Introduction to Photonics
Professor Balaji Srinivasan
Department of Electrical Engineering
Indian Institute of Technology, Madras
Manipulation of Light Intensity & Polarization
Lab Demonstration

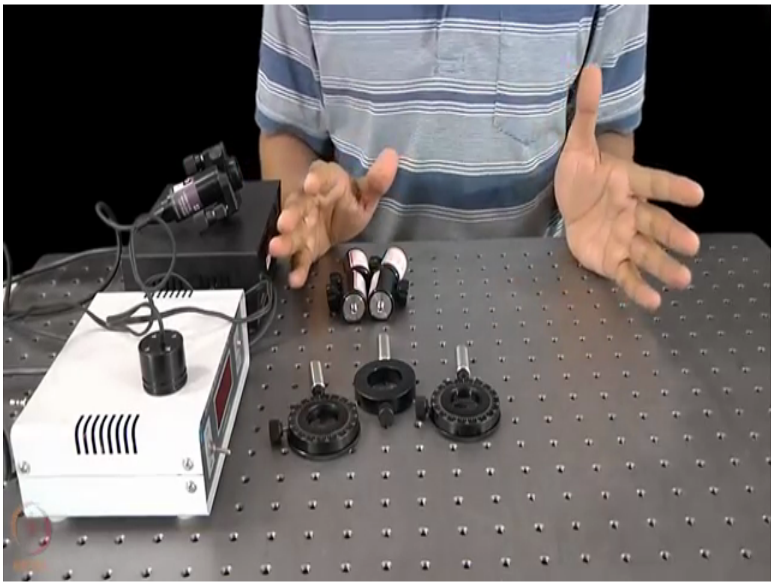
Welcome back to another lab session, today we are going to see manipulation of light intensity and polarization. So as shared in the lab manual we have three objectives for today's lab. First would be a verification of malice law, second would be changing the polarization of input beam using a birefringence material and then seeing the by birefringence property of some plastic materials.

According to malice law if a polarizer I have a seat polarizer with me here, so if the polarizer is placed in the path of a incoming linearly polarized light then the transmitted light will have the intensity given by I cos square theta, where I is the intensity of the incoming beam, theta is the angle between the polarization of the incoming beam and the pass axis of thus the sheet polarizer. So the pass axis of this sheet polarizer is changed so the angle these angles keeps on changing so the intensity on the other side will keep on varying, so that is what we will try to see using our setup today.

And secondly we will so secondly what we will do is in the path will place some by birefringence material which is chains of polarization. So even due to that material we will see the change intensity even if this angle is kept fixed and there is something in between it changes the polarization angle of the incoming beam then we will see a change intensity because again something has changed the polarization angle and then made a net angle between the incoming beam and the polarizer sheet.

So in the second part we will see the working of quarter wave plate and half wave plate both has been explained in class so we will just see the same thing in action here and the third part will be just an observation of by birefringence property in some plastic material where due to plasticity there is some residual stress developed in the material and that stress results into some birefringence property being shown by it is common plastic like a scale and anything common.

(Refer Slide Time: 2:21)



So here we have everything that we need for the malice law experiment. So I have two polarizers, the optical stand, laser mounts laser with a laser mount and laser driver unit and I have pinhole detector and pinhole detector measurement unit. So I will set up everything and we can start then we can start the experiment.

(Refer Slide Time: 3:44)

So here we have setup for the malice law experiment so I have a laser's light source which is a linearly polarized light source driven by a laser driver, then I have a pinhole detector to measure the intensity of that laser beam and pinhole detector gives the reading in currents which is proportional to the laser intensity and the scale can be adjusted to either micro ampere or milli ampere as needed, then I have a polarizer here whose pass axis I can just change using this setup.

So you can see as I am changing the pass access angle of this polarizer there is a change in current signifying the change intensity of the transmitted laser beam okay but so actually this laser source is not a perfectly linearly polarized light source so as to make it a linear polarized light source I will place one more polarizer in between. So now I have placed one more polarizer in between and then I will just try to so now this light I can assume as a perfectly linearized polarized light and then I can adjust the angle of this polarizer to get the maximum here first.

So now I can place my analyzer the second polarizer I will call it as analyze so you can see as I am changing the pass axis of the (polarizer) analyzer you can see the change in intensity of the laser beam. So now if you can if you plot this angle of this polarizer versus the current you will get a cos square fit for that data and so that will the verification of malice law.

(Refer Slide Time: 5:44)

S.No	Angle of Analyser	Output Current from the Detector (mA)
1	0	22.5
2	10	21.9
3	20	19.6
4	30	16.2
5	40	11.5
6	50	6.5
7	60	2.8
8	70	0.5
9	80	0.0571
10	90	1.3
11	100	4.1
12	110	8.4
13	120	12.2
14	130	16.2
15	140	20.2
16	150	22.5
17	160	23.2
18	170	23.6
19	180	23.1
20	190	21.6
21	200	19.5
22	210	15.5
23	220	10.7
24	230	6.4
25	240	3
26	250	0.7
27	260	0.0088
28	270	1
29	280	3.5
30	290	7
31	300	12.2
32	310	15.8
33	320	19.8
34	330	22
35	340	23.1
36	350	23.3
37	360	22.4

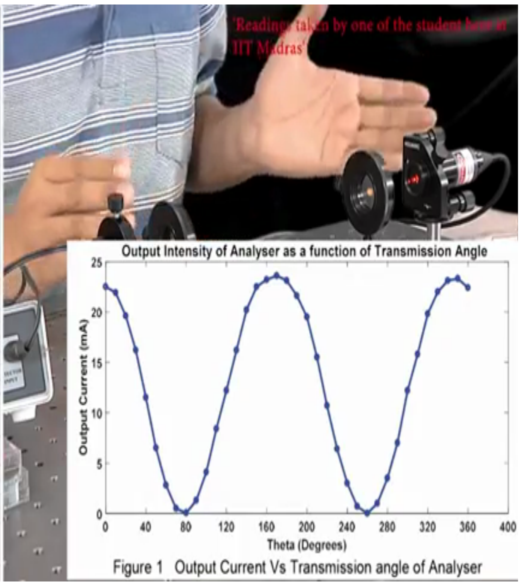


Figure 1 Output Current Vs Transmission angle of Analyser

So in the table here on the screen we will present to you the data recorded, so you can see the data and the corresponding plot and it shows the cos square variation of the transmitted intensity of light.

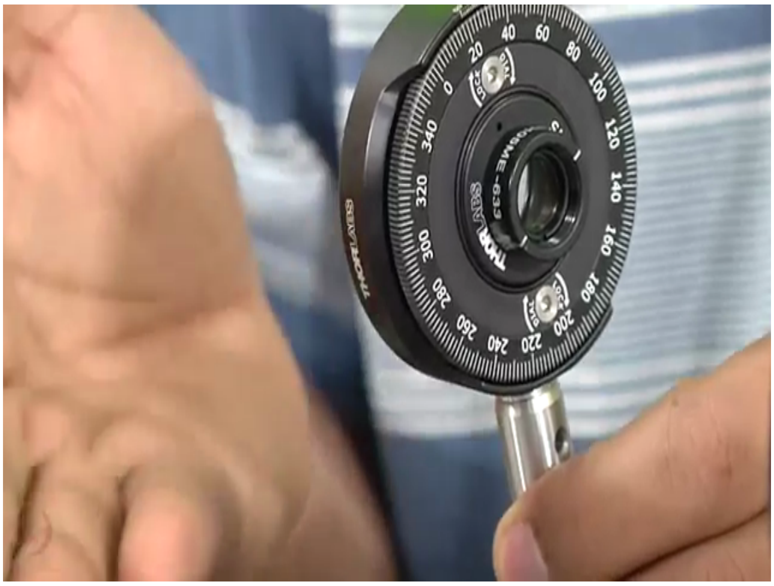
(Refer Slide Time: 5:56)

Okay, so now we will move on to the next experiment that is characterizing half wave plate and quarter wave plate. So to do that we have this general setup, where we have the very same setup that we use for malice law, only difference here is the analyzer is kept at cross angle to the polarizer. So due to which the intensity output intensity will fall to 0, so I will just adjust the polarizer angle to make the output in intensity fall to 0. So you can already see that the output intensity is in micro ohms, so I will further rotate the power analyzer till it goes to 0, okay so this is a minimum that I got.

(Refer Slide Time: 6:44)

So this is the general analyzer polarizer setup, which is used to analyze any material which just changes the polarization of a beam because now right now right now this analyzer polarizer angle has been set to cross angle so that the output intensity is minimum, but if you place anything which changes the polarization just that interferes with the polarization here that will result in some intensity at the output and the intensity change will be proportional to the polarization change produced by that material.

(Refer Slide Time: 7:17)



What is this? A rotating frame wave, so this is the half wave plate with me and it has a fast axis marked on onto it and I can change the fast axis by rotating the rotating frame. So now if this fast axis is kept at some angle theta to the polarizer angle so as explained in class the half wave plate rotates the polarization of the incoming beam by 2 theta, so the same effect will observe here using the cross analyzer polarizer setup.

(Refer Slide Time: 7:51)

So now I have placed the half wave plate in between the cross analyzer polarizer setup and I have placed such that that the fast axis of this half wave plate is along the polarization of the incoming beam light. So you can see that there is no rotation because if it is a 0 degree it is not rotated and that is why the current is still at the minimum. So now if I place a fast axis at some angle theta to the polarization of the input beam the output beam will have the polarization rotated by twice the flat fixed angle compiled to the input beam.

(Refer Slide Time: 8:28)

So now if I rotate the half wave plate by some angle theta say 20 degree, so I will start the rotation here so from here I will just rotate it, so if I rotate it by 20 degree.

(Refer Slide Time: 8:48)

So you can see that the current here at the detector has increased, so this is because the half wave plate has brought about the rotation of the input beam by 40 degree because it was kept at 20 degree to the polarization of the input beam, so it has rotated the input beam by overall 40 degree and we can verify the same by rotating the analyzer by 40 degree to get back the minimum intensity.

(Refer Slide Time: 9:20)

Here we'll rotate the analyzer till we get a minimum back over there. So I will start rotating so you can see that reading right now is in some milliamps so I will start the rotation so you can see that there is a minimum somewhere around here at 16.8, so any further above that is increasing that side as well as increasing this side, so somewhere here there is a minimum here 16.8.

(Refer Slide Time: 9:55)

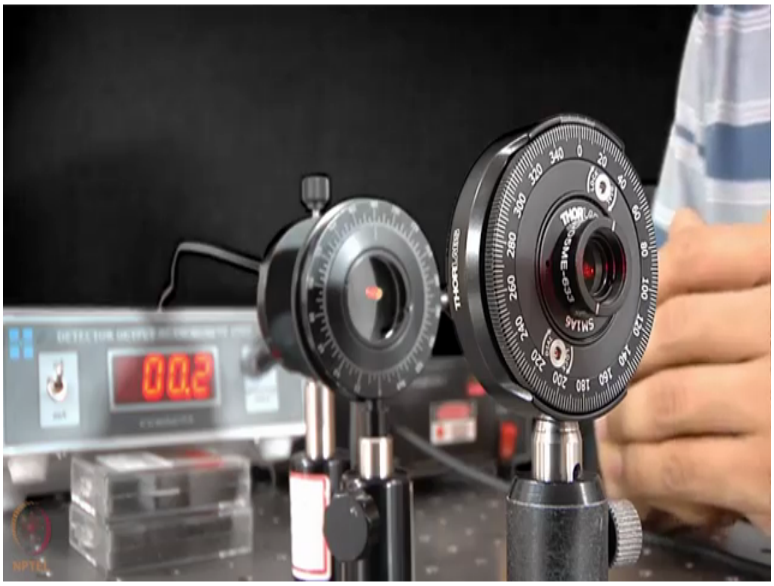
So now we can see that reading here (())(9:57) so it is doing 140 degree, so you can see that the now the total angle by which I rotate the polarizer is from 180 to 140 degrees so it is 40 degree. So this is how this shows that the half wave plate has rotated the input beam by 40 degree when it was kept at when it is fast axis was kept at 20 degree to the input beam, so this concludes the half wave plate characterization.

(Refer Slide Time: 10:31)

So now we will move on to the quarter wave plate so we have so we'll replace the half wave plate in the set up by a quarter wave plate. So here also fast axis is marked, so we will do the same experiment here so what we will do here in this case is we will keep the quarter wave plate at 45 degree to the polarization of the input beam, we will keep the fast axis at 45 degree to the polarization of the input beam.

So this will result in the circular polarized light and now circular polarized light once analyzed through analyzer should give us the constant current for all the angles as explained in the class already as already explained in the class.

(Refer Slide Time: 11:07)



So now I have placed the quarter wave plate in between the cross analyzer polarizer setup and I have placed it in such a way that the fast axis of this quarter wave plate is aligned with the polarization of the input beam that is why you can see that the intensity is still maintained it is at the minimum right now 0.

(Refer Slide Time: 11:25)

So now the quarter wave plate is placed at 0 degree so from here if I rotate the quarter wave plate by 45 degree so I have rotated the quarter wave plate by 45 degree.

(Refer Slide Time: 11:51)

Once I rotate the quarter wave plate by a 45 degree to make the fast axis of quarter wave plate to be at 45 degree to the polarization of the input beam, the output of the quarter wave plate is going to be circularly polarized light. So now the output of the analyzer is a constant irrespective of the angle of the analyzer. So you can see that I am rotating the analyzer here but that current is very much constant here so fluctuation is to 4.9, 5, from 4.4, 4.6, so from 4.0 to 5.0, so after a 360 degree of rotation you can see that there is a very little fluctuation in the current. So you can say that the beam here is circularly polarized and that was due to the quarter wave plates and that explains the working of the quarter wave plate.

(Refer Slide Time: 12:44)

So now the third part of this today's lab session would be to demonstrate photo elasticity in different dielectric materials so photo elasticity is a property shown by some of the materials under stress, where they start showing by birefringence, so I have a plastic spoon which during the manufacturing process will develop some residual stress and that points to all those points will show some birefringence so the birefringence of light.

So if I put this in the if I put the spoon in the laser beam path you can see that there will be spike in current due to the by fringes shown by the plastic, you can see as I move it the current will changing because of the different stress at different point, so it is showing different birefringence at different point. So similarly I have many different materials there is different plastic dielectric materials I have a glass, I have a qubit (())(13:49).

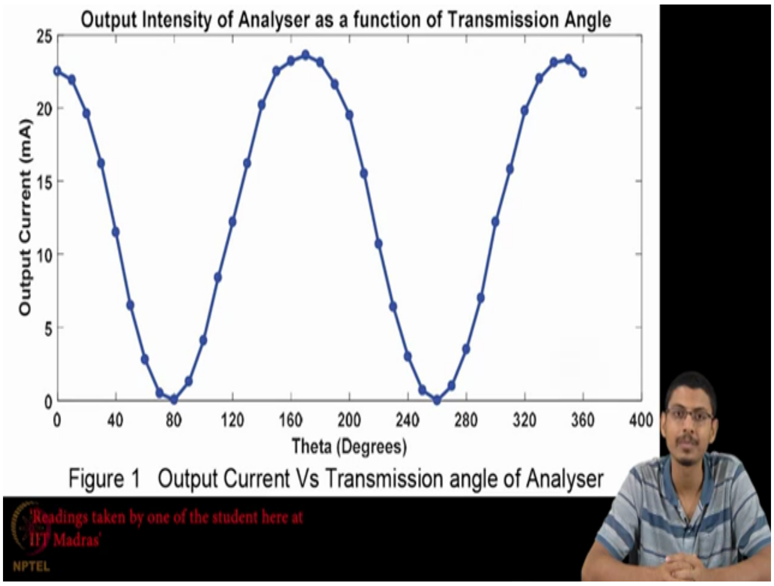
So in this way we can actually take image of stress pattern inside a dielectric material, so one easy way of that would be just instead of the laser source we can use a monitor as a source of linearly polarized light so or it can be a mobile screen also if it has OLED screen so that will also be a source of linearly polarized light. For analyzer you can use a polarizing sheet as analyzer, you can place it at the cross angle to the polarization of the light coming from the screen.

(Refer Slide Time: 14:25)

For a pinhole detector you can use another mobile phone camera to take a picture of the stress pattern. So this is a setup, so in this setup now if you introduce anything in between any plastic dielectric material which will switch source photo elasticity and you just take a photo from your mobile phone you will see the stress pattern inside the plastic. So image as shown here on the screen actually shows one of the image taken when very this similar way and you can clearly see the stress pattern inside the plastic.

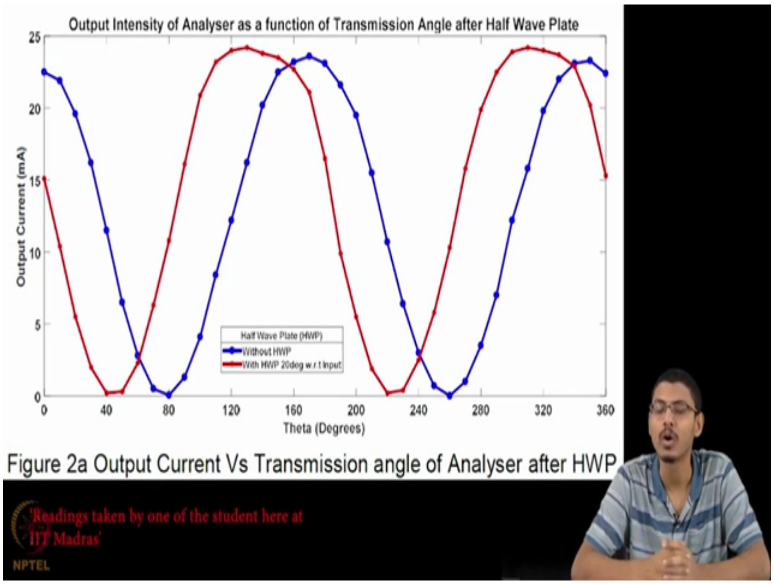
So there are some of the few images shown here in the screen for glasses for different colour of screen and you can see the stress pattern inside. So the point on the screen which is a in bright is actually the point on the plastic where there is a large residual stress and wherever it is almost white it is like there is no residual stress at that point. So you can characterize use this phenomena to find the stress pattern in any transparent dielectric material.

(Refer Slide Time: 15:35)



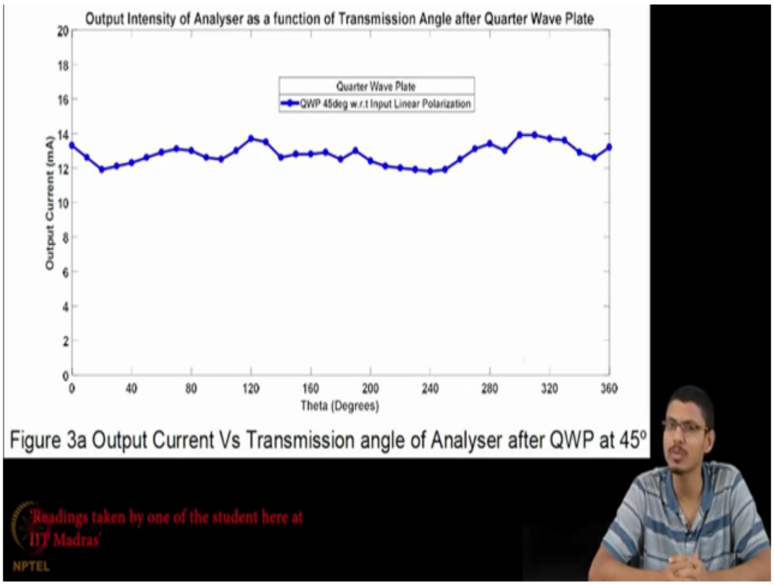
So here on the screen malice law plot has been shown so here we have what we have done is we have recorded the intensity output intensity of the laser beam at different angle of at different analyzer angle. So you can see that this fits to the cos square curve so this verifies the malice law and then moving on to the half wave plate, you can see the plot for half wave plate.

(Refer Slide Time: 15:54)



So you can see when the half wave plate was rotated by 20 degree when see that up (()) (16:00) curves shift by 40 degree and if it is rotated by 45 degree this plot shift by 90 degree compared to the original malice law plot.

(Refer Slide Time: 16:14)



Then for the quarter wave plate you can see that for the intensity remains for the quarter wave plate you can see that the output intensity remains almost constant for the different angle of analyzer. So that concludes the today's session, thank you for being with us.