SHAOUL EZEKIEL: Now we're ready to look at the state of polarization of the transmitted and reflected beams on a glass-air interface as a function of the input polarization of the light and also as a function of the input angle of incidence. The setup is here is the laser. The laser beam we reflected by this mirror into this quarter-wave plate. So we have here, we have circularly polarized light. Then we pass it through the polarizer here.

So in this region, we have plane polarized light. And the polarization is set by the transmission axis of this polarizer. Here's our prism. Here is the transmitted beam over here. And here is the reflected beam over here.

Now, just to make sure that, indeed, in this region here we have plane polarized light incident at the prism, we will take this polarizer and test that, indeed, the light is plane polarized in this region. In a way, we're checking on this polarizer.

So let me put a screen over here so we can see the light. So now, if indeed the light is plane polarized, then I should be able to extinguish it by simply rotating the transmission axis of the polarizer here. And here, indeed, you can see that I can extinguish the light. So indeed, the light is plane polarized.

I now will change the transmission axis of this polarizer, let's say, to some angle here and then again check that, indeed, I can extinguish the light again at this angle. Let me go back over here. And yes, indeed, I can extinguish it And you can see that there is 90 degrees between this polarizer and this polarizer.

So now we're happy that the light is, indeed, plane polarized in this region regardless of where I set the transmission axis of the polarizer. Let me put it back to vertical. We'll take this polarizer out, take the screen. Now we're ready to study the state of polarization of the transmitted beam and the reflected beam.

First, we start with the transmitted beam. So I'm going to place the polarizer in the way of the transmitted beam like this. And with the state of polarization coming in along the vertical plane, as shown here, I'm now going to demonstrate that the light transmitted is indeed plane polarized. And, as you can see, I can extinguish it with this polarizer here, which means the state of polarization is linear and also perpendicular to this horizontal axis.

Now I will change the state of polarization of the input beam, let's say to some angle like this. And now let me see if I can extinguish it again. Yes indeed, I can extinguish it again. And you also notice that the angle here is orthogonal to the angle here. So we've shown that the state of polarization of the transmitted beam is indeed plane polarized regardless of the orientation of the transmission axis of the polarizer here.

Now we're going to look at the state of polarization of the reflected beam. So now I'll put the polarizer here in the way of the reflected beam then adjust the reflected beam to go through the polarizer. And let's see again with the polarization at this angle, with the input polarization at this angle. Let me now rotate the analyzing polarizer here to see whether, indeed, I can-- first let me transmit the maximum amount of light. Let me see now if I can extinguish it. And indeed, I can, which shows that for this orientation of the transmission axis of the input polarizer, indeed I have plane polarized light.

Let me check it for vertical polarization. And indeed, I can extinguish it here too. And I'll do one more of the horizontal polarization, about so. And let me see if I extinguish that. And indeed, I can extinguish the light. So again, we've shown that the state of polarization of the reflected beam is plane polarized, again regardless of the orientation of the transmission axis of this polarizer.

Now we're ready to look at the state of polarization of the reflected beam after the critical angle or the totally internally reflected beam. But first, I'd like to convince you that we are looking at the totally internally reflected beam. So let's look at the setup again.

This is the transmitted beam. And this is the reflected beam for any angle of incidence below the critical angle. So as I increase the angle of incidence until I reach the critical angle, you can see that the transmitted beam is extinguished. And all we have left is the reflected beam. So from here on, this is the totally internally reflected beam.

So I'm going to now adjust the angle of incidence to about 50 degrees or so this direction. And now I'll place the polarizer in the way to analyze the state of polarization of the totally internally reflected beam.

Now, the input polarization is-- p polarization, or polarization in the horizontal plane, is set by this polarizer. Let's see what the state of polarization is of the totally internally reflected beam. And you can see that, indeed, I can extinguish the light, which means that for p polarization input, the polarization of the reflected beam or the totally internally reflected beam is plane polarized, and indeed, also p polarization.

Now let's go to s polarization. It means polarization in the vertical plane. So we are here about vertical. Let me now adjust the analyzer here to see whether I can extinguish the beam again. Let me do a little more tweaking. Just a little bit more, and indeed, you can see that I can extinguish the beam again. This again says that for polarization in the vertical plane or s polarization, the polarization of the totally internally reflected beam is also s polarization, also linear polarized and s polarization.

Now let me go away from s or p polarization by changing the angle of the transmission axis of the polarizer, which means what I'm doing is changing the orientation of the plane of polarization of the input b. Now let's see if we can extinguish the beam.

As you can see, the intensity varies as I rotate the polarizer. But I cannot extinguish it like I did before. This implies that there is a phase shift between the s and p polarizations in the totally internally reflected beam. In fact, let me change the input orientation to about 45 degrees. And indeed, again, I cannot extinguish the beam.

And this, again, implies that the state of polarization of the totally internally reflected beam for this kind of orientation of the polarization of the input beam, that indeed, the totally internally reflected beam is elliptically polarized. And this elliptical polarization can be made use of. For example, for a 50 degree angle of incidence, one can get a phase difference between s and p polarization of about 50 degrees.

This phase shift, then, is very interesting and has been exploited for the construction of quarter-wave plates and half-wave plates simply by taking advantage of this phase shift on reflection on a glass-air interface. For example, a quarter-wave plate requires two such reflections to make up 90 degrees. And a half-wave plate requires four such reflections.