquad \nabla \times \vec{H} = \varepsilon \frac{\partial \vec{E}}{\partial t} \qquad \nabla \cdot \vec{E} = 0 \qquad \nabla \cdot \vec{H} = 0$$

$$\nabla \times \nabla \times E = -\mu \frac{\partial}{\partial t}(\nabla \times \vec{H}) = -\mu\varepsilon \frac{\partial^2 \vec{E}}{\partial t^2} = \nabla(\nabla \cdot \vec{E}) - \nabla^2 \vec{E} = -\nabla^2 \vec{E}$$

$$\Rightarrow \boxed{\nabla^2 \vec{E} - \mu\varepsilon \frac{\partial^2 \vec{E}}{\partial t^2} = 0}$$

$$\nabla^2 \vec{E} - \mu\varepsilon \frac{\partial^2 \vec{E}}{\partial t^2} = 0$$

- **Velocity** of the plane EM wave: $v = \dfrac{1}{\sqrt{\mu\varepsilon}}$
- **Wave number:**

$$k = \omega/v = \omega\sqrt{\mu\varepsilon} = \frac{2\pi}{v/f} = \frac{2\pi}{\lambda}$$

- Assume $\vec{E} \propto e^{j\omega t}$ (phasor)

$$\Rightarrow \nabla^2 \vec{E} + k^2 \vec{E} = 0$$

- Suppose $\vec{E} = \vec{E}(z)$

$$\Rightarrow \frac{d^2 \vec{E}(z)}{dz^2} + k^2 \vec{E} = 0$$

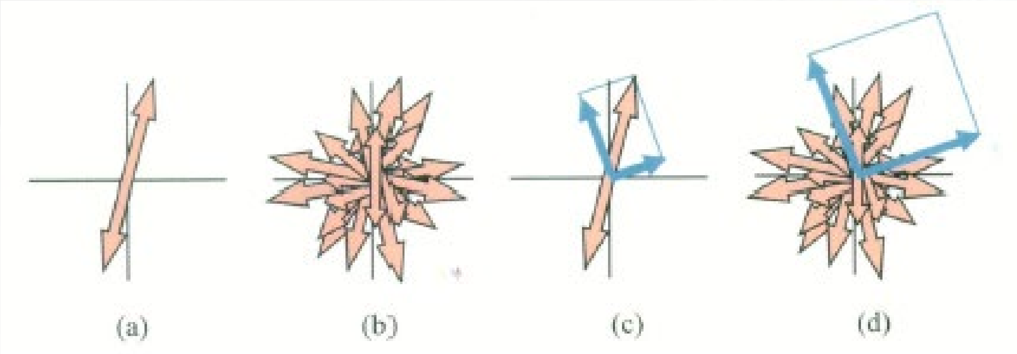
$$\Rightarrow \vec{E}(z) = \vec{E}_0^{+} e^{-jkz} + \vec{E}_0^{-} e^{jkz}$$

Traveling wave in ***+z*-direction:**

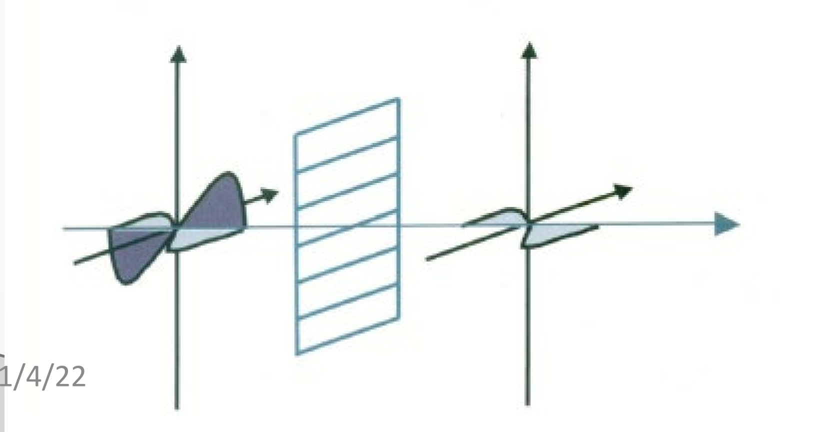
$$\vec{E}_0^{+}(z,t) = \mathrm{Re}[\, \vec{E}_0^{+} e^{-jkz} \cdot e^{j\omega t}] = \vec{E}_0^{+} \cos(\omega t - kz)$$

EX1：Polarizers

- Virtually all light sources used in optical displays are unpolarized

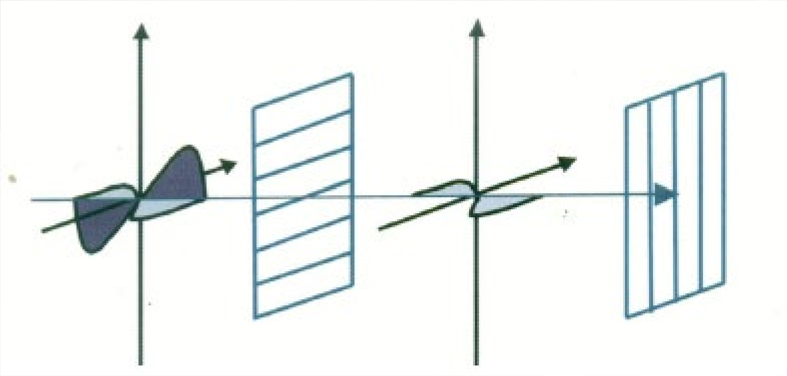


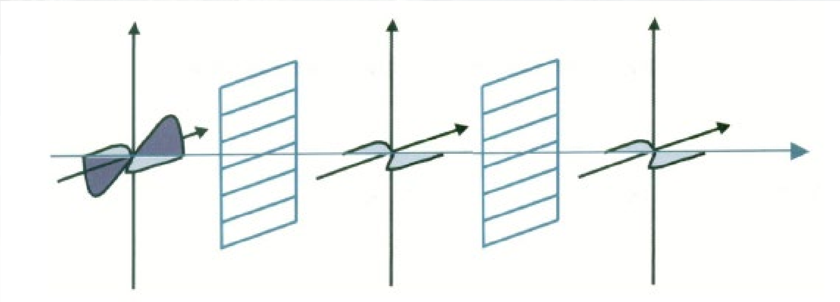
- Polarizer produces a beam of polarized light from a beam of unpolarized light



EX1：Polarizers

- Crossed polarizers = switch OFF





- **Malus's law: I(θ)= I(0) $\cos^2$ (θ)**

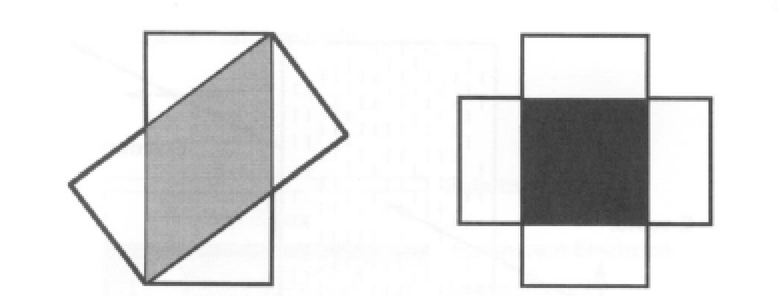
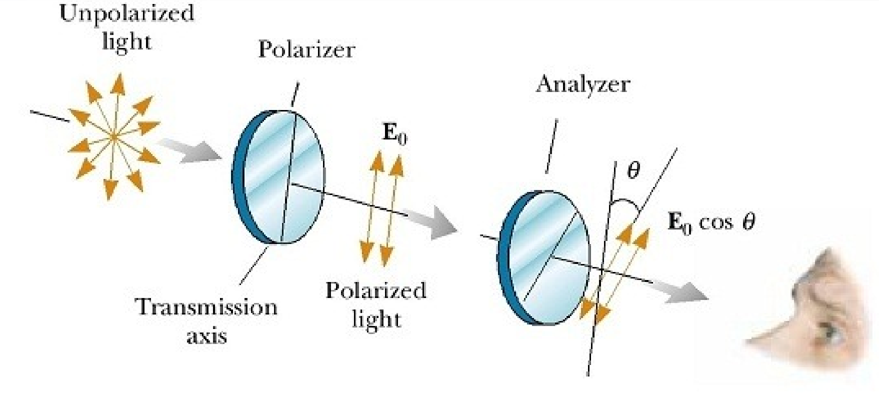
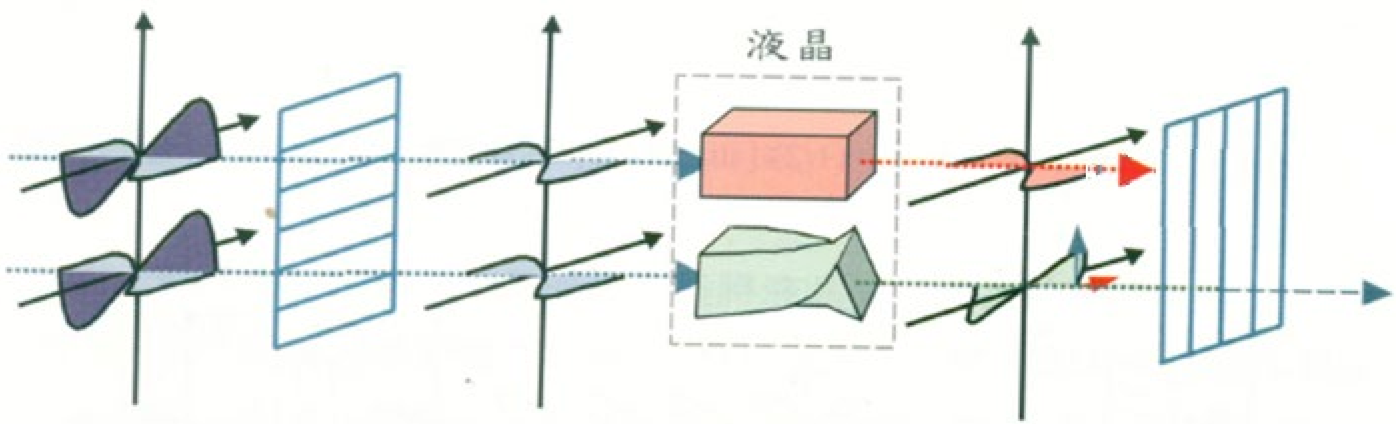


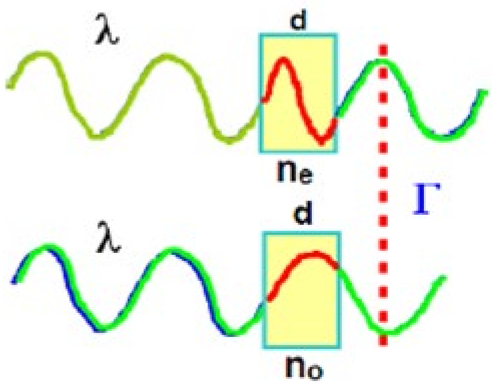
Figure 1.3. Transmission of unpolarized light through two polarizers in series.



EX2：Phase Retardation (相位延遲)

- Liquid crystal = Light valve



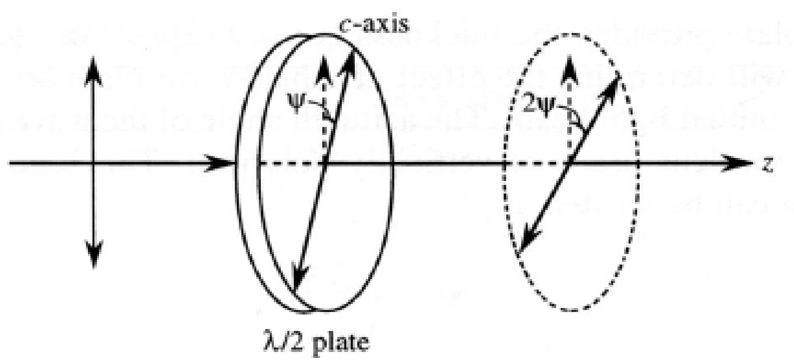


Phase Retardation Γ:

$$\Gamma = \frac{2\pi d}{\lambda/n_e} - \frac{2\pi d}{\lambda/n_o} = \frac{2\pi d(n_e - n_o)}{\lambda}$$

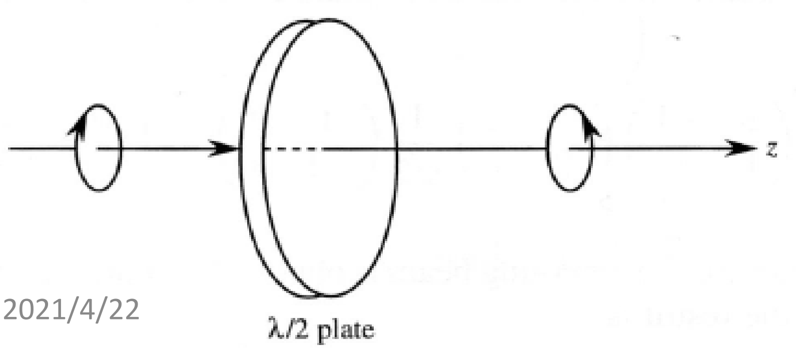
EX2：Half-wave (λ/2) plate

- A half-wave plate has phase retardation $\Gamma = \pi$
- $(n_e-n_o)d = \Delta n d = \lambda/2$ (or odd multiples 1,3,5….)



ψ = input polarization angle relative to c axis

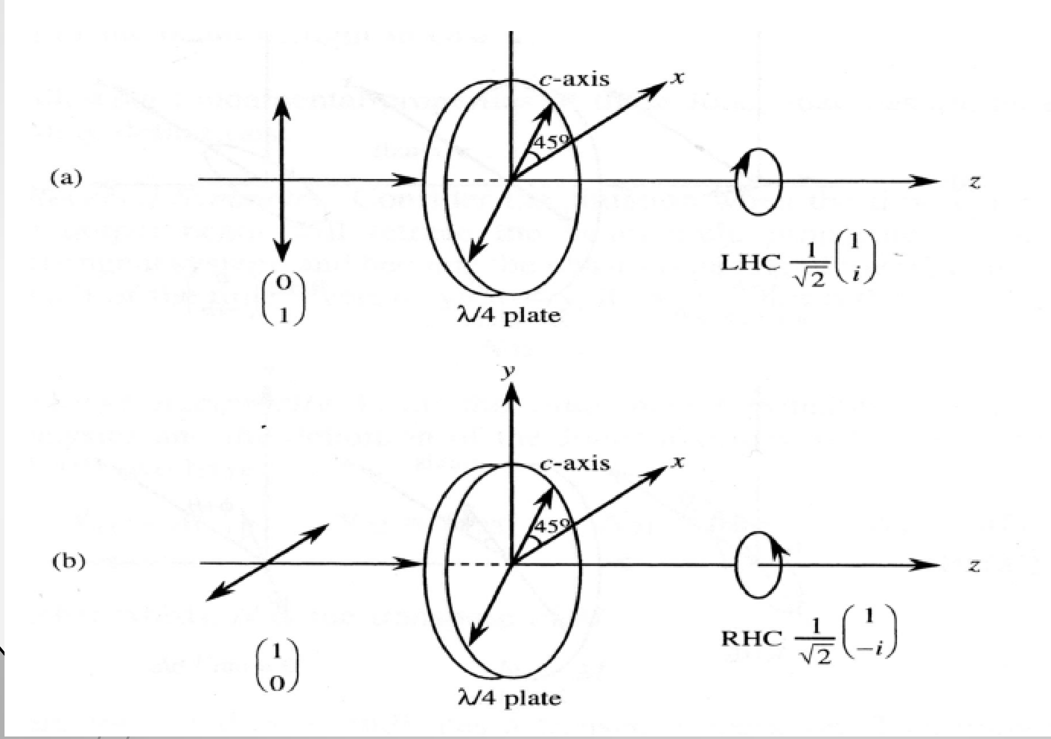
- Can rotate a linear polarization by an angle 2ψ
- Note: *rotation by 90° if ψ = 45°*



- Can change R to L (or L to R)
- Circular polarization conversion regardless of ψ angle

EX2： Quarter-wave (λ/4) plate

- A half-wave plate has phase retardation $\Gamma = \frac{\pi}{2}$ (which depends on wavelength λ)
- (ne-no)d = Δnd = λ /4 (or odd multiples 1,3,5….)



EX2： Quarter-wave (λ/4) plate

$$E_x = E_0 \cos(kz - \omega t)$$

$$E_y = E_0 \cos(kz - \omega t - \pi / 2)$$

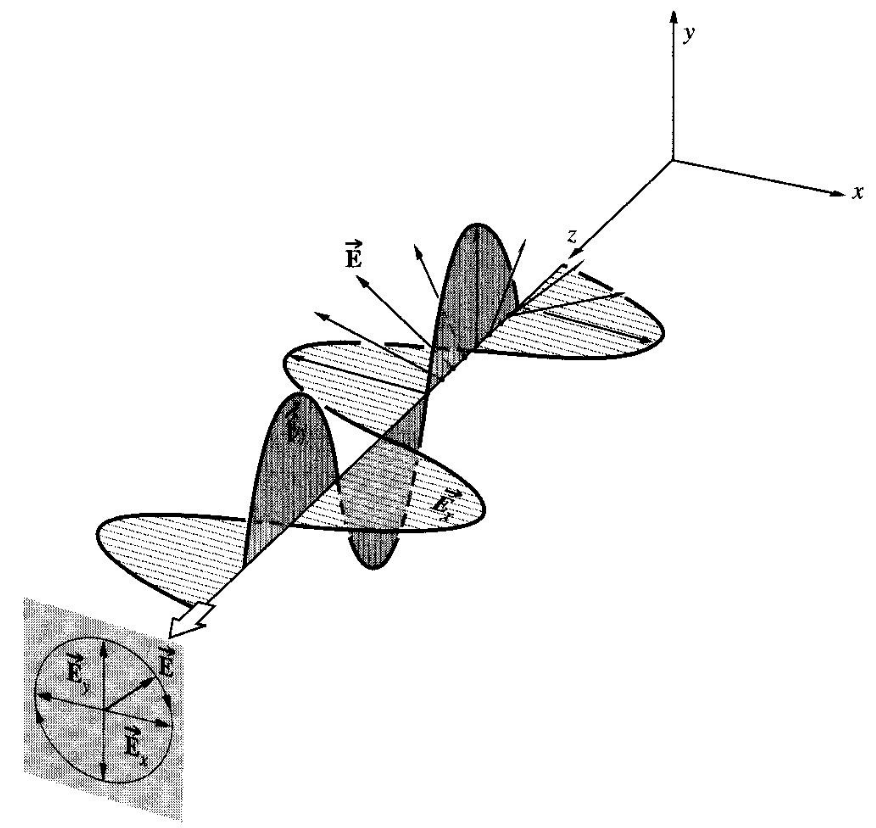
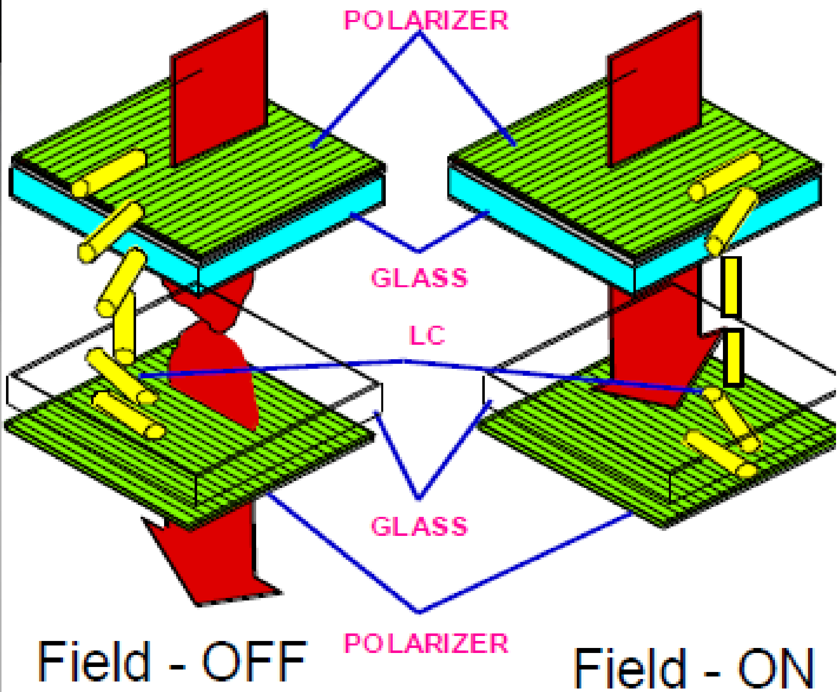
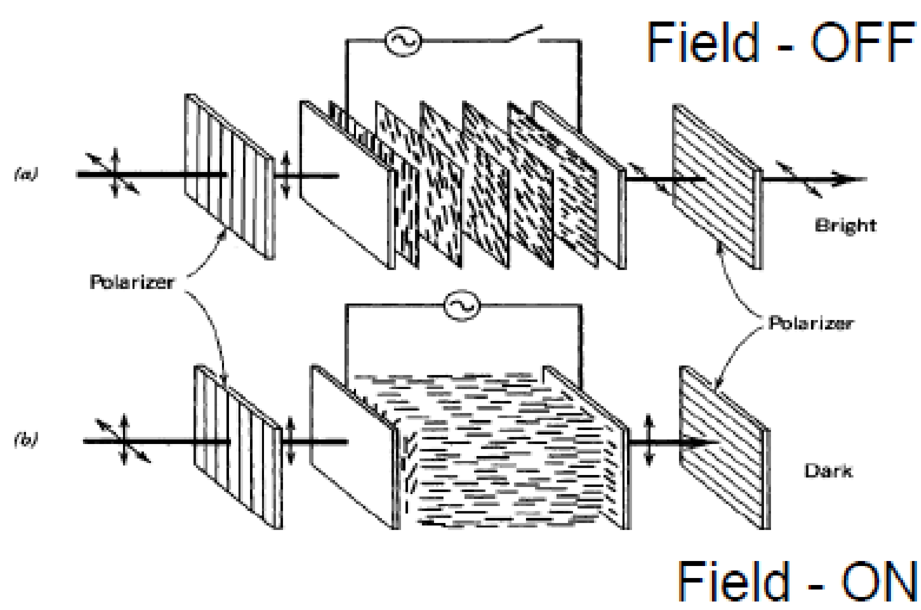


Figure 8.3 Right-circular light. (*a*) Here the electric field, which has a constant amplitude, rotates clockwise with the same frequency with which it oscillates. (*b*) Two perpendicular antennas radiating with a 90° phase difference produce circularly polarized electromagnetic waves.

EX3：TN (Twisted Nematic)

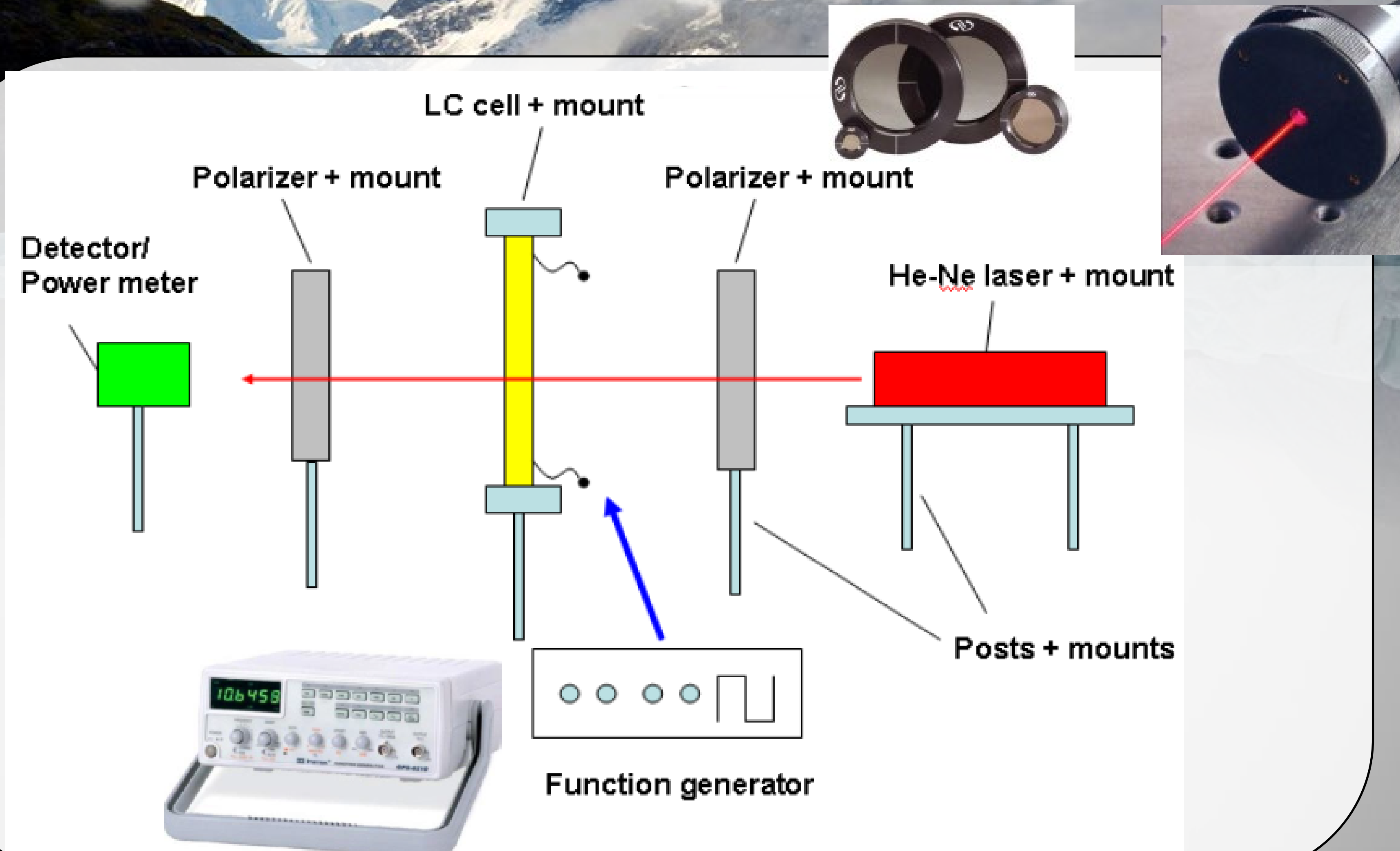
- By applying a small voltage, 0-5V, LC molecules align with E, twist structure disappears





Normally White

Experiment Setup（架構）



實驗六. 液晶與偏振實驗 預報問題

- 比較normally white 和 normally black LCD的差別？(可以在上實驗課時觀察一下實驗中的液晶模組為哪一類型)
- 生活中具有polarizer特性的現象與基本原理?

預報內容提醒：

- 實驗名稱
- 實驗目的
- 實驗架構
- 實驗原理

何為偏振光（比較線偏振，圓偏振，橢圓偏振差異）請用電場描述!

- 預報題目