MITOCW | Optics: Destructive interference - Where does the light go?

PROFESSOR: In this demonstration, we're going to explore a very curious phenomena in two beam interference, which is, where does the light go when we have destructive interference or a dark field? And we'll use our normal Michelson Interferometer to study this phenomena. Here it is.

We have the laser here. It is the beam from the laser being reflected by mirror here, and then we go through this lens, then from the lens onto this Mirror and then from this mirror, then we enter the Michelson Interferometer. Here is one arm of interferometer, and here is the other arm. And then the beams leaving the interferometer will go onto this mirror, through this lens, and then onto the screen.

Now as you can see on the screen, we have circular fringes. And the inset, we have enhanced the effect, so that you can see the fringes a bit better. Now what I'm going to do is move this mirror here slowly, until I equalize the arms of the interferometer. So I can make the diameter of the central fringe very large.

As you can see here, the diameter of the central fringe is getting bigger. And then as I get closer and closer to equal path. And as you can see now, the size of the central fringe is getting even bigger, until I reach somewhere over here, which is almost approximately where the paths are equal. And then you can see that, if I press now over here, I can change the path length difference or the misalignment to give me a uniform dark field.

As you can see, again, I'm going to press, again, here. And you'll see that the field goes completely dark and then bright, depending on the path length difference. Now just to show you that, indeed, when the field is dark that we really have light in the interferometer. So what I will do, I will block one arm, and then, again, let's take a close up.

Then you can see that when I block one arm that, indeed, there is light coming off the interferometer block one arm, and then I block this arm. And you can see, again, that there is light coming out. But is when I have the beams interfering, then I can get the field to go completely dark as in here.

So it's not that there is no light there. It's just because they are interfering, and the interference is destructive interference. So the question is, where does the light go when we have total darkness coming out of the interferometer. In order to study this, let's examine the interferometer a little bit more closely.

Let me remind you, again, what's going on in here. The light enters the interferometer and gets reflected by this beam splitter onto this mirror. And then this mirror reflects light back into the beam splitter. A portion of which leaves the interferometer, and then the other part, the other 50%, goes back in this direction actually into the source.

The other arm, again, reflects the light back into the beam splitter, and then we have the reflection off the bean splitter then interferes with the beam coming from the other arm. And that's what we've been seeing on the screen, but let's keep track of the beam that passes through the beam splitter, again, back into the source to interfere with the beam coming from this arm. Now in order to do this, I'm going to use this beam splitter here. And then I will place it over here, so that I can reflect the light out here.

So I can look at and monitor the beam going back into the source. And then when we come back, we have it all nicely adjusted. So we can see both spots, the interference of the beam going in this direction, as well as the normal interference pattern that we've seen on the screen.

Now that I have the beam splitter in place to monitor the light returning to the source, let me show you how we're going to look at it on the screen. The light then coming out of the interferometer back into the source will be reflected by the beam splitter here. Then I've added a mirror here to reflect the beam into the lens.

And then from this lens, we get the spot on the left. So the spot on the left on the screen then is associated with the light that's returning to the source. The spot on the right is the spot that we looked at before. That's the one that's coming through this lens, and then, as you can see, we've added some white lines to make the lens a little bit more visible.

And then this is the beam that is coming out of the interferometer that we looked at before. So again, the spot on the left is the beam returning to the source. The spot on the right is the beam that's leaving the interferometer that we've seen before. And now, let's take a close look at the intensities in these two spots as I press on the table to change the path lens difference in the two arms of the interferometer.

And as you can see as I press on the table that when the spot on the right goes dark, the spot on the left is bright. And then when the spot on the left is dark, the spot on the right is bright. So you can see that they alternate, and I'll do it, again, when the spot on the left is dark. This one on the right is bright, and then the one on the right is dark.

The other one is bright, so you can see the intensities alternate. This implies that when we have constructive interference in one beam, we have destructive interference in the other beam and vise versa. Now in order to see the effect even better, I'm going to take this mirror, and change, and move it backwards.

So I can change the length of one of the arms, so we can get back to the rings. Now as we see on the screen and close up, we see the effect even more dramatically. The spot on the right is our normal beam that leaves the entire parameter, and the spot on the left is the one that is associated with the beam going back into the source.

And I think you can see it here very clearly that when the central fringe is dark in one spot, you can see that on the other spot, it's opposite. So when it's dark in one, it's bright in the other. When it's bright in one, it's dark in the other, and this is a very even more dramatic way of showing it.

So we've seen that when no light comes out of the interferometer, all the light goes back into the source, which means that when we have destructive interference in one beam, we have constructive interference in the other beam. The puzzle is that in order to get destructive interference, it means that the path length difference between the two arms must be either a half wavelengths of light or odd multiples of half wavelengths of light. Now, if indeed the path length difference is half wavelengths of light, then why isn't there destructive interference in the beam going back into the source? Because the paths are identical. So the puzzle I want to leave you with to think about is, how's that we get constructive interference in one beam and destructive interference in the other beam when the two paths are indeed the same in both cases?