Engineering Physics 1
Prof. G.D. Varma
Department of Physics
Indian Institute of Technology-Roorkee

Module-03
Lecture-02
Interference of Light - Part 02

In the previous lecture I described the basic theory of interference, what is difference between constructive and destructive interference, superposition principle, methods to find the resultant of two or more than two sinusoidal waves of same frequency and acting in the same direction at a point in a space, what is condition for constructive and interval destructive interference, in terms of path difference and phase difference;

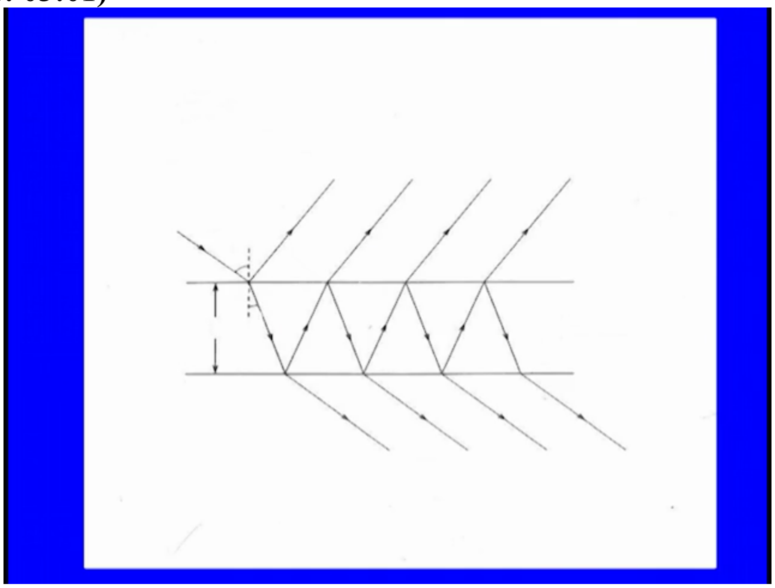
How the intensity of result and wave vary with the phase difference of the interfering waves what are the conditions to observe a Stationary interference pattern and how to get two coherent sources for interference, by using division of wave front and division of amplitude. And I also discuss some famous experimental setup, which are used in laboratory to observe interference pattern based on division of wave front such as Young's Double Slits, Fresnel Biprism and Fresnel Double Mirror Experiment.

Mostly in all undergraduate optics labs, Fresnel Biprism experiment is performed with the help of this experiment. Wavelength of monochromatic light can be determined by measuring the fringe width with the help of a travelling microscope. I have given the expression of fringe width in the previous lecture, by measuring the required parameters experimentally, with the help of this equation wavelength can be determined.

With the help of this experiment, it is also possible to determine thickness of a transparent plate. For this, the plate is introduced in the path of one of the interfering beams and resulting shift in the position of Central bright fringe is measured with the help of a travelling microscope. The required expression I have already obtained in the previous lecture. Here, it should be noted that with monochromatic light it is not possible to recognise the central bright fringe.

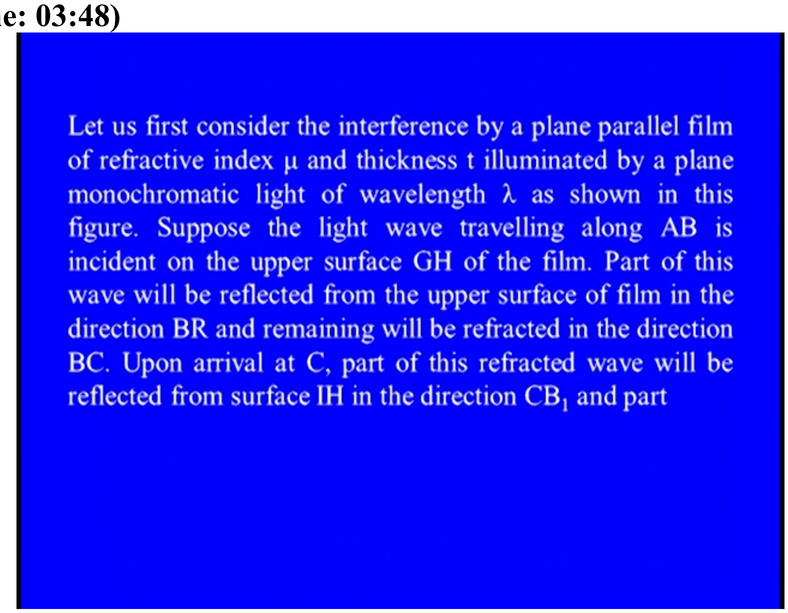
But if we use white light, then, central bright fringe will be wide and few fringes adjacent to this will be coloured. So, shift in central bright fringe on introducing the plate can be measured easily by using white light source. Now I am going to describe the formation of interference pattern by division of amplitude.

(Refer Slide Time: 03:01)



In this case, the Internet beam is divided into two persons by division of its amplitude by partial reflection and refraction by some optical devices. The two portions afterwards recombined to produce interference effect. For example, if a plane wave falls on a thin film, then, the wave reflected from the upper surface interferes with the wave reflected from the lower surface. The colours when thrown by thin films of oil on water by soap Bubbles or bike racks in a piece of glass can be explained by the phenomenon of interference of light by division of amplitude.

(Refer Slide Time: 03:48)

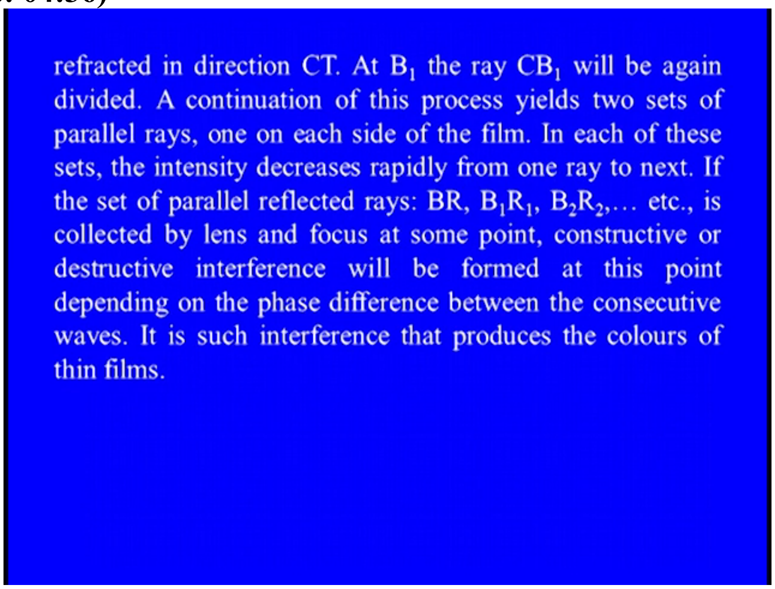


Let us first consider the interference by a plane parallel film of refractive index Mu and thickness t illuminated by a plane monochromatic light of wavelength Lambda as shown in this figure.

Suppose, the light wave travelling along AB is incident on the upper surface GH of the film, part of this wave will be reflected from the upper surface of fill in the direction BR and remaining will be reflected in the direction BC.

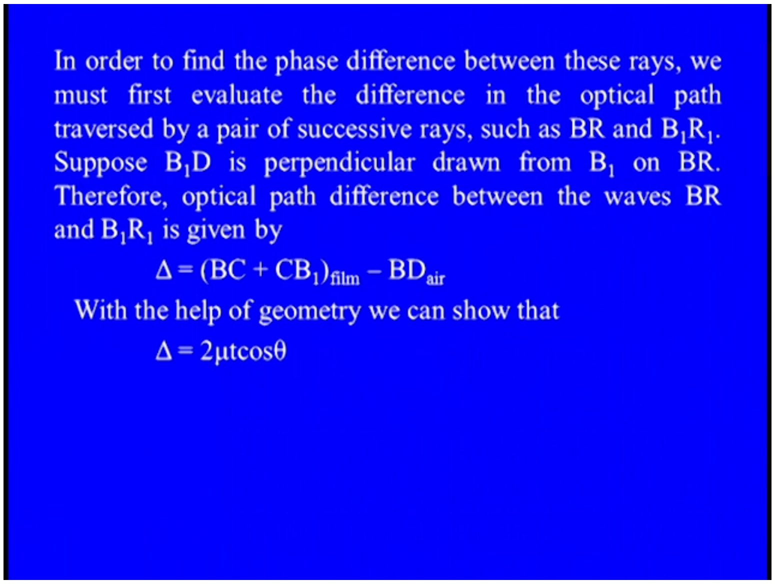
Upon arrival at C, part of this reflected wave will be reflected from surface IH, in the direction CB1 and part refracted in direction CT.

(Refer Slide Time: 04:36)



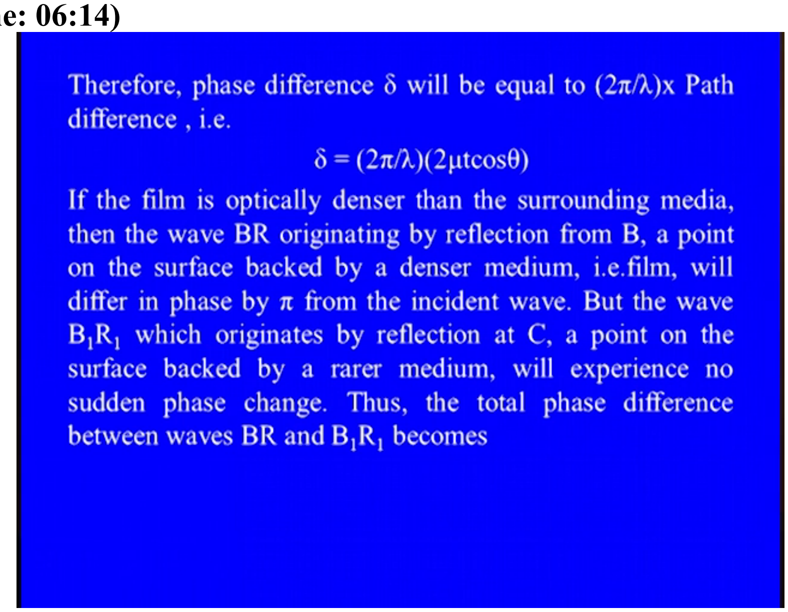
At B1 the ray CB1 will be again divided. A continuation of this process yields two sets of parallel rays one on each side of the film. In each of these sets, the intensity decrease rapidly from one ray to next. If the set of parallel reflected rays: BR, B1 R1, B2 R2 etcetera is collected by lens and focus at some point constructive and destructive interference will be formed at this point, depending on the phase difference between the consecutive waves. It is such interference that produces the colours of the thin films.

(Refer Slide Time: 05:31)



In order to find the phase difference between these rays, we must first evaluate the difference in the optical path traversed by a pair of successive rays, such BR and B1R1. Suppose B1D is perpendicular drawn from B1 on BR. Therefore, optical path difference between the waves BR and B1R1 is given by BC + CB1in film - BD in air. With the help of geometry, we can show that this path difference will be = 2 Mu t cos theta. Therefore, phase difference Delta will be given will be = 2 PI by lambda into path difference that is 2 PI by lambda into 2 Mu t cos theta.

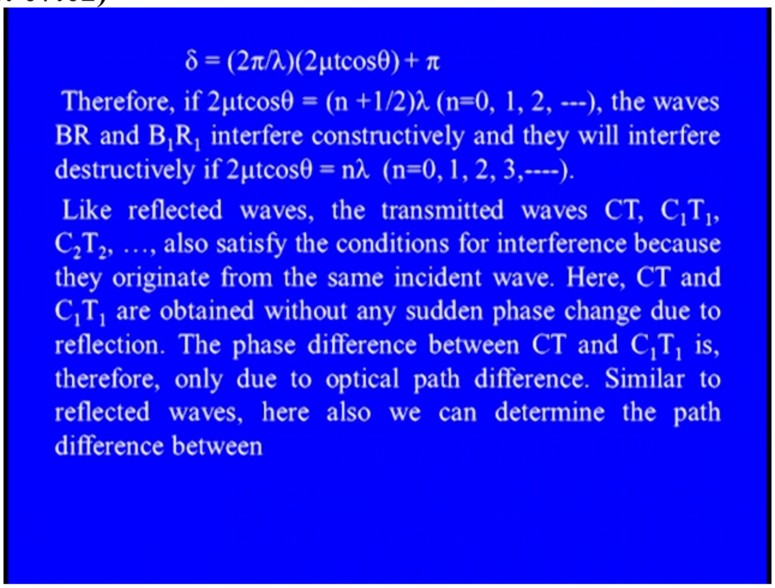
(Refer Slide Time: 06:14)



If the film is optically denser than the surrounding media, then, the wave BR originated by reflection from B, a point on the surface backed by a denser medium, that is, film will be different phase by pi from the incident wave. But the wave B1 R1 which originates by reflection at C, a point on the surface backed by a rare medium, will experience no sudden phase change.

Thus the total phase difference between waves B R and B1 R1 becomes 2 PI by lambda into 2 Mu cos theta + Pi.

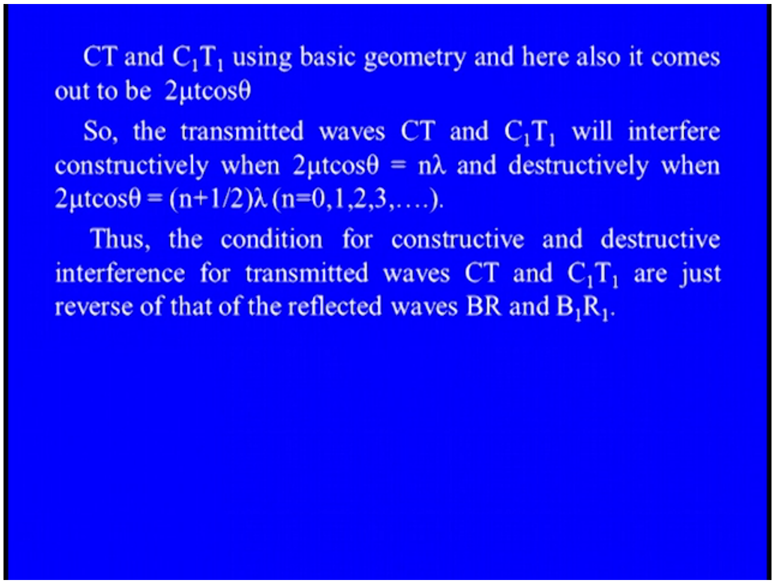
(Refer Slide Time: 07:02)



Therefore if 2 Mu t cos theta = n + half lambda where n is integer, the wave BR and B1R1 interfere constructively and they will interfere destructively if 2 Mu t, 2 Mu t cos theta is = n lambda where n is again integer. Like reflected waves, the transmitted waves CT, C1T1, C2T2 etcetera also satisfy the conditions for interference because they originate from the same incident wave. Here CT and C1 T1 are obtained without any sudden phase change due to reflection.

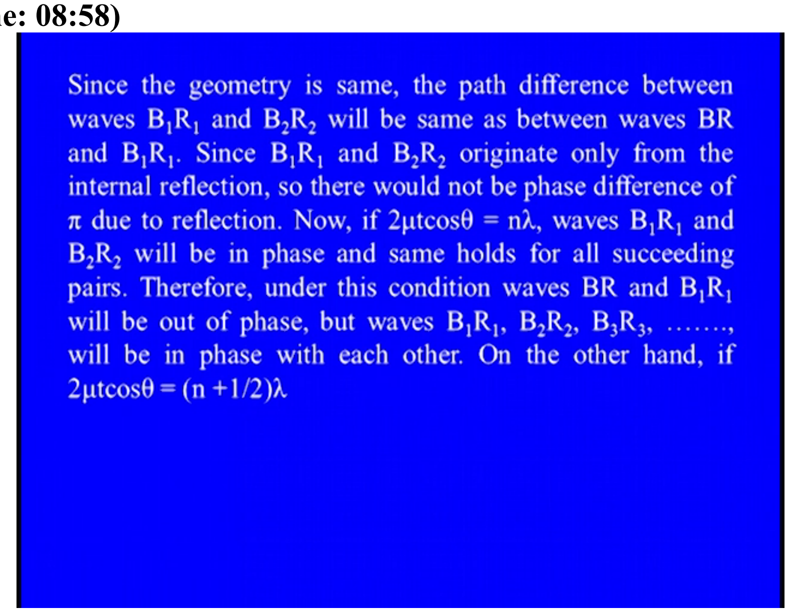
The phase difference between CT and C1T1 is therefore only due to optical path difference. Similar to reflected waves, here also we can determine the path difference between CT and C1 T1 using basic geometry.

(Refer Slide Time: 08:11)



And here also it comes out to be 2 Mu t cos theta. So the transmitted waves CT and C1T1 will interfere constructively went 2 Mu t cos theta is = n lambda and destructively when 2 Mu t cos theta is = n + half Lambda. Thus, the condition for constructive and destructive interference for transmitted waves CT and C1T1 are just reverse of that of the reflected waves BR and B1R1.

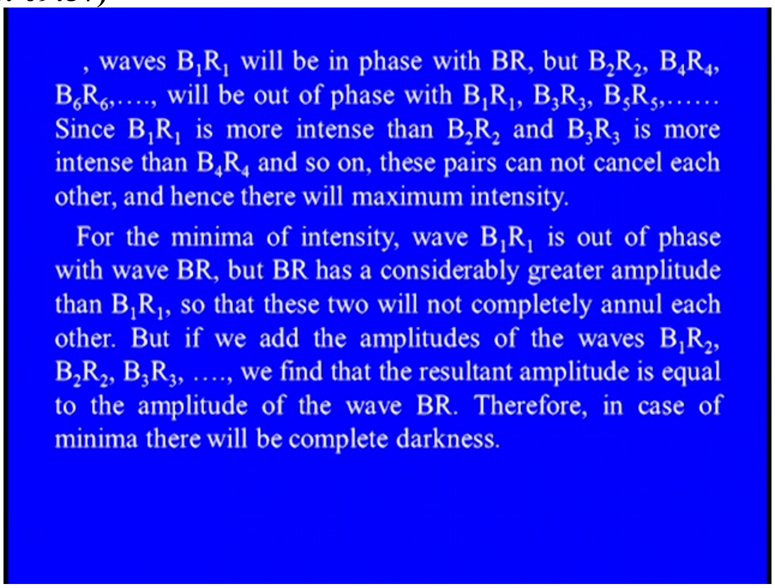
(Refer Slide Time: 08:58)



Since the geometry is same, the path difference between waves B1R1 and B2 R2 will be same as between waves BR and B 1R1 since B1R1 and B2R2 originate only from the internal reflection so there would not be phase difference of Pi due to reflection. Now if 2 Mu t cos theta is = n lambda waves B1R1 and B2R2 will be in phase and same holds for all succeeding pairs. Therefore, under this condition, waves BR and B1R1 will be out of phase.

But waves B1R1 and B2R2, B3R3 and so on, will be in phase with each other. On the other hand, if 2 Mu t cos theta is = n + half of Lambda

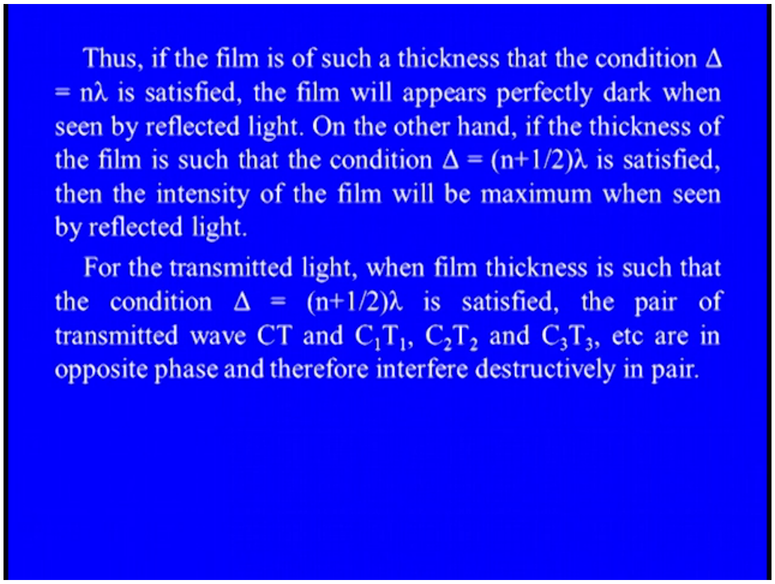
(Refer Slide Time: 09:57)



, waves B1R1 will be in phase with BR, but we B2R2, B4R4, B6R6 and so on, will be out of phase with B1R1, B3R3, B5R5 and so on since B1R1 is more intense than B2R2 and B3R3 is more intense than B4R4 and so on. These pairs cannot cancel each other and hence there will be maximum intensity. For the minima of intensity wave, B1R1 is out of phase with wave BR, but BR has considerably greater amplitude than B1R1, so that these two will not completely annul each other.

But if we add the amplitude of the Waves B1R2, B2R2, B3R3., we find that the resultant amplitude is = the amplitude of the wave BR. Therefore, in case of minima there will be complete darkness.

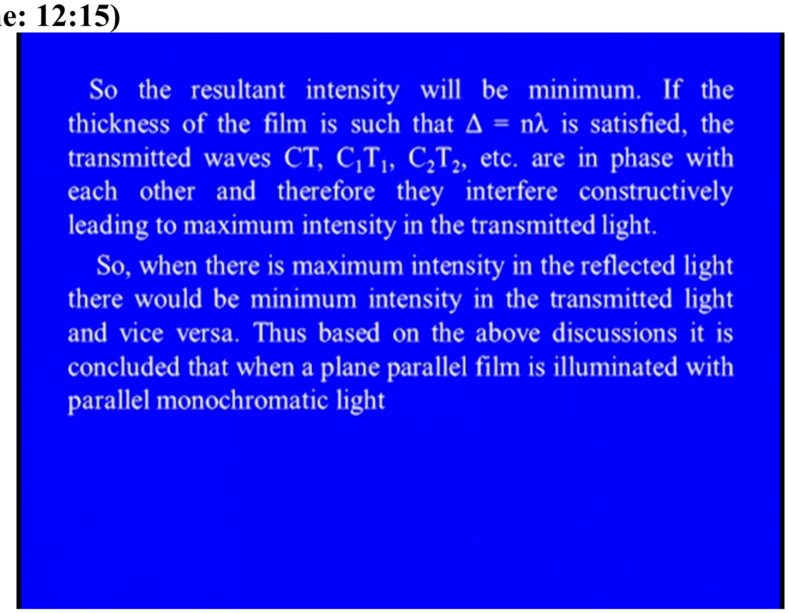
(Refer Slide Time: 11:19)



Thus, if the film is of such a thickness that the condition path difference is = n Lambda is satisfied, the film appears perfectly dark when seen by reflected light. On the other hand, if the thickness of the film is such that path difference is = n + half Lambda then the intensity of the film will be maximum, when seen by reflected light. For the transmitted light, when film thickness is such that the condition delta of path difference is = n + half Lambda is satisfied.

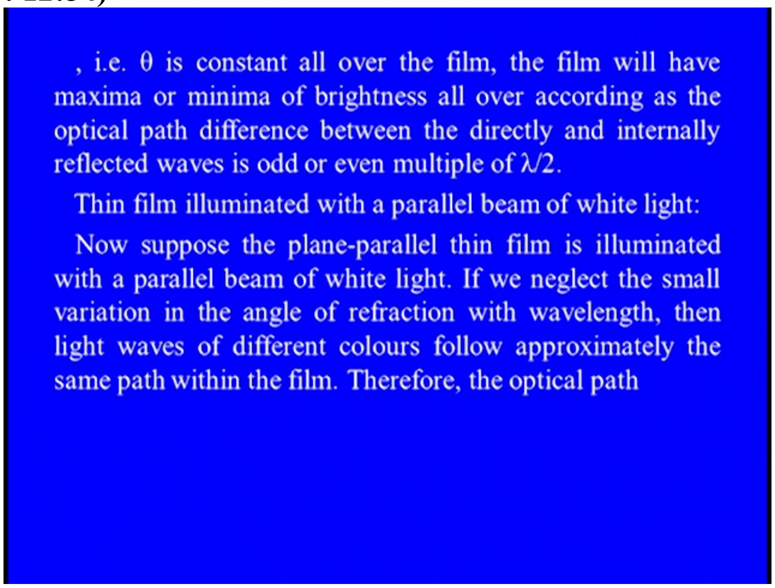
The pair of transmitted wave CT, C1T1, C2T2, C3T3 etcetera are in opposite phase and therefore interfere destructively in pair. So, the resultant intensity will be minimum if the thickness of the film is such that path difference

(Refer Slide Time: 12:15)



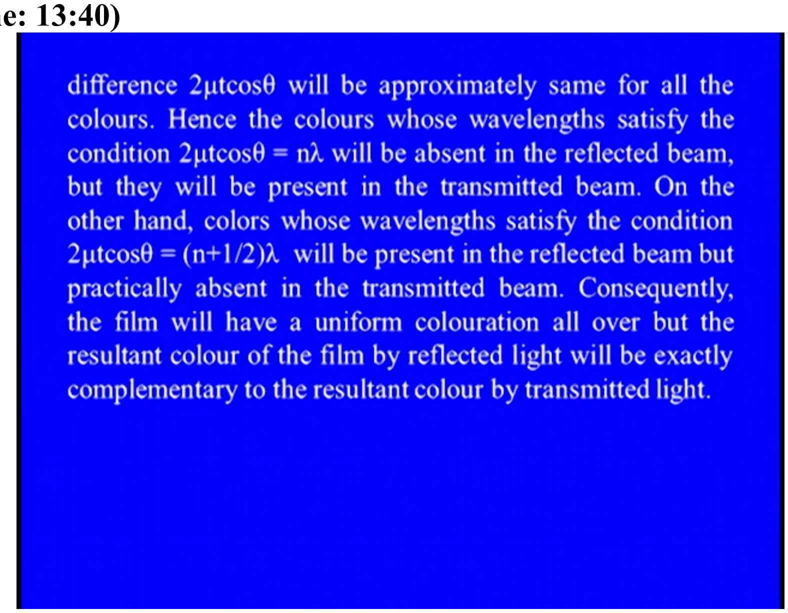
is n lambda is satisfied, the transmitted waves CT, C1T1,C2T2 etcetera are in phase with each other and therefore they interfere constructively leading to maximum intensity in the transmitted light. So, when there is maximum intensity in the reflected light, there would be minimum intensity in the transmitted light and vice versa. Thus based on the above discussions, it is concluded that when a plane parallel film is illuminated with parallel monochromatic light,

(Refer Slide Time: 12:54)



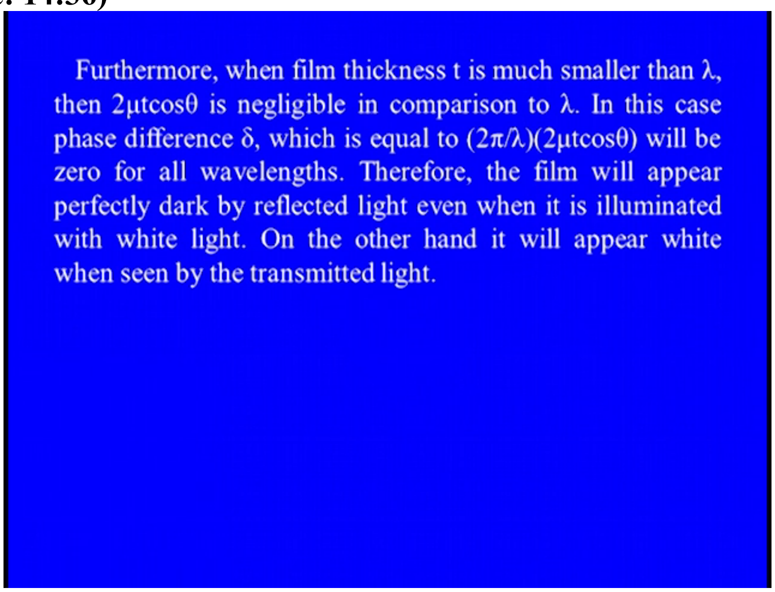
that is theta is constant over the film, the film will have maxima or minima of brightness all over according as the optical path difference between the directly and the internally reflected waves is odd or even multiple of Lambda by 2. Now, suppose the plane parallel thin film is illuminated with a parallel beam of white light, if we neglect the small variation in the angle of refraction with wavelength then light waves of different colours follow approximately the same path within the film.

(Refer Slide Time: 13:40)

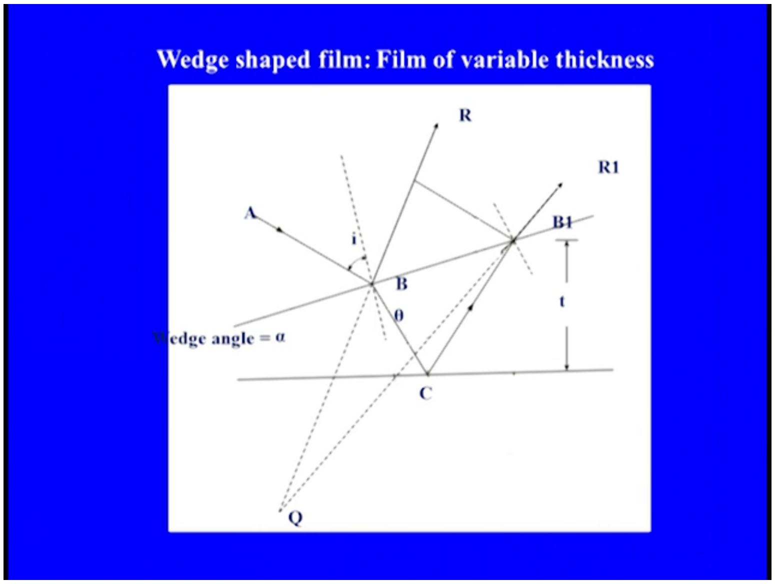


Therefore the optical path difference 2 Mu t cos theta will be approximately same for all the colours. Hence, the colours whose wavelength satisfy the condition 2 Mu t cos theta is = n Lambda will be absent in the reflected beam. But they will be present in the transmitted beam. On the other hand, colours whose wavelength satisfies the condition 2 Mu t cos theta is = n + half Lambda will be present in the reflected beam. But practically, absent in the transmitted beam.

Consequently, the film will have a uniform coloration all over. But the resultant colour of the film by reflected light will be exactly complementary to the resultant colour by transmitted light.
(Refer Slide Time: 14:36)



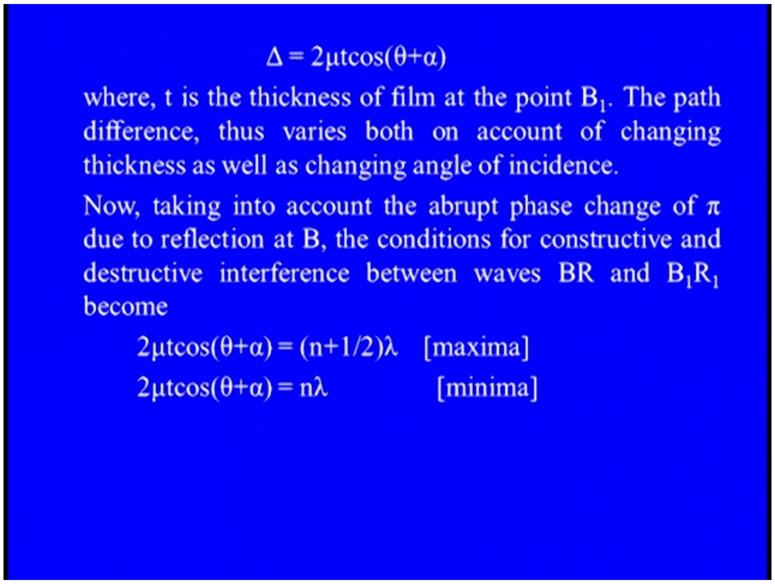
Furthermore, when film thickness t is much smaller than lambda then, 2 Mu t cos theta is negligible, in comparison to Lambda; in this case, phase difference Delta which is = 2 Pi by lambda into 2 Mu t cos theta will be 0 for all wavelength. Therefore, the film will appear perfectly dark by reflected light even when it is illuminated with white light. On the other hand, it will appear white when seen by transmitted light. Now, let us consider a film in the shape of a thin wedge whose side form a small angle alpha as shown in this figure.
(Refer Slide Time: 15:15)



Now, suppose this film is illuminated with plain monochromatic light waves. Here also, the directly reflected wave BR and internally reflected wave B1R1 originate from the same incident wave propagating along AB. And hence, they are capable of producing observable interference effects. Here, the two interfering waves do not reach there, along parallel path but they appear to diverse from a point Q in the rear of the film. So, destructive and constructive interference occurs at the point Q which is however virtual.

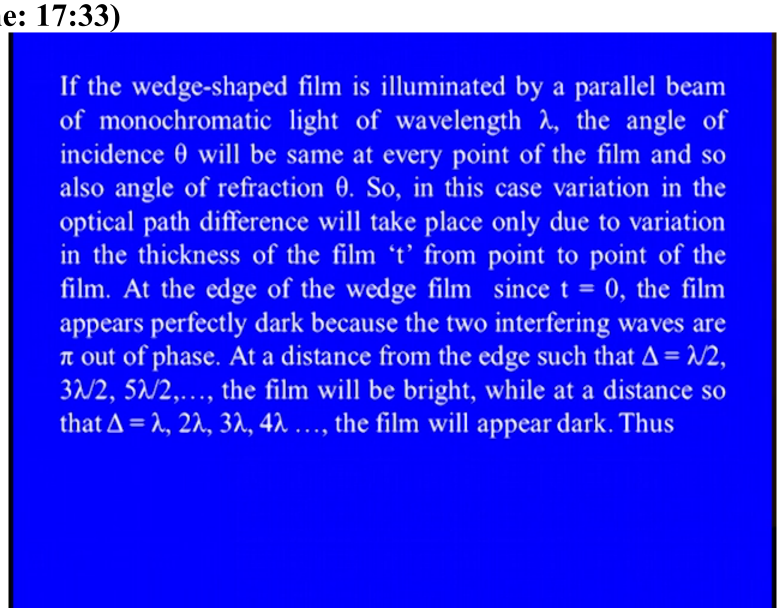
If the two interfering waves BR and B1R1 fall on lens, they will cross each other at a real point Q prime, the focus conjugate of Q. As a consequence, really reinforcement are destructive interference would occur at 2 prime. Thus Q will be the position where the interference fringe appears to be formed. From geometry, we can find the optical path difference Delta between the waves B R and B1 R1 and this comes out to be:

(Refer Slide Time: 16:39)



2 Mu t cos theta + alpha, where t is the thickness of film at the point B1; The path difference thus varies both on account of changing thickness as well as changing angle of incidence theta. Now, taking into account the abrupt phase change of Pi, due to reflection at B, the condition for constructive and destructive interference between waves BR and B1R1 becomes 2 Mu t cos theta + Alpha is = n + half Lambda for maxima and 2 Mu t cos theta + Alpha is = n lambda or minima.

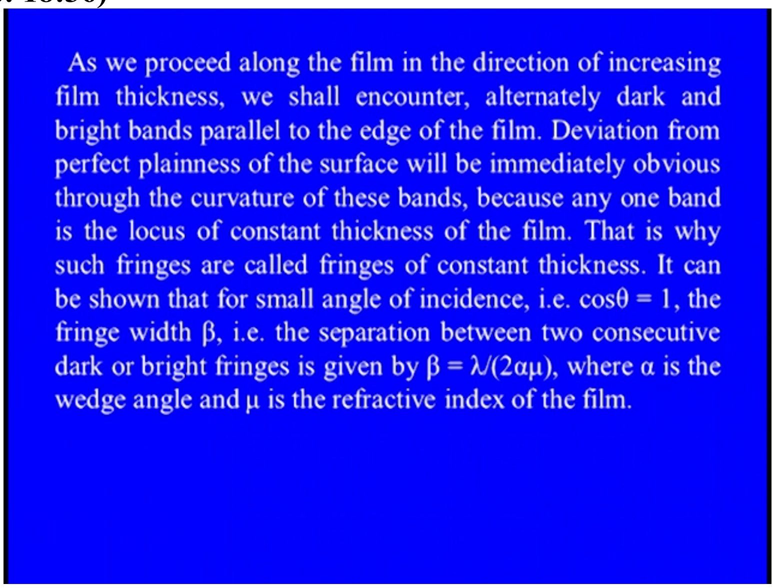
(Refer Slide Time: 17:33)



If the wedge shaped film is illuminated by a parallel beam of monochromatic light of wavelength lambda, the angle of incidence theta will be same at every point of the film and show also angle of refraction. So, in this case, variation in the optical path difference will take place only due to variation in the thickness of the film t from point to point of the film. At the edge of the waves, film wedge films since t is = zero, the film appears perfectly dark because the two interfering waves are Pi out of phase.

At a distance from the edge such that the path difference is = lambda by 2, 3 lambda by 2, 5 lambda by 2 and so on. The film will be bright while at a distance so that path difference is = lambda, 2 Lambda, 3 lambda, 4 lambda and so on. The film will appear dark.

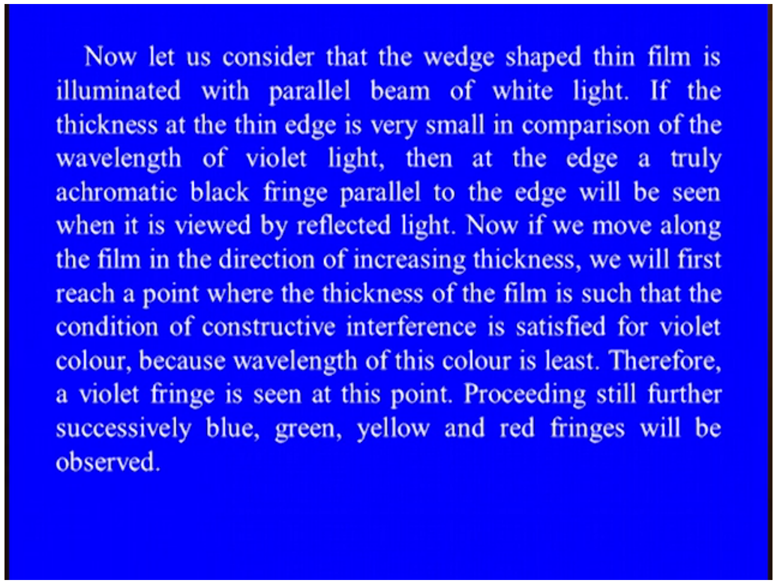
(Refer Slide Time: 18:36)



Thus as we proceed along the film, in the direction of increasing film thickness, we shall encounter alternatively dark and bright bands parallel to the edge of the film. Deviation from perfect plainness of the surface will be immediately obvious through the curvature of these bands. Because anyone band is the locus of constant thickness of the film. That is why such fringes are called fringes of constant thickness.

It can be shown that for a small angle of incidence that is cos theta nearly = 1 the fringe width beta that is the separation between the two consecutive dark or bright fringes is given by Lambda upon 2 alpha Mu where alpha is the wedge angle and Mu is the refractive index of the film. Now, let us consider that the wedge shaped thin film is illuminated with parallel beam of white light.

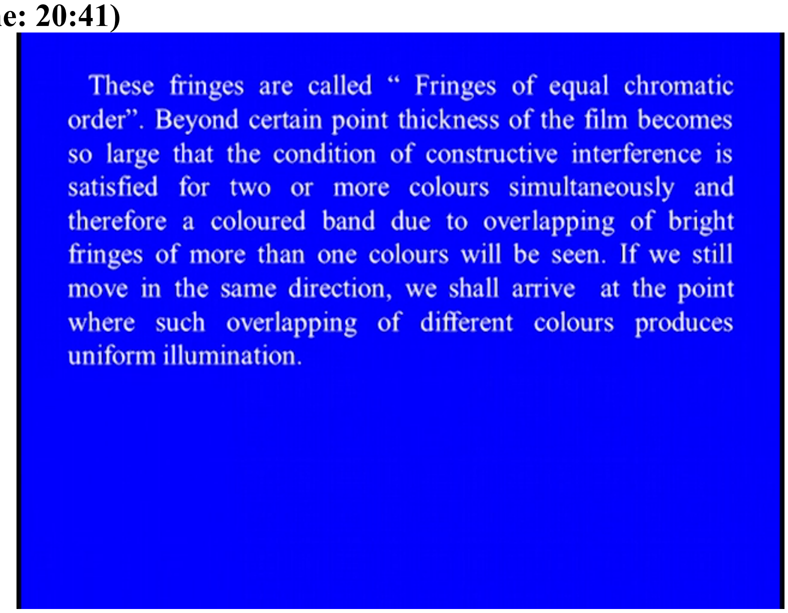
(Refer Slide Time: 19:45)



If the thickness at the thin edge is very small in comparison of the wavelength of violet light then at the edge a truly acromatic black fringe parallel to the edge will be seen when it is viewed by reflected light. Now, if we move along the film in the direction of increasing thickness, we will first reach a point where the thickness of the film is such that the condition of constructive interference is satisfied for violet colour because wavelength of this colour is released in the visible spectrum.

Therefore, a violet fringe is seen at this point. Proceeding still further successively blue, green, yellow and red fringes will be observed.

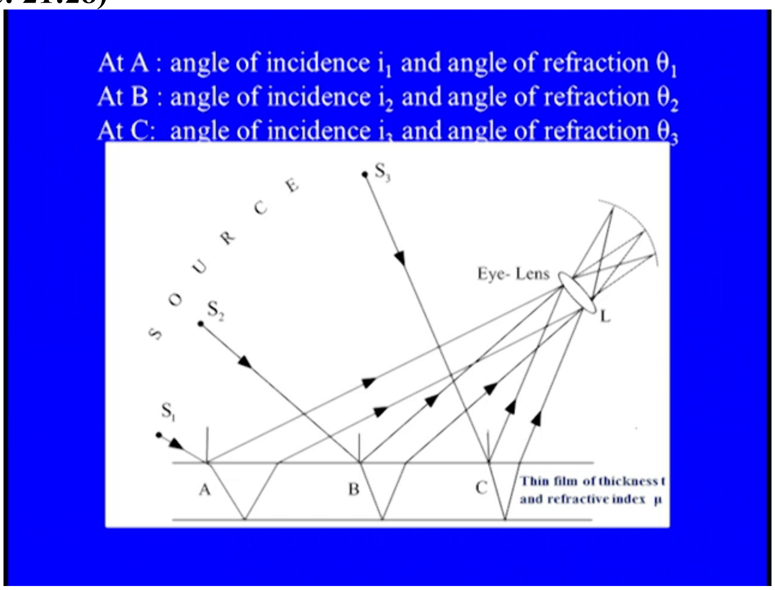
(Refer Slide Time: 20:41)



These fringes are called fringes of equal chromatic order. Beyond certain point, thickness of the film become so large that the condition of constructive interference is satisfied for two or more colours simultaneously and therefore a coloured banned due to overlapping of bright fringes of more than one colours will be seen. If we still move in the same direction, we shall arrive at a point, where such overlapping of different colours produces uniform illumination.

Now let us consider that a thin parallel film is illuminated by using extended white source as shown in this figure.

(Refer Slide Time: 21:28)



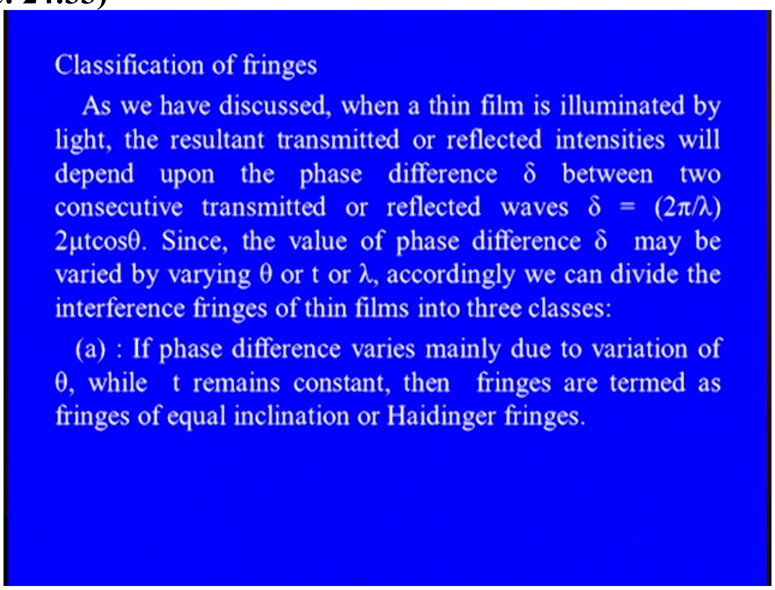
In this case, light from each point of the source gives rise to a pair of coherent waves on reflection from the film and cos theta is not same for all of them. Each point of the film is also seen by light from different points of the extended source safe. If at points A, B, C, the condition 2 Mu t cos theta 1 is = n one + half Lambda 1, 2 Mu t cos theta 2 is = n 2 + half Lambda 2 and 2 Mu t cos theta 3 is = n3 + half lambda 3 are satisfied respectively.

We shall observe a bright band of Lambda one at A, bright band of Lambda 2 at B, the bright band of lambda 3 at C and so on. Thus we shall observe a set of equal inclination colour bands, if the film is of variable thickness, we shall again observe a set of colour band each being a locus of equal thickness of the film. The colour of any particular region of the film changes, if the I is shifted to a new position.

Now, light from other points of extended source is reflected from that particular region of the film, at different angles to I. In effect, 2 Mu t cos theta alters throughout the film leading to change in colours exhibited by thin film. This clearly explains the origin of colour exhibited by a thin film of vial; while on the surface of water or colour of soap bubbles by light reflected from the sky. It should be noted that bright colours will be seen only when film is extremely thin.

That is up to few wavelengths thick. The colours become fit for thicker films and for such cases the direction of incidence should be kept nearly normal. Otherwise at other angles, the directly and indirectly reflected coherent waves may get separated to such an extent that their wave front may not interfere each other and they may get so far apart that only one wave enters the I at a time. And so, all colours effectively may vanish when viewed by naked eye. Now, let us discuss the classification of fringes.

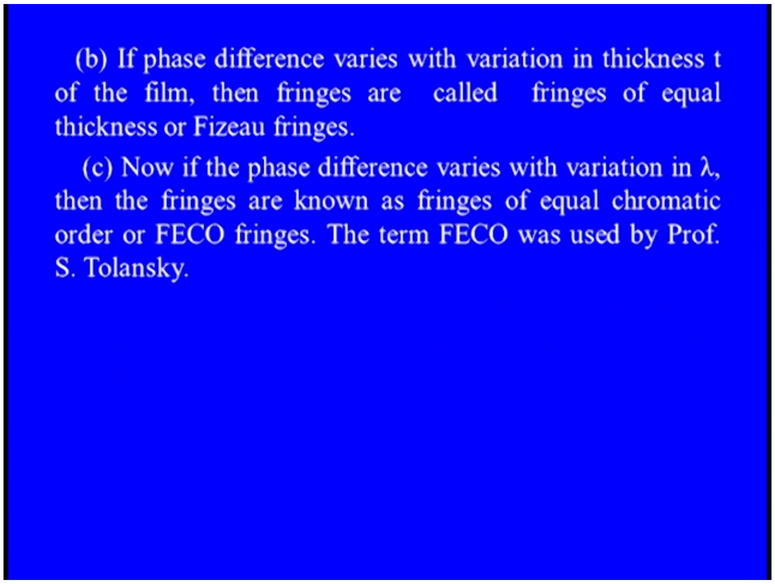
(Refer Slide Time: 24:33)



As we have discussed, when a thin film is illuminated by light the resultant transmitted or reflected in densities, will depends upon the phase difference Delta between two consecutive transmitted are reflected waves. And phase difference is given by 2 Pi by lambda into 2 Mu t cos theta. Since the value of the phase difference Delta may be varied by varying theta, or t, or lambda, accordingly, we can divide the interference fringes of thin films into three classes.

If phase difference varies mainly due to variation of theta, while t remains constant then, fringes are termed as fringes of equal inclination or Haidinger fringes.

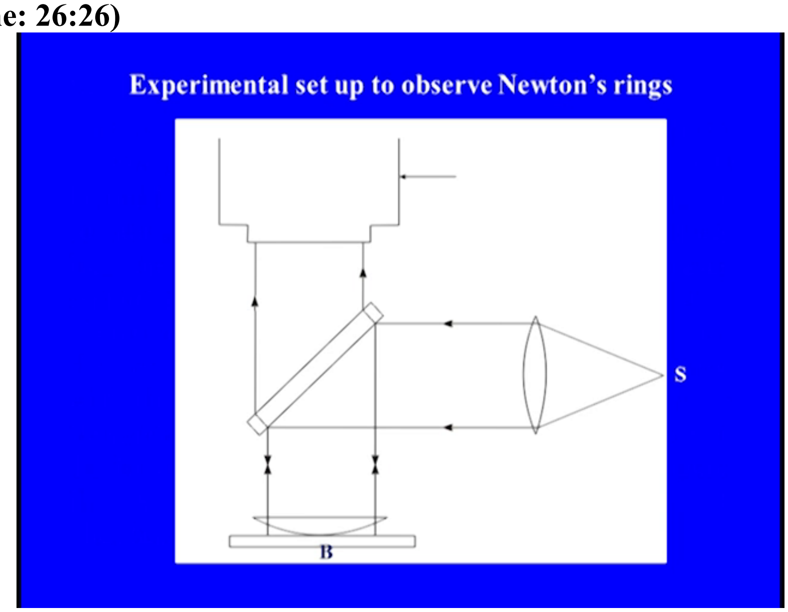
(Refer Slide Time: 25:32)



If phase difference varies with variation in thickness t of the film then, fringes are called fringes of equal thickness or Fizeau fringes. Now, if the phase difference varies with variation in Lambda then, the fringes are known as fringes of equal chromatic order or FECO fringes. The term FECO was used by Professor S Tolansky. Now, in this lecture, I will describe some of the experimental setup used in laboratory to observe the fringes of equal thickness and fringes of equal inclinations one.

One of the most important experiments which is based on the division of amplitude is Newton ring experiment.

(Refer Slide Time: 26:26)

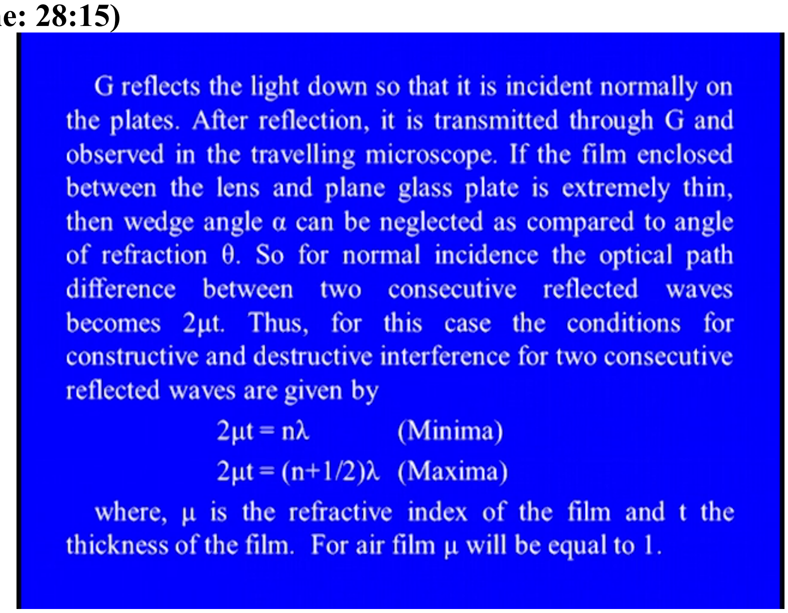


In this experiment a thin air film are progressively increasing thickness in all direction from one point can be formed by placing a plane convex lens of large radius of curvature on a plane glass plate such that its convex surface faces the plate. The air film does form possesses a radial symmetry about the point of contact and when it is illuminated normally with monochromatic light, the observed interference fringes are circular ring concentrate with the point of contact.

These rings are known as Newton's ring. The experimental arrangement to observe the Newton rings in laboratory is shown in the figure. Here, A is a Plano convex lens placed on the glass plate B. The glass plate G reflect the light down so that it is incident normally on the plates, after reflection, it is transmitted through G and observed in the travelling microscope. If the film in close between the lens and the plane glass plate is extremely thin, then, wave single alpha can be neglected as compared to angle of incidence theta.

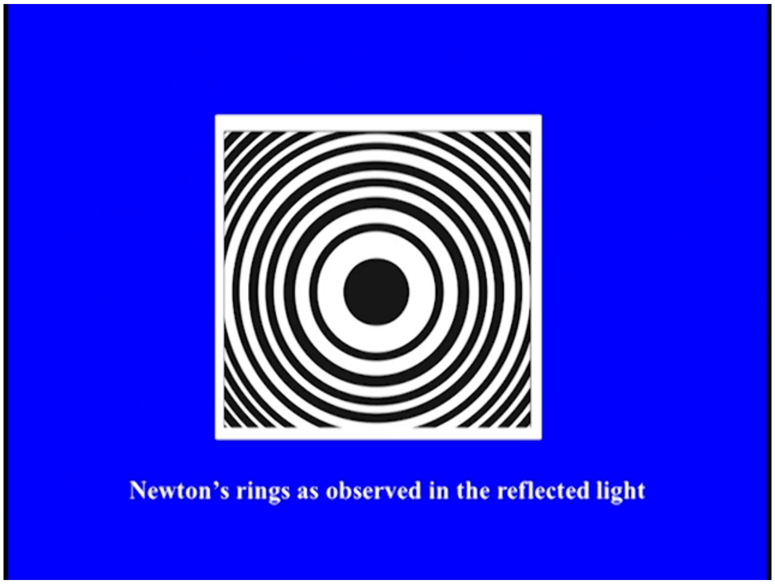
So, for normal incidence the optical path difference between the two consecutive reflected waves become 2 Mu times t. Thus, for this case, the condition for constructive and destructive interference for two consecutive reflected waves are given by

(Refer Slide Time: 28:15)



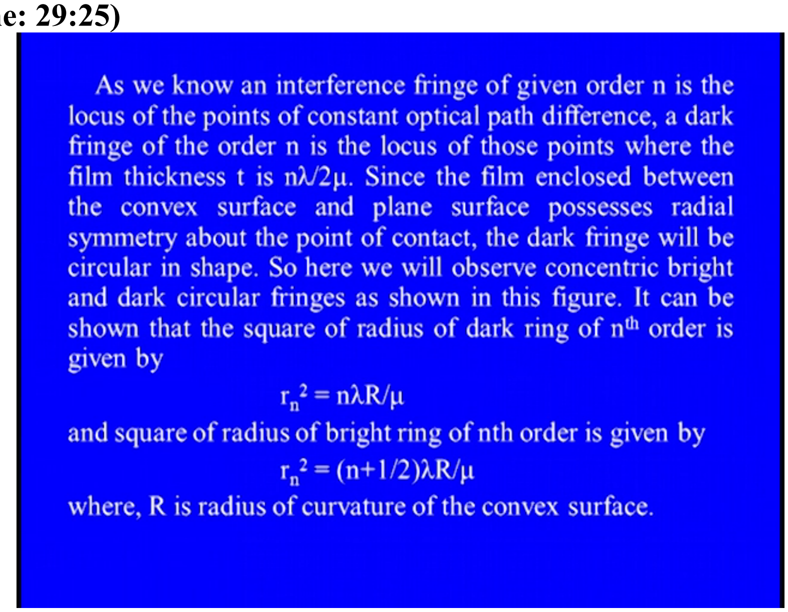
2 Mu t is = n lambda for minimum and 2 Mu t is = n + half lambda for maximum where Mu is the refractive index of the film and t the thickness of the film. For air film, Mu will be = one. As we know an interference fringe of a given order n is the locus of the points of constant optical path difference.

(Refer Slide Time: 28:43)



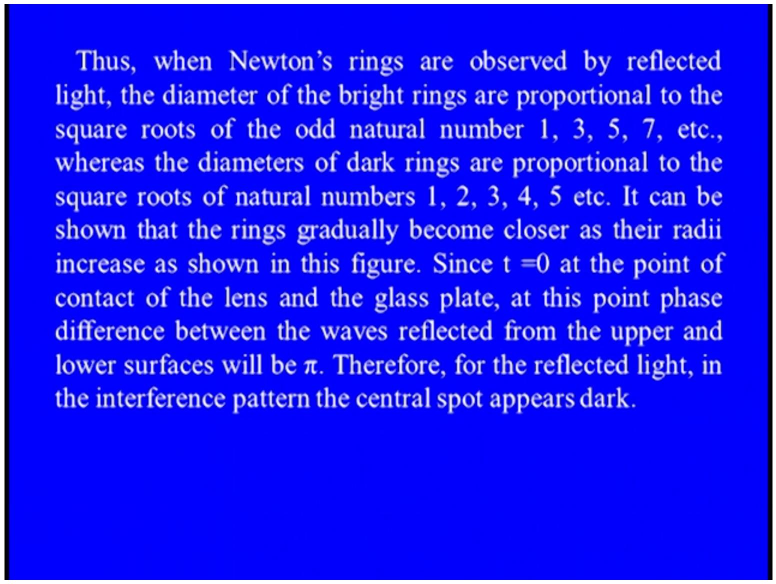
A dark fringe of the order n is the locus of those points where the film thickness t is n Lambda upon 2 Mu. Since the film enclosed between the convex surface and the plane surface possesses radial symmetry about the point of contact, the dark fringe will be circular in shape. So, here we will observe concentric bright and dark circular colour fringes as shown in this figure. It can be shown that the square of radius of dark ring of nth order is = n Lambda

(Refer Slide Time: 29:25)



R divided by Mu and square of radius of bright ring of nth order is = n + half Lambda R upon Mu, where R is the radius of curvature of the convex surface.

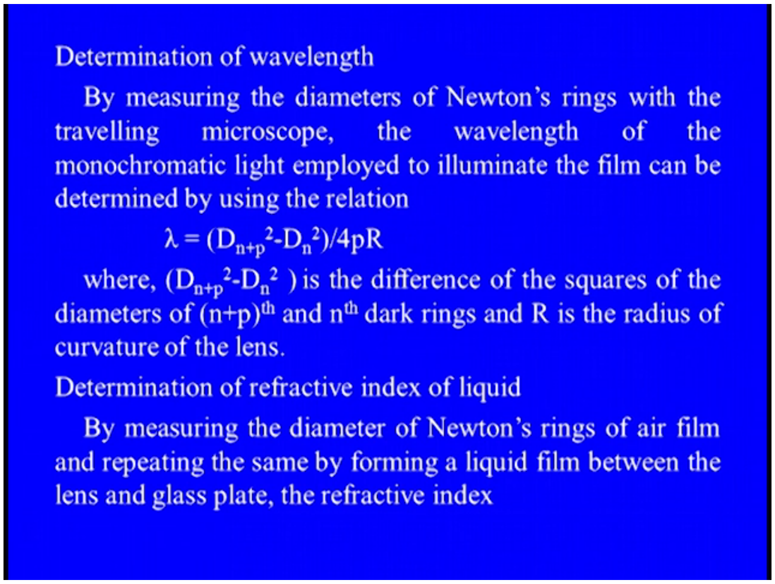
(Refer Slide Time: 29:49)



Thus, when Newton rings are observed by reflected light, the diameter of the Bright rings are proportional to the square root of the odd natural numbers like 1,3,5,7, so on. whereas the diameters of dark rings are proportional to the square root of natural number 1, 2, 3, 4 and so on. It can be shown that the rings gradually become closer as their radii increase as shown in this figure. Since t is = 0 at the point of contact of the length and the glass plate at this point phase difference between the waves reflected from the upper and lower surfaces will be Pi.

Therefore, for the reflected light in the interference pattern, the central spot appears dark. But if it is seen in the transmitted light, the central spot will be bright. Now, I will discuss some important application of Newton's ring experiment. One of the, one example of, is the determination of the wavelength of the monochromatic light used.

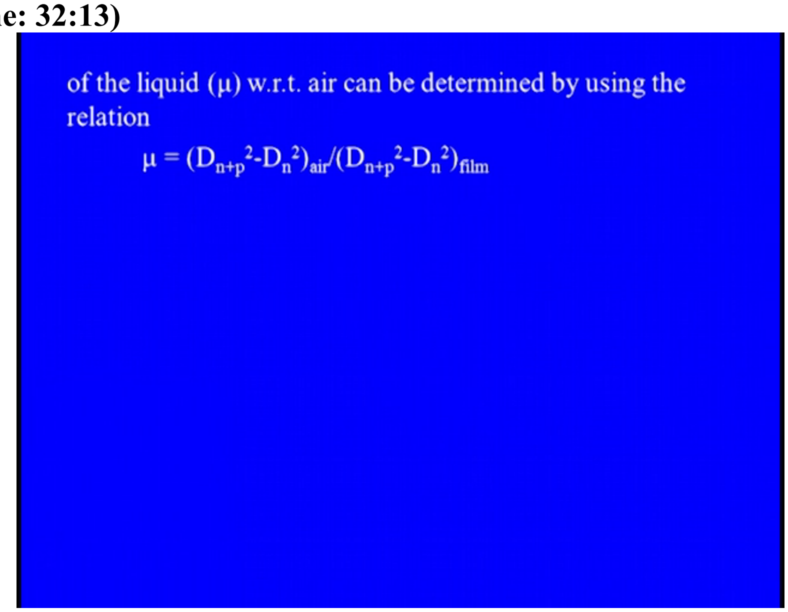
(Refer Slide Time: 31:07)



So, for this purpose we have to measure the diameter of the Newton rings with the help of the travelling microscope and by using the relations Lambda is = Dn + p square - Dn square upon 4 p R where Dn + p square - Dn square is the difference of the squares of the diameter of the n + pth and nth dark rings and R is the radius of curvature of the lens. With the help of Newton's ring experiment it is also possible to determine the refractive index of a given liquid.

For this purpose also we have to measure the diameter of the Newton rings with air film as well as that as well as by introducing the liquid in the glass plate and convex lens.

(Refer Slide Time: 32:13)

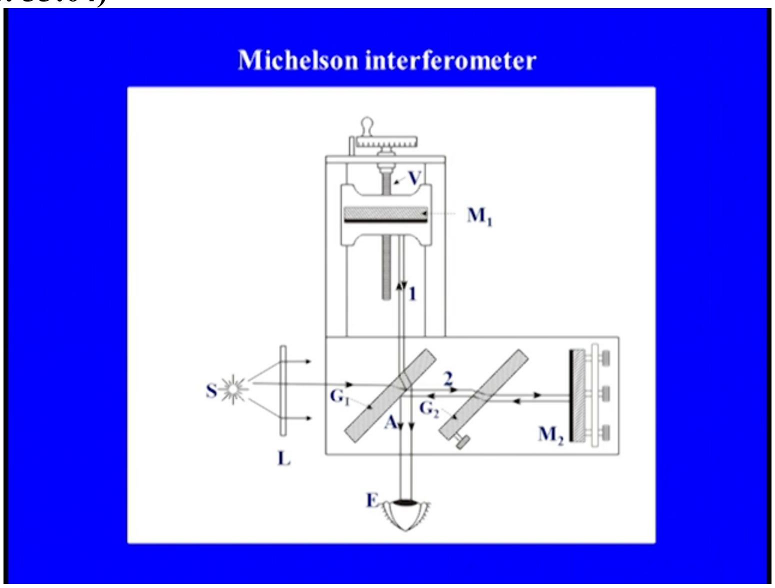


And by using the expression Dn + p square - Dn square of air divided by Dn + p square - Dn square for film, we can determine the refractive index of the liquid. We can show with the help of Newton's ring experiment, we can determine the wavelength of the monochromatic light used.

And we can also measure the refractive index of a given liquid. Only thing is that we have to determine the diameter of the Newton rings precisely by using the travelling microscope.

Now, I will discuss and other important experimental setup which is based on division of amplitude is known as the Michelson interferometer.

(Refer Slide Time: 33:04)



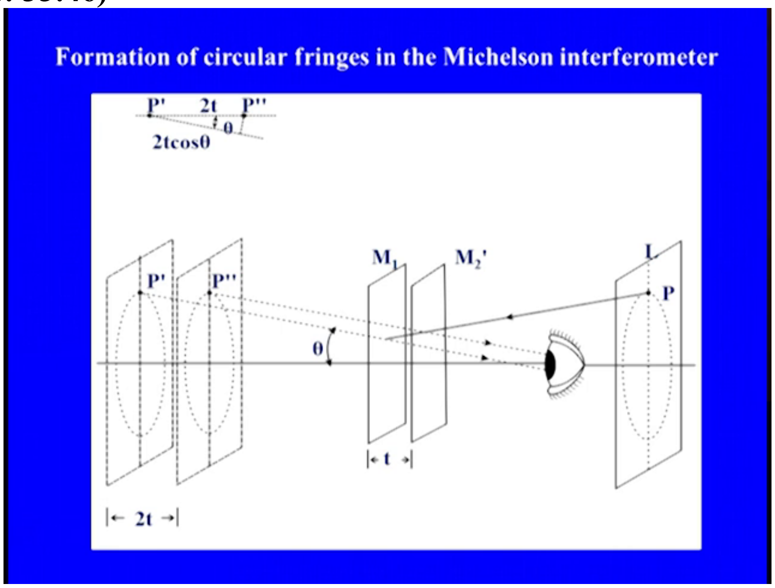
The main optical part of this interferometer consists of two highly polished plane mirrors, M1 and M2. Two plane parallel glass plates G1 and G2 of equal thickness as shown here in the figure. The mirror M2 is fixed while M1 can be moved such that during the motion it remains exactly parallel to its proceeding position. Normally the rear side of the plate, G1 is lightly silver, so that the light coming from source S is divided into reflected beam one and transmitted beam 2 of equal intensity.

The beams one and two are reflected back from mirror M1 and M2 as shown in this figure respectively. The reflected beam 1 is transmitted through G1 along A and reflected beam 2 is reflected from G1 along AE. These two waves travelling along AE are derived from the same source by division of amplitude. So, they will satisfy the condition of interference and hence interference fringes can be observed by looking into mirror M1 through G1 from position E provided, proper adjustments are made.

Here the glass plate G2 is called compensating plate. Its purpose is to equalise the total optical path of the being reflected from M1 and the total cost of the corresponding beam reflect it from M2. This is essential when white light is used, but not for monochromatic light. In the Michelson interferometer, fringes of various forms such as straight line, circle, parabola, ellipse, hyperbola, can be observed depending upon the angle between the Mirrors M1 and M2.

But in the laboratory, the interferometer is adjusted for circular fringes for various applications. Therefore, here I will discuss the formation of circular fringes in the Michelson interferometer.

(Refer Slide Time: 35:46)



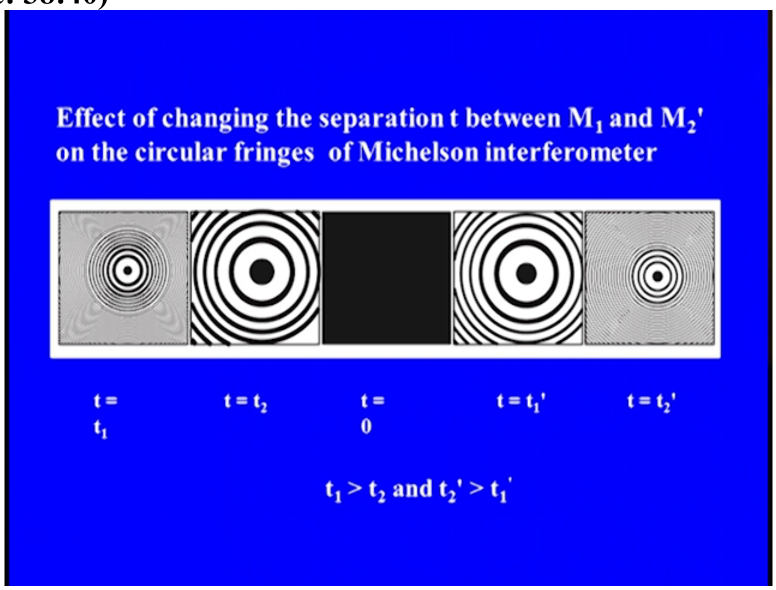
To obtain the circular fringes, the Mirrors M1 and M2 are made exactly perpendicular to each other with the help of screws attached with the mirror and to see good quality fringes, extended live shows is used. An extended source may be obtained by placing a ground glass screen in front of the source of monochromatic light. The origin of circular fringes can be understood with the help of this diagram.

Here M2 prime at the virtual image of M2 formed by reflection in G1. We can also think the extended source as being held behind the observer and forming to virtual images L1 and L2 in M1 and M2 Prime respectively. These virtual sources are coherent, if t is the separation between M1 and M2 prime. The virtual sources will be separated by 2t when t is exactly and integral number of half wavelength that is the path difference 2t is = an integral number of whole wavelength, all the range of light reflected normal to the Mirrors will be in rage.

Rays of light reflected at an angle power bill in general not be in rage the path difference between the two rays coming to the I from corresponding points P prime and P double prime is 2t cos theta as shown here in the figure. The angle theta is necessary the same for the two rays when M1 is parallel to M2 prime so that the rage are parallel. Hence when the I, is focused to receive parallel rays the rage will reinforce each other to produce maximum for those angle theta satisfying the condition 2t cos theta is = n Lambda.

Since for a given n Lambda and t, the angle theta is constant. The maximum will lie in the form of circle about the foot of the perpendicular from the I to the mirrors. Fringes of this kind when parallel beam are brought to interfere with the phase difference determined by angle of inclination theta are called fringes of equal inclination.

(Refer Slide Time: 38:40)



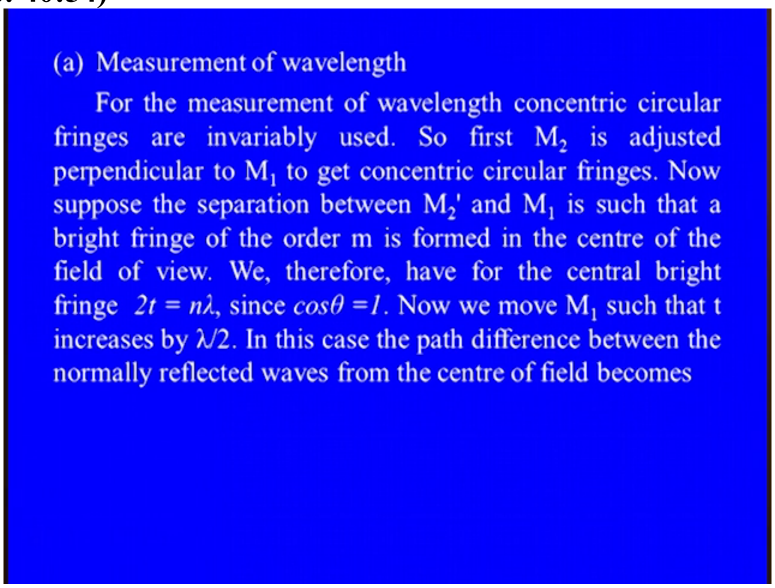
In this figure, effect of changing t on the fringe pattern is shown. When M1 is moved slowly toward M2 Prime so that t is decreased; then, the radius of a given rings given ring characterized by a given value of order n must decrease, because the product 2t cos theta must remain constant. The Rings therefore, shrink and vanish at the centre. The ring disappearing each time t decreases by lambda by 2.

This follows from the fact that at the centre cos theta is = 1 then 2t is = in Lambda so the change n by unity must change by lambda by 2. Now, as M1 approaches M2 prime, the ring, rings become more widely spaced until finally we reach a critical position where the central fringe has spread out to cover the whole field of view. This happens when M1 and M2 Prime are exactly coincidence that is = 0.

Because under this condition, in the path difference is 0 for all angles of incidence if the mirror M1 is moved still farther, it effectively passes through M2 prime and new widely spaced fringes appear, growing out from the centre. These will gradually become more closely spaced as the path difference increases. Now, I will describe some of the applications of Michelson interferometer.

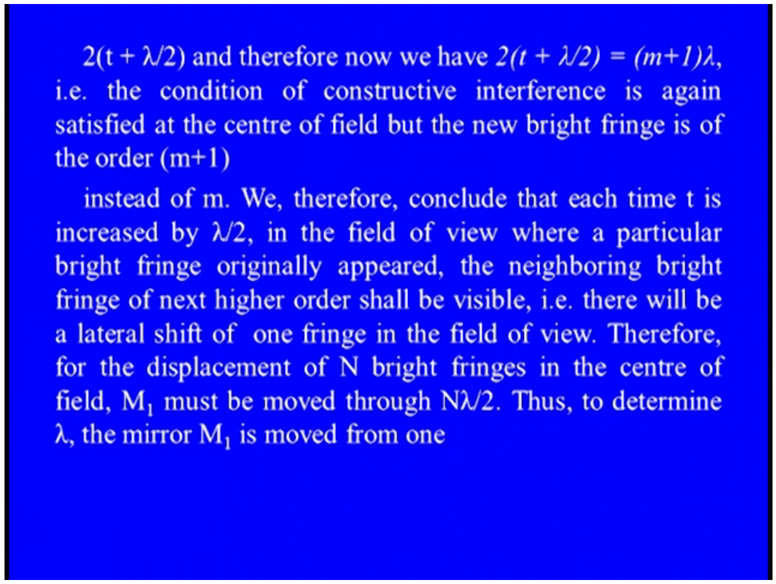
One important up location of this interferometer is the measurement of wavelength of monochromatic light. For the measurement of wavelength, concentric circular fringes are invariably used.

(Refer Slide Time: 40:54)



So, first M2 is adjusted perpendicular to M1 to get concentric circular fringes. Now, suppose the separation between M2 prime and M1 is such that a bright fringe of the order M is formed in the centre of the field of view. We, therefore have for the central bride fringe, 2t is = n lambda since cos theta is = one. Now, we moved M1 such that it increases by lambda by 2. In this case, the path difference between the normally reflected waves from the centre of field becomes to 2t + lambda by 2.

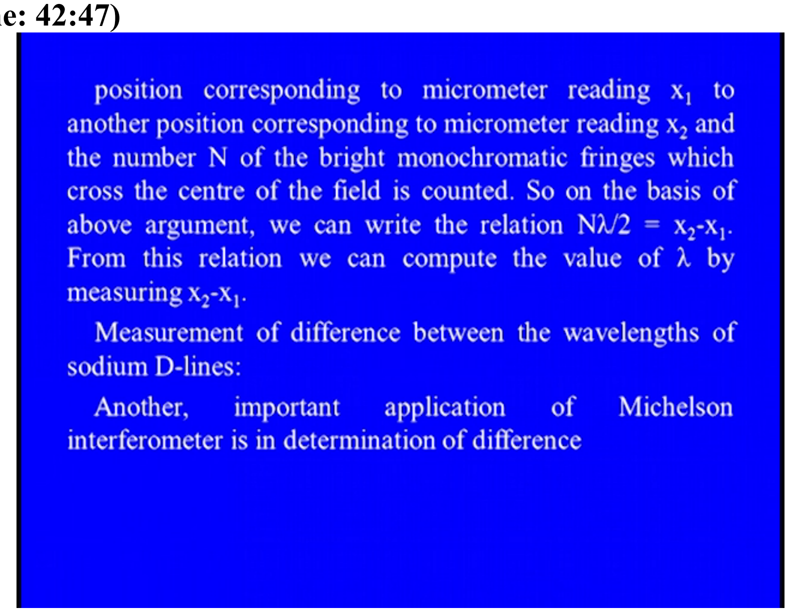
(Refer Slide Time: 41:43)



And therefore, now we have 2t + lambda by 2 is = m + 1 Lambda. That is the condition of constructive interference is again satisfied at the centre of field. But the new bright fringes now are of the order one + one instead of M. We therefore, conclude that each time t is increased by Lambda by 2 in the field of view, where a particular bright fringe originally appears. The neighbouring bright fringe of next higher order shall be visible.

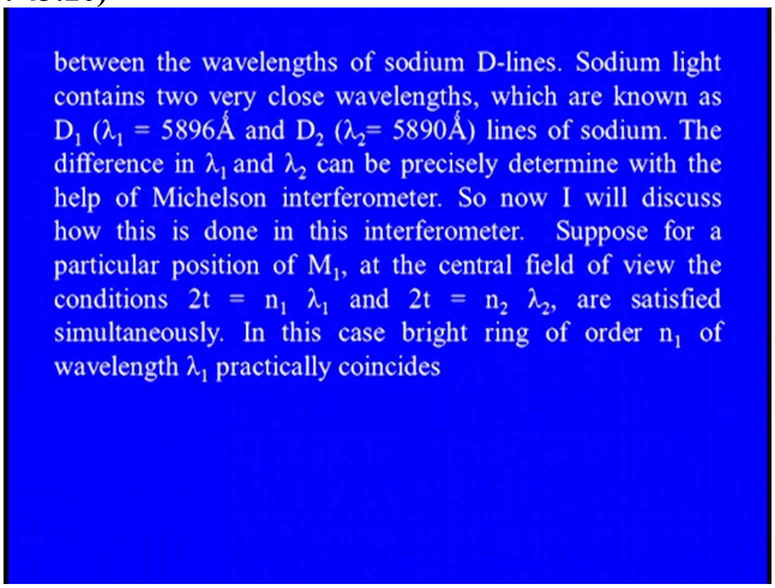
That is, there will be a lateral shift of one fringe in the field of view. Therefore for the displacement of n bright fringes, in the centre of M1 must be moved through N lambda by 2.

(Refer Slide Time: 42:47)



Thus to determine Lambda the mirror M1 is moved from one position corresponding to micrometre reading x1 to another position corresponding to micrometre reading x2. And the number of the bright monochromatic changes which cross the centre of the field is counted. So, on the basis of every argument we can write the relation and Lambda by 2 = x2 - x one. From this relation, we can compute the value of Lambda by measuring x2 - x1.

(Refer Slide Time: 43:20)

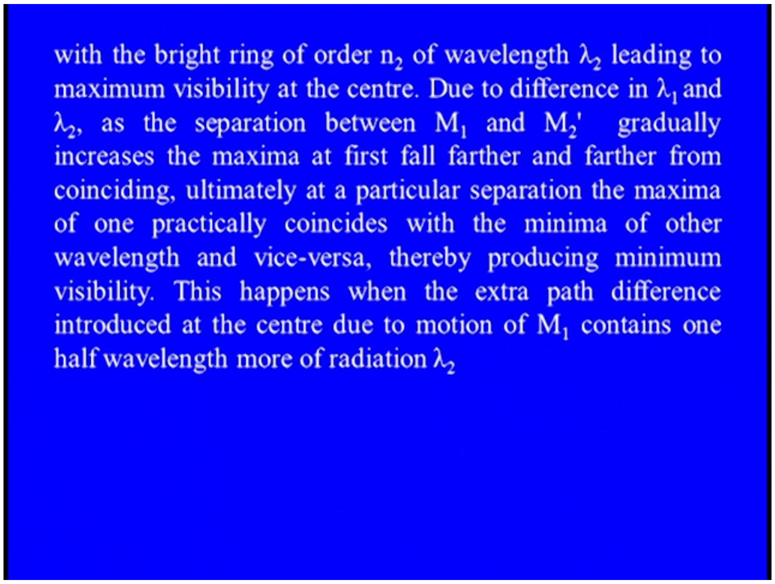


Another important application of Michelson interferometer is the determination of difference between the wavelengths of sodium D-lines. Sodium light contains two very close wavelengths which are known D1 of wavelength 5896 angstrom and D2 lines of wavelength 5890 angstrom. That difference in lambda 1 and lambda 2 can be precisely determined with the help of Michelson interferometer.

So, now I will discuss how this is done in this interferometer. Suppose, for a particular position of M1 at the centre field of view the condition 2t is = M1 Lambda 1 and 2 t is = M2 Lambda 2 are satisfied simultaneously, where lambda 1 and lambda 2 are the wavelengths of D1 and D2 line of sodium respectively.

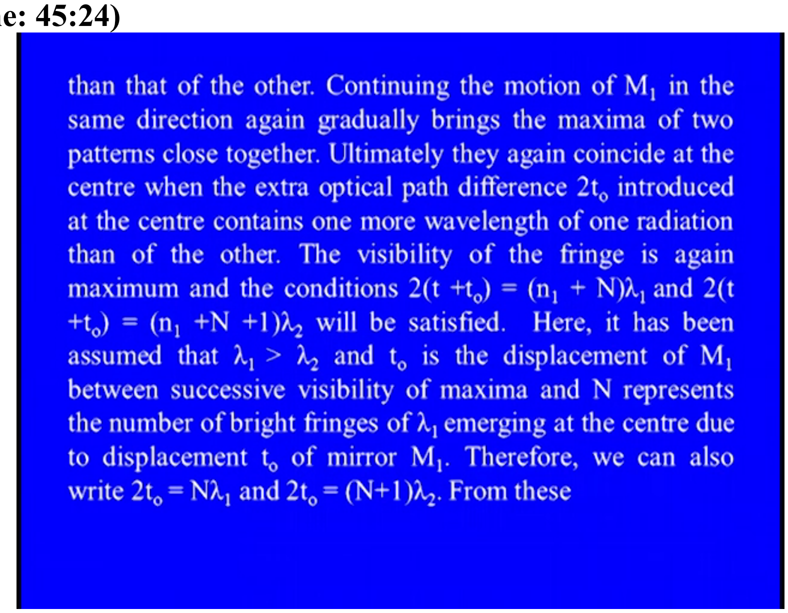
In this case, bright ring of order n1 of wavelength Lambda 1 practically coincides with the bright ring of order n2 of wavelength Lambda 2 leading to maximum visibility at the centre.

(Refer Slide Time: 44:32)



Due to difference in lambda 1 and lambda 2 at the separation between M1 and M2 prime, gradually increases the maxima at first fall further and further from coinciding and definitely at a particular separation the maxima of 1 practically coincides with the minima of other wavelength and vice versa thereby reducing minimum visibility. This happens when the extra path difference introduced at the centre due to motion of M1contains 1 half wavelength more of radiation Lambda 2

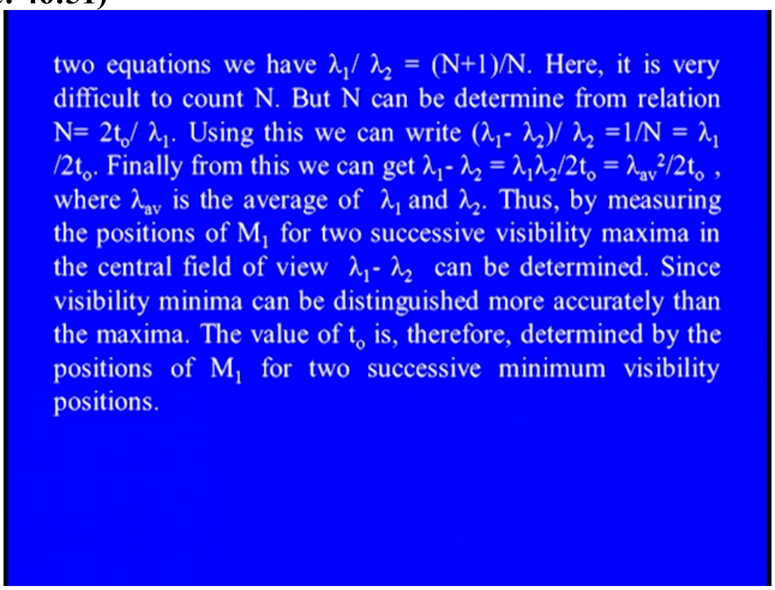
(Refer Slide Time: 45:24)



than that of the others. Continuing the motion of M1 in the same direction again, gradually brings the maxima of two patterns close together. Ultimately, they again coincides at the centre when the extra optical path difference 2t naught introduced at the centre, contains one more wavelength of one radiation than of the other. The visibility of the fringes is again maximum and the conditions 2t + t naught is = n1 + capital N into lambda 1 and 2t + t naught is = n1+ capital N + 1 into lambda 2 will be satisfied.

Here, it has been assumed that lambda 1 is greater than lambda 2 and t naught if the displacement of M1 between successive visibility of maxima and capital N represent the number of bright fringes of wavelength lambda 1 emerging at the centre due to displacement t naught of mirror M1. Therefore, we can also write 2t naught is = capital N lambda 1 and 2t naught is = Capital N + one 1 into lambda2.

(Refer Slide Time: 46:51)

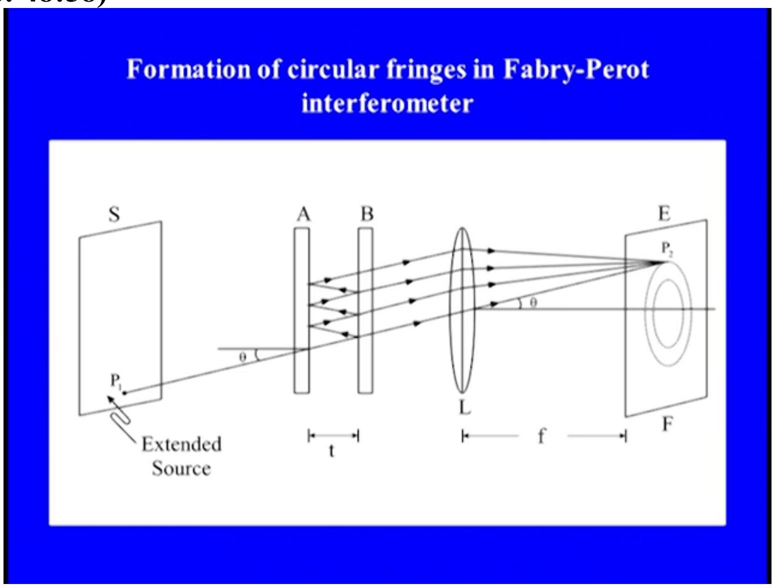


From these two equations, we can write lambda 1 by lambda 2 is = N + 1 divided by N. Here, it is very difficult to count N, but N can be determined from the relation capital N is equal to2t naught divided by lambda 1. Using this, we can write lambda 1 - lambda 2 divided by lambda 2 = 1 over capital and which is = lambda 1 divided by 2t naught. Finally from this, we can write lambda 1 - lambda 2 is = lambda 1 into lambda 2 divided by 2t naught which will be nearly = lambda average square divided by 2t naught;

Where lambda average is the average of lambda 1 and lambda 2, thus by measuring the positions of M1 for two successive visibility Maxima in the central field of view, lambda 1 - lambda 2 can be determined. Since visibility minima can be distinguished more accurately than the Maxima, the value of t naught is therefore determined by the position of M1 for two successive minimum visibility positions.

Further, in order to minimize the mirrors, normally the position of mirror M1 is noted for 10 successive visibility minima and from this the separation between value t naught can be determined more accurately. Now, I will discuss another important interferometer which is known as the Fabry Perot interferometer.

(Refer Slide Time: 48:58)

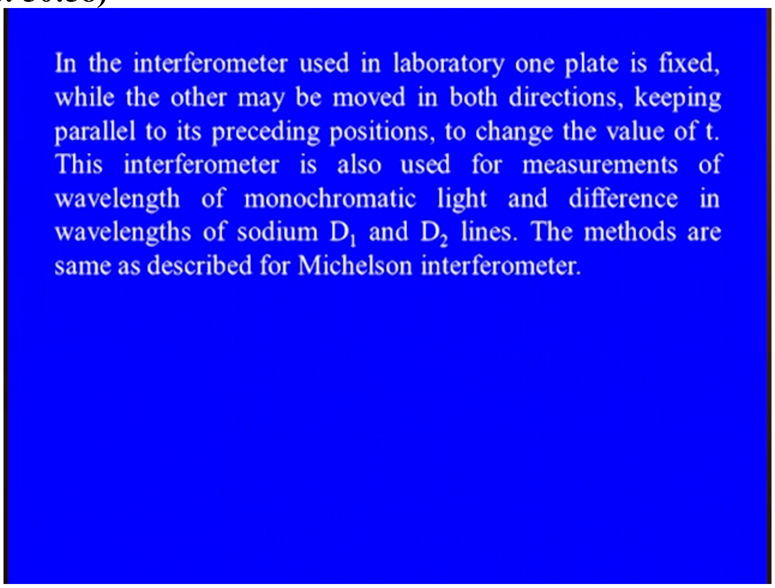


In this interferometer, the interference fringes are produced in the transmitted light after multiple reflections in the air film between two plane glass plates thinly silvered on the inner surfaces as shown in the figure. To observe the fringes a broad source of monochromatic light is used. Suppose a ray from the point P1 on the extended source is incident at the angle theta, this will produce a series of parallel transmitter rays at the same angle which may be brought together at the point P2 on the screen if with the help of a lens.

The condition for reinforcement of the transmitter is is 2t cos theta is = m lambda where m is integer for air film of thickness t. This condition will be fulfilled by all points on a circle through P2 with their centre at O, the intersection of the axis of the lens with the screen EF. When the angle theta is decreased, the cosine will increase until another maxima is reached for which M is greater by 1, 2, 3, and so on so that we have for the Maxima a series of concentric rings on the screen with O, their Centre.

These rings are known as fringes of equal inclination. In this case, effect of changing t on circular fringes is same as for as we have discussed for Michelson interferometer. In this inter, in the interferometer used in the laboratory, one plate is fixed.

(Refer Slide Time: 50:58)



While the other night more in both direction keeping parallel to its preceding position to change the value of t. This interferometer is also used for the measurement of wavelength of monochromatic light and difference in wavelength of sodium D1 and D2 lines. The methods are same as described above for the Michelson interferometer. So, let me summarize what I have discussed in this lecture.

So, in this lecture I have discussed how to get interference pattern by division of amplitude by taking example of thin parallel films of constant thickness as well as taking the film of variable thickness. And I also discussed how this colour effect is observed through thin films. And I discuss three important experiments which are usually performed in the laboratory.

Like a Newton ring experiment, Michelson interferometer and Fabry Perot interferometer and how to determine the wavelength of monochromatic light, by using these experimental setups. Thank you