4) Give the applications of Michelson's interferometer in detail.

2.2.2.4. Thickness of a Thin Transparent Sheet (Refractive Index of Thin Film)

Suppose a thin transparent sheet is placed in the path of one the interfering beams and the refractive index and thickness of this sheet is μ and t respectivelly. As a result, this beam will have an increased optical path as light travels more slowly in any medium than in free space.

In the given medium, the optical path will become μt and the increase in the optical path will be (μ – 1) (t = μt – t) on passing through the medium.

As we know that the beam traverses the sheet twice, total increase in optical path is given as 2(μ – 1)t.

The process includes the setting of interferometer to parallel fringes that uses white light. The cross-wire is set on the central white fringe. Now the thin sheet is located in the path of the interfering beams.

Conversely, there is a shift in fringe system. Now n number of fringes are calculated among the cross-wire and the new position of the central white fringe, therefore:

$$2(\mu - 1)t = n\lambda \qquad .....(1)$$

If we know the refractive index μ and wavelength λ then we are able to determine the thickness of the sheet. It is calculated as:

$$t = \frac{n\lambda}{2(\mu - 1)} \qquad .....(2)$$

If we know the thickness t of the sheet then we can determine the refractive index from the given relation:

$$\mu = \frac{n\lambda}{2t} + 1 \qquad .....(3)$$

Example 12: Find the thickness of the plate. In Michelson's interferometer a thin plate is introduced in the path of one of the beams and it is found that 50 bands had crossed the line of observation. If the wavelength of light used is 5896 Å and $\mu = 1.4$.

Solution: We have $\mu = 1.4$, $n = 50$, $\lambda = 5896 \times 10^{-10}$ m

The thickness t is found from the relation

$$t = \frac{n\lambda}{2(\mu - 1)} = \frac{50 \times 5896 \times 10^{-10}}{2(1.4 - 1)} = 0.3685 \times 10^{-4} \text{ m.}$$

1) What is resolving power of grating? And also discuss the expression for resolving power with example.

3.4.4. Resolving Power of Grating

The capacity to form separate diffraction maxima of two wavelengths which are very close to each other is known as Resolving Power of a diffraction grating.

The diffraction grating is preferred only when two distinct spectral lines with approximately the same wavelength such as a sodium dipole are clearly visible. The significant property of a diffraction grating is its capability to resolve two or more spectral lines that have approximately the same wavelength.

The Rayleigh's criterion of resolution states that 'the limit of resolution of a grating is defined as the smallest wavelength difference $d\lambda$ for which the spectral lines can be just resolved at the mean wavelength λ'.

The resolving power of grating can be measured by using the ration of $\lambda/d\lambda$. It is the smallest difference in two wavelengths which are just resolvable by grating and is the wavelength of either of them, or the mean wavelengthλ.

Expression for Resolving Power of Grating

Figure 3.28 shows that AB is a plane surface of a plane transmission grating with grating element (a + b) and total number of slits, N. Let us suppose that there is a beam of light which is consist with two wavelengths λ and $(\lambda + d\lambda)$incident normally on the grating.

Again from to **Figure 3.28**, XY is the field of view of the telescope, the n^{th} primary maxima of a spectral line of wavelength λ at an angle of diffraction θ_n and $(\lambda+d\lambda)$ at an angle of diffraction $(\theta_n + d\theta_n)$ is P_1 and P_2 respectively.

According to the Rayleigh criterion, two wavelengths λ and $\lambda+d\lambda$, will be resolved if the position of P_2 matches the first minima of P_1, such that the two lines will resolve if the principal maxima $(\lambda + d\lambda)$ is in the n^{th} order and is in that direction $(\theta_n + d\theta_n)$ falls over the first minima of λ in the same direction $(\theta_n + d\theta_n)$.

The following are the methods by which the quantitative relationship between the known parameters is obtained by considering the first minima of λ $(\theta_n + d\theta_n)$ in the direction:

The principal maxima of λ in the direction θ_n, can be represented as:
$(a + b) \sin \theta_n = n\lambda$ .....(1)

The equation of minima is, $N(a + b) \sin \theta = m\lambda$

Where m = all integral values except 0, N, 2N, ...nN, because for these values of m, the condition of maxima is satisfied and we get different maxima.

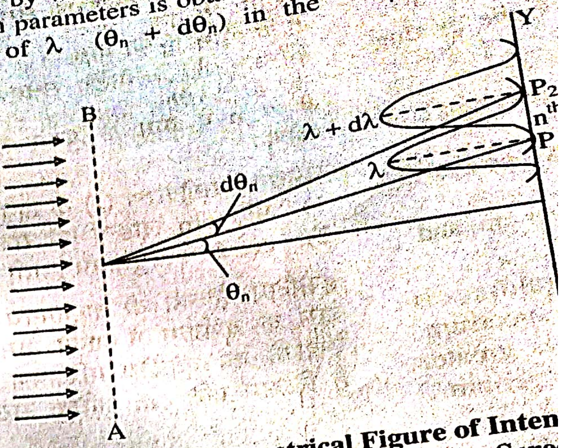

Figure 3.28: Geometrical Figure of Inten[sity] Distribution of Two Points on the Scre[en]
(चित्र 3.28—स्क्रीन पर दो बिंदुओं के ती[व्रता] वितरण का ज्यामितीय चित्र)

On putting the value of m as (nN + 1), the first minima adjacent to n^{th} principal maxima in the direction $(\theta_n + d\theta_n)$ can be obtained.

Thus, first minima in the direction $(\theta_n + d\theta_n)$ can be represented as

$N(a + b) \sin(\theta_n + d\theta_n) = (nN + 1)\lambda$ .....(2)

The principal maxima of wavelength $(\lambda + d\lambda)$ in the direction $(\theta_n + d\theta_n)$ is,

$(a + b) \sin(\theta_n + d\theta_n) = n(\lambda + d\lambda)$ .....(3)

On multiplying equation (3) by N, we get

$N(a + b) \sin(\theta_n + d\theta_n) = nN(\lambda + d\lambda)$ .....(4)

By using equations (2) and (4), we obtain

$$(nN + 1)\lambda = nN(\lambda + d\lambda)$$

$$\therefore \quad nN\lambda + \lambda = nN\lambda + nNd\lambda$$

$$\therefore \quad \lambda = nNd\lambda$$

$$\frac{\lambda}{d\lambda} = nN \qquad .....(5)$$

The above equation is the necessary expression for the resolving power of the grating with total slits N and diffraction order n.

From the above expression, it is concluded that the resolving power is directly proportional to

1) The order n of the spectrum, and
2) The total number of lines N on the grating surface.

From equation (1)

$$(a + b)\sin\theta_n = n\lambda$$

$$\therefore \quad n = \frac{(a + b)\sin\theta_n}{\lambda}$$

$$\frac{\lambda}{d\lambda} = \frac{N(a + b)\sin\theta_n}{\lambda} \qquad .....(6)$$

Therefore, Resolving Power Granting = Total Aperture [...] Dispersive Power

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Example 16: Calculate the minima number of lines per cm in a half inch width grating to resolve the wavelength 5890Å and 5896Å?

Solution: Given that n=1, $\lambda = 5890\,\text{Å}$

And $d\lambda = 5896 - 5890 = 6\,\text{Å}$

We know that Resolving power of a grating,

$$\frac{\lambda}{d\lambda} = nN \quad \text{Or,} \quad N = \frac{1}{n}\left(\frac{\lambda}{d\lambda}\right)$$

$$\text{Therefore, } N = \frac{1}{1}\left(\frac{5890}{6}\right) = 981\,/\text{cm}.$$

4) Describe the types of retardation plates and also give the equations.

4) मद
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5.2.5. Retardation Plates

A retardation plate is an optically transparent material where a beam of polarized light is classified into two orthogonal components. They retard the phase of one component respective to the other after that again combines the components with new polarisation characteristics into a single beam.

Following are the two types of retardation plates which are as:

1) **Quarter Wave Plate (QWP):** These wave plates are consisting with the doubly refracting crystal such as calcite or quartz. The refracting faces of the crystal of the crystal are cut parallel to the direction of optic axis and the thickness of refracting faces is like that it introduces a phase difference of $\pi/2$ or a path difference of $\lambda/4$ between the emerging ordinary or extraordinary rays.

If refractive indices for the ordinary and extraordinary rays are μ_O and μ_E respectively and then its path difference between O and E rays for normal incidence will be:

For negative crystals = $(\mu_O - \mu_E)t$

For positive crystals = $(\mu_E - \mu_O)t$

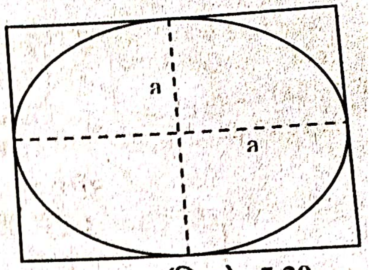

Figure (चित्र)—5.20

Where t = the thickness of the quarter wave plate. While $\lambda/4$ be the quarter wave plate introduces a path difference.

Henceforth, for negative crystals;

$$(\mu_O - \mu_E)t = \frac{\lambda}{4}$$

$$\text{Or, } t = \frac{\lambda}{4(\mu_O - \mu_E)} \quad .....(1)$$

And for positive crystals,

$$(\mu_E - \mu_O)t = \frac{\lambda}{4}$$

$$\text{Or, } t = \frac{\lambda}{4(\mu_E - \mu_O)} \quad .....(2)$$

When introduced in the path of a plane polarised light. Light this quarter wave plate is used to produce circularly and elliptically polarised.

Limitations: For particular wavelengths, this QWP is designed. Due to this reason it is not useful for other wavelengths.

2) **Half-Wave Plate (HWP):** These types of wave plates are consisting with the doubly refracting crystal. The refracting faces of the crystal are cut parallel to the optic axis and the thickness (t) of refracting faces is like that it introduces a phase difference of π or a path difference of $\lambda/2$ between the ordinary or extraordinary rays.

The path difference for negative crystal will be: = $(\mu_O - \mu_E)t$

The path difference for positive crystal will be: = $(\mu_E - \mu_O)t$

As, $\lambda/2$ be the half-wave plate which introduces a path difference when a plane polarised light is passed through it. Therefore, For negative crystal:

$$= (\mu_O - \mu_E)t = \frac{\lambda}{2}$$

$$\text{Or, } t = \frac{\lambda}{2(\mu_O - \mu_E)} \quad .....(1)$$

For positive crystal = $(\mu_e - \mu_o)t = \frac{\lambda}{2}$

$$\text{Or, } t = \frac{\lambda}{2(\mu_E - \mu_O)} \quad .....(2)$$

Both (quarter and half wave plates) plates are known as retardation plate because they retard the motion of one of them.

Example 8: What will be the thickness of a quarter wave plate when the wavelength of light is 5890Å. Given μ_E = 1.553 and μ_O = 1.544.

Solution: Given that, λ = 5890Å = 5.890 × 10^{-5}cm; μ_E = 1.553 and μ_O = 1.544

The thickness of the quarter wave plate of positive crystal is

$$t = \frac{\lambda}{4(\mu_E - \mu_O)}$$

$$\text{Therefore, } t = \frac{5.890\times10^{-5}}{4(1.533-1.544)} = \frac{5.890\times10^{-5}}{4\times.009}$$

$$= \frac{5.890\times10^{-5}}{3.6\times10^{-2}} = 1.636\times10^{-8}\ \text{cm.}$$

12) Discuss the various applications of holography.

7.5.5. Application of Holography

The applications of holography are as follows:

1) **Holographic Interferometry:** Holography is a widely used technique which is used for making accurate interferometer measurements. One can use conventional interferometry to make measurements on highly polished surfaces of simple shapes. One can make measurements on three dimensional surfaces of arbitrary shapes and surface conditions by using holographic interferometry. It is also used in non-destructive testing.

   For example, Holographic monitoring is possible for objects in machines that are subjected to heat or pressure stress. The faults in the parts are observed in the changing interference patterns.

   The application of holographic interferometric techni ques follows several procedures. The double exposure interferometry makes two exposures of the same emulsion with the same reference wave in which one with the original object and the other with the object to be compared.

   It is possible to compare the two objects by comparing the interference pattern created by the reconstructed object wave from the two interfering. The two objects generally correspond to the same object under different conditions of strain.

2) **Holographic storage of digital data:** In holographic images, the digital data can be recorded as bright and dark spots.

   A hologram has the capacity to hold a very large quantity of data because it can have many "pages" that are captured at various angles with respect to the plate. The pages can be read out one by one by illuminating the hologram with a laser beam at different angles.

3) **Ultrasonic Hologram:** The term "ultrasonic hologram" suggests that the waves forming the hologram are not necessarily electromagnetic in nature. The holographic principle is independent on the transverse nature of the radiation.

   Holograms generated by using ultrasonic waves are very useful because such waves have the ability to penetrate objects that are opaque to visible light. Such Holograms are are very useful to get 3D image inside the opaque recording.

4) **Holographic Image Formation:** Holography was first used to create three-dimensional images. Let us consider the problem that arrises at the time of image formation of a number of small dynamic objects whose positions are not known.

Example 10: Calculate the critical angle and acceptance angle of given optical fibre, if the refractive indices of the core and the cladding are 1.6 and 1.3 respectively.

Solution: Given that $n_1 = 1.6$ and $n_2 = 1.3$

Critical angle is calculated as;

$$\sin\phi_c = \frac{n_2}{n_1} = \frac{1.3}{1.6} = 0.8125$$

$$\therefore \phi_c = 54.3°$$

Acceptance angle is calculated as

$$\theta_0 = \sin^{-1}\left[\sqrt{n_1^2 - n_2^2}\right] = \sin^{-1}\left[\sqrt{1.6^2 - 1.3^2}\right]$$

$$= \sin^{-1}(0.92) = 66.8°$$

Angle of acceptance cone $= 2\theta_0 = 133.6°$