❑ Diffraction grating:

A repetitive array of diffraction elements either apertures or obstacles which has the effect of producing periodic alternation in the phase, amplitude or both of the emergent waves is said to be a diffraction grating. The corresponding diffraction pattern is known as spectrum.

There are two types grating:

1) Transmission grating

2) Reflection grating

❑ Plane transmission grating:

These are one type of diffraction grating which are prepared by ruling equidistant parallel line on a glass surface. The lines are drawn with a fine diamond point. The space between any two lines is transparent to light and the lined portion is opaque to light. Such a surface act as plane transmission grating. The grating used for the study of the visible region of the spectrum contains about 15000 lines per inch or 1000 lines per cm.

❑ Grating constant:

Each ruled line behaves as an opaque line while, the transparent portion between two consecutive ruled lines behaves as a slit. If '*a*' is the width of a clear space and '*b*' is the width of a ruled line, then the distance ($a + b$) is called grating constant or grating element.

Polarization

❑ Natural light:

The light is a transverse electromagnetic wave in which an electric field and a magnetic field vibrate in a direction perpendicular to the direction of propagation of light through space. Most light sources in nature (sunlight, firelight) emit unpolarized light i.e., light consists of many wave-trains whose directions of vibration are completely random. Therefore, the light in which the planes of vibration are randomly distributed about the propagation direction of the light wave is known an unpolarized light or natural light.

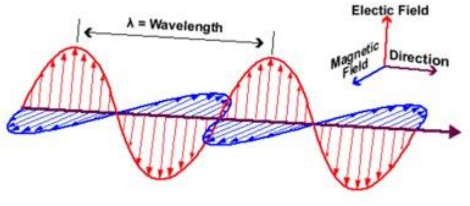


Fig. 1. Electromagnetic wave.

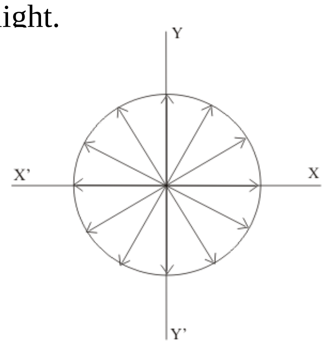


Fig. 2. Vibrations of the beam of unpolarized light.

❑ Polarization of light:

The polarization of electromagnetic waves refers to the direction of the vibration of electric field. When an ordinary light is passed through the tourmaline crystal, the light is polarized and the vibrations are confined to only one direction perpendicular to the direction of propagation of light. This light is said to be plane polarized and the phenomena is known as polarization of light.

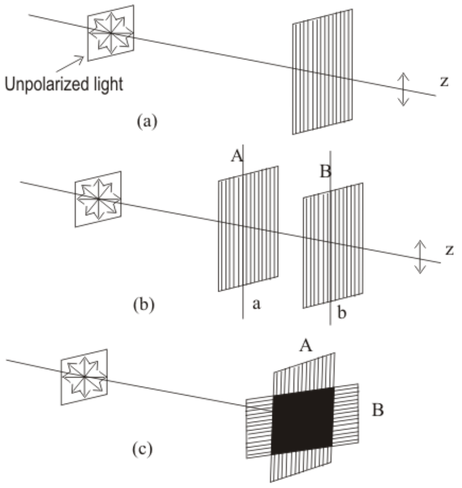


Fig. 3. Polarization of light.

❑ Classification of polarization and their production and detection:

Polarization of light can be classified into the following categories:

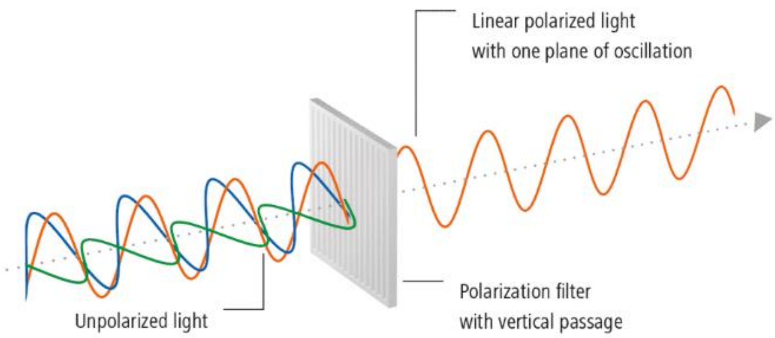
1) Plane polarized light/ linear polarization

2) Circularly polarized light/ circular polarization

3) Elliptically polarized light/ Elliptical polarization.

1) Plane polarized light:

When a natural beam of light is passed through a tourmaline crystal, the light is polarized and vibrations are confined to only one direction perpendicular to the direction of propagation of light. This light is said to be plane polarized light.

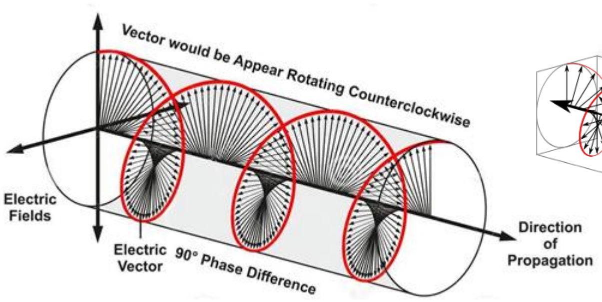


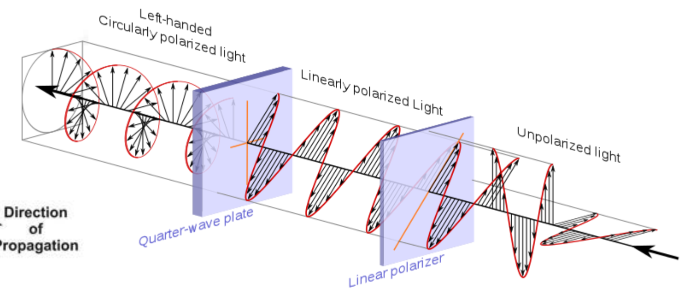
Production: A beam of monochromatic light is passed through a nicol prism. While passing through the nicol prism, the beam is split up into extra ordinary ray and ordinary ray. The ordinary ray is totally internally reflected back at the Canada balsam layer and is absorbed, while the extraordinary ray passes through the nicol prism. The emergent beam of light is plane polarized.

Detection: A beam of monochromatic light is allowed to fall on a nicol prism. The nicol prism is rotated. If on rotating the nicol prism, light is completely extinguished twice (in each rotation of the nicol prism), the beam is plane polarized.

2) Circularly polarized light:

The circularly polarized light has a polarization state in which, at each point, the electromagnetic field of the light wave has a constant magnitude and is rotating at a constant rate in a plane perpendicular to the direction of the wave. In this case, the amplitude of the vibrations remains constant but the direction changes only.





Production: Circularly polarized light can be obtained with the help of quarter wave plate. A beam of plane polarized monochromatic light is allowed to incident normally on quarter wave plate. The direction of vibrations of the incident ray make an angle $45°$ to the direction of the optical axis of the plate.

Let us consider two mutually perpendicular coherent linear vibrations

$$x = a\cos 45° \sin\omega t$$

or, $$x = \frac{a}{\sqrt{2}}\sin\omega t \;\dots\dots\dots\dots\dots (1)$$

and $$y = a\sin 45° \sin\left(\omega t + \frac{\pi}{2}\right) = a\sin 45° \cos\omega t$$

or, $$y = \frac{a}{\sqrt{2}}\cos\omega t \;\dots\dots\dots\dots\dots (2)$$

Squaring Eq. (1) and (2) and adding, we get

$$x^2 + y^2 = \frac{a^2}{2}\left(\sin^2\omega t + \cos^2\omega t\right) = \frac{a^2}{2}$$

$$\therefore \quad x^2 + y^2 = \frac{a^2}{2}$$

This is the equation of a circle; hence the emergent light will be circularly polarized.

Detection: If the original beam after passing through the quarter wave plate is extinguished twice in each rotation when studied by a rotating nicol prism, it is circularly polarized.

3) Elliptically polarized light:

To produce elliptically polarized light, the two waves vibrating at right angle to each other having unequal amplitudes should have a phase difference of $\frac{\pi}{2}$ or path difference of $\frac{\lambda}{2}$.

Let us consider two coherent linear waves

$$x = a\sin\theta\cos\omega t \quad \dots\dots\dots\dots\dots (3)$$

$$y = b\cos\theta\cos(\omega t - \tfrac{\pi}{2}) \text{ [As } \delta = \tfrac{\pi}{2}]$$

or, $$y = b\cos\theta\sin\omega t \quad \dots\dots\dots\dots\dots (4)$$

Now, squaring Eq. (3) and (4) and adding, we get

$$x^2 + y^2 = a^2\sin^2\theta\cos^2\omega t + b^2\cos^2\theta\sin^2\omega t$$

$$\frac{x^2}{a^2\sin^2\theta} + \frac{y^2}{b^2\cos^2\theta} = 1$$

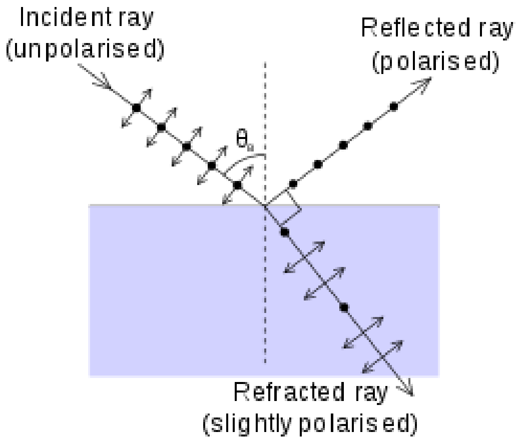
Which is the equation of an ellipse. Then the emergent beam will be elliptically polarized.

Detection: The beam is allowed to fall on a nicol prism. If the beam is elliptically polarized, the intensity varies from a maximum to a minimum value when the nicol prism is rotated.

❑ Applications of polarization of light:

i) Polarization is used in sunglasses to reduce the glare.
ii) Polaroid filters are used in plastic industries for performing stress analysis tests.
iii) Three-dimensional (3D) movies are produced and shown with the help of polarization.
iv) Polarization is used for differentiating between transverse and longitudinal waves.
v) Polarization is used in infrared spectroscopy.
vi) It is used in seismology to study earthquakes.
vii) In chemistry, the chirality of organic compounds is tested using polarization techniques.
viii) It is used in communication and detection systems such as fiber optics (waveguides), fast light modulators, lasers, radars, satellite communication.
ix) It is used in liquid crystal display technology.
x) It is used in optical microscopy in medicine, biology, geology, physics, chemistry.
xi) It is used in optical spectroscopy.
x) It is used in material science.

❑ Polarization by reflection:



Polarization of light by reflection is done by reflecting off the unpolarized light in a nonmetallic reflecting surface. The amount of polarization will depend on the angle of incidence of the light and the composition of the material used for the reflecting surface.

Metallic surfaces reflect light in various planes of vibrations; hence, the light will continue in its unpolarized state. Nonmetallic planes will reflect most of the vibrations at a single plane parallel to the plane of incidence. When light hits the material and crosses the interface, the atoms absorbs the light temporarily and the electron starts vibrating in the direction of the electric field of the refracted ray. This gets re-emitted with an electric field vector which is perpendicular to the direction of propagation of the wave. The reflection coefficient of light will go to zero between the angles of 0° to 90°, since the electric field goes parallel to the plane of incidence. At this angle, the reflected light will become linearly polarized.
The angle of incidence of light at which light becomes linearly polarized is known as Brewster's angle. The Brewster's angle is given by

$$\theta = \tan^{-1}\frac{n_t}{n_i}$$

where, n_t is the refractive index of the material on which the light is incident and n_i is the refractive index of the material to which light reflects back.

- **Polarization by Refraction**

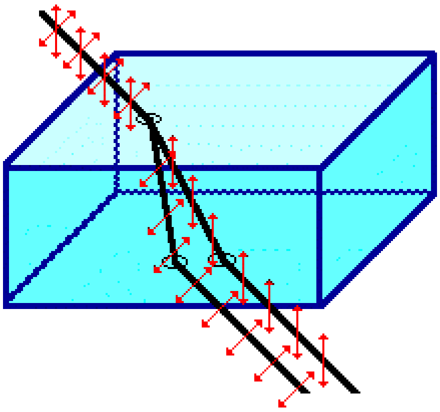


Fig. 1. The two refracted rays passing through the Iceland Spar crystal are polarized with perpendicular orientation.

Polarization can also occur by the refraction of light. Refraction occurs when a beam of light passes from one material into another material. At the surface of the two materials, the path of the beam changes its direction. The refracted beam acquires some degree of polarization. Most often, the polarization occurs in a plane perpendicular to the surface. Iceland Spar, a rather rare form of the mineral calcite, refracts incident light into two different paths. The light is split into two beams upon entering the crystal. Subsequently, if an object is viewed by looking through an Iceland Spar crystal, two images will be seen. The two images are the result of the double refraction of light. Both refracted light beams are polarized - one in a direction parallel to the surface and the other in a direction perpendicular to the surface. Since these two refracted rays are polarized with a perpendicular orientation, a polarizing filter can be used to completely block one of the images. If the polarization axis of the filter is aligned perpendicular to the plane of polarized light, the light is completely blocked by the filter; meanwhile the second image is as bright as can be. And if the filter is then turned 90-degrees in either direction, the second image reappears and the first image disappears.