WAVE OPTICS
Prof. Samudra Roy
Department of Physics
Indian Institute of Technology Kharagpur
Lecture - 23: Newton's Ring (Cont.)

Hello, student, welcome to the wave optics course. Today we have lecture number 23, where we continue the concept of Newton's ring, the formation of Newton's ring, and a few more aspects of this topic. So, let me write, today we have lecture number 23. So we already introduced how Newton's rings are formed and how from that spectrum and whatever fringe pattern we have. From that fringe pattern how one can figure out the wavelength of the unknown light? So today we are going to study a few more aspects of Newton's rings. So first let me draw once again the basic structure of Newton's rings, where we have this kind of a glass plate over which. This is the contact point of the glass and then this a plano-convex surface and then this is O is the center of the curvature that it has and the light falls here and then reflected back from this surface and another light falls here and reflected back from this surface and these two lights are essentially interfering with themselves to form the pattern. In order to form a pattern, they should maintain a phase relationship among them. So suppose this separation from here to this is say T of m. So that is the path difference, from which we can calculate the path difference and we calculated that, for maxima, we have the condition 2n tm, where n is the refractive index of this region. Normally it is air and it is 1 but let us put this value as n, then that value is 2m minus 1 lambda by 2, this is for maximum. Similarly for minima, one can find out that this path difference should be simply 2m of lambda by 2. So in the first case, it is an odd multiple of lambda by 2 for maxima, and for minima, we have the even multiple of lambda by 2, so here the m value can go from 1, 2, 3 etcetera, and here the m value takes 0, 1, 2.
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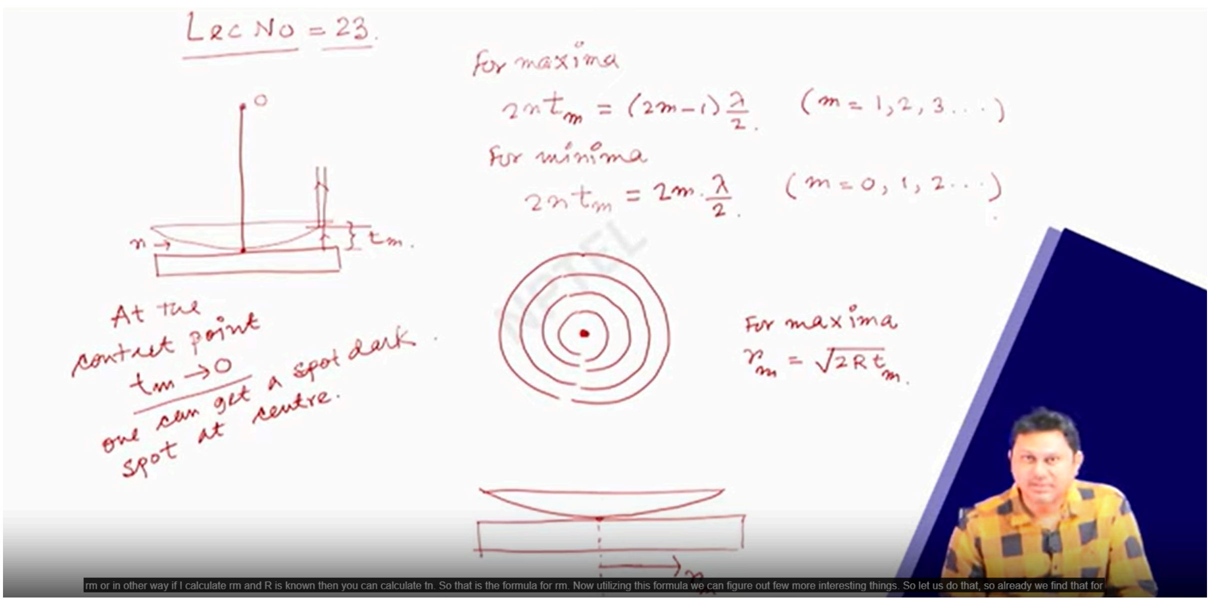

So at this point, you may note that at the contact point, the value of Tm is zero. So from these two equations, one can easily figure out that this condition can happen for minima, so that means at the contact point since tm is equal to zero, one can get a dark spot at the center. So, if I draw a structure which are concentric circles, this is the fringe pattern that one can see in this experiment but the central spot will always be dark in this setup because of this condition. So after having you know these conditions of maxima, minima we can play with this and try to find out a few more interesting aspects. Also, one important thing we calculated was the, so let me draw it here only, so the fringe is formed based on the structure and suppose some maxima is here at the point rm, r is measured from this, we calculated that rm for maximum, rm was root over of 2 of R t of m that we figure out also in the last class, that means if we know the path difference, if we know the thickness and if we know the R then we can calculate the value of rm or in another way if I calculate rm and R is known then you can calculate tn. So that is the formula for rm. Now utilizing this formula we can figure out a few more interesting things. So let us do that, so already we find that for maxima one can have, so what we get here, is 2n tm, 2m minus 1, lambda by 2. So that I should write here. So for maxima, we get 2n tm that is equal to 2m minus 1 lambda by 2, here m goes to 1, 2, 3 etcetera. In a few cases, it is also written as 2m plus 1, lambda by 2, but these are the same in that case m can also take the value 0. Well from here, we can find out that tm for maxima should be 2m minus 1 lambda by 4n. So that is the value of tm, so if I incorporate also we had for bright fringe rm is equal to root over of 2 of R of tm, now tm is this quantity. So for the bright fringe, the radius is this, that is the value I can simplify that R 2m minus 1 and then it is lambda divided by 2n, where m is an integer and takes the value 1, 2 etcetera. So that means if suppose we have a bright fringe here Newton's ring, I'm calculating the value of rm of that bright fringe. So if I now calculate the diameter of this bright ring, the diameter of the bright ring is simply Dm is equal to 2 of rm, 2 multiplied by the radius that is the diameter of the bright ring. So, then we can write that Dm square is simply equal to 2m minus 1 into R lambda all divided by 2n into 4 or diameter should be 2 into 2m minus 1 lambda R by n, that is the diameter of the bright ring.

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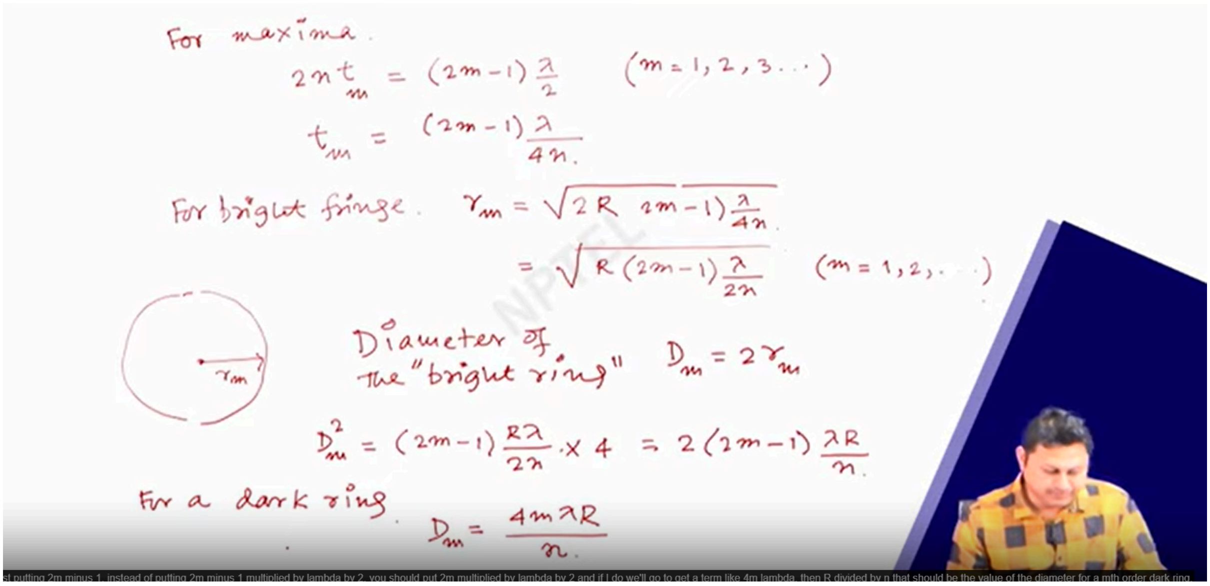

So, what we are doing here, is trying to find out what should be the difference between the mth and say m minus 1st order dark ring because if I manage to get that value then we can find out how the diameter of the ring throughout the length is varying and we will see that this value is a function of m. So that means over the distance of the diameter of the ring, the width of the diameter of the ring will be affected by this. It is not the same for all the rings. So if I calculate this for a bright ring then for a dark ring we can simply have Dm equal to, just putting 2m minus 1, instead of putting 2m minus 1 multiplied by lambda by 2, you should put 2m multiplied by lambda by 2 and if I do we'll go to get a term like 4m lambda, then R divided by n that should be the value of the diameter for an mth order dark ring. Now, mth order dark ring so suppose this is a dark ring, the central ring, another dark ring can also be possible here, say this is this dark ring is say mth or m plus 1th dark ring and this is say mth dark ring, so m plus 1th dark ring and mth dark ring I know the general formula of the diameter of mth dark ring. So I can write that Dm square is equal to 4 of m of lambda R divided by n. So, the difference of the mth and m plus 1st order dark ring in the diameter can be calculated simply by just putting m to m plus 1. So, what I am trying to do is make a difference in the diameters of m plus 1st and mth dark rings, you can do that for bright rings, also mth dark rings. So, that difference if I write delta Dm that should be Dm plus 1 minus Dm. Now, from here we can write Dm plus 1 square is equal to 4 lambda R divided by n into m plus 1. So if I simply put this result here then it should be 2 root over of lambda R by n and then root over of m plus 1 minus root over of m. Now this value is independent of m. So that means if I increase the value of m then the separation will be smaller and smaller. So one should note that for a large m, the value of delta m is small, which means the rings gradually become narrower as their radial increases. So that means if I look at Newton's ring we can see that the separation between these two rings is consecutive, and dark rings will gradually reduce, which means over a large distance what happened, the rings are gradually becoming narrower and that is an interesting feature of Newton's ring. So if I see the ring then there are many ring structures available in this superposition of two lights in different systems. We can also see there is a Michelson interference problem where also we have a circular fringe kind of pattern.

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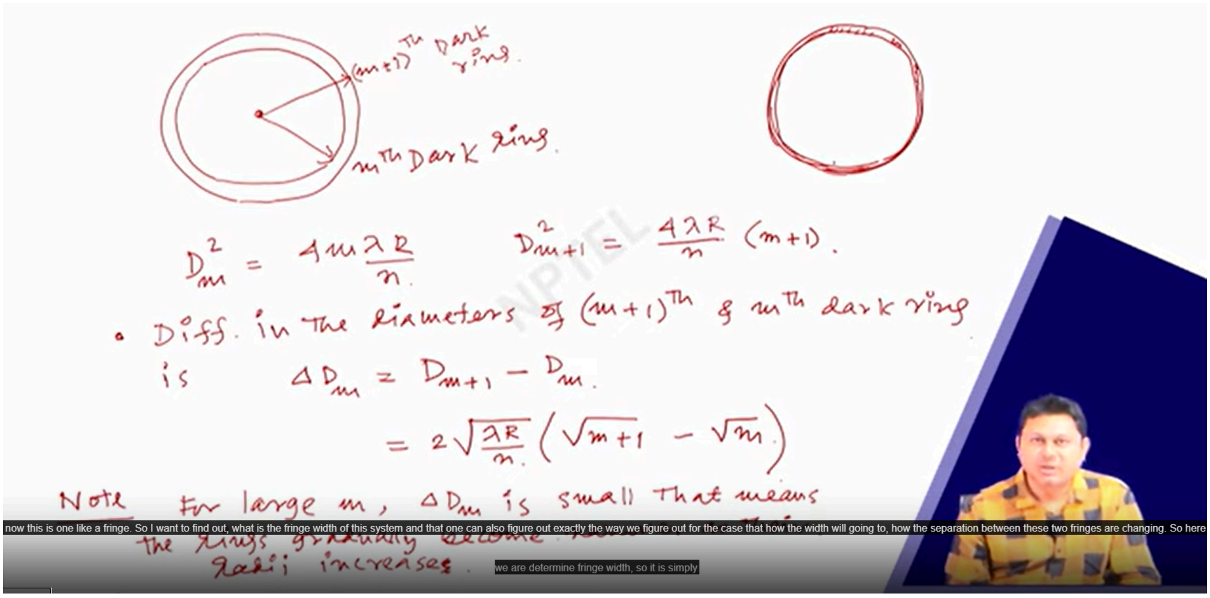

Here also find a circular fringe but the identity of this kind of fringe is this quality if delta m is small then the rings gradually become narrower. So that is one aspect I wanted to discuss and then next that is important is how somebody can measure the fringe of the width of these rings because these rings are not like this line, it should have some width. If I draw one ring very close, my drawing is not perfect, but try to draw. So this is one ring. So now this is one like a fringe. So I want to find out, what the fringe width of this system is so that one can also figure out exactly the way we figure out for the case how the width will go, and how the separation between these two fringes is changing. So here we are determining fringe width, so it is simply with calculation, we already have a bright ring, so let us start with the bright ring in this case. So for a bright ring, we have Dm square is equal to 2 into 2 m minus 1 lambda R divided by n. What happened to the next ring? m should be replaced by m plus 1 that's all. So we should write at 2 lambda R divided by n and then 2 m plus 1 minus 1. So once we know the value of Dm square and Dm plus 1 square of that then we can calculate this, so their difference, Dm plus 1 square minus Dm square is simply this minus this. And it is easy to just check, it is 2 lambda R divided by n. If I take this term common, then the rest of the term is simply 2m plus 1, 2m minus 1, 2m plus 1 minus, 2m minus 1. So, you should have simply 2 terms here and that leads to 4 of the lambda of R divided by n. Now I write as Dm plus 1 minus Dm and Dm plus 1 plus Dm which will be equal to 4 of lambda R whole divided by n. Now we checked in the previous calculation that when m is large then the separation between m plus 1 and m minus 1 is reduced. So this value I can write as this is equivalent to 2 of D of m. If that is the case, then we simply have Dm plus 1 minus Dm, that value is equal to 4 of lambda R divided by 2 of Dm which is equal to 2 of lambda R divided by Dm straightforward calculation I am doing. I am showing that by utilizing the expressions I can find out many aspects or different results related to the structure of the fringe pattern. So the fringe width, interesting quantity fringe width Beta which one can define as Dm plus 1, minus Dm divided by 2 because we are dealing with diameter that's why I need to put it divided by 2 is simply lambda R whole divided by n Dm. Again you can see that beta is inversely proportional to the value of Dm.

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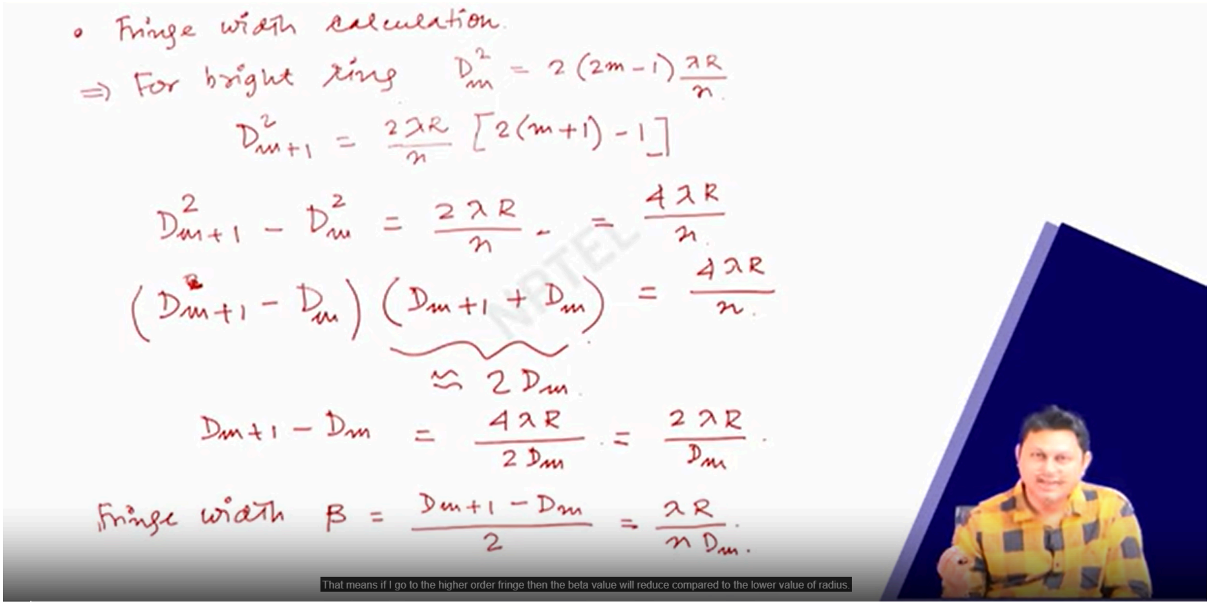

That means if I go to the higher order fringe then the beta value will reduce compared to the lower value of radius. Finally, I like to show another thing that one can determine, The next day we can discuss this briefly, utilizing this Newton swing structure one can also determine the refractive index of a liquid. So this is the determination of the refractive index of a liquid. So the structure is simple, in one case we have the conventional setup, where this plano-convex lens is placed on a glass block and this is where this quantity is air having refractive index na. In other cases, what happened? That I have the structure, this plan convex lens is here but instead of the air we have some liquid placed here, I am setting this region too, so this is now liquid with some refractive index say nl. Now this is case one and this is case two. So for air, we can calculate this quantity, which we already calculated actually. So, I am not going to go into detail that Dm plus p minus Dm square this is for air that we calculate and this value is 4p where p is the order lambda R divided by na exactly the similar thing we can do for the liquid, where we can calculate this quantity that Dm plus p square, minus Dm square for liquid, under the placement of the liquid I calculate this experimentally. Now the left-hand side I can calculate experimentally. So, if I now divide this equation we simply have Dm plus p square, minus Dm square, which we calculate experimentally divided by Dm plus p square, minus Dm square, this is liquid also can be calculated experimentally both the thing we calculate experimentally which simply comes out nl divided by na. For the air, normally na is very close to 1. Then utilizing this expression, one can simply find out what is the value of the refractive index of the liquid by just calculating the left-hand side using the experiment setup. So on that note, I would like to conclude here, I don't have much time to discuss more about this. But roughly we cover Newton's rings problem, which is an extensive problem. In many cases it is used, I believe the students who are taking this course in their lab also may have these experiments. That's why I wanted to go through these things in detail and I show all the aspects of the formation of Newton's rings and the related calculation. In the next class what I will do is I will calculate What happens when we use some sort of interferometer, optical interferometer and what is optical interferometer. It is a system that is such that changing the cavity, means changing the length of two mirrors or two plates. I change the path difference essentially, I am changing the path difference, and by changing the path difference what we can do? We find the change in the interference pattern that is produced and from that also we can calculate a few things like web lens etcetera. So that we're going to cover in the next class. So with that note, I would like to conclude here, thank you very much for your attention and see you in the next class.

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