Experimental Physics - II
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Lecture – 42
Theory of diffraction (Contd.)

in last class I have discuss about the form of a diffraction. a single slit diffraction, double slit diffraction and n slit diffraction that is are grating diffraction. now, I will discuss just very elementary concept of a Fresnel diffraction. Fresnel diffraction this experiment is very easy. Arrangement for experiment is not difficult one, but the mathematical treatment is slightly complicated.

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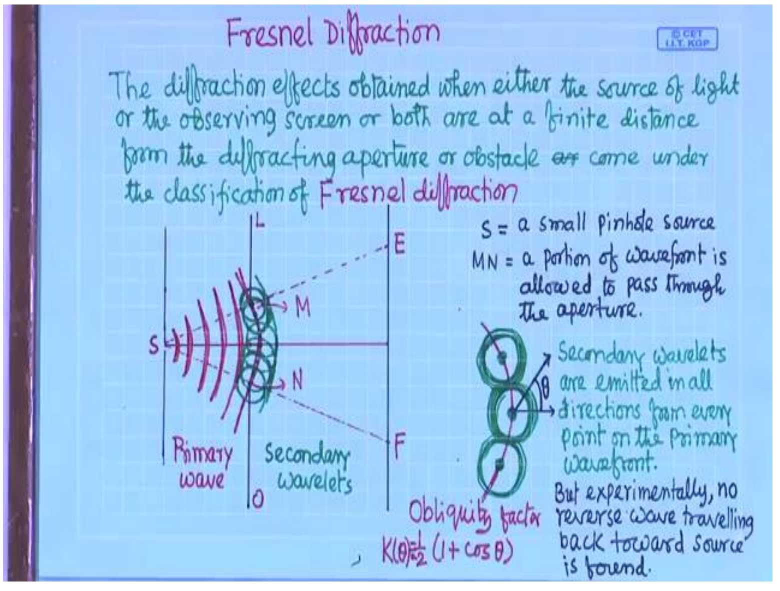

let me just discuss the Fresnel diffraction in simple way. Fresnel diffraction as I mentioned that, the diffraction effect obtained when, either the source of light or the observing screen or both are at a finite distance. From the diffracting aperture or obstacle come under the classification of Fresnel diffraction. that I told earlier.

here actually this concept of that concept of this wave front that secondary; if so this from wave front. Now, we are getting this secondary wavelets. that concept is very important to realize the effect to realize the Fresnel diffraction. if we have a source is the primary source. from the source this spherical waves wavelets or wave fronts you are getting.

now, you have a aperture ok; you have a aperture. Now, this wave front is on this aperture. Now here, if you think that this the waves there will be this secondary wavelets and corresponding, wave front you will get that way they proceed on the screen this is the screen on the screen what will be the effect of intensity of the light?

that is what source is that finite distance; and the screen also have finite distance. we are interested to find out what will be the effect what will be the intensity distribution on the screen S is a small pinhole source, N M N M that is a small portion of wave front is allowed to pass through the aperture. And this whatever we have done.

this is secondary wavelets, that is are emitted in all direction; in all direction from every point on the primary wave front. this red one is primary wave front. each point we will act as a secondary source and the secondary wavelets we will emit. And this will be emitting all directions. as if this is source it should show in back side also there should be the three should be the waves.

in backward backside in forward direction there will be waves that is fine the secondary wavelets is a moving that we are telling. emits wavelets in all directions in backward also there should be the then there should be the wave reverse wave travelling towards the source. But experimentally it is found that no it is not possible. you do not never get any backward wave.

always we get forward wave to encounter that part what about the experimental observation to consider that this experimental observation. we have to consider this one factor that is called obliquity factor. the amplitude of the wavelets whatever it is reaching on the screen. it will depend on the; it will depend on the direction of the direction of the wavelets

If this angle is theta this amplitude will be modified with this obliquity factor that factor if I tell K theta. that is equal to half 1 plus cos theta; that means, if theta is 90 degree. along this direction 90 degree theta is 90 degree this, so these factor will be half, these factor will be half. That means, light going in this direction the intensity of that light will be just one fourth.

Whatever the light is going this side wavelets are going this side theta equal to 0. what about the intensity will be there amplitude will be there? this side amplitude will be half of that this obliquity factor is multiplied with the amplitude and that is why amplitude will not be same in all directions. it will depend on the theta. that is the obliquity factor that was considered.

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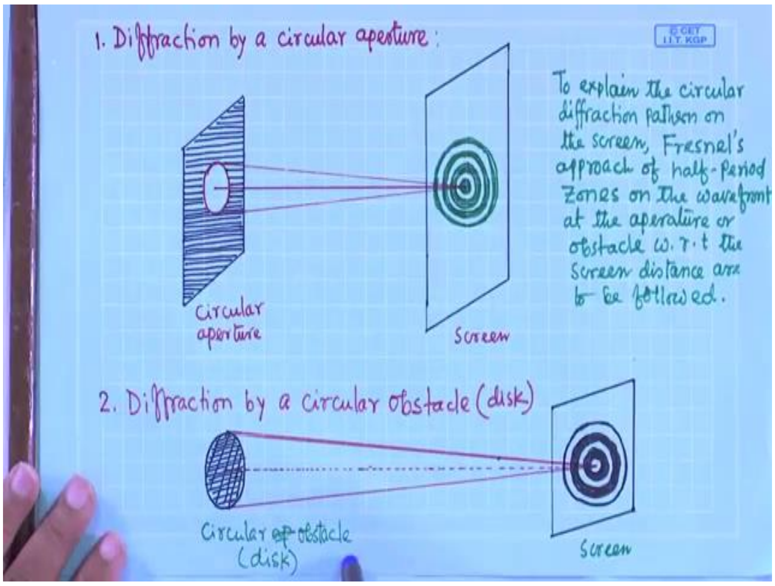

diffraction by a circular aperture; that means, you have a source infinite distance from that source light is coming and falling on this screen where there is a circular aperture. or obstacle where there is a circular aperture, so light will pass through this circular aperture then the screen is placed at a finite distance here.

on the screen due to circular aperture; on the screen the we will get this type of intensity distribution. we will get a ring pattern; we will get ring pattern or circular diffraction pattern on the screen now, how it is formed; how it is formed as well as when diffraction by a circular obstacle? this kind of things light should not pass along this direction.

we should not get any. this is the is the normal to the center of the circular aperture what will be the intensity at this point; at this point. these are the center is this point is on the axis passing through the center. other points we tell the half center here I understand this at the center light should be there, but it’s a dark by dark by. it can be at the center, it can be center one it can be dark, it can be b depend on some factor.

sometimes we can see that if we if screen distance if we change. at some distance we are getting dark at some distance we are getting b ok; and then alternate one we are getting.

in circular obstacle, so at the center here this is this dotted line actually this is the passing is the normal to the center of this disk and it’s on the screen at this point ok, axis on this we tell that axis passing through the center.

at this at the center here. we will get also taking this one as a center, so we will get circular diffraction pattern. And in this case surprisingly this at the center all the time it is b. It does not matter you are changing the screen distance at all the time it will be b. it’s supposed to be dark, because there should not be any light directly passing. light is coming from this other part of the circular obstacle. but here all the time it is b on the screen. this type of things we get diffraction pattern we get. these are the due to the Fresnel diffraction.

how it happened? to understand that one, to understand that one Fresnel itself he has developed constructed Fresnel’s half pure zones. because if even there Fresnel half period zone, we can from that concept from that approach. We can explain this Fresnel that diffraction pattern. just let me discuss the this what is that Fresnel half period zones.

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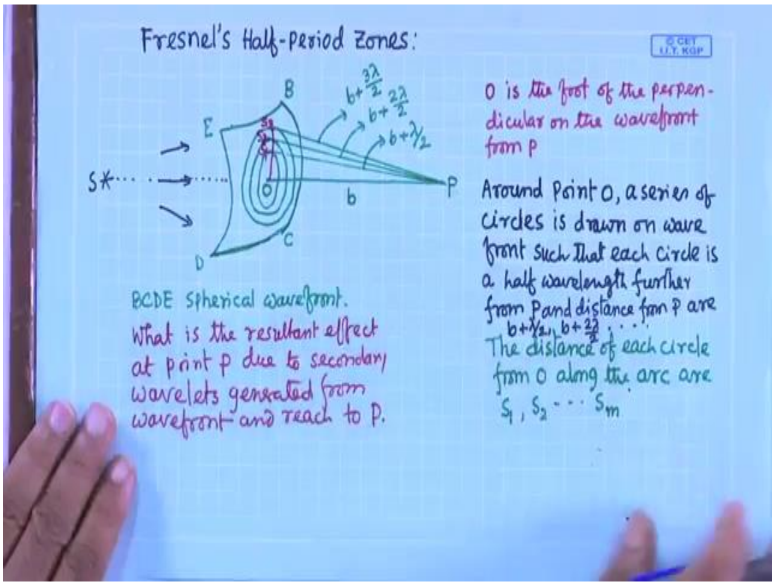

Fresnel half period zone is, if you take a source from the source spherical wavelets are spherical wave fronts are coming. this is a portion of this on that spherical wave front Now, from point P at point P this is the wave front now at a point P; you want to see the effect of this wave front now from point P; if you just draw a normal on the wave front, on this wave front that O on the wave front is the foot of the perpendicular of the perpendicular on the wave front from P now, around P on the wave front a series of circle is drawn on wave front such that, each circle is a half wave length further from P.

And distance from P are b; plus, lambda by 2 b plus 2 lambda by 2 b plus 3 lambda by 2. What is the b? b is OP; b is OP. And now if you draw the circles ok; draw the circles in such a way. each circle this circle distance of this circle is, so distance of the center from P is b. then distance of the circle is from P is b plus lambda by 2 half wavelength more.

next circle that is the b plus 2 into lambda by 2 3 into lambda by 2. that way if you draw circles, if you draw circles. And the distance of the circles from this O, from O along the arc along the arc are say S 1, S 2, S 3 etcetera this S m for n the n th zone. so, this zones this area between two circle area between these two circles.

there is we tell zone and if you just proceed this area. this is the area and then next area next between these two circle this next area. these are called zones. And we tell half period zones this area this area. we tell this half period zones because their light will come from these zones to P. their path length difference will be from each other from one after another.

whatever light coming from here; so, whatever from this region; from next region. this path difference will be lambda by 2 from the next one it will be between these two successive 2; it will be lambda by 2 all the time lambda by 2 from the beginning, so lambda by 2 then 2 lambda means lambda 3 lambda by 2, 4 lambda by 2 etcetera.

this path difference between two successive areas; all the time it will be lambda by two that is why it’s called half period zone it’s called Fresnel’s half period zones. now, from this construction, we would like to find out this what is the area. area depends on what. that would like you see or what is the path difference with respect to OP; what is the path difference with S 1 P, S 2 P, S 3 P sm P?

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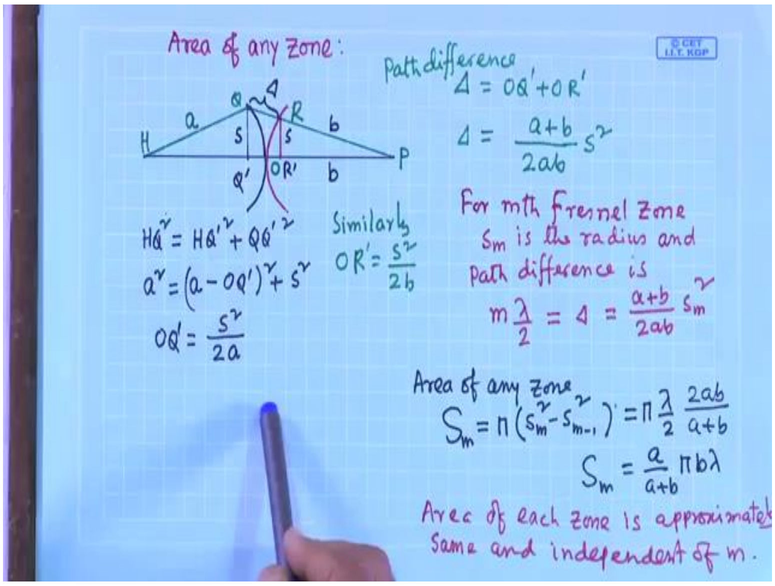

let us see. area of the zone to find out area of the zone this is the this is the wave from black one we consider the black one the wave front And this H shows, from H shows this lighter spherical this wave front is coming Now, from this center of this wave front if this is a; this distance is a; this distance is a; that means, this H Q; H Q this distance also a .

now, if you draw a circle from P; if you draw a circle its it is touching; it's a wave front is this wave front is tangent to this at this point then what will happen, this is the screen distance this is the screen distance from this wave front ok; if it is b and these are source distance if it is a

actually, light from H one light from this wave front these are coming at P. Another light this if you consider this point on the wave front this light is coming from H; and then from this wave front is a it is light is reaching here at P. what is the path difference between this two. And if say this this a and b is very large compared to the compared to the S; what is the S?

From the center this radius, radius of the concentric circle drawn on the its the yeah is the more or less we can say the radius, but it's a difficult to say the radius. it's the along the R, what are what are the distance from the center? that is an if it is not plane wave. it's a difficult to say, but this more or less we can say that is the radius of this circle.

here in general, so this is the this is the first this point Q; it is the for first circle of first zone plate half period zone or second or a what are in general that is why we have considered S. now, to find out it path difference, see if you just draw a normal from Q that is a normal on this HP that is the Q dash and from this point it's the R dash it's the R point R and this is the R dash.

, if you so what you can see this is a; this is also a this part and this part is same and now in this case you see this path this is this is b and this is b up to R it is b Now, additional path is Q R you know additional path is Q R now this Q R if you draw the normal from here. QR is that path difference that is nothing, but O, Q dash plus O, R dash. O, Q dash plus O R dash

path difference between these two one is passing through the center. And another is passing through the say through the through the edge of the to the one edge of the of the half period zone. on middle of the half period zone what will be the then path difference between these two area that is why that is del. this you can find out.

from here you can write HQ square HQ square equal to HQ dash square plus O Q dash square from here we can find out O, Q dash equal to a square by 2 a. approximation we have taken that this ac is here that Q is very small compared to a and b.

similarly, for this other path also you will get O R dash equal to a square by 2 b. del path difference you are getting from this two contribution this plus this a plus b divided by 2 a b S square. this also one can write that 1 by a plus 1 by b half 1 by a plus 1 by b into a square. in that form also one can write. if this is the path difference.

for m th Fresnel zone this S; we can write S m is the radius of that from the from the center from the center this S m is the radius. And the path difference will be if it is m th this here you will see the lambda this b plus m into lambda by 2 this one will be m into lambda by 2 path difference this del is the m lambda by 2 m lambda by two equal to del.

And that del what is del that we have calculated it depends on a b and S. It depends on b and a, which zone we are considering. Of course, form th Fresnel zone we can write this from here that so this is so this S m we can find S m square we can find out from here S m square we can find out. area will be; area will be this is the radius S m is a radius.

pi S m square that will be area of the area of the for that circle. And S m minus 1, so just n minus 1 circle that area will be pi S m minus 1 square. difference of this will be will give the area between this 2 m minus 1 and m th circle, so area between these two. area of any zone of these two zone we can write that area.

this we have written capital S form th zone. this difference between these two successive this areas. so from here you can find out that S m equal to a by a plus b pi b lambda one interesting thing you can see that, although we have found the area of the m th zone, but this is independent of m. that is why this can be the area of any zone.

this zone is area of each zone is approximately same. Because, some approximation we have taken for this. that is why this actual area of each zone is approximately same area of each zone is approximately same and independent of m. Fresnel's zone we constructed Fresnel constructed. this in such a way from each zone whatever light will come at P, P is the point on the axis passing through the center of the wave front.

light will come from each zones. their wavelength difference will path difference will be lambda by 2 Between successive zones path difference always it will be lambda by 2 now then what will be the intensity or the amplitude at point P? that that is what we are interested to know then you will know the intensity.

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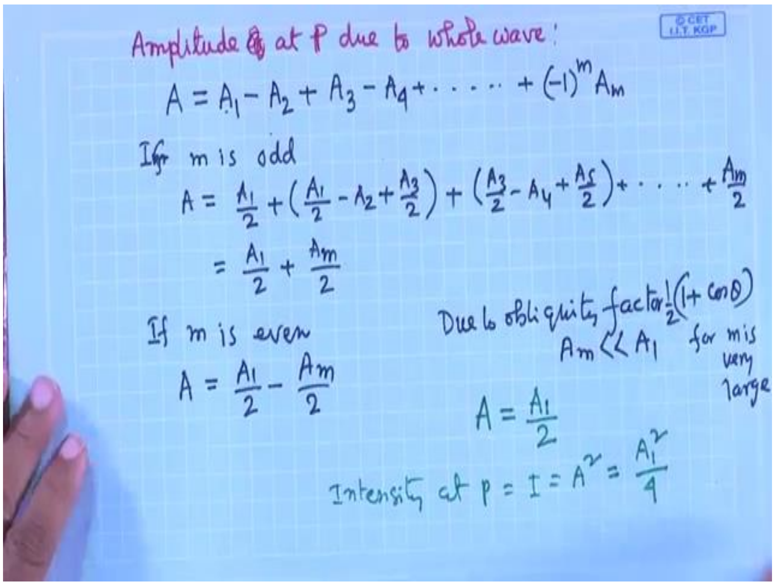

amplitude at P; due to whole wave front so we can so write this total amplitude at P A equal to A 1 from first zone; then second zone second half period zone. it will be just a phase difference is just opposite pi phase difference lambda by 2 path difference it will be. then A 1 minus A 2 ok, opposite phase it will come with opposite phase.

minus A 2 plus A 3 minus A 4 etcetera minus 1 to the power m A to the power m not a to the power n m. for m th zone this A is the amplitude from the m th zone if m is odd, if m is odd. this we can rearrange like this m is odd. if it is 3 A 1, A 2, A 3. I can write A 1 by 2 plus A 1 by 2 minus A 2, A 3 plus A 3 by 2 plus A 3 by 2

this term is going extra A 3 by 2. if it is odd, then this A m by 2 is going to be extra. here what is telling this half of the amplitude from the first zone and half of the amplitude from the second zone. on the average this two will be equal to the amplitude from the second zone. that is the concept because amplitude from each zone they are not same.

Why they are not same? Because of obliquity factor they will decrease. that is why here we have taken average this way. that this will be cancelled only left A 1 by 2 plus A m by 2. Similarly, if m is even then you can show the same way rearranging that one. that a will be A 1 by 2 minus A m by 2.

Actually, due to obliquity factor, if m is very large. this amplitude am will be very small negligible compared to A 1 from first zone. that is why this A amplitude due to the whole wave front at P whoever the amplitude. this amplitude in just half of the for amplitude for the first zone we just half of it will be the resultant amplitude at P. And corresponding intensity will be just square of it

at P what will be the intensity? just it’s the its the intensities there is not because of whole wave front you know for whole wave front if everything is added, then what will happen? A 1 plus A 2 plus A 3 both are all are equal to so that will be m A m square A square that will be the intensity ok, but most of them are cancelled is intensity.

at point P at the center of center point if you consider. from there again we have to draw a normal on the wave front find out the footprint, foot of the normal. And we have to we have to we have to see how many with how many. we have to; we have to again find out the zones half period zones. And how they are how many they are contributing they are.

that way for different points one can find out the intensity distribution on the screen. this just preliminary there are more complicated examples and there are other ways to calculate. this is the one way to calculate so that is for simple case we use this one. one of the application is zone plate. just that I will discuss and complete it.

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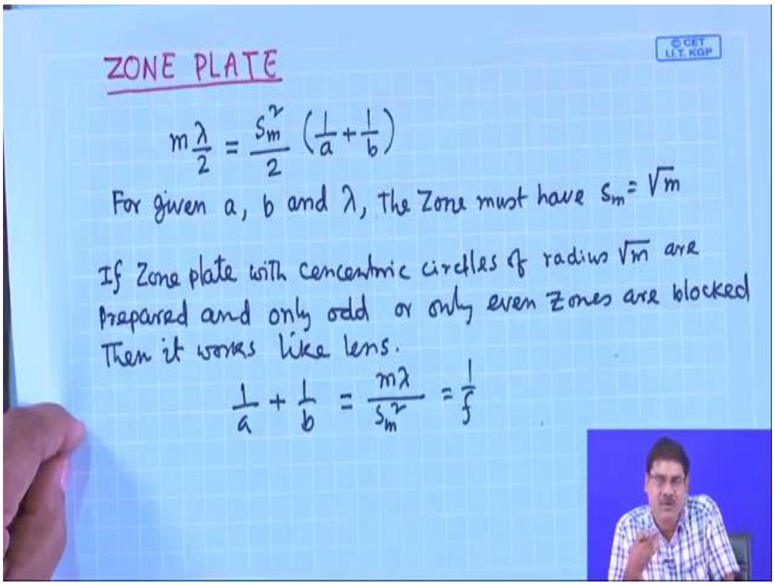

Zone plate, now from half Fresnel's half period zone we have seen. And from there this we have we have seen the expression m lambda by 2 equal to ah. What we have seen S m square 2, a b divide by a plus b. that we can write in this 1 by a plus 1 by a Now if you imagine that for a given a b, a is from obstacle source distance b is from obstacle this screen distance image distance. And this lambda for a given this three quantity parameter.

The zone one area ok; zone must have; zone must have this S m equal to these are constant then these are constant. S m square will be the is proportional to m. that is why for a particular a b and lambda we can construct zones it's a radius, its S m is this that concentric circle we are doing.

these are radius ok, so that radius if you take that is square root of m means first zone this is the if you take one. Then, second zone this square root of 2, square root of 3, square root of 4, square root of 5 In some unit length unit if you take this radius and on a plate you take a plate you take a pen and paper and you draw the concentric circle with this radius 1, 0.1 root 2, root 3, root 4.

Then you will get the your constructing the zone plate, you are constructing the Fresnel half period zones Now, either or zones or even zones if you just make opaque ok; use the black ink and just close that odd zones or even zones either odd zones or even zones and other are transparent Then what will happen? Then, a 1 minus a 2 plus a 3 minus a 4. what about the opposite phase this wavelets are coming?

now, they are not coming; all are coming those are in phase Coming from first zones, then third zones, then fifth zones or other way; second zones or 4th zones or 6th zones all amplitude will be added at P; a 1 plus a 3 plus a 5 all will be added in P. you will get huge intensity at the center you will get huge intensity at the center as convex lens does.

if you put light on a convex lens all light will be considered the focal point. High in very huge intensity will get at the focal point. that is why if you see this one this relation a 1 by a plus 1 by b equal to m lambda S m square as if this is 1 by f. 1 by b minus or plus 1 by u equal to 1 by f b and u nothing, but the source distance and object distance and image distance.

here a and b source distance and screen distance this is like just focal point is a depending on the cc radius of this S m you know choosing this one. you can it's just like convex lens of different focal length you can produce. this way we the device we fabricate so that is called zone plate Alternate zones are blocked and other zones are oven opaque transparent.

light will pass through that and you will get the action like convex lens., I think I will not discuss more on this Fresnel's diffraction in laboratory. of we will try to demonstrate one explain based on the zone plate.

So, thank you for your attention.