**Experimental Physics - II**

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**Lecture - 33**
**Interference phenomena (Contd.)**

in last class we are discussing about the coherent source, for interference it is very important otherwise we cannot see the interference effect. source has to be temporal coherent as well as spatial coherent, how to get the coherent source from same source we have to generate two source. how to generate?

two ways, there are two ways: one is wave front division and another is amplitude division. there is different way to do that. that now I will discuss how we generate coherent source in our laboratory; that I will discuss now.

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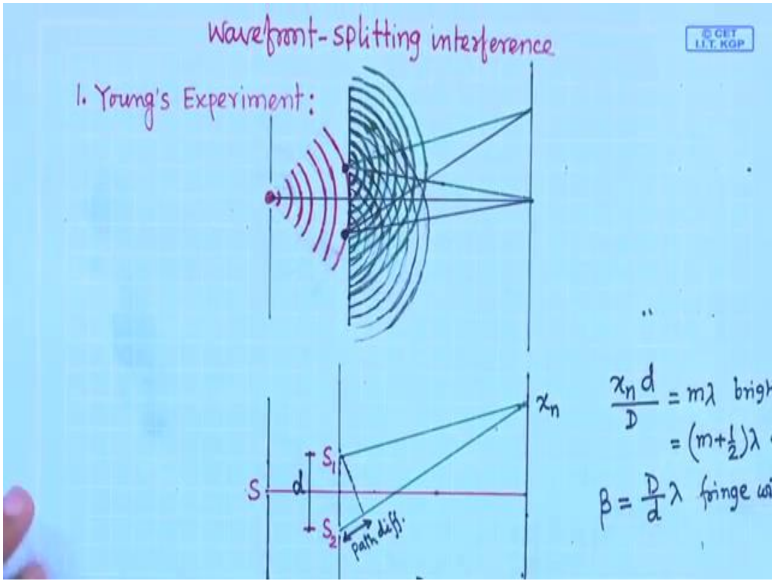


this first coherent source is generated, the experiment was demonstrated. that is based on wave front splitting interference and that was very famous Young’s experiment. that was we have a single source and if you have a screen with two pinhole, now light is falling on the screen from the source, source S then this two pinhole will act as a source generated from the same source; say as if its wave fronts are split into two.

we will from this source S 1 and S 2 you will get wave front S 1 and wave front from S 2. they will interfere, they will interfere. depending on the position of the screen you can see the, you can find out in principle the find out the phase difference or path difference between these two waves. So that two waves here it is coming. They are coming from two source S 1 and S 2, but this two source are generated from the single source. then we expect that they will be coherent source,

only as I told that it is a we deviate from the ideal concept, but that is why there is a limitation on the distance of the between the two sources S 1 and S 2. Size of the sources, distance of the screen where we will observe; there is a limitation. But we have to know that limitation and we have to choose everything in such a way that, it will satisfy the coherent condition.

Young's double slit if these two source if they are their distance are d small d and screen we have put its a capital D. already we have I have discussed that condition for fringe will be this x d by capital D equal to m lambda and m plus half lambda that will be condition for that and fringe will be beta equal to capital D by small d into lambda. there is the fringe width. Now, this experiment one can perform to measure the wavelength of the light monochromatic light.

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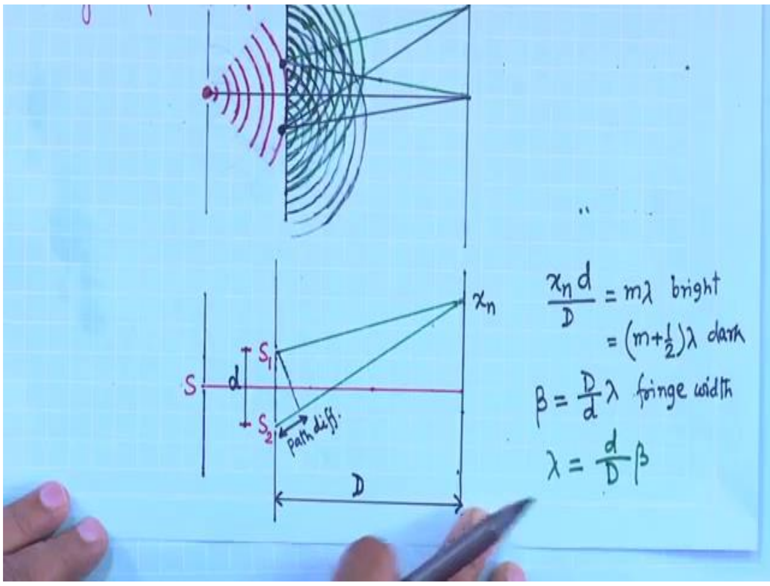


if I want to find out the wavelength; lambda will be equal to small d by D beta, right. we have to do arrangement; we have to do arrangement for. this small d and capital D for this case is very easy to find out because this is the two pinhole on a screen. the distance we can measure is the in millimetre distance and these distance is in centimetre or meter distance, only we have to measure the fringe width we will see the fringe here on the screen. we have to use scale; we have to use scale and we have to measure the, but it is it may be difficult to see these fringe width bare eye  we use one can use the traveling microscope; one can use the traveling microscope their eye piece is there; we will see the magnified image as well as there is a scale with this microscope traveling microscope.

we can get the reading We can get the reading of different band dark fringe position from there we can find out the beta. there is the interferometer, there is the interferometer using the this is the application of the interference.

Using this method, it is this arrangement total arrangement it is called interferometer. we can find out the wavelength of the light this was the first experiment this Young's experiment, similar experiment in different way people tried in different actually in different way.

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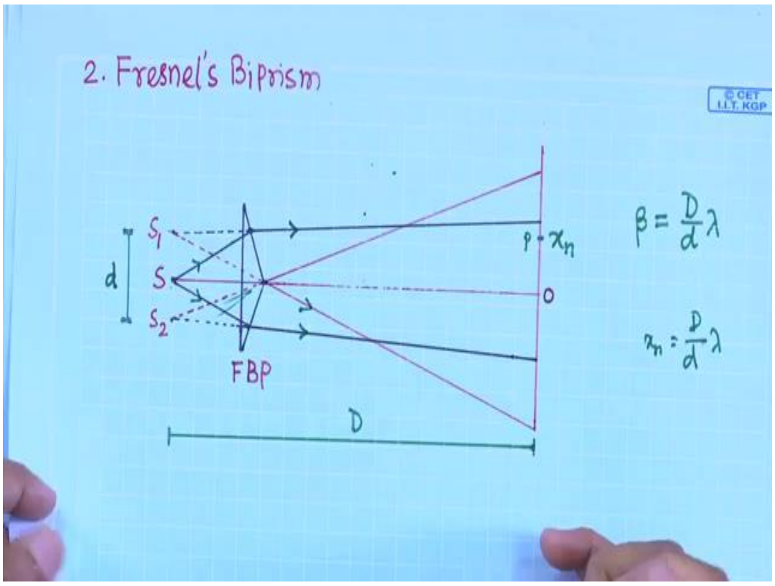


Next one is Fresnel's Biprism this is another way to generate the coherent source from same source to generate two source. this is the biprism; this is the two, this is one prism, and this is another prism. they are joined at this point. that is why it is a biprism. this is for this is biprism if the source is put here ok, on this axis you can say source is put here, it can be another place also then it is. if you connect the source and this phase h, then it will cut perpendicularly it will cut the screen. that point is central point.

if you consider that these two light are, these two light are falling on the from this point source to light falling on this. one is refracted this way. this two light and one is refracted this way another is refracted this way and another light it is a falling here it is the. these are two prism you know. from this one prism it is the refracted this way and from another prism it is refracted this way, from this side of this prism; we will get this is the refracted waves and this is another refracted waves. if you extend; them backward as if this light is coming from this point whatever this light we are getting.

they are coming from this point. this is from another prism we are getting this is the refracted another is this one. as it these two lights to observer these two light are coming from this point. this S 1 and S 2 will be virtual source power source S. this biprism actually generating two virtual source from the same source. now we are comfortable that we have, now we do not need to think about the other things; whether it is Fresnel's biprism or what we do not bother.

but we cannot disturb this element, but what we are looking now? We have two source S 1 and S 2, how it is generated that we described. Now, they are distance are d small d and screen distance capital D and this if we are looking the point here, point P say this point P at this point what is the say nth fringe is observed. there will be interference and we will see the fringes pattern. if nth dark fringe is obtained, we know this that x n equal to that basically, x n equal to capital D by small d into lambda right.

that is the distance from the central fringe, zeroth fringe to the nth fringe It can be dark or bright. that condition we have to put n plus half lambda or n plus half into lambda or n lambda anyway fringe width will be this. this is the similar whatever the we have discussed only here difference is that we are generating two coherent source in different way.

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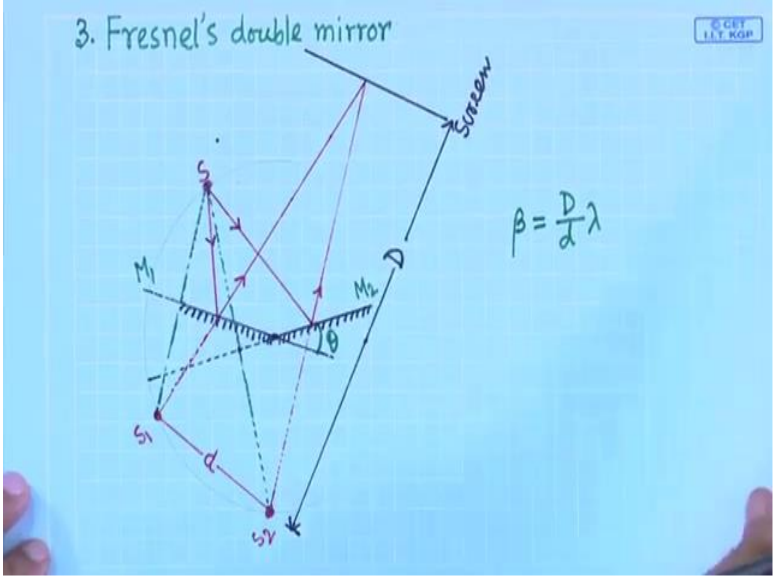


similarly, how it is generated that I explained; similarly, another method is used to that is called Fresnel's double mirror, the Fresnel's double mirror. this if this is one mirror and this is another mirror M 1 and M 2, then if source is here, now this is one ray from the same source, one ray is falling here another ray is falling here. So now, it is from this mirror it is reflected like this and from this mirror it is reflected like this ok; from same source two waves are falling on the two mirror.

these two mirror or put in an angle and these two mirror meet at this point at this point if you consider another rays another rays another two rays falling on two mirror. if you draw here reflected one and now you will see if you extend them backside. there will be image from each source, and it is clear that this is a mirror and there is an object here source here. just backside you will see image right. image you will see there is the perpendicular, it will be perpendicular distance from the mirror and the distance from the mirror of the source and the image will be equal distance,

I can draw a perpendicular on this mirror extension of this mirror dotted line and this is the extended not extended reflected rays. if I extend just backside these two on these perpendiculars it is crossing at this point. this will be the image S 1 will be the image of source S, similarly S 2 will be the image of source S from mirror 2, with this arrangement we are getting two virtual source S 1 and S 2, it is generated from the same source. Now, this is d small d, and this is capital D, this screen is put.

this refracted rays from these two mirror they are coming and they are meeting on this screen at this point, Other rays will meet at different points, they will interfere will get see the interference pattern their fringe width will be capital D by small d into lambda, measuring the fringe width actually and these capital D and small d, one can find out the lambda. Or, other if you know the lambda you can find out measuring the fringe width you can find out the, what is the distance between two virtual source. this; only different wave we are producing the coherent source to virtual source,

So far whatever this biprism Fresnel's biprism, Fresnel's double mirror we discuss; Young's double slit these are Young's double slit, if the where we are this the condition situation, we are seeing these. These two source we are getting the distance small d, we are putting screen at capital D. Then fringe width will be what is the relation, the same relation it is following. And at the another point I should tell that at the if you I think here it is easy to understand. at this point light is light will come from these two source, if you two source light their path difference will be 0 at this point right.

here we get canter fringe, second order fringe. then upside first order, second order, third order; downside first order, second order, third order etcetera. for whatever the three I have discussed Fresnel's biprism, this Lloyd's this panels mirror double mirror as well as this Young's experiment; in all cases at the canter we will get fringe. Now, exceptional of that another method we will follow people follow; that is called Lloyd mirror that is called Lloyd mirror.

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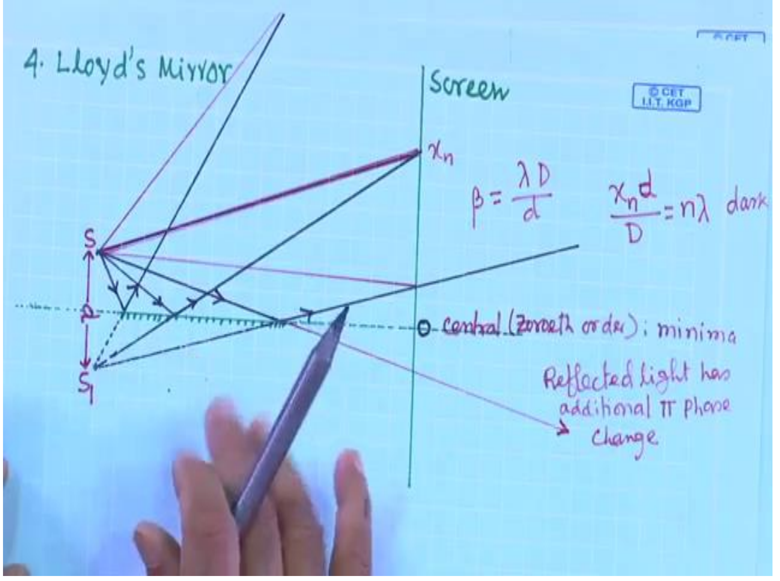


in case of Lloyd mirror we use single mirror; we use single mirror. this is source S; this is screen position. here we will get this is a mirror. there will be image of this mirror S 1. this S 1 as if this light is coming from S 1, actually this is the reflected light from the mirror. we will get reflected light as if this is coming from S 1 as well as the position of the source is such that we will get the direct light also from that source. there will be overlapping of the light coming from the dx source as well as coming from the reflection as if it is coming from the virtual source S 1,

now in this case one is real source, and another is virtual source produce from the same source. these two will be coherent and we will see the interference pattern on the screen. Now, here at the canter at the canter the zeroth order. their zeroth order will be dark order dark fringe, not fringe like other three cases. why it happens? It happens because one light is coming directly another light is reflected is reflected from the mirror as if it is the. So now, there will be additional phase change due to the reflection,

all time it does not happen. it happens only when it reflected, when it reflect from the from the interface of from the interface of rarer medium and denser medium, light is coming from the rarer medium and falling on the denser medium from the denser surface, if it is reflected then these there is an abrupt phase change of phi. If other way light is coming from the denser medium and it is falling at the interface of the denser and rarer medium, reflected in the denser medium. in that case there is no abrupt phase change; that you have to remember.

that is the things we follow, there is a reason for that of course, I am not going to discuss that one. that we have to remember and consider it in these reflected waves are additional phase change phi means path different lambda by 2. that is why whatever condition was there so for dark condition n plus half into lambda; that now additional lambda by 2. that lambda by 2 another side lambda by 2 that will go ok; it will remain n lambda.

So now, n lambda whatever the condition for bright, now it is becoming condition for dark. that is why at the central fringe we get dark, but unfortunately for this case we do not see the central one because, the overlapping region. this is the from extreme end up this one is from the extreme end of the mirrors. this is the reflected waves; below this we cannot get reflected this reflected wave this will be between these and from extreme in another end this. reflected wave we will get between these two and direct rays it is a, it will come direct rays between these and this side,

overlapping of reflected and direct rays will be in this region ok, will be in this region only; because this reflect rays is limited within this, although we are getting broader range of the direct rays. interference only we will see in the overlapping region. we will see the interference pattern on top of this point. that is why here, and we do not see the central fringe. But interesting is that it is the different from the other courses I have discussed. We will just exchange; the condition is exchanged between the dark and b these are very whatever I have discussed there are want to more process to produce the coherent source, but these are the common source people use in the laboratory to do the interference experiment. Next, I will discuss about the amplitude splitting interference,

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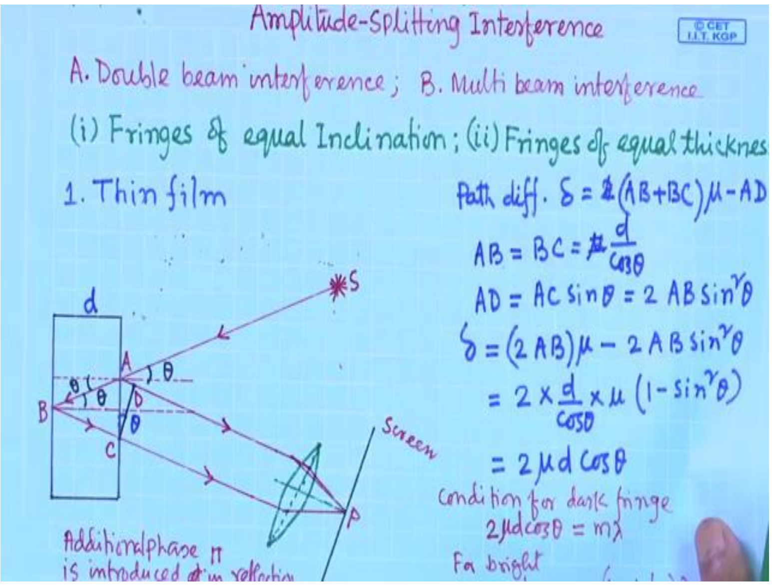


far we discussed wave front splitting interference. this is the amplitude splitting interference. in this case here I have written this double beam interference and multi beam interference. it can be double beam interference; it can be also multi beam interference and in this case, there are fringe we see. two types it is called fringe of equal inclination and fringe of equal thickness ok; fringe of equal inclination or fringe of equal thickness

I will discuss few cases where we see amplitude splitting interference. And, it will be either double beam interference or multi beam interference or also it will be either fringes of equal inclination or fringes of equal thickness. we will understand from the discussion. if you take a thin; so thin film, if you take a thin film means thickness is very small. one source put here so now, this light is coming, and one is reflected, one part is reflected, and another part is transmitted or refracted. it is the splitting of amplitude.

Now, it is a this one is reflected back from this surface and it is a passing through another surface. we are getting two beam generated from the same beam Two reflected beam we can say one is reflected from this surface top surface another is reflected from the bottom surface. this rays have path the additional path difference because of the one is from; these are same for both rays. one is this another is additional path it is traversing through the thin film and then if you draw a normal; this path will be equal.

path difference will be the delta will be AB, AB plus BC AB plus BC into mu it is the if this is the refractive index of this thin film into mu minus AD, it is near outside if it is a minus AD, right. if incident angle is theta; refracted angle also we are considering theta because, here this thickness is very small, we consider thin film. from the geometry you can find out that this path difference is 2 mu d cos theta. What is theta? Theta is this incident angle.

from this source there are there will be many rays fall on the thin film, but all will have different angle, all will have different angle. an there and for each case since it is thin film. that d is constant; d remain constant, but theta will vary. for same angle; for same angle, it can from a cone you know. over a circle we will get; over a circle we will get same inclination angle there will be path difference is constant over a circle. we will get a fringe depending on the path difference whether dark will get, or we will get.

for different angle we will get different circle, different order of the fringe. that is why it is called the fringes of equal inclination and because here thickness is constant; thickness is constant thickness is not varying it is constant. condition for dark fringe is same, this is the path difference equal to m lambda and for fringe 2 mu d cos theta equal to m plus half lambda. this; one can see the interference from the thin film from the where thickness is constant it is not varying. fringe we will see because of the fringe of equal inclination.

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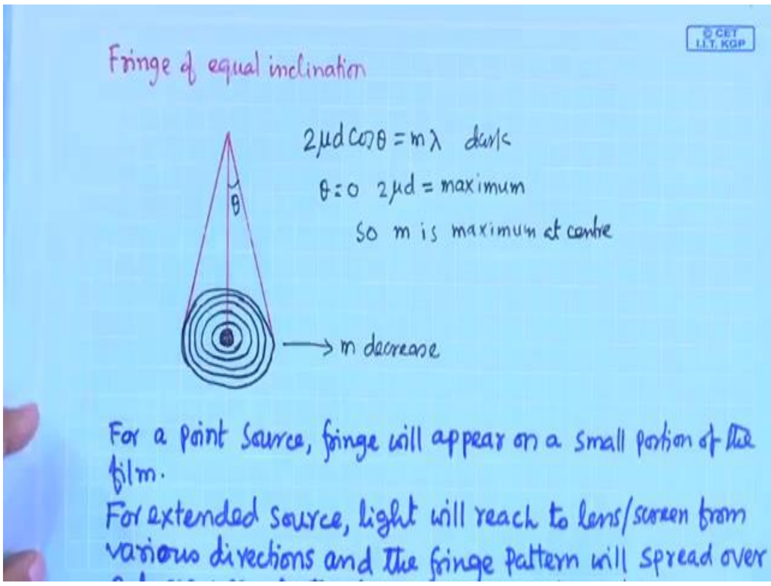

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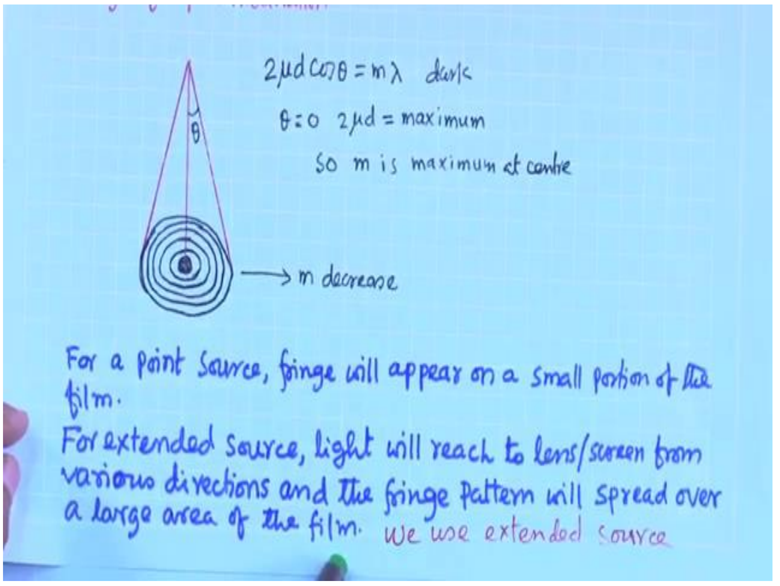


Similarly, why as I already mentioned that why it will be fringe of fringe of equal inclination we will see. that I try to already I have I told you; actually, for a we need extended source for this kind of experiment.

For a point source fringe will appear on a small portion of the film ok, for extended source light will these two lens or screen from various direction and the fringe pattern will speed over a large area of the film. that is why we use extended source for in case of this amplitude division, amplitude splitting interference. in all cases more or less we use the extended source,

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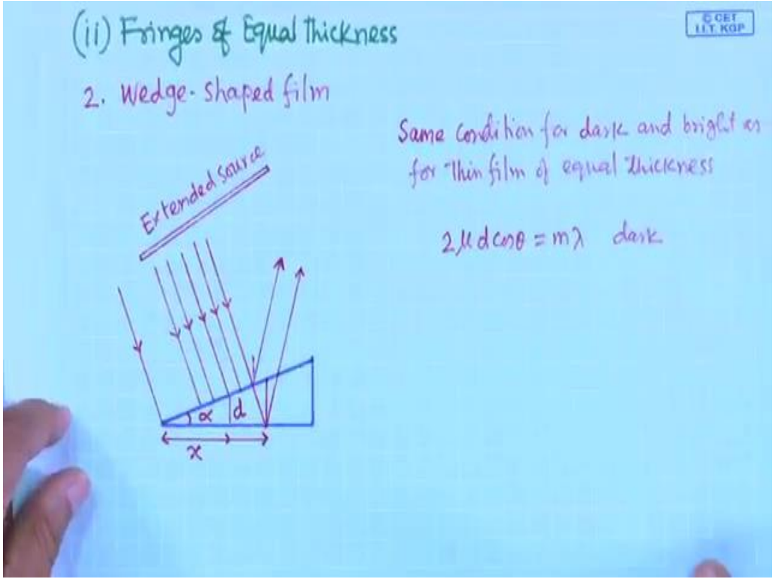


fringe of equal thickness; fringe of equal thickness this is the example of fringe of equal thickness. wedge shaped film, wedge shaped films is two plates two plates if we just inclined them. here cross section I have drawn. this is one surface of the plate, this line is on the surface of the plate and this is another line on another plate if they inclined at alpha, angle is alpha and from source. from each point there will be source at different angle ok, there will be different angle.

if we consider a set of parallel source falling on it; that angle will be same for all rays and they will be; this is the; this is one is reflected from the top surface and another is reflected from the bottom surface  from each you will get; this from its a now extended source for these one day each day what will happen; you are getting these two reflected. One is from top and another is from bottom. phase difference path difference will be depending on the thickness at this point.  that is the same way 2 mu d cos theta equal to m lambda.

if for this if theta is 0 then 2 mu d equal to m lambda. Now, here m lambda this condition here in this case we will get dark condition. Why? That means, additional pi by phi phase is introduced in one of them yes. if it is not air film wedge film, if it is some glass film refractive index is higher than this here outside. this reflected ray will suffer will get this abrupt phase change of y whereas, from this interface it will not happen because these are denser, this is rare. its interface is denser rare interface and this interface is rare denser interface,

in one case there will be pi by phi phase change another case there will not be any phi phase change. this is the example of the here now thickness is varying at different point you know. if it is reflected from this point; here two waves again we will get. they will interfere. we will get here thickness are different. we will get different order. although angle is same, angle is same cos theta for all rays, but for all rays their thickness is difference. we will get different; we will get different path difference for different, difference set of reflected rays.

because of the variation of the thickness we are getting fringes. that is why it is called fringes of equal thickness,

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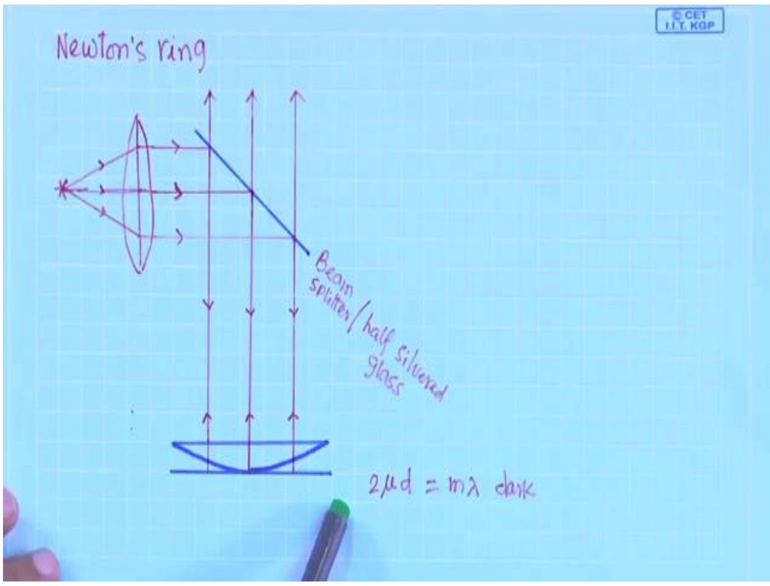


classic example is that Newton’s ring know is very famous experiment Newton’s ring. there wedge film you used; a glass plate on top of glass plate if put a Plano convex lens ok; Plano convex lens this now between this plate surface between these curved surface and this glass plate surface. this wedge shaped film. actually, whatever I showed you now it is the in both side from the thickness 0 to varying this side going higher and this other side also 0 to varying.

here thickness at this point and at this point same. we will get here concentric rings because here thickness is varying. for same inclination perpendicular inclination, we will get the concentric rings and here also there will be additional phase change, because two interface you know. One is reflected from the curved surface another will enter into the air film and reflected from the flat surface of the glass. there will be this the rays reflected from the flat surface; it is travelling more path.

there will be path difference 2 mu d ok, cos theta is 0 cos theta is 1 because normal incident generally we take for this case. and this two interface from where this two reflected rays we are getting their interface are different. in one case there will be phi phase change. that is why this dark m lambda this path difference equal to m lambda. that will be conditioned further and now you see this where d equal to 0 m equal to 0. that will be the canter fringe and that canter fringe all the time in this case it is will be dark. dark canter one in this case it will be dark, then dark bright, dark be will get concentric ring,

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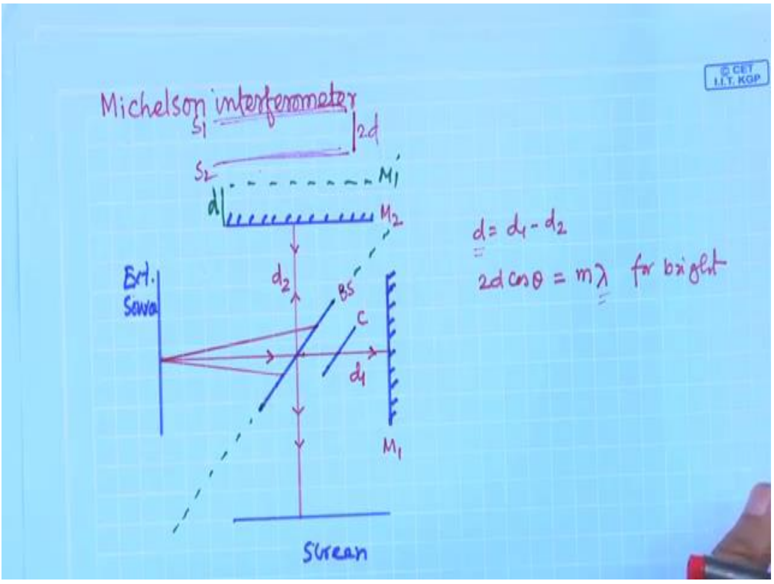


another very important interferometer Michelson interferometer, there also this is also example of this is example of equal thickness you know. in this these two mirrors are there two mirrors are there M 1 and M 2, they are placed like this this is the beam splitter of or these half silver plate extended source from extended source light are coming falling on this beam splitter.

if we just consider one beam this one is coming. one part is reflected amplitude division of amplitude ok, another part is transmitted or refracted and or transmitted going this way And, from this this is reflected from here and then from mirror 2; it will be reflected back and transmitted coming downward. these will be reflected back from the mirror M 1 and from this beam splitter it will be reflected downward. in downward we will get two rays reflected from mirror 1 and mirror 2. if this is the starting point; these rays are travelling twice, these rays are travelling twice, and this is the same path.

path difference will be basically; path difference will be 2 d, if this difference d equal to d 1 minus d 2. path difference will be 2 d equal thickness as if this someone from here observer will see this is placed at a 45 degree that is why this is happening. from this beam splitter, it will see from beam splitter it will see that observer will see that this light whatever coming from this mirror reflected from this mirror. this mirror image will be somewhere here. that whatever the d 1 d 2 this image of this mirror M 1 it will be somewhere here M 1 ok; this distance is d,

now also if you look at this; think this beam splitter is a mirror. also you will see the source ok, you see the source somewhere if you just draw the normal on this corresponding image of the source, you will get here, As if this you are see image through the beam splitter, you are see image from the beam splitter and now source is here. Now, this source is reflect in front of this source two mirror is there M 2 and M 1 or M 1 dash whatever.

you will see the image of the source here on this mirror; for M 2 whatever the distance you will get I think I will use another colour. you will see the source image one is here, and another is I think here, this source is from mirror 2 S 2 and this source will be from mirror M 1. as if this is the source distance this image distance of the source sources; from mirror 1 and mirror 2. these if there this mirror distance is d then image distance become double 2 d,

now due to the inclination of this inclination angle this is the 2 d cos theta equal to m lambda. to understand from where this cos theta is coming this is the inclination angle ok, inclination angle of different. here to understand that one I think I will skip it; this experiment I will demonstrate in the laboratory. there I will try to tell you how these cos theta, what is that angle theta. is the equal thickness it has to be theta has to be of different inclination angle?

this is the Michelson interferometry; using this one can move the change the mirror distance; that means, one can change the d,  And, one can see the one can see the path difference will change path difference will change for a particular order,  If you look at the centre fringe it has m now path difference is changing. this order will change at the same position. you will see these, this fringe as if it is appearing or collapsing at the centre

using this phenomenon, we can do the experiment and measure the wavelength of the light and other things also we can do using the Michelson interferometer, this is very useful interferometer. I will demonstrate this experiment in the laboratory. I think this background is enough whatever experiment on the interference we will demonstrate in the laboratory. this discussion will be helpful those experiment in the laboratory. I will stop here.

Thank you for your attention.