MITOCW | Optics: Quarter-wave plate | MIT Video Demonstrations in Lasers and Optics

PROFESSOR: In this demo, we're going to illustrate the basic use of a quarter-wave plate. And, as we know, a quarter-wave plate is used to change the state of polarization of light from plane polarized, for example, to elliptical, and, under certain conditions, to circular polarized light. So we'd like to do that using this setup.

We have a laser-- a helium-neon laser. And here's the beam from the laser. We're going to reflect it through this mirror and then reflect it again through a second mirror. Then we pass it through this polarizer, and the beam coming through the polarizer then hits the screen.

This polarizer, the transmission axis of which is shown by the white arrow, sets the state of polarization of the light here in this region. No matter what the state of polarization is before the light reaches the polarizer, the polarizer then will clean it up and set it according to the transmission axis. And right now, the transmission axis is along the vertical, as shown by the white arrow.

But just to check this we'll use the analyzer, which is another polarizer. And we place it over here. The white arrow is along the vertical direction and labels the transmission axis of this polarizer. So let's see, indeed, whether the light here is plane polarized.

So I'm going to rotate the analyzer and see if I can extinguish the light. Now, what I would like to do is look at this extinguishing of the light more closely in the bottom left-hand corner, which is a close-up of what you see on the screen. And, here, you can see that the extinguishing is pretty complete, which shows that, indeed, the light in this region is plane polarized.

So let me set the analyzer back so that we're transmitting the maximum intensity, which means the transmission axis is lined up with the transmission axis of this polarizer. Now we're ready to bring in the quarter-wave plate. Here's the quarter-wave plate. I'm going to place it in this position, secure it.

Now, this quarter-wave plate has, as we know, two principal axes. One of them is labeled by the white arrow here. And, again, we know that when this light is propagated along the principal axis of the quarter-wave plate, there's no change in the polarization. It's just like a piece of glass.

Let's check that. So we take the analyzer again, and we rotate the analyzer to see, indeed, whether the light is plane polarized. And, as you can see, maybe I didn't get the labeling here. But, as you can see, the light is pretty close to plane polarized.

Now, we know that there are two principal axes. So let's turn the arrow to 90 degrees and show the fact that when light propagates along the other principal axes, the light here is again plane polarized, which means it cannot get past this polarizer when the transmission axis is orthogonal to the initial polarization set by this polarizer. So now we've established that, indeed, when we propagate along principal axes of the quarter-wave plate, nothing happens to the light. It just stays plane polarized.

Now, we're going to demonstrate the actual use of a quarter-wave plate, which changes, for example, in this case, the state of polarization from plane polarized light to elliptical, depending on the angular position that we set the quarter-wave plate at. So let's start with a very small angle away from the principal axis. And, now, we want to look at the intensity on the screen and also in the insert to see whether, first of all, the light gets extinguished, and also watch the intensity as I rotate my analyzer.

Now, you can see the minimum is around here. It's not 0. And the maximum is around here. which shows that the light is elliptically polarized, certainly not plane polarized as it was before.

Now, if you want circular polarization, we have to rotate the quarter-wave plate to about 45 degrees from one of the principal axes. And if the light is indeed circularly polarized, then we wouldn't see any change in intensity as we rotate the transmission axis of the analyzer. And let's see if we got this close. Now, you can see, as I'm rotating the analyzer, you can see that the intensity on the screen doesn't change all that much, which shows that the light is certainly polarized.

In summary, we've shown that a quarter-wave way plate can change the state of polarization of light. In particular, we've demonstrated that if plane polarized light is incident on the quarter-wave plate and the quarter-wave plate is oriented appropriately, we can get elliptically polarized light. If the quarter-wave plate is oriented at 45 degrees with respect to the state of polarization of the light, then we can get circularly polarized light.