PROFESSOR: In this demonstration, we're going to look at multiple-beam interference. We'll use a plane parallel cavity at the beginning. And then, we'll go on to a cavity using spherical mirrors. The setup is here. We have a laser, helium-neon laser. And here's the output from the laser. Then, we reflect the beam from the laser into an optical isolator. It's made up of a polarizer and a quarter-wave plate. And the output from the isolator is over here. It's then reflected by this mirror into the plane mirror cavity.

So now, if we take a close look at the cavity, you can see that it's made up of two plane mirrors. Here's one of them. And here's the other. The spacing between them is only about 3.5 millimeters or so. And one of the mirrors is attached to a piezoelectric crystal over here, so that we can change the length of the cavity by simply applying a voltage to the piezoelectric crystal.

As you see, the mounts are pretty hefty to make sure that the cavity is stable. And adjustments can be made to the cavity by using the knobs over here. The output of the cavity, as you can see, will be then displayed on the screen over there. Now, if we bring in the screen as an insert, we can see that we have many, many dots. And each dot represents a reflection by the pair of mirrors.

And you can see as I misalign the mirrors, I can separate out the individual spots. As I come in close to alignment-- now, let me go to the other side, show that I can spread it out the other way. And then, if I change the vertical alignment, I can move them all over the place. Now, I'm ready to bring them all in, so that they can interfere with each other. When they're separated, of course, they can't interfere with each other. Now, they are merging together.

And then, very soon we'll see them interfering. You can see already they're interfering. And now, it's dark. Now, I can press on the mirror here. You'll see that I can change the intensity from bright to dark. And in order to see it a little bit more clearly, on the control condition, I'm going to turn on a sweep voltage to the piezoelectric crystal. So maybe I can tweak the alignment a little bit better.

Now, you can see it's going from dark and bright-- very nicely when the beams interfere. Now, let me separate out the beams. The interference stops. Then as I bring them back in when I have pretty close to perfect alignment, you can see how they all interfere together. And the intensity goes from bright to almost dark. Now, in the next part of the demonstration, I'm going to put a detector on the output and see what we see with the detector.

I have now added the detector, so that we can look at the output of the cavity both on the detector, as well as directly on the screen. So here is where I put the detector. The output of the beam is reflected by the beam splitter here onto the detector. And the output of the detector then goes onto the internal oscilloscope. Also, since this is a beam splitter, the direct output of the cavity can still be monitored on the screen.

Now, let's look at the screen of the oscilloscope. As you can see, we have two resonances. But let's forget about one of them. Let's just concentrate on one. What this represents is the intensity transmitted through the cavity as a function of pathlength difference. And the pathlength difference is being scanned by the piezoelectric crystal I mentioned before.

You can see, if I block the light, then that's where the zero is. And when the light is unblocked, you can see that I get a peak intensity due to the interference of the multiple beams and then to very little intensity due to, again, destructive interference of the multiple beams. Now, let me bring in the other resonance. And the other resonnance is due to the fact that every time the cavity length is changed by a half wavelength of light, then we see another resonance.

The spacing between the two resonances is given by the velocity of light C divided by twice the length of the cavity, or C over 2L. Another interesting thing that you want to observe is the quality factor, so-called the finesse of the cavity. And the finesse of the cavity is defined as the free-spectral range, which is the separation between these two resonances, divided by the width of the resonance. In this case, the finess is about 30. Or sometimes, I can adjust it to about 50 or so because my mirrors have 95% reflectivity.

So what I'd like to do now is show what happens as I misalign the cavity. As you can see, every time I just have to touch the cavity, and the resonances move. You can see now as I'm misaligning just by turning the knob just slightly, you can see that the finesse goes way down because of the misalignment. Now as I try to pick it, and I hope I can do it on camera, and here we are. I can always bring it back where I was before. Now you can see, if I just tap on it, I can move the resonances all over the place.

Now, let's look at the spot on the screen at the same time as we look at the output of the detector on the oscilloscope. So this spot on the screen then is going to appear in the insert. And you can see that if I misalign-- let me do the misalignment again-- you can see that you can also notice it on the screen also-- that the spot is misaligned.

Let me see if I can get it again. Here we are. Now, I'm going to take the automatic scanning out. And instead, I'll do the scanning by hand. So let's look at the spot. Now you can see, I can vary the intensity from bright and dark by just simply leaning on the mirror to change the length by very little bit. Then, if we can now look at the oscilloscope output, we can see that when the spot is pretty dark, there's not much output. And then, as I play with the cavity here, I can make the output of the detector go big and then to nothing.

Now so far, we only looked at the light transmitted through the cavity as a result of multiple-beam interference. We did not look at all at the light reflected back from the cavity as a result of multiple-beam interference. I need to modify the setup just a little bit, so that we can observe the light reflected back from the cavity. And when we do that, we'll see that we can learn a lot from it.

Now, the setup has been modified, so that we can observe the light reflected from the interferometer. Here's the modification. All we've done is added a beam splitter over here, so that the light reflected from the interferometer will be sampled-- here it is. And then, we pass it onto this mirror over here, reflected onto this beam splitter here, and then into detector number 2.

Since this is a beam splitter, we can also observe the reflected light onto the screen. Here is this left-hand spot. The spot on the right is our transmitted beam. As you can see, if I misalign the cavity, you can see that both of them will misalign.

Now, what I'm going to do, I'm going to take the scanner off and do the scanning by hand. Now if you watch both spots, you'll see that the one on the right that we've seen before flashes, which means the intensity goes very high and then very low. But the spot on the left doesn't seem to do anything.

Question is, is there anything happening for the spot on the left when the transmitted beam is going through high peaks and low valleys? In order to do this, we should look at the oscilloscope, which represents the output of the two detectors. Now, let me put this scan back on again. And let's look at the oscilloscope. The lower trace is the transmitted light as we've seen before. The zero is here, and the peak transmission is over here.

The upper trace is the one associated with the light reflected from the cavity. If I block the reflected beam into the detector, you can see that the zero is over here, which is in line with that little marker. Let's do it again. Here is the zero. And when we have no light transmitted, there's a lot of light reflected. When we have a lot of light transmitted, which is the peak of the transmission resonance, we have suddenly less light being reflected, but not quite zero. Remember, zero is over here.

And the reason why we don't dip all the way to zero is because the interference is not complete. And maybe you want to think about that. Now, let's see what happens when I misalign the cavity. Let's look on the screen again. The upper trace, as we see, is the reflected beam. And the lower trace is the transmitted beam. As I misalign, first you see that the length of the cavity changes. All we need is a lambda by 2, and we get a change.

But then, as I misalign some more, you can see that the finesse drops, or the width of the resonance grows. And then as I realign, indeed both of them are effected essentially in the same way. So when we have peak transmission in the transmitted light, the reflected light goes through a minimum. Ideally, it would go through zero. But we don't have an ideal setup.

In the next part of the demonstration, we're going to show what happens when the beam going into the cavity is not the collimated beam. In this setup so far, the beam going into the cavity was reasonably collimated. So what we'll do, we'll put a lens, and we will then generate an expanding beam that enters the cavity. So let's see what happens when we have such a beam going into the cavity.