# 實驗四
# 電光調變器實驗

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# Modulator (調變器)

實驗目的

- 了解電光調變器的操作原理及使用方式

➢ 在光纖通訊系統中，把要傳送之信號加載到光波上的過程就是調變。

➢ 光調變器就是實現從電信號到光信號的轉換的元件。

**EA Modulator**

**Electro-absorption**

**AO Modulator**

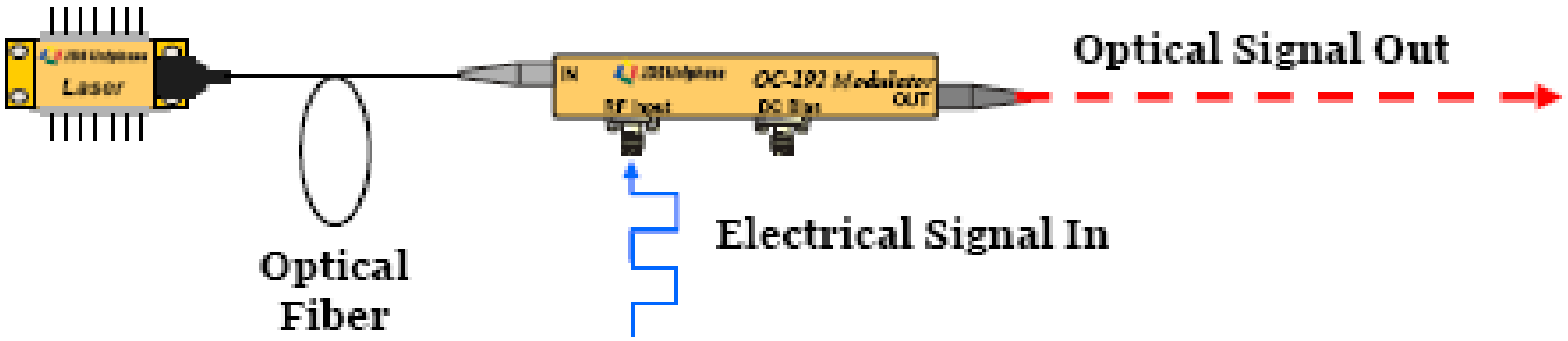
**Acousto-Optical**

**EO Modulator**

**Electro-optical**

# Modulator (調變器)

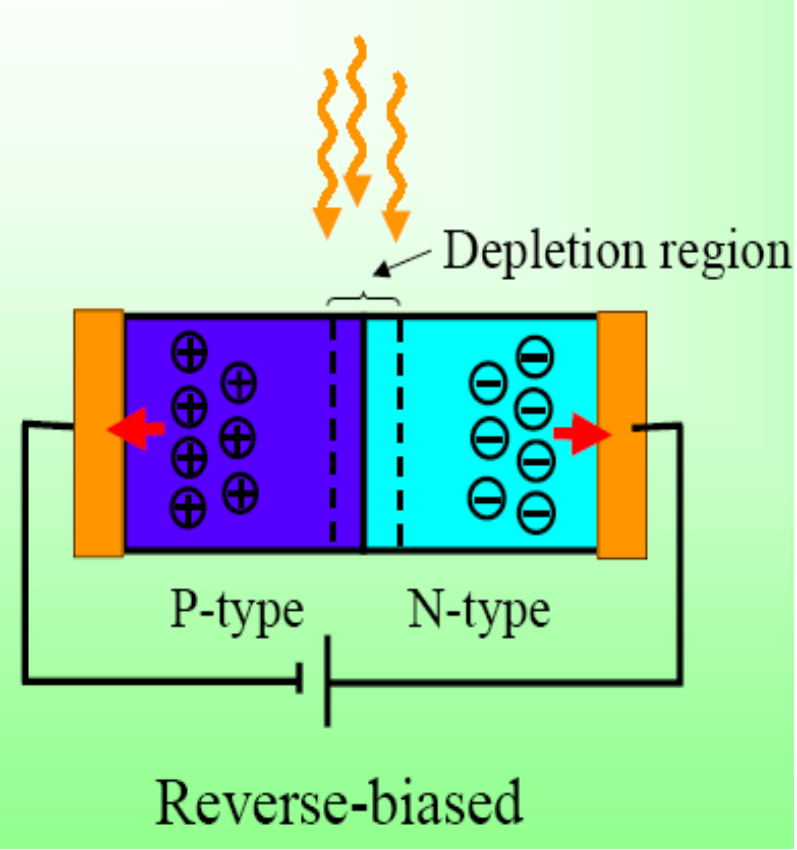
實驗架構




**Laser source**

**實驗當中使用： Tunable Laser**

# Electro-absorption (EA) modulator



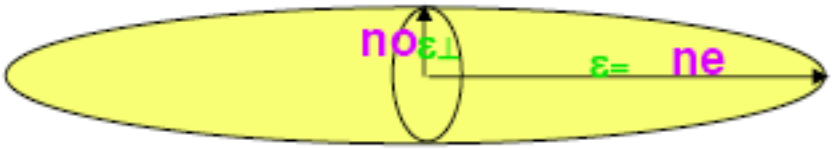

- When the P-N structure in LED is reverse-biased, it becomes light absorption
- At zero-bias, absorption is weak. Under strong reversebiased, absorption is strong.
- Light intensity is then modulated by signal voltage.

http://ntuee.org/data/photonics/Chapter6.pdf

# Birefringence (雙折射)

Definition:

- The material has a single axis of **anisotropy**.
- Decomposition of a ray of light into two rays (ordinary ray & extraordinary ray) when it passes through certain types of material.

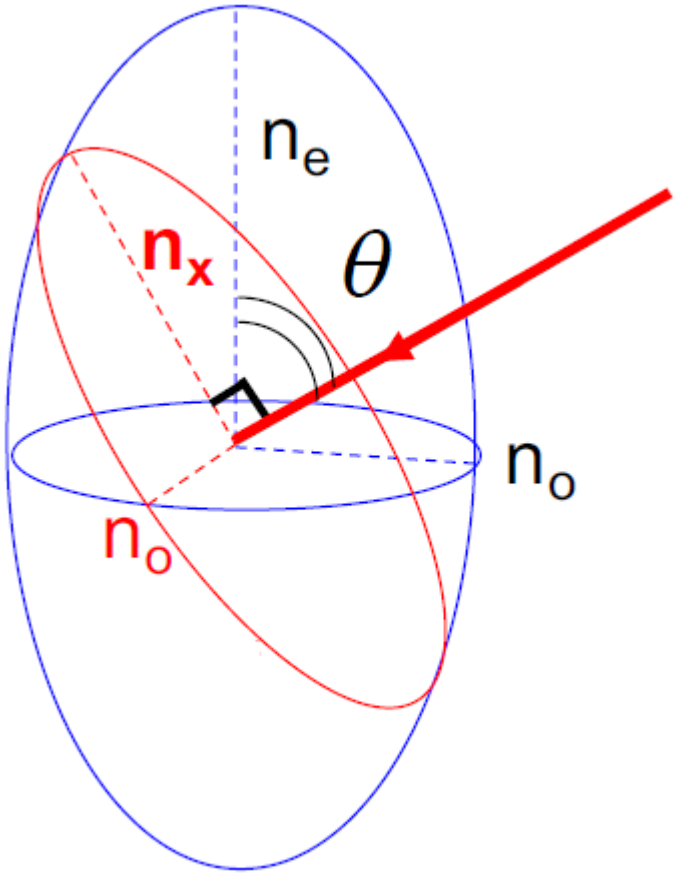



E.g. LC (液晶), $LiNbO_3$ (鈮酸鋰)…

# Effective $n_e$

- In general, when light is incident at an angle $\theta$ relative to the director (// to $n_e$)
- the two refractive indices for the two polarizations are $n_o$ and $n_x$, where $n_x$ is given by:

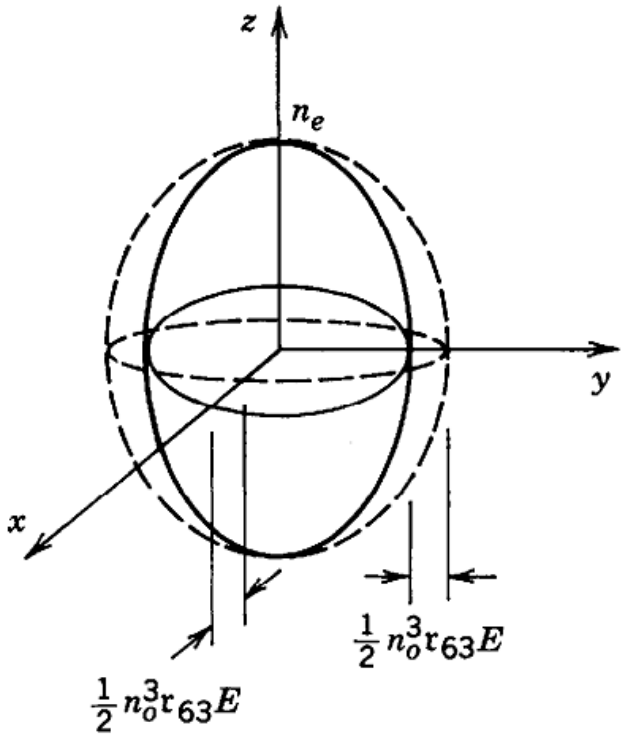
$$nx(\theta) = ne(eff) = \frac{1}{\sqrt{(\frac{\cos\theta}{n_o})^2 + (\frac{\sin\theta}{n_e})^2}}$$

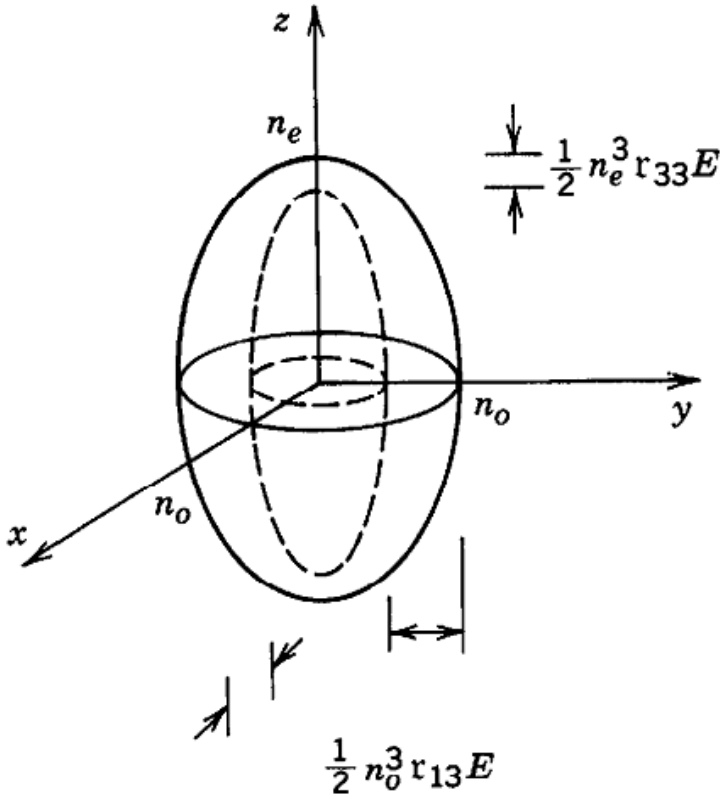



Intersection plane ⊥ to the incident light

# Electro-Optic Effect

- 當外加電場於晶體內部時, 晶體的電荷分佈及晶格結構會微量變形



# Electro-Optical Effect (電光效應)

- 外在電場引起電光晶體折射率變化。
- 折射率改變會使得通過晶體的光波傳播特性改變。
- LiNbO3
- KH2PO4 (KDP)

**Applied Electric Field "E"**

**Non-linear electric-optical effect <Kerr effect>**

$$\left(\frac{1}{n^2}\right) = rE + rE^2$$

r：電光晶體上各方向的電光係數

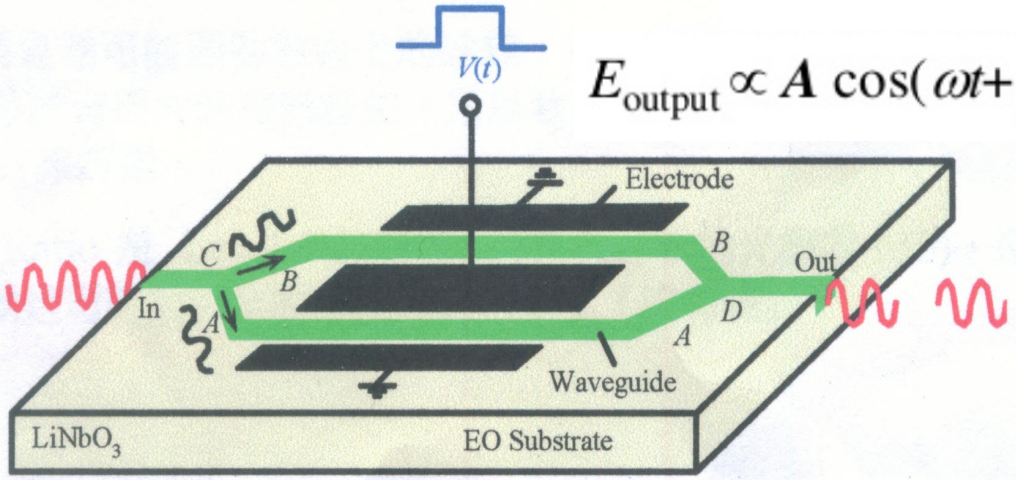
**Linear electric-optical effect <Pockels effect>**

# Electro-Optic (EO) modulator

- 以積體光學的技術在LiNbO3晶片上以光波導的型式製作出Mach-Zehnder干涉儀。
- 在光波導上方製作電極。
- 當電訊號通過電極時所形成的電場會改變光波導的折射率，使得o-ray和e-ray形成光程差，在會合時產生干涉。
- 當電場變化時同時改變干涉結果，即調變合成光波的振幅。

# Optical switching: Mach-Zehnder Modulator

- The input light is split into two coherence wave A and B, which are phase shifted applied voltage, and then two will combine in the output arm.
- The output amplitude depends on the phase difference (optical path) between A and B branches. The output power is proportional to $\mathbf{E^2_{output}}$



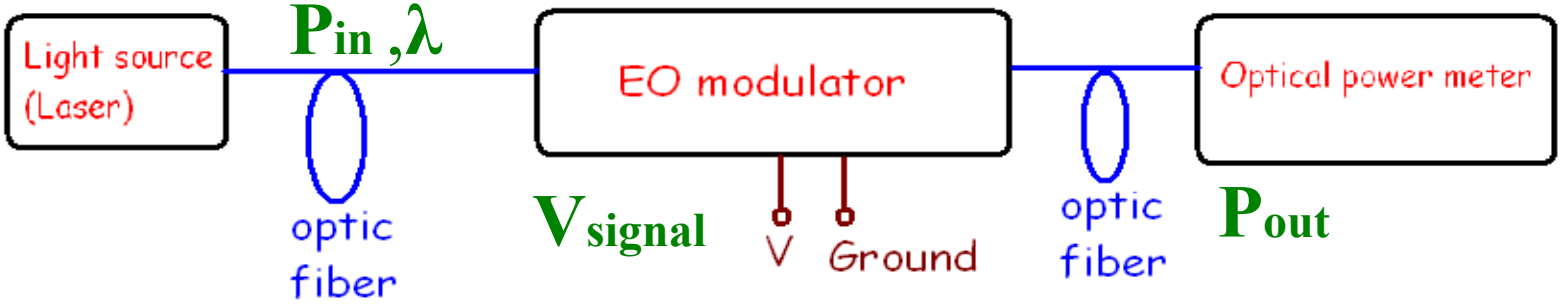

Mach-Zehnder Modulator

$$E_{output} \propto A\cos(\omega t+\phi) + A\cos(\omega t-\phi) = 2A\cos\phi\cos\omega t$$

# Setup (實驗配置圖架構)



Power meter




**Keithley 2400**

# 預報問題

(1) 在非等向性晶體中，何謂單光軸晶體，和雙光軸晶體？

(2) 請描述單光軸線性電光效應，折射率橢球在外加電場下的各方向折射率表示方式？（進一步用矩陣表示）

**預報內容提醒**

- **實驗名稱**
- **實驗目的**
- **實驗架構**
- **實驗原理**
- **預報題目**