Experimental Physics – II
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Lecture – 44
Double Slit Diffraction

today I will demonstrate Double Slit Diffraction experiment. we are in first year's physics laboratory of IIT, Kharagpur. let us let us know what the aim of this experiment is.

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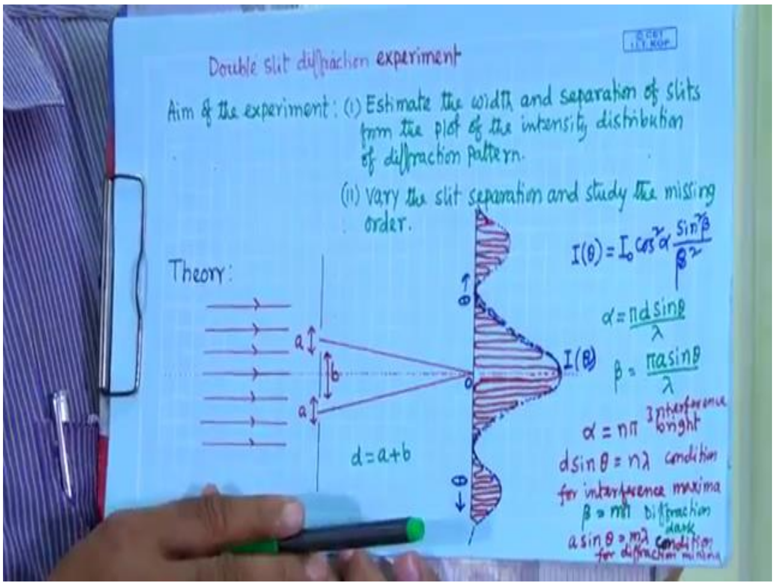

aim of this experiment is estimate the width and separation of slits from the plot of the intensity distribution of diffraction pattern and second aim is vary the slits separation and study the missing order double slit in single slit you have seen this only one. one open path on the screen; now, in this case there are two open path and these two open path are separated that is the opaque phase opaque. here the two slit both have the same width, two slits having the same width that is say a and this opaque that part is width is b.

slit separation then middle to middle we can tell a plus b equal to d a plus b equal to d d is the slit separation and a is the slit width of both slit we would like to measure the slit width as well as the slit separation measuring same way measuring the intensity as a function of angle as we have measured for single slit experiment the same experiment .

we will just we will replace the single slit by double slit, and we will see the pattern on the screen. first, we will see the pattern on the screen and then screen will take away and the pattern will fall on the photocell. And, we will take reading of the photocell as a function of it is position in transverse direction, in transverse direction whatever the light direction it transverse direction will measure the intensity as a function of position of the photocell

that is as a function of theta. we will measure the intensity, light intensity that photo current or photo voltage of the photocell is proportional to this intensity of light. here in this double slit that intensity will vary as a function of theta that equal to I 0 cos square alpha sin square beta by beta squared. in single slit whatever you have seen I 0 sin square beta by beta squared that is there, an additional factor is there that is cost squared alpha where alpha equal to pi d sin theta by lambda and beta equal to pi a sin theta by lambda.

in case of single slit the beta was there, here also beta is there additionally alpha is there. these alpha just in alpha these a is replaced by d, then it became alpha. In beta if you replace a by d by d then it is alpha Now, this intensity will vary it depends on theta of course, but that intensity will control, will be controlled by these two factors. intensity of what these factors sin square beta by beta squared how it varies as a function of theta that we know. this blue graph you can tell

Now, this other red part you are seeing that is, that is it is a because of this cos square alpha. you remember that cos square alpha in case of interference this term was there; cos square alpha in that there we use cos square pi that pi was the phase difference here also the same that this term has appeared this it is a cos square alpha it is telling that the only see the interference pattern this red whatever we have drawn. that is intense that the interference of the interference because, here as if these two slits will acts as a this just like Young's double slit experiment in interference.

we will get these two source. light coming from these source they will interfere we will see the interference pattern. Now, only difference we are seeing that this intensity of different orders of the interference fringe that intensity is not same, it is the intensity is more modulated by the effect of single slit. it is envelope, it is the envelope due to the single slit diffraction here we will see both the effects, the interference effect as well as single slit effect here again that a light will diffracted in a different angle from two source the light will be diffracted at different angles. for the same angle from this source and this other source they will interfere, at different angle they will interfere, and you give the interference pattern, and this is also single slit, this is also single slit individually. that single slit effect is there. Now, this effect is coming single slit effect is coming from both the slit. that is there additionally interference effect is there.

this type of diffraction pattern we will see on the screen. Now, for beta this we have seen that we will get diffraction minima, we will get diffraction minima diffraction minima single slit diffraction minima at a sin theta equal to m lambda; m is the order first order, second order, third order of the diffraction minima. And, for this term when alpha equal to n pi when alpha equal to n pi then this term what will happen? this is cos term and other one sin term.

whatever the for sin term was there. for m pi now, for cos term we will get just opposite effect. m pi it was giving the minimal there for alpha equal to n pi n and m both are plus minus 1 plus minus 2 etcetera. we will get maxima for alpha equal to n pi. that is the interference b fringe this is the condition for interference b fringe. d sin theta, d sin theta will be equal to n lambda this is the condition for interference maxima.

here red this interference pattern we are seeing for that the condition d sin theta equal to n lambda, n equal to 0 plus minus 1 plus minus 2 etcetera and a sin theta equal to m lambda already we are familiar from the single slit. these that diffraction minima n is not equal to 0, but m equal to plus minus 1 plus minus 2.

Now, here one interesting thing is that for a particular theta, for a particular theta if what will happen if both condition is satisfied then what will happen? For a particular theta if both condition is satisfied then what will happen? this diffraction minima at that angle if we get diffraction minima; that means, no light is going in that direction no light is diffracted in that direction.

then how you will get the interference pattern, interference maxima in that direction? we do not see interference maxima at that angle. that is why we tell this is the missing order, we tell this is the missing order. missing order is if both for a particular theta both are satisfied. this by this theta is same, d by a equal to n by m n and m that value will depend on the ratio of that this ratio of n and m will depend on the ratio of d and a d by a.

that means, if d by a if it is say 2 if it is say 2 then n equal to then m equal to d by a it is 2 and that equal to n by m. n will be equal to 2m That means form equal to 1, n is 2. What does it mean? for first order diffraction minima, second order principle maxima second order principle maxima we will be missing. second order, then fourth order, sixth order, eighth order those principle those interference maxima we will be missing in the first order, second order, third order at those that those are the place of the diffraction minima.

if we get different ratio of this d and a you can see the variation of that. what will happen in centre maxima this is the 0, this is the maxima for n equal to 0 So now, if d equal to 2a if d equal to 2a d equal to 2a then second order fourth order will be missing; that means, this is the central maxima of the diffraction.

in the central maximum of the diffraction you will get three interference maxima; one is central one and other is both side first order n equal to plus 1 and n equal to minus 1 first order both side you will get If this ratio is 3, then third order, sixth order, ninth order that will be missing; that means, apart from the central one you will get these both side up to second order first order second order that means, in central maxima of the diffraction you will get five fringe interference fringe.

And, when you will get five interference fringe lobe side lobe this the intensity is very poor for the due to the single slit diffraction effect. here you will a third one is missing that is a first order second order of interference things then third is missing then you will get fourth, fifth and sixth one will be missing; that means, inside here that you will in lobe side lobe you will get two fringe, two interfere fringes fourth and fifth, sixth is missing, seventh and eighth, ninth will missing

that means, here whatever the number of you will get 2n plus 1 when you we will get here n 2n plus 1 means both sides n plus n and this central one is n. 2n plus 1 number of interference maxima you will see in the central diffraction maxima and inside maxima secondary maxima in secondary diffraction maxima side lobes there you will see n number of if it here n plus 2n plus 1 number. here you will.

from there you will get the value of n you will get the n and then you can find out you can find out the if you count from this if it is 2n plus 1. you will see the you will see the n number of n number of fringe here. that is n-th. that will be if fifth order is missing. you will get 9 fifth order is missing you will get 9 here.

fifth is missing then here you will get 4 that means, up to here you will get fourth order. 2n plus 1 means up to fourth order you are getting fifth is missing here you will get 4 interference maxima in the lobes. that is why here if it is 2n plus 1 number then in lobes it will be n number which order is missing you can find out and from there this ratio also you can tell what the ratio of a and b. is

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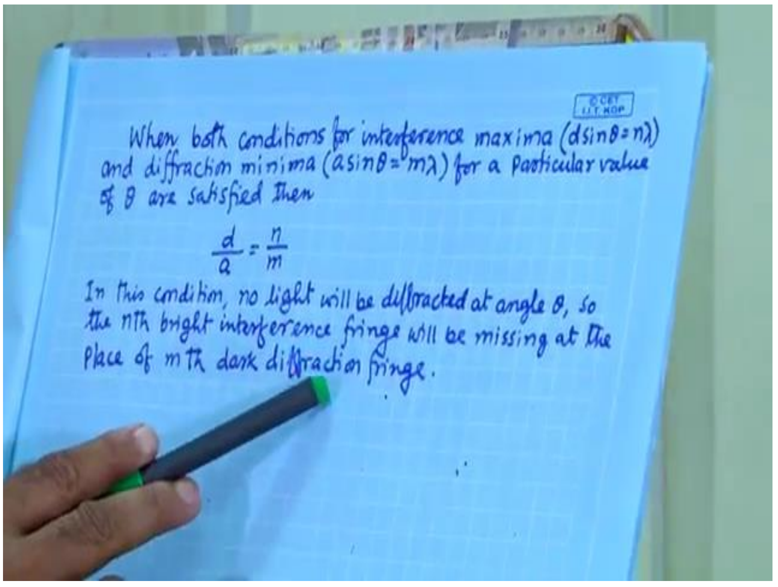

we can study the interference that missing order in case of double slit experiment. when both conditions for interference maxima and diffraction minima for a particular value of theta are satisfied then d sin theta by a sin theta equal to n by n lambda by m lambda. this is the in this condition no light will be diffracted at angle theta.

the n-th b fringe interference fringe will be missing at the place of the m-th order diffraction fringe. which order will be missing that will depend on the ratio of d and a we will study the also missing order in this experiment?

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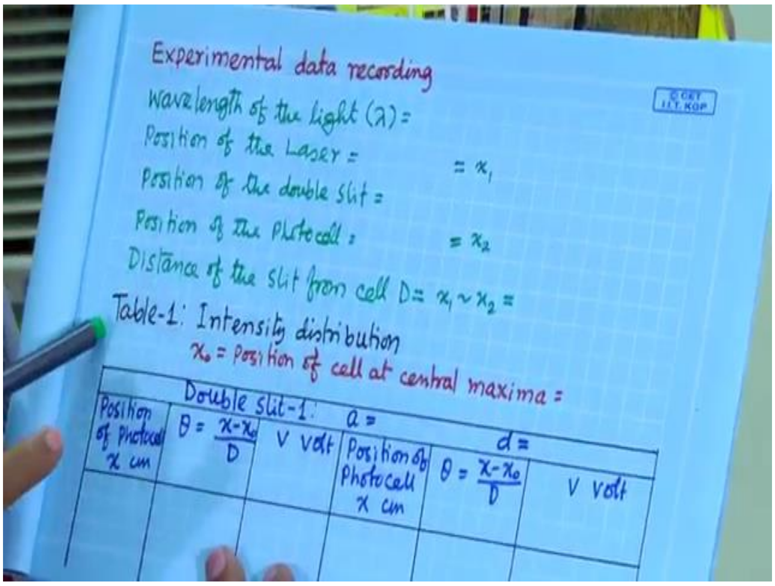

for this experiment data wavelength of the light you note down, position of the lasers, position of the double slit, position of the photocell. distance of the slit from the cell see if it is x 1, x 2 just you can find out. this experiment is exactly same as the for single slit whatever we have done. we will do this experiment for three sets of three or four sets double slip double slit where the d and a ratio are different

for first double slit double slit 1, this you just measure the intensity as a function of x as a function of x d is constant d will remain constant capital d. we can find out theta just like a single slit you note down the photo current or voltage as a function of theta or as a function of position of the photo cells in the transverse direction of the light.

that is x and x 0 is the position of the cell at the central maxima that we should note down and then this x minus x 0 you will get for different x, note down this. here also you go towards the left to note down and then again you come back to left and again note down for that you note down you will be to draw two graph intensity versus the angle theta.

And, from that graph you can find out the you can find out the what you can find out you can find out you can find out the you can find out the diffraction minima that is the app. But, between two diffraction minima what are the what are the interference maximum intensity of interference maxima. that also you will get as I showed the graph this type of graph you will you will get. the red one red one you will get, and you will see this there is a modulation, there is a modulation of this intensity like this

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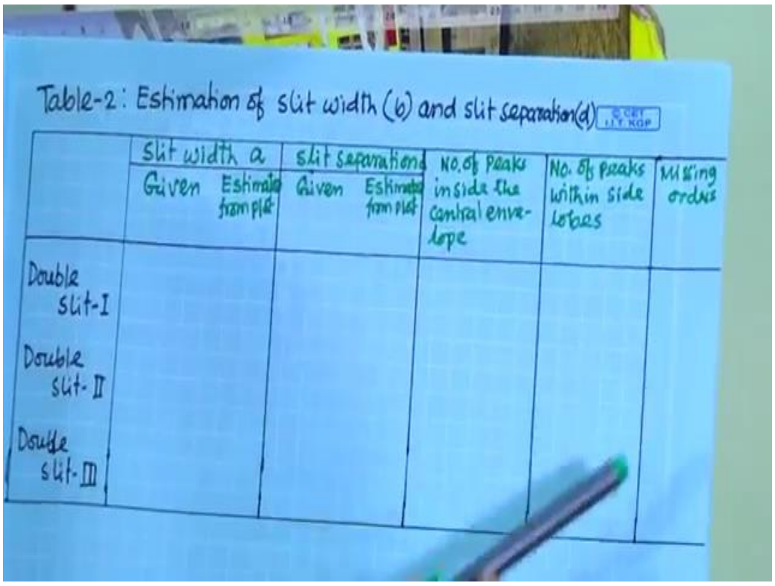

there is the intensity distribution we will get and then we will estimate the slit width and slit separation we will use three sets of double slit as I mentioned. slit width a; this slit width is given on the by company on the double slit. that we will note down and from the experiment we will estimate then we will compare we will compare then.

And, then also for slit separation it is given. slits separation is given and estimate from lobes number of peaks inside the central envelop means central diffraction maxima inside how many number of peaks are there interference peaks interference peaks, interference fringe ok, interference maxima. that we will note down for each case for each case and then number of peaks within side lobes as I mentioned we will note down.

And, from there from this two as I mentioned this will find out the missing order which order is missing then you will see this second order missing or third order or fourth order that depends on this reason. that also we will be able to check I think I will now demonstrate the experiment.

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here you see this again the same just we have replace the we have replace the we have replace the single slit by double slit. I think from this side we will show this slit.

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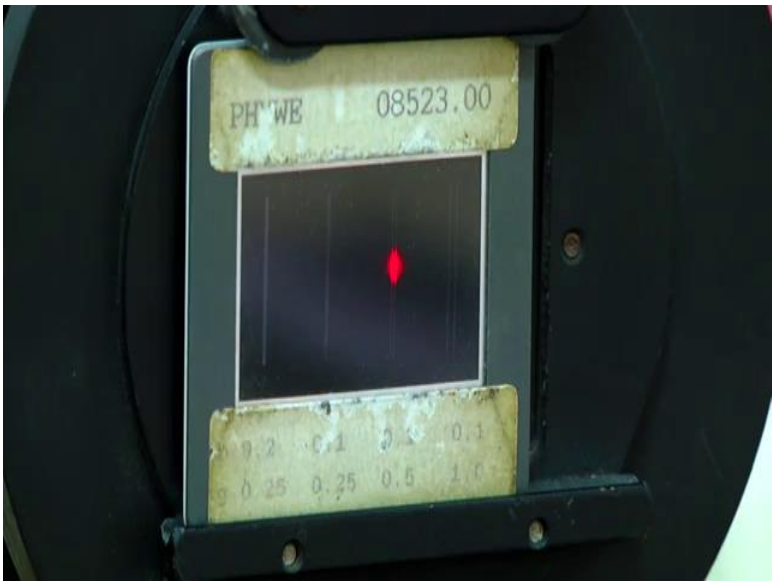

you can see this four this four lines on the surface four lines 1 2 3 4. I have put light on the fourth one I have put light on the fourth third one I put light laser light on the third one. this is the laser this is the laser; laser light is coming.

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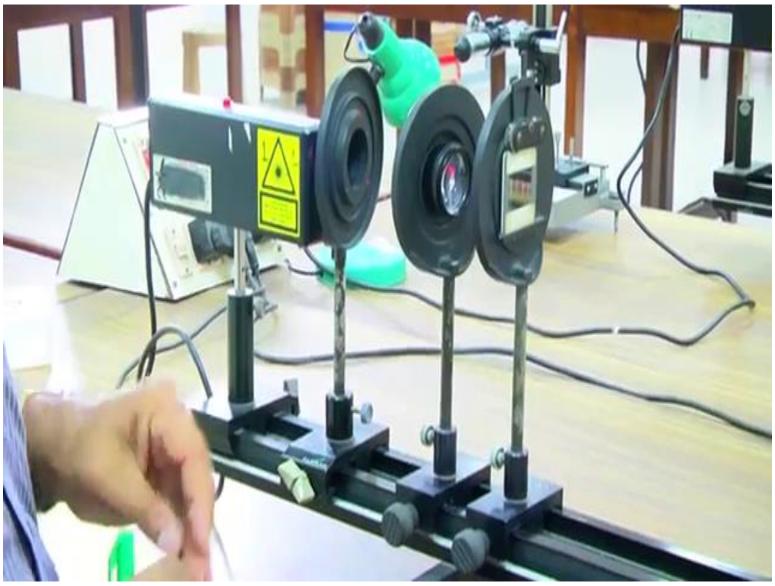

And, here we have used two lens their focal length is their focal length is 20 and 100 this combination of two lens we have taken is here this it is a double slit you know. this light should fall on the both slit. if light is very narrow, we do not use these lens system, then you may it you may you may not get this sufficient size of the beam which will cover the which will cover the both slit and.

here actually light with the help of this lens system two lens system falling on the falling on the falling on the double slit on the same surface we have four double slits and here it is written you know what is there what is the a value what is the a value and b value. for first one it is written for first one it is written probably a value is 0.2 and d value is 0.5 and for second double slit it is written a value is 0.1 millimetre and then d value d value say slit separation that is 0.25

then third one where light is there this a value is 0.1 and d value is 0.5 and then last one fourth one is a value is 0.1 and d value is d value is 1 d value is 1 you can see this is a millimetre order. From here you can see the separation increasing between the two slit. slit width are constant, but this their separation slit separation that mean b part a plus b part is the opaque part between the two slit that part is increasing

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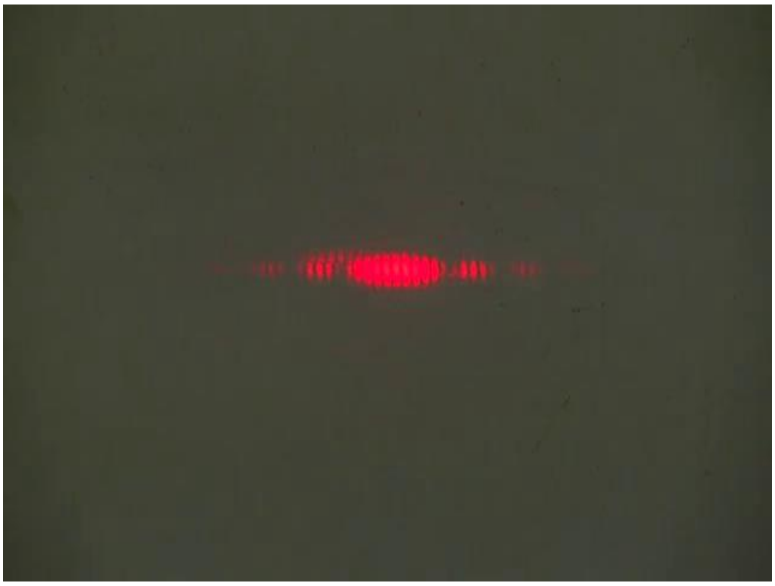

now I think we will show this image we will show this image, yes. here you can see I have said it I will. here you can see that you can see that this is the diffraction central maxima. Now, in diffraction central maxima you can see and both side there are minima, there are minima, diffraction minima and then diffraction secondary maxima.

Now, in secondary maxima there are interference fringe as I mentioned and in central maxima you see also there are interference fringe at present at present, I have used this a double slit where a is a is 0.1 and these 0.5. what is the ratio? d by a what is the ration? Is ratio is 5 ratio is 5 by 1. 5 by 1 equal to n by m small n by small m; n is the order of interference fringe, interference maxima and m is the order of diffraction single slit diffraction minima so that means, n equal to 5m.

when m is 1, n will be 5; that means, as we mentioned that m equal to 1 means you for a particular angle theta this light is supposed to go that side in that direction. Now, that is the direction for diffraction minima. no light will go in that side then we supposed to get fifth orders maxima interference maxima there. then how you will get the maxima there where if light is not going in that direction that is the concept of missing order.

at the first order of diffraction minima where we supposed to get fifth orders interference maxima, but that will not be there. fifth order will be missing, then it is second order diffraction a minimum tenth order will be missing, but here it is difficult to see here it is difficult to see, but I can see the second order diffraction minima. there we supposed to get tenth one that will be missing. now, let us just see these central one.

in central one how many we supposed to get how many how many of interference maxima? fifth one is missing, central one n equal to 0 that is there, then first order, second order, third order, fourth the order 4 and central one is 1, 5. And, other side first order, second order, third order, fourth order 4, 4, 8 plus 1 9 we should we will get 9 fringe 9 maxima interference maxima in the central diffraction maxima. Fifth one both side fifth one is missing. then sixth, seventh, eighth, ninth one will come in the side lobes side lobes side lobes.

inside lobes there should be 4; number of interference maxima will be 4 and in central will be 2n plus 1 that is 9. now, here slightly difficult, but that, but this in when you will plot taking the intensity, taking the taking the photo current. there you will be able to see clearly this a number of fringe. here you if I count I can see 1 2 3 4 5 6 7 8 9, yes and these in lobes I can see clearly 1 2 3 fourth one is looks slightly a weak because it depends on you know it depends on, because intensities in lobes it is varying.

And, this fourth one this in the lobes this fourth one why it is weak? another explanation I can tell you that this in secondary maxima it is not we are not getting the intensity fall symmetrically in both side with the angle reason is that reason is that the secondary maxima secondary first order maxima it will come at 1.435 it is not coming at 3 by 2 pi or 5 by 2 pi, it is coming slightly less than that

that peak you are not getting at 1.5 you are getting at 1.435 ok, but the interference maxima if they are spacing on or equal interference maxima they are spacing at equal. this here in the out of this four, this first, second, third whatever it we will get intensity this modulation this diffraction modulation. last one, that intensity will decrease, that I will show you.

As I told that here whatever the interference you are getting here you see that this maxima are not exactly at 1.5 it is at 1.43. it is a towards this side. maxima is shifting this side that is why this order will be more intense compared to the last one that is why here there is supposed to be 4 and clearly three we can see and the last one I can see here, but that is the weak comparatively compared to others other three that is why you are not probably able to see in the video, but it is there.

now I will show you I think what we can do just for this slit for this slit width and slit separation we can measure the intensity distribution using the photocell same way using the photocell same way as we did for the for the single slit.

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this is the photocell here we will measure the I think it is I will switch on yes, it is there. here we will measure the voltage it is we have chosen this 20 volt scale if light is, I put off, then it is showing some value that is because of other lights. you should switch off this other light ok, then you will get here 0 value or yes, I think that is the reason that because of the other light in the room.

anyway, here also if I what we will do we will vary we will vary the position same scale as micrometre we have used for the single slit here also same.

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I can see the change you see. it was 11, 12, now 4, now it is 3, now yes. now, again it is increasing why it should not be 3, it should be say almost 0 almost 0 I have stopped it this way just you have to vary, but here comparatively the single slit this double slit you have to vary slowly in smaller slit because you have to you have to you have to get the intensity variation of the interference fringe with small step you can vary and take the reading.

Now, I will go to the second set of I will go to the second set of yeah, a double slit where I think I will go this is a is 0.1 and d is 0.25. Now, you see this is just the half of it was earlier whatever now I am using this slit separation is 0.5 and slit width is 0.1 that second one I am using. there slit width is 0.1 same, but their slit separation is a half of it 0.25.

then this in central you are getting how many? You are getting you are getting 9, now it should reduce this number should reduce how many should get it is a that you can calculate. it should come around a 5 or 7 because it is not the integer you may see 5 or you may see 7. I am going I am changing to the second slit.

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Yes, I am now at second Now, clearly see change I can see 1 2 3 4 5 yes I can see the 5 one it is a this if ratio would be this 2 then I could get 5, if ratio would be 3 I could get 7, but it is in between. I think other one is difficult to say, but it is not the integer. I will get the I will get the integer value.

you can now we can tell that third order will be missing because central one then I am getting 2; then third order, sixth order will be missing. third order, sixth order will be missing. in lobe you will get two interference fringe. Yes, I am getting two we can see this you are getting the diffraction minima first order diffraction minima, after that you are getting yeah it is 2.

Again, there are some weak a weak one, but it is difficulties is that it is not integer. that is why it is two or slightly it is a more than two it looks to me, but one is very prominent and. Another in both sides I can see two more, but one of them is better than the other one. that is because of that factor 2.5 it is neither 2 nor 3 in between

now, for this again you would take out and this you measure the intensity distribution. next I will just show you the fringe these very interesting that is why I am showing to discover the to study the. this one is point a 0.2 and 0.2 this a is 0.2 and d is 0.25 this one point then ratio is 1.25; b by a the ratio is 1.25.

that means, say it is a then approximately 1. n equal to n equal to m; when n equal to m; in central n equal to m. you will see this in central how many we will see if n equal to m. for first orders for first order m equal to 1 n is 1; that means, a first order second order third order that will be missing that will be missing tactically you will not see you will not see any interference pattern only what you will see you will see the diffraction pattern you will see the diffraction pattern

diffraction central maxima and then you are getting minima same this diffraction minima, then secondary maxima, minima, secondary second order secondary maxima and that is what happening here you see the exactly you are getting similar to the single slit whatever you got. this central one is very b one and this side one side whatever you are getting that is the secondary maxima and between this secondary maxima or central maxima secondary maxima you are getting no light.

that is the a secondary that the diffraction minima first order, second order, third order and interference fringe, interference maxima and missing because it coincides more or less coincides with the diffraction minima if it is you could see if it is both are equal you could see, yes. if both are equal. both are equal what does it mean? If both are equal a plus b equal to d you know if b is if a is 0.2 and d is 0.25, then what is b? b is 0.05 it is a almost negligible separation

that is why it is a it is behaving like a single slit it is behaving like a single slit that is why you are seeing this type of pattern similar to the diffraction single slit diffraction. that is this is the way we can study the we can study the missing order I think nicely we could see as well as of course, the similar way or that we have a measured the slit width of single slit.

here also you can measure the slit width as well as slit separation from angle theta because one is a sin theta equal to m lambda another is a d sin theta equal to n lambda. measuring the intensity variation one can find calculate the a and d slit separation, slit width and slit separation I will stop here.

Thank you for your attention.