WAVE OPTICS

Prof. Samudra Roy
Department of Physics
Indian Institute of Technology Kharagpur

Lecture - 60 : Production of polarized light

Hello, student, welcome to the wave optics course. Today we have lecture number 60 and in today's lecture we are going to discuss how polarized light can be produced. So we have lecture number 60 today and today our topic is production of polarized light. So, you know any interaction of light with matter whose optical properties are asymmetric along the direction of the transverse of the propagation vector provide the means of polarization in fact. So, I am going to discuss the meaning of that. So, let me write about any interaction of light. So, basically the production of the polarization light can be done by light matter interaction, but the interaction should be such that the optical properties are asymmetric. So, that is a major thing. So, let me write down any interaction of light with matter whose optical properties are asymmetrical along the directions transfers to the propagation vector that provides a means of polarizing light. So what I am trying to say is suppose the light is propagating along this direction that is k vector, so something along this direction which is the transverse direction of the k the optical property is asymmetric that means it is not symmetric in nature then what happened that there is a possibility this light matter interaction. So this is an asymmetric optical property then in this light matter interaction one can get as polarized light as outcome in general. So meticulously we will discuss a few cases. So there are few important processes through which polarization can be possible. I am just listing down here the most well known or important processes for polarization are dichroism, by means of reflection, one can polarize the light by reflection scattering and birefringence. So roughly these are the techniques that are used to get the polarized light. So let us start with this dichroism system. So simply it is the most simple case I am going to discuss here and the most useful example is the wear grid polarizer. So suppose I have a concept of this. And here these are the lines suggesting that these are thin copper wire. It is making a net like this and an unpolarized electromagnetic radiation when I say unpolarized, that means the polarization is not defined, it can be any direction and I can write it like this, this is unpolarized light and I am going to get an outcome. I am going to get polarized like this. Why? I will discuss. This is a polarized light. So, when an unpolarized electromagnetic wave vector is incident on a system of this thin copper. So, this is a system with thin copper wire placed parallel to each other. The E, along the length of the horizontal wire that is this, is mostly absorbed here and the horizontal component does not do any work. Here the horizontal component does not work on the electrons that are distributed over this wire. So what happens is that the horizontal component will be exhausted with this system where the vertical component will not be doing much work. So no absorption will be there. So the vertical component will pass through. So that means with a very simple way we can do that kind of polarization. But for effective polarization, the spacing between the wire should be very very small and that should be even less than lambda. So, there are few. So, what will the horizontal component do? So, this is the system and these are the wires I'm drawing as a magnified version. So two components of any vector can be divided into two components, one is vertical and another is horizontal. So this horizontal component will take part because it is parallel to this, it is having the same alignment. So this component will be used here to make joule heating and it will be absorbed by these wires and that's why this component will no longer be there on the outside. Outside means in this region, its output, the vertical component which is not exhausted, which is not utilized much when throughout the when it is passing through the system will remain unchanged and we will get this kind of polarization at the output. This is a way we can simply polarize the light. But the problem is the effective polarization of the space, the effective for efficient polarization, this spacing should be much less than the wavelength use that is lambda. So making the spacing with that amount is very difficult actually by using the copper wire. So, for the microwave it is okay. So, for microwave this kind of system should be useful where we can make the spacing of the order of wavelength and microwave can be polarized but for visible light the lambda is very very small and it is very difficult to formulate this kind of to generate this polarization through this system, so Polaroid are used for that. So there are systems which are called Polaroid. So in Polaroid what happened was that a sheet, containing a long chain of polymer molecules, acted like this copper wire that aligned parallel to each other. So, polarize is a sheet where these polymer molecules are aligned parallel to each other and these light components parallel to the alignment of the polymer chain get absorbed in the same way that we discussed and the perpendicular component will be transmitted. So, the same system we are using here, but instead of putting copper wire with the spacing of the order of lambda, we are using Polaroids that naturally produce, that naturally gives us this kind of system where the polymer molecules are arranged. So, the pass axis is accordingly defined and that is the direction through which the light is polarized and if we have two polarizer placed side by side here or this polaroid plate we place like this and whose pass axes are perpendicular to each other, then if I produce a light here, the first case, a unpolarized light get polarized first.

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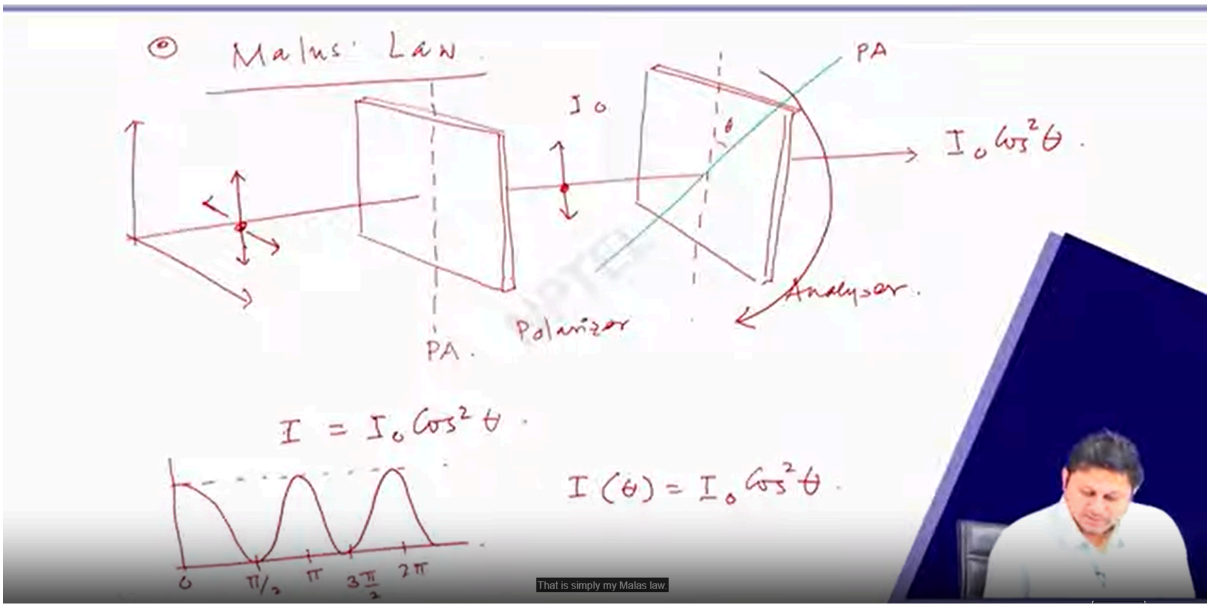

After passing through the polarizer and then if we rotate this another Polaroid film we have and if we rotate this 90 degree. So that its pass axis is now perpendicular to the previous one,

then here we don't get any light. So there will be no light. So this first one is generally called the polarizer and since we analyze the state of the light, we call it analyzer. So, this is the way we can do it. And not only that, we can rotate this analyzer. And when we rotate this analyzer, there is only a small amount of light one can get. If it is exactly perpendicular, then we will not get. If there is an angle between the two pass axes, then we get something. So, that basically leads to something very interesting called Malas law. So in Malas law again we have our polarizer sitting here whose pass axis is like this and we have another polarizer here which analyses the light, so we can call it an analyzer as well. And we have the pass axis along this and let me draw the pass axis a different color maybe in green. So the pass axis is essentially direction and this angle is say theta and then I will try to find out what is the intensity at this. So this is again a polarizer and this is an analyzer. Unpolarized light is passing through this system and we get a polarization here and now I have a pass axis which is not perpendicular to the polarized direction of this polarization but having an angle theta to the previous one. So in that case if I have intensity here i naught, so the intensity that I will get the output is i naught cos squared theta, that is the malas law. So at this point i will be i naught and cos squared theta. So if somebody plots what happened with the theta then the intensity is going to change in this way, this is a cos square function. So 0 and this is pi by 2, this is pi, this is 3 pi by 2 and this is 2 pi and so on. So that means if I start rotating this entire thing then this is the way the intensity will vary and intensity is essentially the function of theta. So, I will get i theta is equal to i naught cos squared theta and that is my Malas law. That is simply my Malas law. So, next we will discuss how to polarize the light by reflection. So, that is also an interesting thing. So, polarization by reflection. So what happened? In a few cases we find that suppose, let me draw this figure first. So after having the malas law now we will check what happened if I just simply allow the light to reflect from a surface and after reflection what is the state of polarization okay. So there is an incident light and then there is a reflected light and refracted light. So the refractive index here is n1 and it is n2 and components are there.
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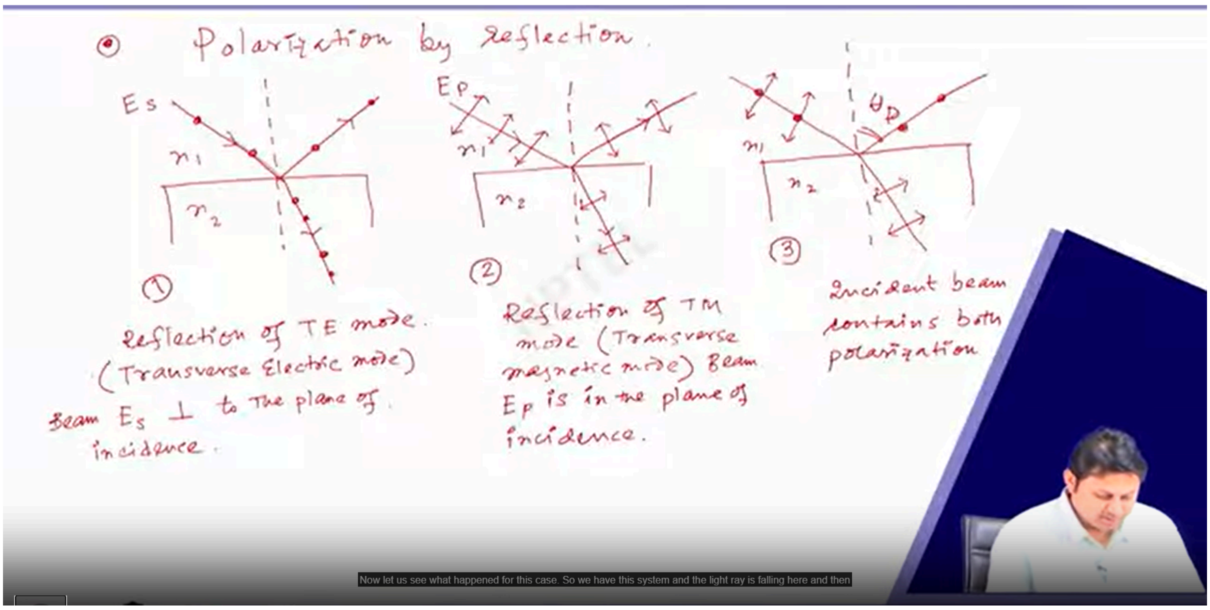

These are the components which are perpendicular to the page of paper. So I launched it. So the electric field is vibrating as perpendicular to the page of paper. That's why I put it. Another case one can consider, this is case 1. Same thing, we have light that is launched here, we have reflected light and we have transmitted light. It is coming like this, this and this. These are dielectric surfaces. So the refractive index is n1 and n2 here. But here the refractive index, so this is called the ES field where the electric field is vibrating perpendicular to or parallel to the surface. I mean it is vibrating parallel to the surface, but here the electric field is vibrating along this direction. It is reflected, this is the case. And what happened that for a specific angle, if these two components are there, let me first draw it. So now both the components are together, sorry because now it is going to polarize. So this component will not be there. Here we have this component. So the reflected component will no longer have this. So here this field is called ep and this is a specific angle for which we have this. We call it theta P. It is called the boosted angle for which. So, this is case 2. This is figure 3, N1, N2. We are going to discuss this actually. So, the reflection of the TE mode, the transverse electric mode, in this case, that we are getting here. So this is a reflection of TE mode, where TE means transverse. Let me write about it. Transverse electric mode where beam ES is perpendicular to the plane of incidence. So, the plane of incidence is this paper. So, it is perpendicular to that. Now, here we get this figure, we get a reflection of T m mode where T m is transverse magnetic mode where beam EP is in the plane of the electric field actually in the plane of incidence. It is perpendicular to the plane of incidence. It is a parallel to the plane or in the plane of incidence. And in this case, the incident beam contains both polarizations. Now let us see what happened in this case. So we have this system and the light ray is falling here and then this is ep, this is the reflected ray and this is the transmitted ray. Now in the transmitted ray there will be vibration along this direction and we have reflection. If I draw the parallel to the reflection, so, this angle is making an angle now and this angle is theta. So, now what happened inside the system, it tried the dipole to oscillate. So, the dipole, so this is the dipole axis. So, the dipole will go inside the material because the dielectric dipole will oscillate.

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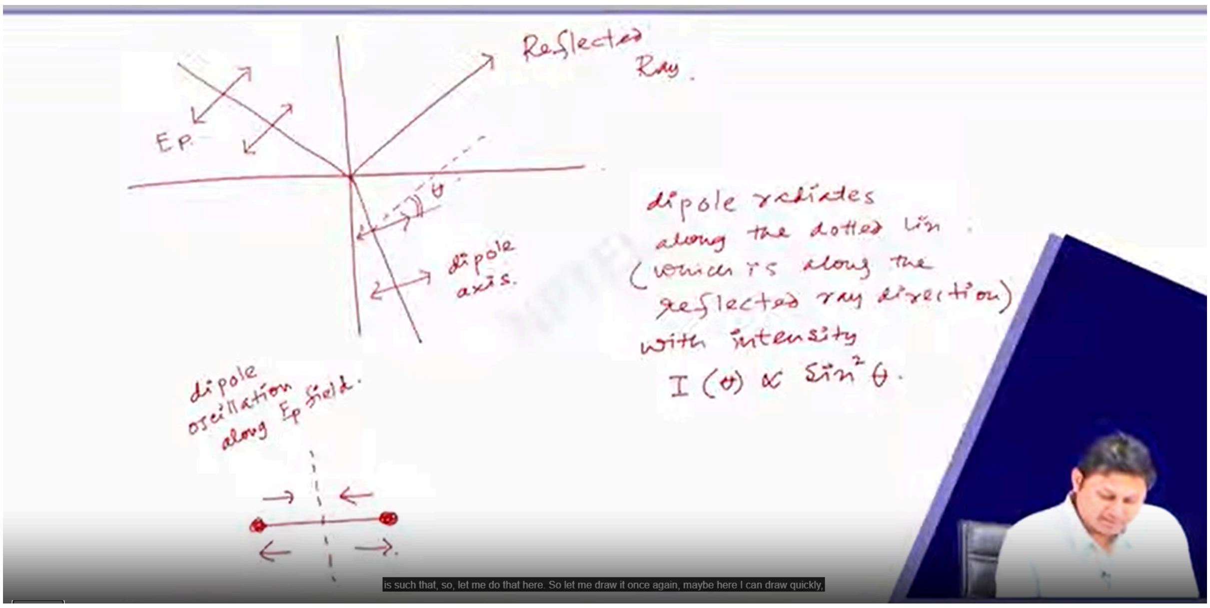

So, now the dipoles will going to oscillate, dipole oscillation along EP field, so this oscillated dipole is going to radiate and this radiation will be the dotted line which is along the reflected direction and that oscillation it will going to oscillate and because the light is coming this way. So the dipole radiates along the dotted line which is along the reflected ray direction with intensity I as a function of theta and that is proportional to sine squared theta that one can get from dipole oscillation theory. So the dipole, when they are oscillating it will radiate and this radiation as I showed that depends on the value of the theta with the dipole axis. So that means along this dotted line it has a maximum intensity and this intensity will reduce along that along the direction of the dipole. So note, here that means, if this vibration, this dipole axis is such that, so, let me do that here. So let me draw it once again, maybe here I can draw quickly, so this angle is theta p and here this is theta t and this is the vibration we are having. So note when the angle between the reflected and transmitted ray is pi by 2 that is I am talking about this angle, the different color may be talking about this angle when it is pi by 2 then some special thing is happening here, then there should be no Ep components because this vibration was due to Ep. So, the reflected ray will only contain the ES1 EP component, so, there should not be no EP component in the reflected ray. So, there should not be any EP component because then what happens is that radiation due to the dipole will be 0 for EP as sin theta will be 0 now okay. So now from Snell's law under this condition I can write this is my n 1, this is my n 2. So that is the condition we are getting these things. So from Snell's law what I get is n 1 sine, so this is theta p. So, n 1 sin theta p will be n 2 sin of theta t that is the condition we are getting. So, theta p, if I look carefully here then this and this plus, this plus, this is 90 degree and this is 90 degree. So theta p plus theta t is 90 degrees, theta p plus, theta t is equal to pi by 2. If that is the case we can get the expression n 1 sine theta p will be n2 cos theta p or tan theta p can give us n 2 divided by n 1 or theta p will be simply tan inverse of n 2 by n 1. So, this is the angle if I launch the light in that particular angle having the knowledge of N2 and N1, then I can partially polarized the light. So, this angle is called the Brewster angle. So, by using this theory, we can get a light after reflection which is partially polarized. So I don't have much time to discuss more today. So whatever we discuss is how to polarize the light with different systems and then we discuss that by using the reflection also we can polarize. So, in the next class, what we do is we are going to discuss the other two ways to polarize the light. One is by scattering and another is by using the birefringence property of a crystal, that is interesting. So, see you in the next class and thank you for your attention.

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