SHAOUL EZEKIEL: Now we're ready to look at multiple beam interference using a cavity with curved mirrors. The setup is here. We have the smaller laser. Because this laser can give us single frequency operation. The beam from the laser goes through this Bragg cell acting as an isolator. And the light, after the Bragg cell, is over here. It gets reflected by this mirror into a polarizer, which I'll explain the reason for a little later. Here's the output of the polarizer getting reflected by this mirror here into the cavity.

So let's look at the cavity right now. It's made out of two hefty mirror mounts. Because we need good stability. The mirrors have the same radius of curvature of 25 centimeters. One of the mirrors is mounted on a piezoelectric crystal over here. And the adjustment to the mirror mounts are over here using these knobs here.

Now, if we come around from the other side, we can see that we have a differential screw over here that would enable us to adjust the spacing between the two mirrors. Right now, the spacing is about 23 centimeters, while the radius of curvature of each mirror is 25 centimeters.

This laser is a special one. We've used it before. It operates at two frequencies, sometimes more. But right now, let's look at the two frequencies. The two frequencies oscillate with different polarizations, orthogonal polarizations, so that by using the polarizer over here we can select, then, either one of the two frequencies so that the output, then, that we can inject into the cavity can be single frequency. If we want more than one frequency, then we just simply rotate the polarizer by 45 degrees. And then we can pick off both frequencies.

Now, the cavity, then, the output of the cavity is over here. And we're going to expand it by the lens, by this lens here, and then onto the screen. Now since the laser is pretty weak, we're going to have to dim the room lights to look at the output transmitted through the cavity. So now we'll dim the lights and see what we can see on the screen.

And here we are on the screen. And what we can see is all sorts of interesting patterns. They're going a little fast right now. But I can slow them down just a little bit. Here we are.

These are the transverse modes or radial modes of the resonator. What I'm doing now is changing the horizontal alignment of the mirrors. And you can see the shapes of the modes vary from a few spots to many spots.

Here we are, some very pretty patterns. And let me see if I can scan by hand. Here we are. I'm scanning by hand, holding the patterns for a little longer. There's a pretty one, lots of spots. These are 0, 1, or 1, 0, depending on how you read these modes. Let me bring it again, the one with the two spots. Another one-- there's one.

Now, what I'm going to do is turn the scan back on again. And then I'm going to change the alignment so we can look at other patterns. Here we are, another set. Going to a vertical, this alignment, now you see that the spots are rearranged slightly. Let me separate them a little bit more. Again, let me switch off the scan and scan by hand slowly.

Again, now, I see the two spots have reoriented themselves with respect to the vertical direction, while before they were in horizontal direction. Now we get some other interesting patterns. Here's an interesting one.

I'm going to turn the scan back on again. And I'm going to now align so that we can get the symmetrical patterns, the patterns that look the same in both the horizontal and vertical directions. Here we are. I think I'm close to that. Let me turn the scan off and bring them in by hand. You can see now the pattern is symmetric. There's one. There's another. There's another. There's another lower one. And here is the lowest order mode, the so-called [? TN ?] 0, 0 mode with a single spot.

And here are the higher order ones. I'm going to put the scan back on again and just adjust the alignment and see what we can get for different spots. Let me separate the modes some more. And we can really get extremely high order modes this way. Here we are. I'll turn the scan off, bring them in by hand.

Well, I think we've seen probably enough of these modes. In the next part of the demonstration, we're going to put a photodetector and look at the output of the photodetector. And will see that the resonant conditions for each high order mode is different.

Just before, we saw the modes on the screen, the modes of the resonator with curved mirrors on the screen as a function of the tuning of the resonator. Now, we're going to look at the output transmitted through the cavity on a photodetector that is associated with the different transverse modes of the resonator.

And the setup is here. The output of the resonator, then, is reflected by this mirror onto a photodetector. And the output of the photodetector is displayed on the oscilloscope.

So we're going to see both the transmission associated with the transverse modes. And also, I'm going to adjust the length of the resonator by means of this translation stage driven by this differential screw. So now, let's look at the-- let's look at the scope and see what we can see.

On the scope, we can see there are lots of modes, lots of resonances associated with the transverse modes of the resonator. Also, we see that the modes are shifting around. And a simple excuse for the shifting around is due to the air currents in the resonator.

So I'm going to reduce this by placing a tube over the light in the resonator. So here is a simple tube. And if I'm lucky, I can do it on camera. If I'm not, we'll have to go back and fix it.

Here is a tube, one end of the tube, and here is-- OK, now that I've got the tube in place, let's go back and look at the oscilloscope. And you can see that the modes are not moving around as much as before. Let me just remind you that the free spectral range is from here to here. The free spectral range of the resonator is this much.

The length of the cavity right now is about 23 centimeters. And remember that the radius of curvature of the mirror is 25 centimeters. So now what I'm going to do is approach 25 centimeters. I want to change the spacing now so that I can approach 25 centimeters, which is the radius of curvature of each mirror. And that's the confocal condition.

Now, as you can see on the scope, the modes are now blending into each other. In fact, you can't even distinguish them. And as I keep going, as I keep getting closer and closer to the-- let me make a DC adjustment here on the scope. As I get closer and closer to confocal, they're really blending into each other. And they're getting very big. And I have to reduce the sensitivity.

And as I approach the confocal, the gain is saturating. So let me just do one more adjustment. Here we are. We see that we get only one resonance. And don't forget that the free spectral range is from here to here. So we get this additional resonance in the middle of the free spectral range, which I leave to you to figure out.

Now-- so when we are confocal, then, we have all the most coalescing. And we also have the appearance of an additional mode in the middle of the free spectral range. And then if I go now and make the cavity longer, again, you see that as I go away from the confocal condition the other way, the-- let me bring up the sensitivity. You can see now that the modes start to pile up on the other side of the resonance as shown.

So what we've seen in this little demonstration is that the various radial modes appear at different lengths of the resonator. And we saw that when we made the length of the resonator equal to the radius of curvature, which is the confocal condition, we saw that the modes coalesced into two peaks. And the spacing between the peaks is half the free spectral range.

And let's look at the scope. Here we are. This is the free spectral range of the cavity. And when we are at confocal, we have the appearance of this peak here, which means that all the modes have coalesced into just two peaks. And we'll leave that for you as an exercise to explain why this has happened.

In the next demonstration, we're going to show how a cavity like this with curved mirrors can be used to analyze the spectrum of laser light.