5.4 Faraday effect
5.4.1 The effect

In 1845, Michael Faraday found that the plane of vibration of linearly polarized light incident on a piece of glass rotated when a strong magnetic field was applied in the

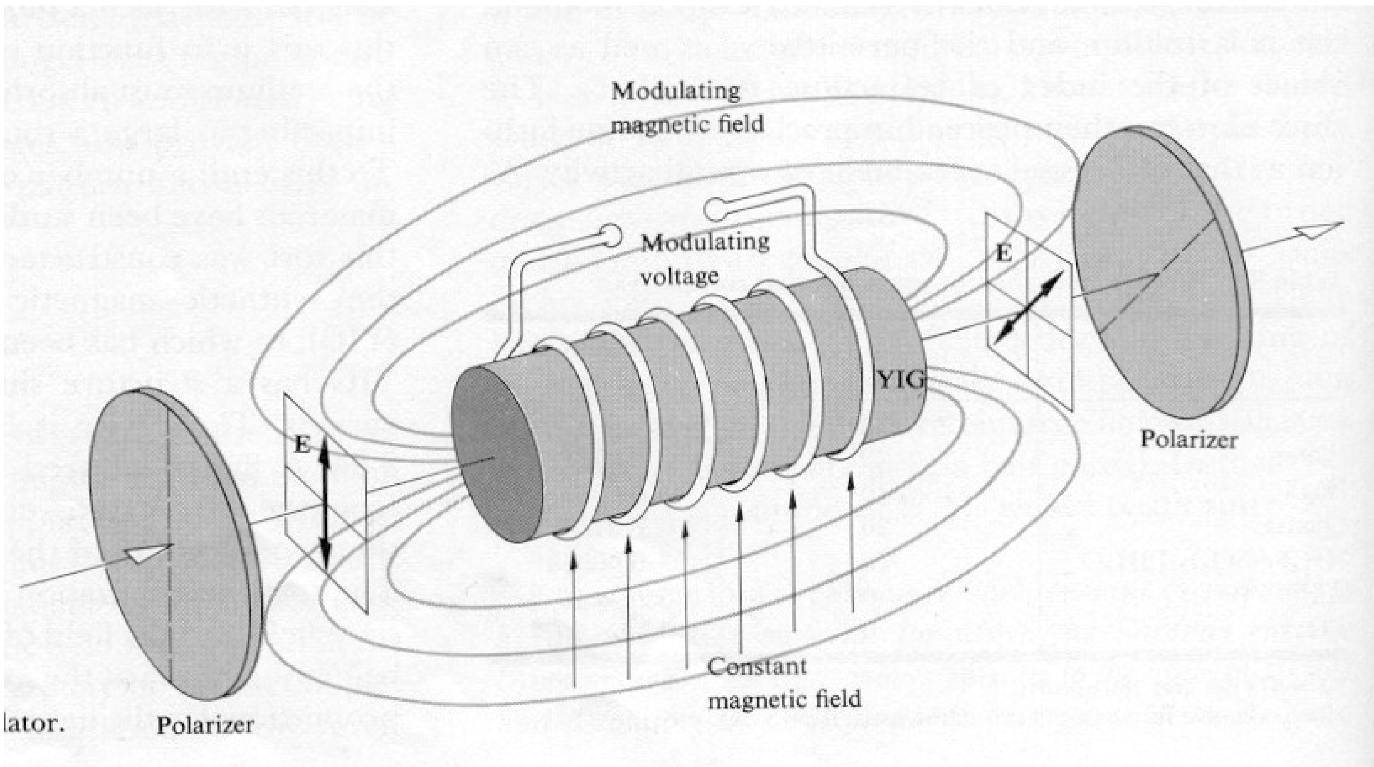

Fig. 5.22 A Faraday effect modulator..

propagation direction. This is known as **Faraday effect**.

Fig. 5.22 shows the experimental setup of Faraday effect.

The angle β through which the plane of vibration rotates is given by a empirically determined expression

$$\beta = \eta B d, \qquad (5.23)$$

where B is the static magnetic flux density (usually in Gauss), d is the length of medium traversed (in cm), and η is a factor of proportionality known as the *Verdet constant*. The Verdet constant for a particular medium varies with both frequency and temperature. Table 5.1 lists Verdet constants of some materials.

Table 5.1 Verdet constants for some substances.

Material	Temperature (°C)	$\mathcal{V}$ (min of arc gauss^{-1} cm^{-1})
Light flint glass	18	0.0317
Water	20	0.0131
NaCl	16	0.0359
Quartz	20	0.0166
$NH_4Fe(SO_4)_2.12H_2O$	26	−0.00058
Air*	0	6.27×10^{-6}
CO_2*	0	9.39×10^{-6}

5.4.2 The explanation

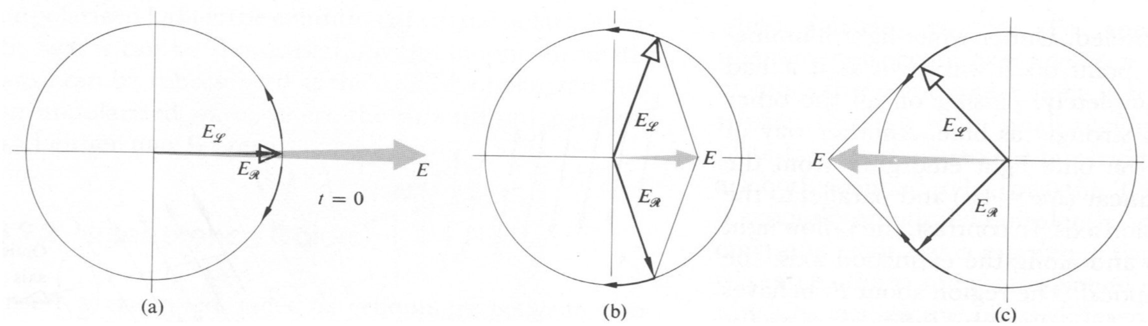

Fig. 5.23 The superposition of an R- and an L-state

A incident linear wave can be represented as a superposition of R- and L-states as shown in Fig 5.23. An elastically bound electron in the material will take on steady-state circular orbit driven by the rotating **E**-field of the wave (while the effect of the wave's **B**-field is negligible). The introduction of a large constant applied magnetic field perpendicular to the plane of the orbit will result in a radial force F_M on the electron. That force can point either toward or away from the circle's center, depending on the handedness of the light and the direction of the constant **B**-field. The total radial force (F_M plus the elastic restoring force) can therefore have two different values and so too can the radius of the orbit. Consequently, for a given magnetic field there will be two possible values of the electric dipole moment, the polarization , and the permittivity, as well as two values of the index of refraction, n_R and n_L.

Suppose the linear polarization is along the positive x-axis at the entrance of the material

After traveling through the sample with thickness d, the R-state rotates an angle $(k_R d - \omega t)$ clockwise and the L-state rotates an angle $(k_L d - \omega t)$ anti-clockwise. The resultant linear polarization direction rotates an angle $\beta = (k_R - k_L)d/2$ as shown in Fig. 5.24. Since $k = 2\pi/\lambda = 2\pi\, n/\lambda_0$

$$\beta = \frac{\pi d}{\lambda_0}(n_R - n_L) \qquad (5.24)$$

The difference n_R-n_L is proportional to the applied B-filed. Therefore Eq. (5.24) is the same as Eq. (5.23).

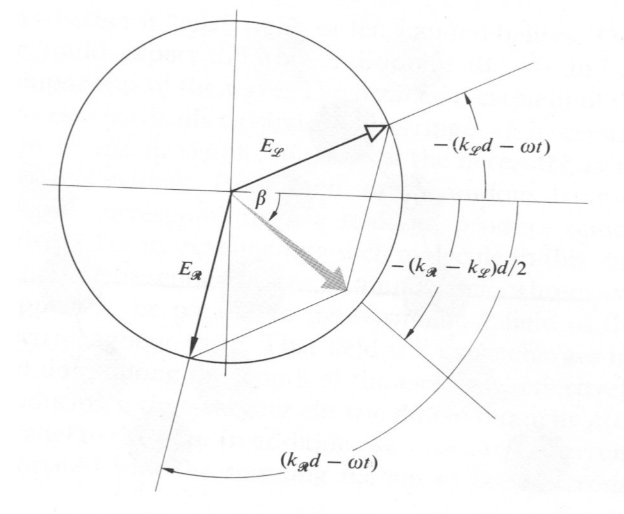

Fig. 5.24 The superposition of an R- and an L-state after traveling a sample of thickness d.