Theme

Date ( )

FARADAY ROTATION

Prelab

I. GOALS

+ Explore the characteristic of Faraday rotation with the apparatus to test the microscopic model.
+ Find the ~~rel~~ relationship between B magnetic field and its effect on optical properties (in this lab : a glass rod)
+ Compute atomic electron coordinates for motion induced by the external E & M field and from the polarization vector P.
+ Calculate the permitivity ε
+ Predict the magnitude and direction of rotation of the Faraday effect.

II: TASKS

☐ 1. Change the direction of the DC input for the solenoid and determine the direction of the polarizer at the other end of the Apparatus. Note down if the rotation is clockwis ~~Etor~~ counter clockwise.

☐ 2. Theoretically find the atomic election coordineites for motion induced by the external B field and from the $\vec{P}$.

☐ 3. Theoritically find ε

☐ 4. Compare the experiment the magnitude and direction of the laser light intensiy and the ~~direction of rotati~~ angle of ~~ten~~ filter with the predicted.

III: EXPERIMENT SETUP

☐ Set up faraday rotation apparatus : laser pointer light source, magnet assembly and sample holder for glass rod, rotating polarizer mount, ~~pc~~ ~~pe~~ photo sensor ~~detector~~.

☐. Hook the sensor up to Data Studio ~~in~~ to the lab's computer

☐. Conneet the ~~vot~~ DC votage generator to the magnetic assembly.

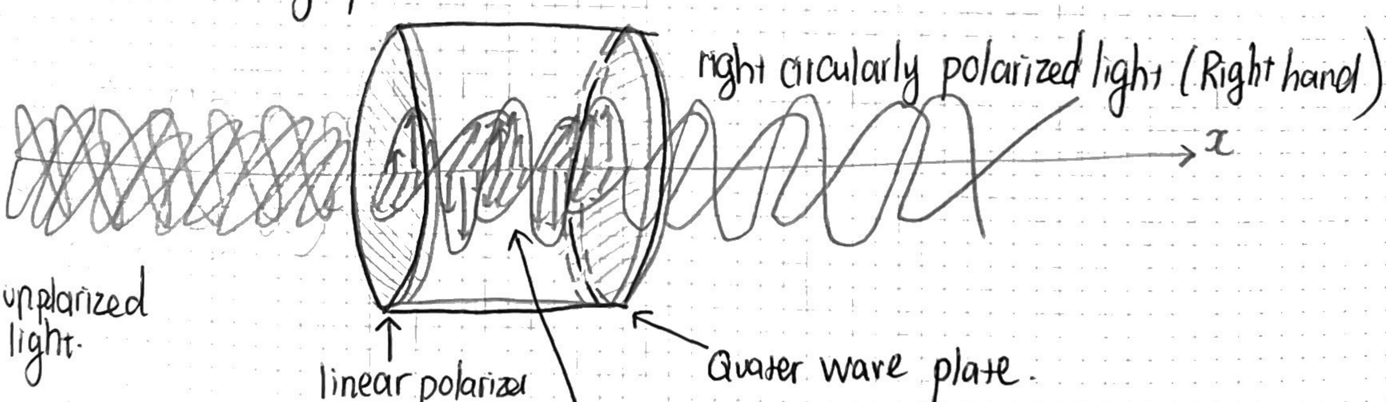
IV: BE SURE TO

+ Not bring Steel Objects Anywhere nearby
+ Align the laser beam correctly and mak sure it get block out by the polarizer to the dimest.
+ Finding the rotation by rotating the polarizer ~~after the~~ during the DC current running through the magnetic assembly to the dimest. The direction of rotating the polarizer is coinside with the Faraday rotation direction.

V: TIPS

+ The optical rotation of light by a refractive medium in a B field was 1st discovered by Michael Faraday in 1845.
+ Faraday used his failed attempt of mastering the telescope glass from the Swiss in this magnetic field set up to see what medium can change the property of light. What he saw was the light can pass through when current flowing through the solenoid.
+ His experiment on light was ~~to~~ decades before the discovery of electric lighting
+ Light wave linearly polarized along x-axis: $E = E_0 \cos(kz - \omega t)\hat{x}$
  + In a refractive medium: $k = \frac{n\omega}{c}$

How a rotating polarizer fiter works?



$E = \frac{1}{2}E_{RH} + \frac{1}{2}E_{LH}$ where $E_{RH} = E_0 \cos(kz - \omega t)\hat{x} - E_0 \sin(kz - \omega t)\hat{y}$

$E_{LH} = E_0 \cos(kz - \omega t)\hat{x} + E_0 \sin(kz - \omega t)\hat{y}$

$= E_0\left(\cos\left(\frac{\Delta n \pi z}{\lambda}\right)\hat{x} + \sin\left(\frac{\Delta n \pi z}{\lambda}\right)\hat{y}\right)\cos\left(\frac{1}{2}(n_L + n_R)kz - \omega t\right) \quad \Delta n \equiv n_L - n_R$

+ The laser beam is linearly polarized but the plane of ~~rotati~~ polarization has been twisted by the B field by the angle.

$$\phi = \frac{\Delta n \pi z}{\lambda}$$

- Say the applied constant B field where r is the transverse motion of an electron in x-y plane.
- $\omega_c = \frac{eB}{m}$ is the cyclotron ~~anglular~~ angular rotation frequency.

$\Rightarrow \vec{r}_{RH} = -\frac{\frac{e}{m}E_0}{\omega_0^2 - \omega^2 + \omega_c\omega}\left(\cos(kz-\omega t)\hat{x} - \sin(kz-\omega t)\hat{y}\right)$

$\vec{r}_{LH} = -\frac{\frac{e}{m}E_0}{\omega_0^2 - \omega^2 - \omega_c\omega}\left(\cos(kz-\omega t)\hat{x} + \sin(kz-\omega t)\hat{y}\right)$

$\Rightarrow$ Induced polarization from medium (glass rod)

$\vec{P} = -Ne\vec{r}$, N is interms of plasma frequency $\omega_p^2 = \frac{Ne^2}{\varepsilon_0 m}$

$\vec{P}_{RH} = \frac{\varepsilon_0\omega_p^2}{\omega_0^2 - \omega^2 + \omega_c\omega}E_{RH}$

$\vec{P}_{LH} = \frac{\varepsilon_0\omega_p^2}{\omega_0^2 - \omega^2 - \omega_c\omega}E_{LH}$

In E&M we know the relationship of $\vec{P}$ to be $\vec{P} = \vec{E}(\varepsilon - \varepsilon_0)$ and most dielectric $n^2 \cong \frac{\varepsilon}{\varepsilon_0}$

$n^2_{RH} = 1 + \frac{\omega_p^2}{\omega_0^2 - \omega^2 + \omega_c\omega}$ $\quad n^2_{LH} = 1 + \frac{\omega_p^2}{\omega_0^2 - \omega^2 - \omega_c\omega}$

- $\omega^2 \mp \omega_c\omega \cong (\omega \mp \frac{1}{2}\omega_c)^2$

$\Rightarrow n_{LH} - n_{RH} = \sqrt{n^2(\omega + \frac{1}{2}\omega_c)} - \sqrt{n^2(\omega - \frac{1}{2}\omega_c)} \cong \omega_c\frac{dn}{d\omega}$

Produced a more detail Φ function

$$\Phi = \omega_c\frac{dn}{d\omega}\frac{\pi z}{\lambda} = \frac{\omega_c\omega z}{2c}\cdot\frac{dn}{d\omega} = \frac{e}{2mc}\omega\frac{dn}{d\omega}\int B\cdot dz \equiv \mathcal{V}\int B\cdot dz$$

~~dis~~ derived by Henri Bequerel, $\mathcal{V}$ is Verdet constant.
Most important since it links the ~~f~~ ω & ω_c
With the restriction of atomic transition g-factor

$$\mathcal{V} = \alpha\frac{e}{2mc}\omega\frac{dn}{d\omega}; \quad 0 \leqslant \alpha \leqslant 1$$

VI: QUESTION to ASK.

1. Does the rotating direction depends on the direction of B field?
2. Does the mag of Faraday lineerly depend on $\int B dz$?

VII: REFERENCES:

[1] Carl W. Akerlof, Univesity of Michigan department of Physic "FAraday Optical Rotation" 2009