SHAOUL EZEKIEL: In this next demonstration, we're going to show how one can get a laser to oscillate at only one frequency when normally the laser oscillates at many frequencies associated with the longitudinal modes. In this case, we're going to look at an argon laser, which is over here. And we're going to do the single frequency selection by placing an etalon inside the cavity. Now, an etalon is a short Fabry-Perot cavity which you then will place inside the argon laser cavity. And we'll be able to select single frequency.

Now, we're ready to look at the spectrum of the light from an argon ion laser. Here is the argon ion laser. And the output is coming from the other end of the laser over here. We're going to reflect it by mirrors onto this mirror here. And then reflected light from this mirror will go onto this mirror and is then reflected into this scanning Fabry-Perot interferometer.

The free spectral range of this cavity is 15 gigahertz. And here is the detector. And we also put a hood over the path between the cavity and detector to prevent room light from reaching the detector. At the same time, we have a beam splitter here. We're going to reflect a little bit of the light into another scanning Fabry-Perot interferometer over here. This is a longer cavity. It has a free spectral range of 1 1/2 gigahertz. Again, the detector for this cavity is over here.

First, we're going to look at the spectrum of the laser light with the 15 gigahertz free spectral range cavity. So now, let's go over to the scope and look at the output spectrum.

Now we can see the output of the 15 gigahertz free spectral range scanning Fabry-Pérot cavity on the oscilloscope. What we see here is the free spectral range, which is, again, 15 gigahertz. That's the separation between these two peaks. And the spectrum of the laser looks like it's about a few gigahertz wide.

The reason for this is that the gain curve in argon laser is pretty broad. It's of the order of 10 to 15 gigahertz. And lots of longitudinal modes oscillate. And they compete with each other. And right now, they're blending to give you this big blob of several gigahertz spectrum.

Now, for many applications, this broad spectrum is not of much use, for example, in applications using interferometry. For such applications, you need to make the laser oscillate at a single frequency. The popular way of generating single frequency in these big lasers is to use an etalon and put it inside the laser cavity to select out a single frequency. So when we come back, we will put in an etalon inside the laser and observe single frequency output behavior.

Now, I'm going to put an etalon inside the laser cavity. Here is the etalon in a holder. It's a very simple thing. It's a piece of glass, parallel piece of glass one centimeter thick. And it has a reflectivity of about 35% on each surface. And it's held in this mount here so I can then adjust it within the laser cavity.

So now I'm going to place the etalon inside the laser cavity. There's a little space here between the Brewster window and one of the mirrors. So here we are. Here's the etalon in place. Now all I have to do now is adjust the alignment. And here we are, now. We get lasing. We have lasing now. And now we're ready, then, to go and look at the output of the spectrum analyzer with this etalon in place.

Since the etalon is a solid piece of glass, I cannot change its length very easily. But I can effectively change its length by misaligning it. In this way, then, I can get a tuning of the etalon by simply rotating the etalon.

Now that we have the etalon inside the cavity, the spectrum is single frequency. And again, the free spectral range is 15 gigahertz. But the output now is single frequency. And, in fact, by adjusting the etalon, I can tune this frequency across the gain curve of the argon laser, which is right now about a few gigahertz. So let me do it again-- over here.

The finesse of the cavity, this 15 gigahertz cavity, is not very high. So what we'll do, we'll switch to the other cavity, the one that has a 1 1/2 gigahertz free spectral range. It has a much higher finesse. And we'll be able to see some interesting behavior of this single frequency operation of the laser.

On the scope, now, we have the output of the 1 1/2 gigahertz Fabry-Pérot cavity. As you can see, the spacing between the modes here is 1 1/2 gigahertz. And the finesse is pretty high, probably of the order of 300 or so.

As we can see, the output of the laser is a single frequency. And now what I'm going to do, I'm going to misalign the etalon and see what happens. Now, what you notice is that, because I'm tuning the etalon, I'm also going to be tuning the laser frequency. But the laser frequency is not tuning smoothly. It's tuning in jumps. So let me do it again.

Here we are, jumps or so-called mode hops of the order of the free spectral range of the laser cavity, which is of the order of 150 or so megahertz, because the laser cavity is about a meter long. So again, let me show you the hops again.

Now, let me try to do it with the other knob on the etalon, since they're less sensitive [INAUDIBLE]. Now you can see the hops much better. Here we are. There's two hops there, one, two. Here we are.

In fact, we expand this scale, and we can make the hops even larger. All right, here the scale's expanded. Let me try again. You can see the hops now much more dramatically. Again, it's about 1 1/2-- 150 megahertz or so per mode hop.

In fact, the intensity is supposed to-- as I tune the etalon, the intensity is supposed to go down, and then hop, and then go up, down, and then hop. Let's do it one last time, one hop, another hop, another hop, and so on. So when we use the etalon inside the cavity, then we should be expecting these mode hops when the etalon gets misaligned or its length changes by a small amount.

Now, when one uses an etalon like this inside a laser cavity, there is one thing that one should never do, and that align the etalon perfectly normal with respect to the axis of the cavity or the laser beam inside the cavity. Because if you do, then you're going to get all sorts of multiple cavities taking place. And the spectrum goes absolutely haywire.

So now I'm going demonstrate that. I'm going to now align the Fabry-- the etalon to be normal to the laser cavity. And we see that the spectrum goes absolutely haywire. And all we have to do is just tilt away. And here we get quiet single frequency behavior. And we go back, and bring it to normal alignment. And here we see the spectrum going absolutely haywire.

So again, the no-no with etalons is not to place them normal to the beam. You just have to tilt them away just a little bit. And you get nice, quiet, single frequency behavior.