Optical Spectroscopy and Microscopy
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Lecture – 58
Fundamentals of Optical Measurements and Instrumentation

Hello and welcome to the course on optical spectroscopy and microscopy and today we will be looking at the experimental system the real system in the lab as it works, we talked quite a bit about in the previous lectures we talked quite a bit about femtosecond laser system ultra-fast laser pulses how do we generate them. So now it is our turn to actually look at a sneak peek at that how we go about doing this in the lab okay. So as I explained in the lectures the system that we have here is a DPSS system diode pumped solid-state laser system.

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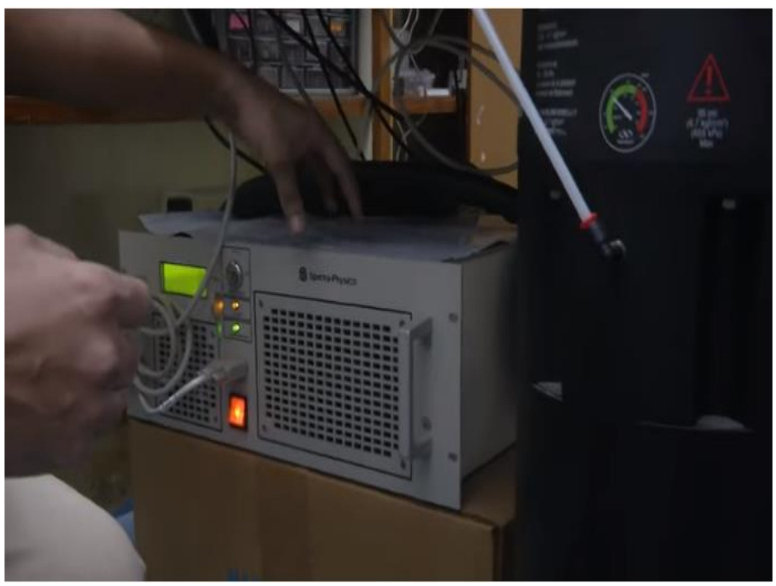

So the whole system starts from down here so where you have array of semiconductor lasers 2 of them 2 bands situated next to each other and driving the converting the electrical power into the light power and those diode arrays are pumped this light into optical fiber which goes through this black cord. This black cord we call it as umbilical it is literally an umbilical because if you had to break this then the whole pump or the whole light power gets terminated and no laser out at all.

So that optical fiber and along with few other cables comes through all the way through here into another laser system. This laser system if you actually look carefully you would see some bit of green coming out from here through this holes that allows you to generate the green laser. So the green laser light out. So the way this works is that the optical fiber that is getting that infrared the near red light goes and get pumps the YAG Nd YAG neodymium yttrium aluminum garnet that Nd YAG.

We saw in the class the Nd YAG wavelength is 1064 nanometers so that is converted to 532 the green that you see here through an intra cavity doublers second harmonic crystal that we talked about again in the class and the light that is coming out from this goes through guide tube into this laser system.

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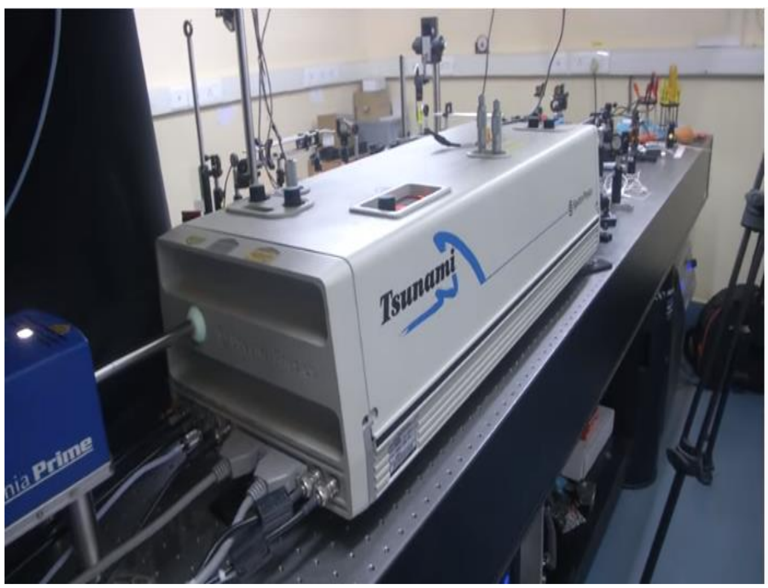

So, what we are going to do is we are going to take this open this up front show by part by part what these different things are doing and before that I want to brief you a little bit about a general good habits in the lab that would be of paramount importance to be followed. The first thing is that when you have a laser system and the light is coming out you want to make sure that does not get into your eye.

So, there is a safety goggle that it is if you had to work with the laser beam that has been suggested and you need to wear that to protect the light coming into the system. But that is only first step or even a preliminary step of the safety. I am of the strong opinion the believer that you need to have quite a good array of supplementary steps that need to be followed in the lab without which you will not be able to I mean this will not be of much use.

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So other thing you would have noticed is that the beam the light beam that is coming out from the laser and then the height of all the optical element will be kept at the waist level right if this is much below and from the floor it is about 3, 3 and half feet. So I do not want to have it at the eye level. So that by accident it does not get into anybody's eye and you never directly look into the mirror.

So we will talk about these alignments when we actually going to go into the description a specific class again lab session where we are going to see how we align the lasers but right now these are I am telling you in terms of the safety point of view. Now let us go and look at the titanium sapphire laser itself and how it the pulses that that gets generated all right.

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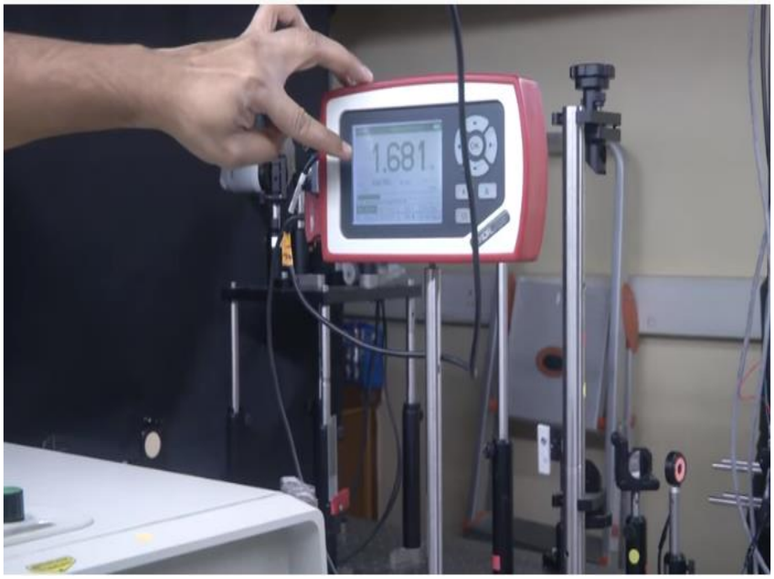

So, now I told you I walked you through the different laser modules here. So, one of the thing that you want to make sure that before we opening it up, we go back and then it is operating in a right position are some of the vital parameters. So, we are right now the laser light out is being put onto power meter and basically it is a thermal sensor. It generates the amount of heat; it is coming out from there. So it measures that you can right now see the readout of this the power meter is that 1.68 watts 1.6823 watts.

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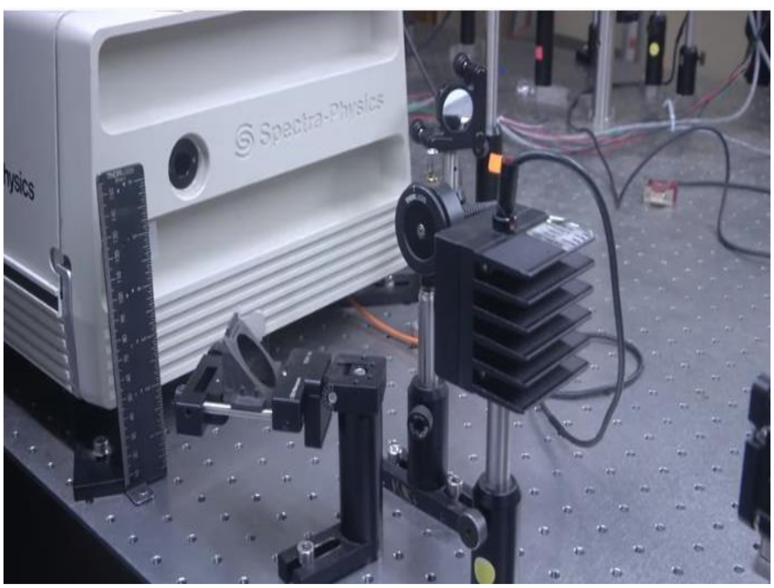

And we also want to make sure that the light that we have the color of the light or the wavelength of the light pulse that we are generating is of a particular range. So, right now to know this we have another pic of a small reflector that is going to go up into an optical fiber here.

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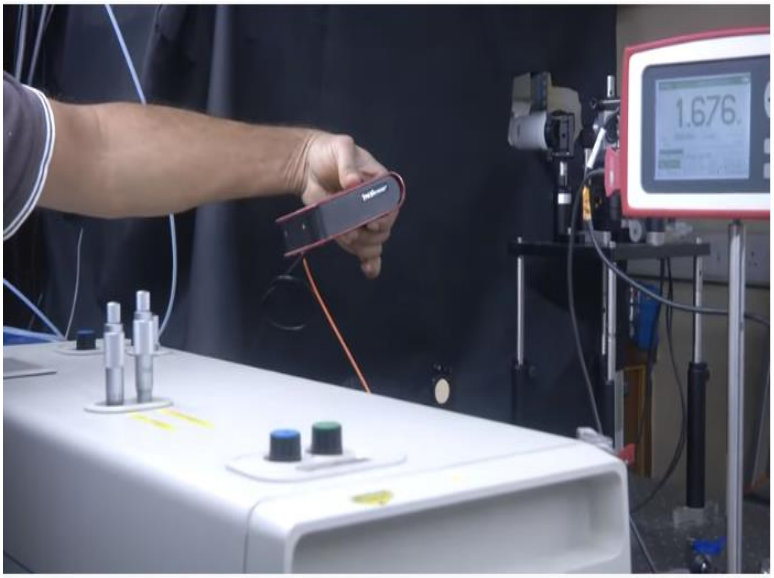

And this goes into a spectrometer that is a fiber optic spectrometer. We will see this in the class, and we will try to construct one such spectrometer not the fiber optic but the spectrometer in the lab session too.

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Where you the light goes inside and then goes inside goes to a grating and then we can actually measure the wavelength. At this point what I am going to do is I am going to flip this mount and you will learn about these kind of optomechanical components during the alignment lecture. But just bear with me for a second and we are going to flip it as we flip it.

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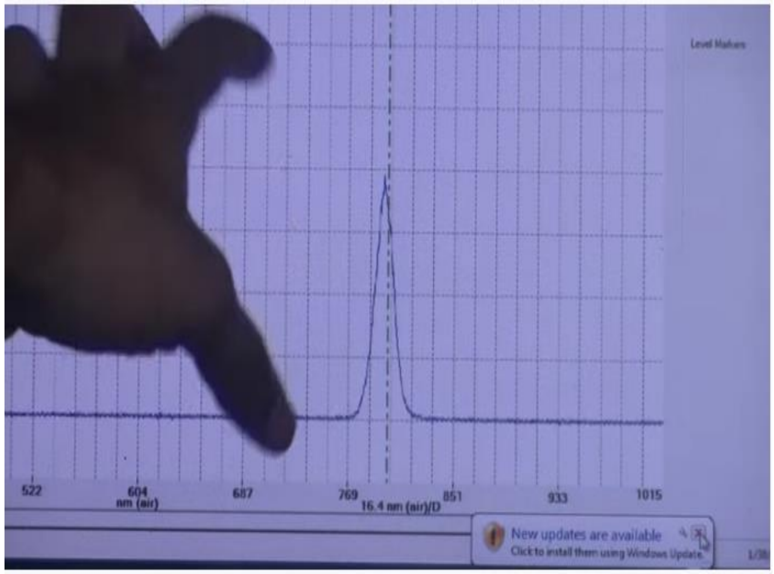

You will see that the output of the spectrometer it is connected to a PC where at this point you can actually see that the light is if you can read it is about 800 nanometers. It is centered around 800 nanometers peaked around that point and there is a finite width to this all right. We will talk more about this and then we will zoom in a little bit more once we open up and come back in. And I also want you to want to draw your attention to two other things.

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There are two diagnostic modules these are directly read out from the photodiode diagnostics we described in the class. One first here tells you the photodiode output it is right now it is very pretty much full and the other green light that tells you if you read it says pulsing which means it is operating I mean it is sensing that the light coming out from the laser is pulsed okay and then the best measure for that is actually you can measure how many pulses per second are coming in.

Right now you are looking at 79 megahertz this is the frequency the units is in megahertz. So, 79 tells you the pulses are coming at the rate of about 79 megahertz we still do not know what the individual pulse width is we have to do go through an auto correlator to measure it but that is again a different session and different class.

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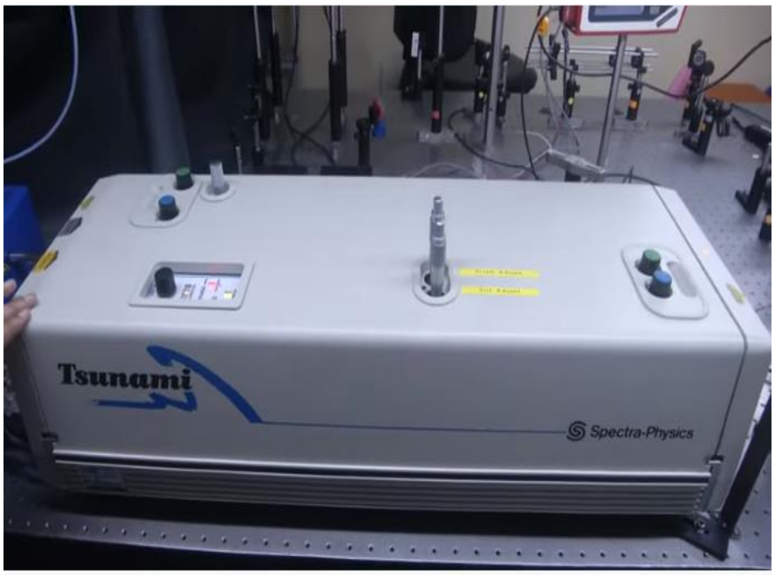

But right now given these quantities what you are going to do is now we will go ahead and take out the lid of this to see the insights of this laser with this information what we will now do is that we will go ahead and open up the lid of this laser the idea here is that we can see the insides of this and then try to relate it to what we have learned in the class. Now we are going to remove the lid up.

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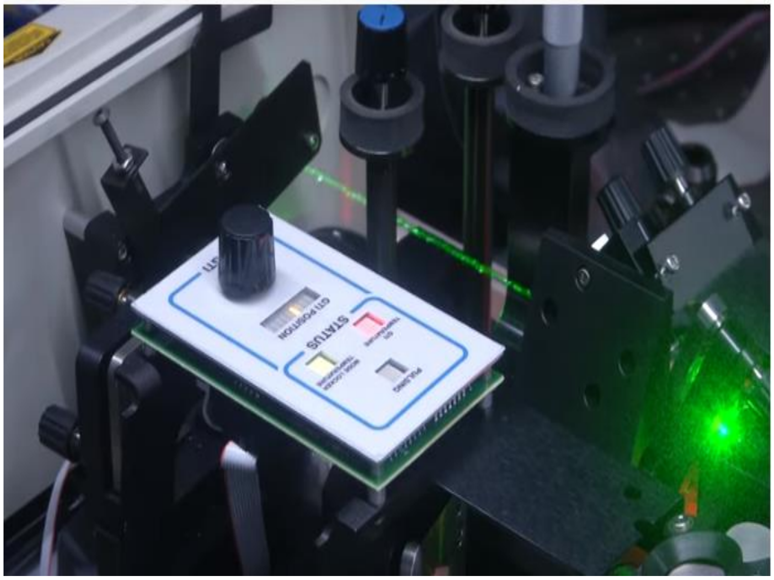

And the moment we remove it we can actually see the insights of the laser. So, right just for safety precaution so that we have removed the laser I mean the lid of the laser and we are going to work on it. So, we make ourselves conscious not the fact there is a shutter that is being provided it is an auto shutter that recognizes that the lid has been removed. So if you had to work on this laser often you have to align and stuff like that. So, then you have to make a conscious effort to actually open the shutter moment we open the shutter now you can see the green light coming out that is a pretty intense light okay.

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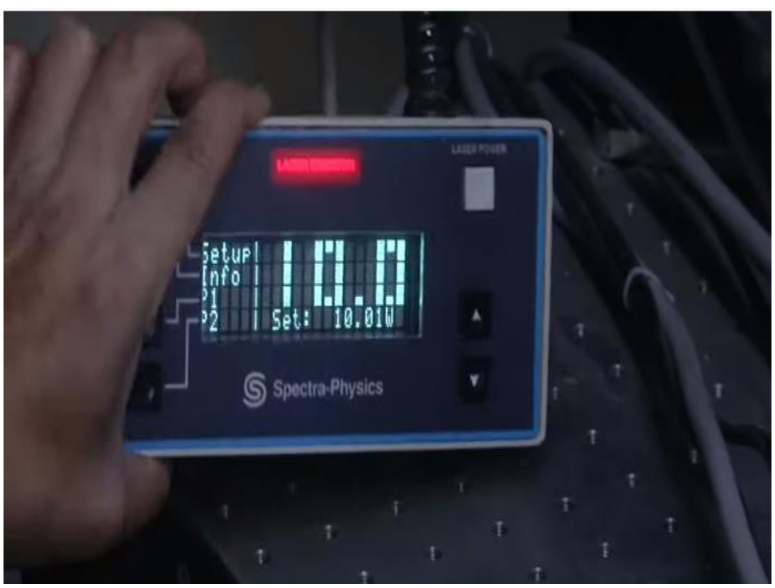

So the green light power are the pumped power as read by this meter is about 10 watts okay. So 10 watts of the green light is coming through this port.

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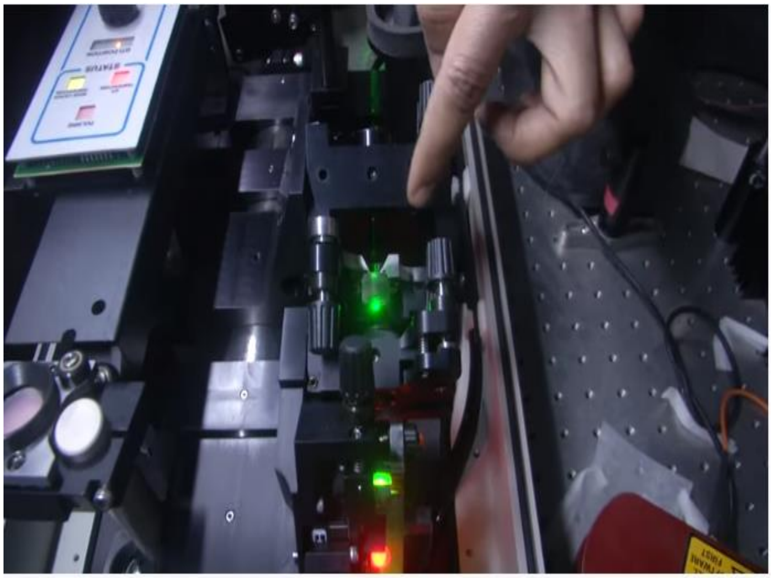

And once it comes through the first place it meets is a mirror and I am going to remove this briefly the lid here. So, that you can actually see this in its all glory you can actually if you go inside so you can see the mirror here that is a pump mirror one and then the light from there enters into the this is the back of the another mirror that is facing down. So the pump mirror two which is going to send out.

So, I am going to let the green light you can actually see the path a little better so the light from it is also operating at a lower power so that the visibility is there but not we do not have a problem with the high intensity laser; and stuff like that. So, the mirror this mirror reflects onto this P2 from P2, it goes inside right remember this is a curved surface. So it goes inside into the dichroic and again there is a curved surface on here.

And so now the light from the P2 goes through the M3 if you remember into the crystal, the crystal is in glowing in all its glory. So, you see that bright red spot there that is the crystal and the crystal emits the titanium sapphire crystal that emits its orange reddish orange glow this is really in infrared. Now that infrared light is collected by both these mirrors, these are the dichroic mirrors and what they do is they let pass the green light and you see that the pump the residual pump.

So, the thickness of the beam also gets reduced drastically and then it goes through this another second mirror before it gets dumped onto the beam dump. But then what you see is that the beam that is of that thickness right you can see the dust particles here right that gives you a good estimate of how wide the beam is and then it is scattering from there and now what you see here is inside a much reduced beam.

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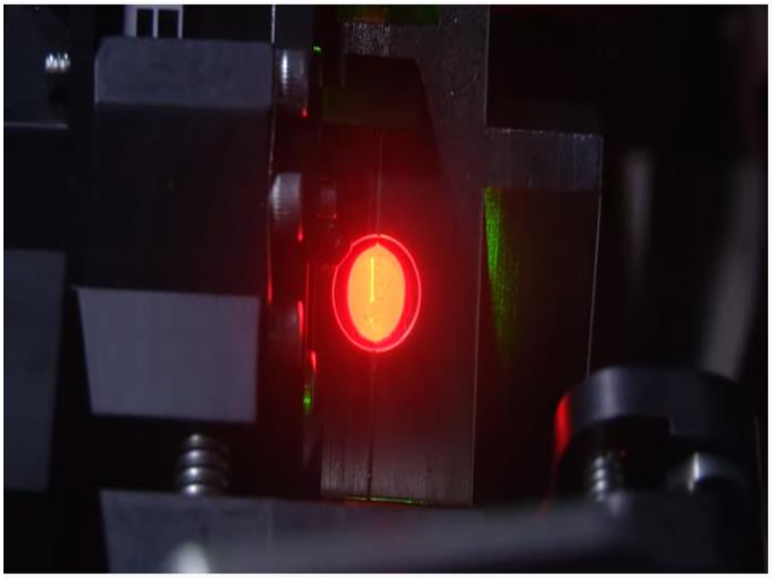

And now as you can see there is a streak of bright orange light within that red spot and the red spot is what the crystal is and the bright orange spot bright orange streak is the path of the green light into the crystal and then all along its path it is actually causing the fluorescence that is what you see it and exit points are brighter and that is where that is what you see it as a small spot. There is line at the ends of the lines kind of defines the length of the crystal. Now compare that to almost the same zoom.

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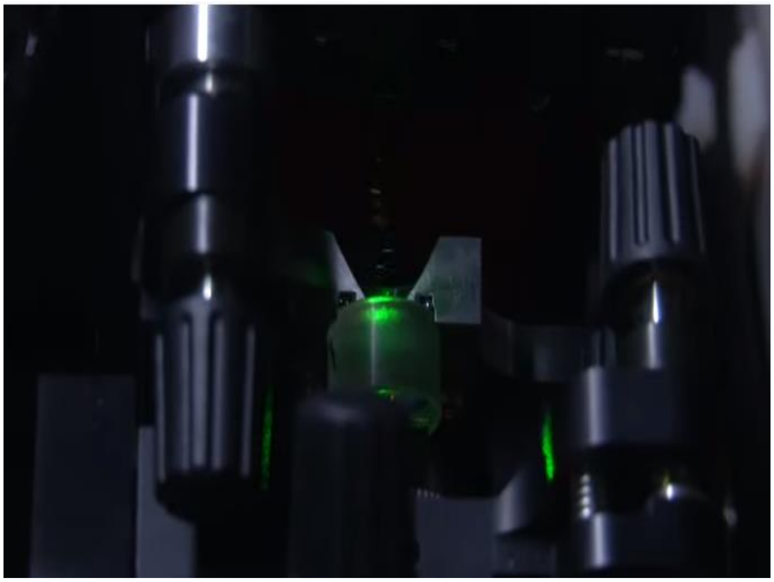

But now a beam that is present in let us say mirror in here. So, you can actually see how high it is actually focusing the mirror in there right that is the pretty wide pretty I would say about 3 to 4 mm wide while that gets down to literally tens of microns down in there. So, that is because of the mirror here it is actually the mirror here that is actually covered and its focuses the beam into the crystal.

Now once the fluorescence scrap happens then the we talked about two arms right the fluorescence collected by this arm we called one arm as a long arm and other arm as short arm. So, there is one this is the crystal fluorescence comes out here as well as fluorescence go out that side. This mirror collects the fluorescence that are emanating halogen coming from here and that gets reflected into down into this mirror right about where I am pointing the finger where my finger is pointing.

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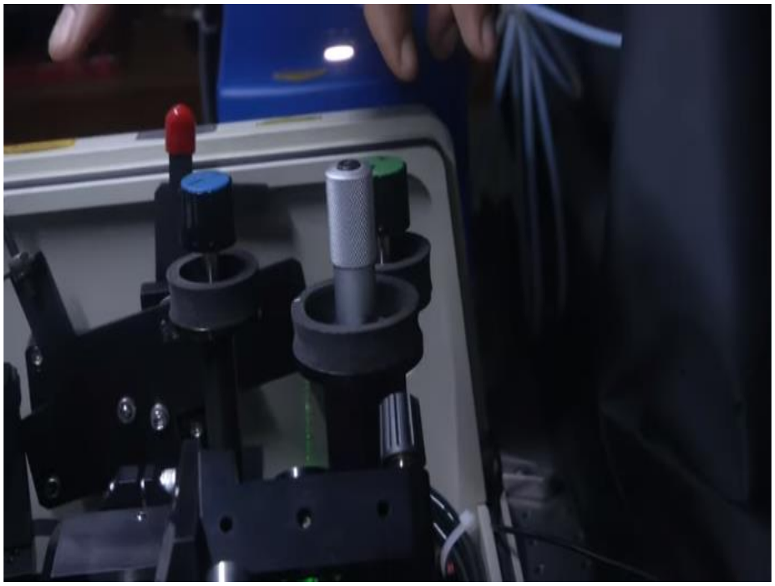

And then these are extensions to adjust the position of the mirror you would have seen me adjusting this to get the best optimal performance of the cover here from outside. So, now that is one and of course this reflects it back, So, the path the fluorescent green comes back again goes into the crystal.

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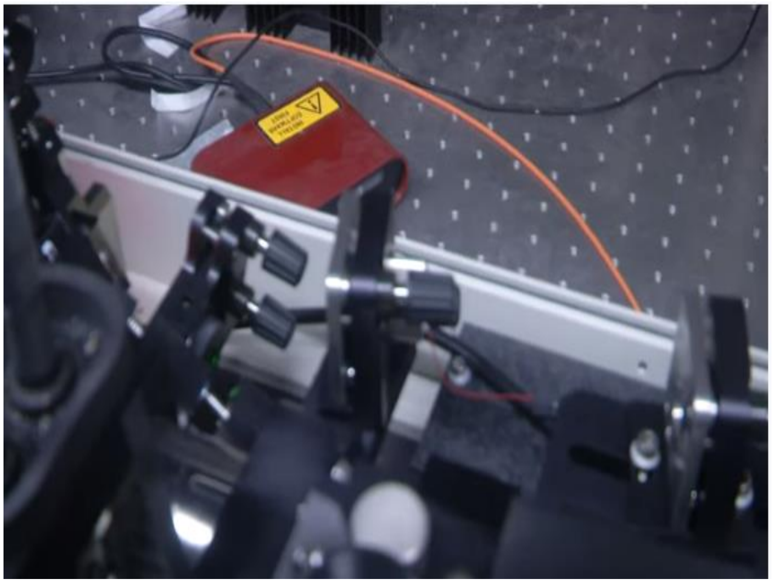

Now the other of the longer arm is a little bit more involved story where the fluorescence hits this mirror goes and hits the next mirror in line and then comes all the way back here.

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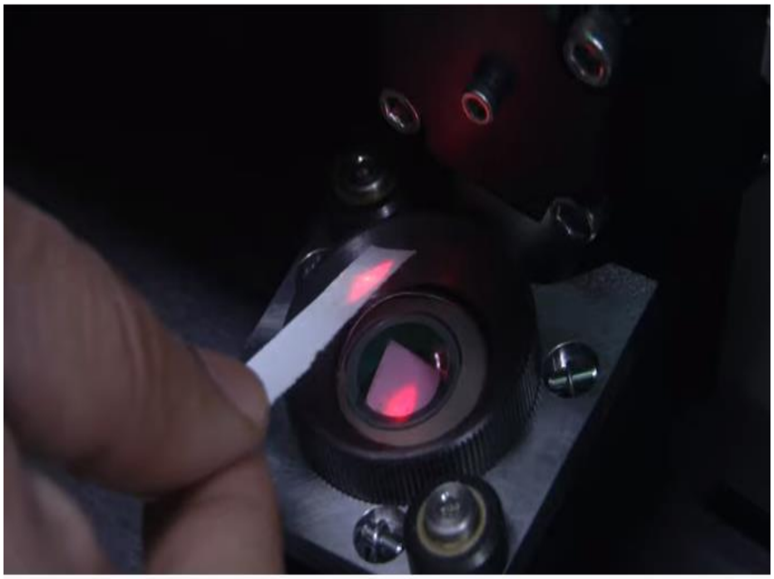

So what I am going to show you is that I am going to intervene the light part and then follow the fluorescence and show you the difference between what the fluorescence and the laser light itself okay. Tsunami went back into the high power regime so where you can see the laser so typically when you are aligning a laser you would see laser engineer or a person who is working on the laser would be working with paper strip or a card something like this.

What he or she is trying to do is to actually figure out where the light is actually hitting on here. So right now if you actually see right there you see a small tiny spot on the mirror right the harder it is for you to see it that good I mean the better it is the condition of the laser because there is hardly any scattering, scattering is a big problem in any light it was a lot of light loss okay. So, now if I intervene this laser cavity with a paper. So, now what you see immediately is that that the spot becoming larger and wider and that is the reason why it is because it is coming right after the prism that is the intervening right before the prism.

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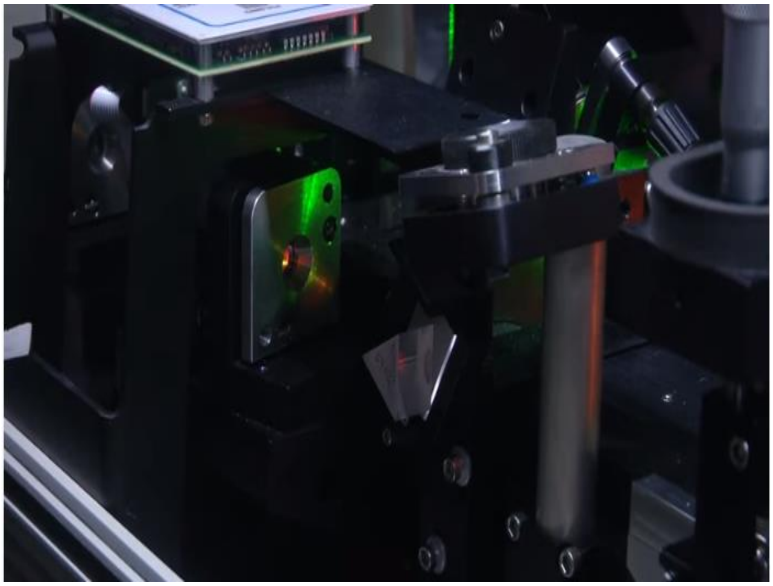

So, right here the beam from the longer after getting collected by this mirror and the crystal gets reflected onto the mirror present here that reflects it back here.

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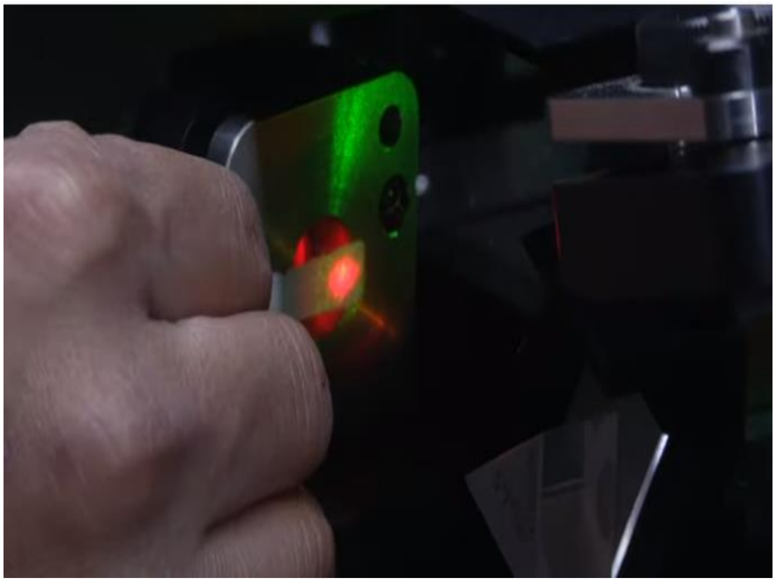

So I am intervening right at the entry point where you can actually see it is a pretty a large round spot and at the same time if you focus on this mirror when I am blocking it you do not see any light at all and it is because I am just blocking all of the light and at the same time it is also I can also do the same thing at the later point and then you will soon see it is getting lost. The fluorescence is still there but there is no lasing okay.

Now how do I know I mean this fluorescence then needs to be directed routed onto the prism right the tip of the prism. So as you can see from the paper it is pretty broad and wide. Now the light coming from this mirror once it hits this prism goes down it bends down right, and we know and hits the mirror down before it goes going up and then coming back onto this prism alright.

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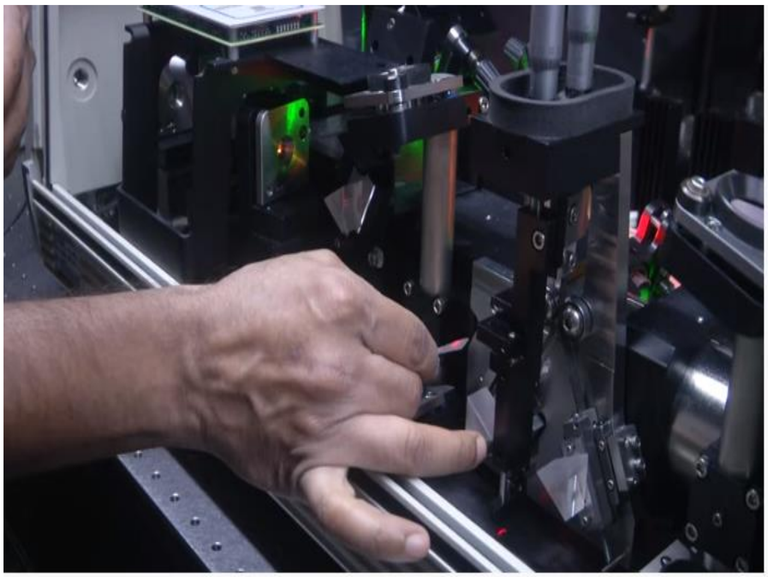

So, now so this prism spectrally disperses the prism here spectrally disperses so that at this point, you have different wavelengths arranged at in different space and that is let it these mirrors are called folding mirrors because if not for this mirrors you have to have a cavity or the laser cavity which is very long right. So, that you can meet that error criteria we talked about this compensation in the class.

So, there are two degrees of freedom one is the length of the propagation length after the first prism. So, the larger the length higher is the angular dispersion which then gets converted into the linear dispersion here by this prism. So, you can see that the beam coming out through here part of it goes through and then the rest of it comes out in a swamp and right here if you focus you have a slit.

So, the light of the angular dispersion after folding through this mirrors gets a meet second form in second prism that makes it the dispersion to be linearly separated in space so and in this linear space, we have a slit, slit is basically two blades that are moving against each other and then by moving the position in this plane, you can actually get to choose which wavelength you want the laser to be operating and the effect of that is that actually as I rotate. We will close down and then I will show you as I rotate this you will see that the spectrometer which we have connected outside to see it that you will see that it is actually moving.

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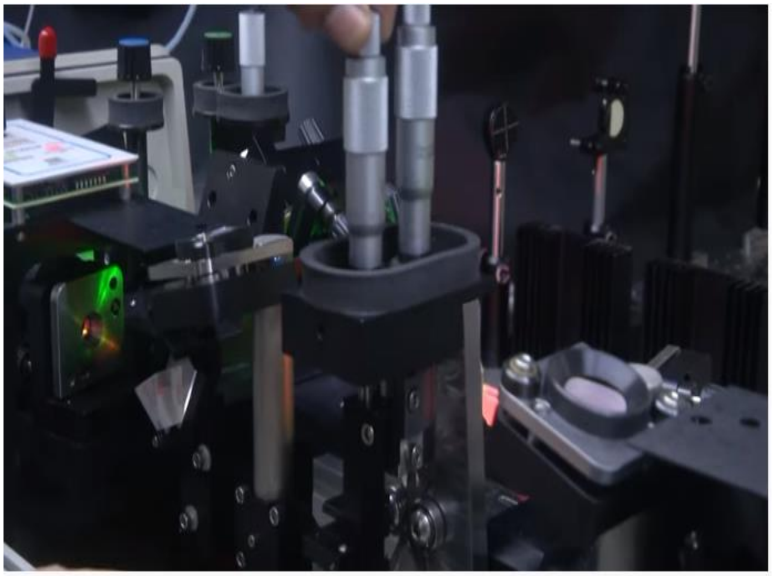

So, now we saw the slit assembly there right, so this slit assembly can be moved in plane by rotating this micrometer screws right. When I actually rotate the micrometer screw you can actually take a look. Down here on this assembly the two in the gap between the two laser blades is going to go up and down as you as I rotate you also can see the color of the laser is changing that is basically the wavelength moving making your eye sensitive to the radar regions. So, now okay so now we can actually hopefully you can see it better.

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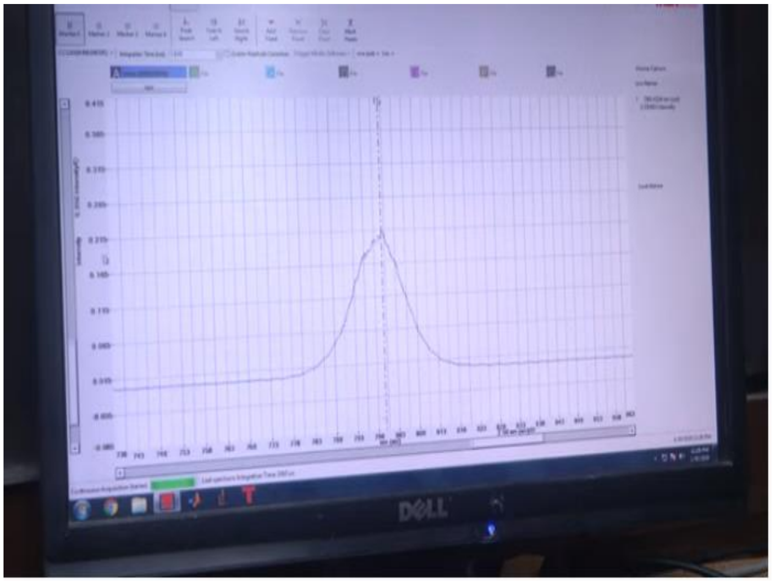

And now if you focus so as we rotate the slit assembly you can also see that the wavelength out for that measured by our fiber optic spectrometer is actually moving right that is really how we achieve this tuning here. So, I am going back and forth and as I was doing you can actually see that suddenly the thin peak became wider that is a good indication of the fact that the light initially was in operating.

So, the light that the peak becoming wider from the sharper peak is indicated over a fact that the light that the laser went from a CW continuous way length mode into a mode lock mode as we know that the mode lock pulse you need a wider bandwidth right so and that is what is the shown here when in a spectrometer when you actually see it what you are seeing is a spread of this width in the peak and that is exactly what you see it.

And here if we actually go ahead and measure the bandwidth. So, if we decide to go ahead and measure the bandwidth. Now you can actually see that it is the peak is somewhere around 790 so that is fine so it is about 800 where my cursor is, and you can see that at this point it is close to about 0.15 so let us say it is 0.2 so roughly about half. So, anywhere from the bandwidth goes from 790 to all the way to about 808 so that is about 80 nanometers of wavelengths all inside that one pulse and it is because of that.

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Now if you look at the yes sir if you look at the indicators of the pulsing that I talked to you about the green light here and the 79 megahertz here you see it. However now what I am going to do is I am going to make it make the wavelength go I will make the mode locking go away. As I do that you will realize that now you will observe a few things one now you can see that the lasing is still out.

Because the photodiode output is still there however you start pulsing any longer and then you have, I mean since it is not pulsing you have a 0 repetition rate and they are almost near 0 repetition rate and that is indicated by the spectrum 2.

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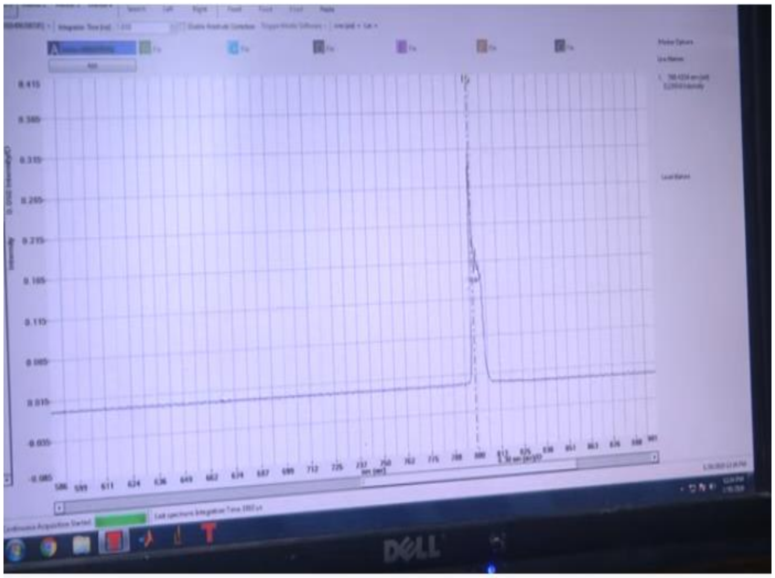

And that is indicated in the spectrum 2 here now you can see it is a pretty narrow extremely narrow and so the peak that you see here is very thin and it is about few millimeters in width alright. So, now the light that is coming out of the slit here is again so it is again made it, it goes through the same prism it again becomes it is put together by this prism and the set of mirrors here and you have your fluorescence coming back on to solid piece of I mean equipment sitting here acousto-optic modulator which together.

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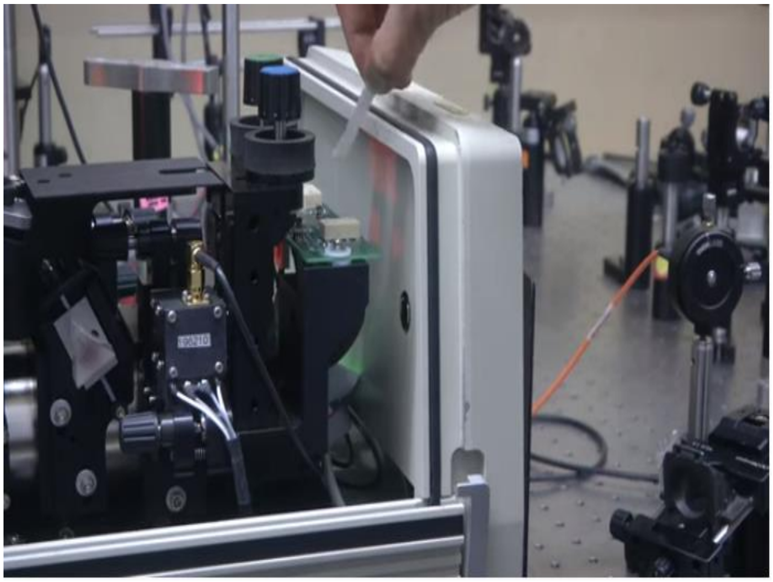

With that the electronics prism here the photodiode on the pulse sensing or the photodiode on the sensor for pulses together allows you to together in here what you have is a photodiode and a bunch of electronics to detect and count the number of pulses and together with this and the AOM in synchrony.

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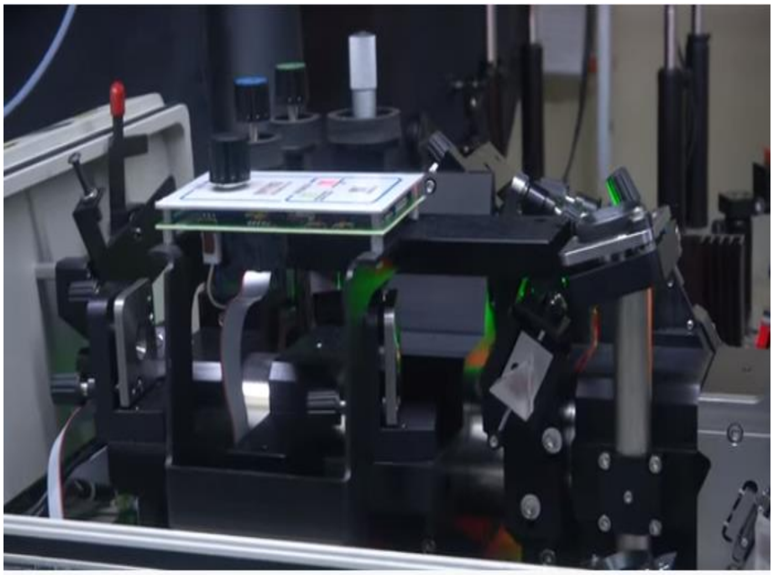

Along with motorized mirror right about here allows you to actually keep the cavity length constant and then thereby keeping the mode locking of the laser pretty stable. Now what you are going to see is that the light coming from the acousto-optic modulator out onto from the acousto-optic moderator goes into an output coupler okay. So, this output coupler can be again adjusted from outside using these two knobs which helps you to keep the laser operating in than the part inside the laser operating in a particular way.

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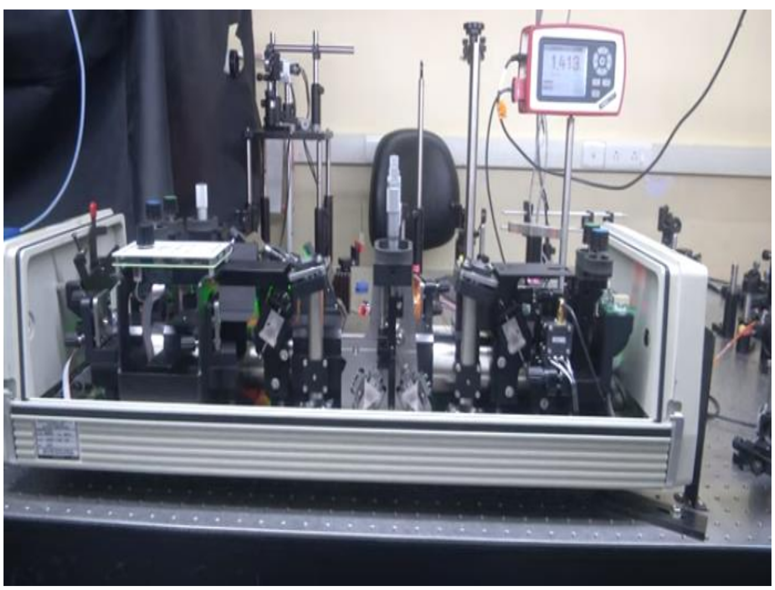

The basics of the alignment and so on and so forth we would be seeing in a separate session but right now that kind of completes our inside view of the femtosecond laser system. I hope you are able to appreciate what this system is in reality and I will see you in the next class. Thank you.