WAVE OPTICS

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Lecture- 63: Birefringent Crystal (Contd.)

Hello, student, welcome to the wave optics course. Today we have lecture number 63 and we are going to continue the topic birefringent crystal. So today we have lecture number 63 and we're going to continue our discussion on birefringent crystals. If you remember in the last class we mentioned three kinds of crystal cutting. For example here this is one crystal, where the optic axis is along this direction and three conditions were there. Let me draw once again and the propagating light was this. So, in the first case both the components of polarized light are perpendicular to the optic axis OA. However, in other cases one is perpendicular and another is parallel. So, we know that if that is the case then what happens is that there will be a difference in the refractive index and these two refractive index correspond to the two components and one can have a phase difference out of that. So the path difference was and the phase difference that one can have for these two components and then this is b, so that is the phase difference that one can have for this kind of structure. For the first case, there is no effect because both the components are perpendicular to the optic axis. So there will be no such change. But in the other two cases, we can have the phase difference and that is the general form. Now by adjusting the d the length of the crystal it is possible to generate the phase difference at as per our desire, for example if the thickness which is D, if the thickness such that the phase difference is equal to pi by 2, then this whatever the crystal we are talking about should work as a quarter wave plate or in short this in a similar way one can have also we can adjust the thickness such that delta phi become pi then this system, whatever, the optical system we're talking about is called the halfway plate.

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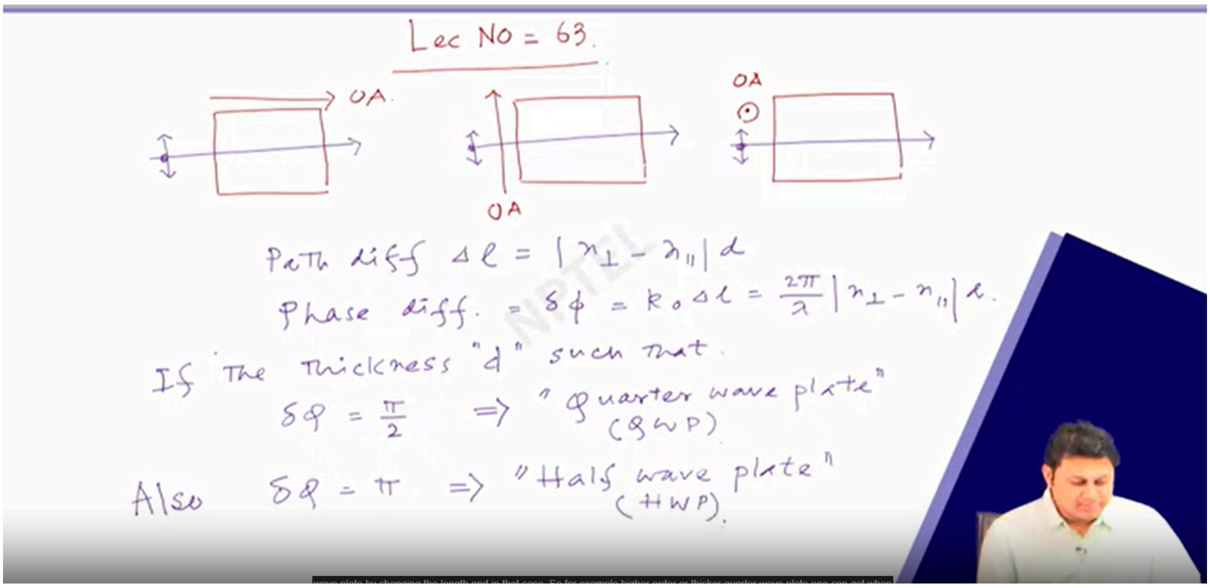

So also one can have the higher order or thicker quarter way plate or half way plate this is half wave plate by changing the length and in that case. So for example higher order or thicker quarter wave plate one can get when delta phi, that is the phase difference between two components is 2 pi m plus, pi by 2, m can be 1, 2, 3 etcetera and such optical systems in general. So such an optical system in general is called that the thing we discuss in our early classes which is phase retarder that is somebody launching. So this is the system and if we launch a light having these two polarization components then in the output we will see that there is a relative phase difference between the components. Okay, so, there will be a relative phase difference between the two and we know that if there is a relative phase difference, then the state of the polarization is going to change. Okay, now, what we want to understand is something that is the different kind of crystal and uniaxial and biaxial crystal to be very precise. So, what is the meaning of that? So, let us define, before that we need to understand once again the optic axis that we mentioned. So the optic axis which we write as OA corresponds to a basically it is not a straight line, it corresponds to a direction c about which the atoms are arranged symmetrically. Crystals like these for which there is only one such direction, that is the direction along which the arrangement of the atom is symmetric, are called uniaxial crystals. Now if there is one case, now, if two such directions are there then those crystals are called the biaxial crysta. So, the direction of the optic axis inside the crystal determines whether they are uniaxial or biaxial; several kinds of crystal are there. We will show what shows this kind of characteristics and what happens if these kinds of crystals are there. So there is a very interesting phenomenon that happens for this kind of crystals and that phenomenon is called the double refraction. This is called the double refraction. What happened? For example we have such crystals, say calcite crystals are CO3 let me draw it. Nicely this part, different color maybe, this blue. So we have a prime this point c and this point c prime along ac prime we have say our optic axis. So this is the direction along which we may have our optic axis. So let me draw the direction of our optic axis. So that means along this direction the atoms are symmetrically placed, this is our oa. Now if an unpolarized light is launched here then one part of the ray which is perpendicular whose polarized component is perpendicular to OA will simply follow the usual, this is the state of the polarization, it will follow the regular refraction laws and move along this direction and this is called the O ray ordinary ray. However, the other component will start deviating from here and it will go to other direction and this component is parallel to the direction of the optic axis since it is parallel to the optic axis, it will move at different velocity and that results a deviation from the o-ray and that we call e-ray. So this phenomenon is in general called the double reflection, this double reflection phenomena we are talking about. So O ray as I mentioned let me write O stands for ordinary ray and that obeys the usual laws of refraction, so, usual law of refraction will be obeyed by this o-ray, on the other hand e-ray which is extraordinary ray it is in general does not obey general laws of refraction. Okay so this is called the double refraction. So one can also understand this with this figure. We will discuss this figure in detail but let me draw it so what happens is this is a surface and when an o-ray falls inside the system the direction of the light I mean the velocity of the light is the same for all the directions. So that's why it behaves, I mean if I draw the velocity of this ellipsoid. So it will be a circle actually. So what happened? So that means I launch a light here perpendicular to the surface of both the cases and suppose this is the component we are talking about. So what happens when it enters in all directions the velocity of this component should be the same. Now let us have our optic axis like this. So this is the direction of the optic axis. So you

can see that the light that launched the polarization is perpendicular to the optic axis. Then what happened? For other polarizations which are parallel to the optic axis, they will move at different speeds in different directions and if I draw an ellipse it will be something like this. So here this is the point where both ellipse and the circle they touch because this is the direction of the optic axis. So in this particular direction the velocity will be the same but what happens is that this wave front if I draw a, so this should touch here, it should not cut. So I need to draw it properly. So that means it should be like this. So just touch here. So in that case what happened is that the light that is moving will go along this direction, so, this is the direction. Let me join it actually and this is the state of polarization which is parallel to the optic axis. It will move like this and come out from the system in this way. Okay, so, this is the way I mean here this is ordinary ray and this is extraordinary ray. Now you can see that if an object is placed here in this point so, if I see from this side we can see the object here as well as if I put these things back here. So for single object, we can have two refracted and since the refracted ray for extraordinary is coming in a different path we can see that the object is basically sitting here as well and if I rotate that ordinary ray will ordinary the object that is generated due to ordinary ray will remain fixed but these things will going to rotate like this way around that if I rotate the crystal like this. So that is an interesting phenomena and I discussed what happens because the ordinary ray and extraordinary ray follow different paths. Why do they follow different paths?
Because the optic axis is such that one component is perpendicular. So that is an ordinary ray and another component is parallel. So this perpendicular or parallel component will move in a different velocity and that's why it happens. So let me note that for uniaxial crystals here, this is one direction along which we have OA that means optic axis. So that's why this is a uniaxial crystal. we have no greater than ne, if that is the case, so, if I write in terms of velocity, so, velocity of the ordinary ray will be smaller than the velocity of the extraordinary ray. So that means here o-ray travels slower at smaller velocity than e-ray, and this is called the velocity ellipsoid, which suggests that V is nought, that is VO, which is represented by this sphere. And this ellipsoid is defined by VE, which is in that case, which is greater than except the direction along the optic axis where both the velocity will travel at same speed. So this is the phenomenon of double refraction. So in the next class we will continue this point. Today we don't have much time. So in the next class, we extend this idea and we find out how the ellipsoid, the refractive index, is the figure that we draw, how one can obtain this figure and systematically one can study the light propagation inside those crystals. So with that note, I would like to conclude here. Thank you very much for your attention and see you in the next class.