Ultrafast Processes in Chemistry
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Module No # 08
Lecture No # 45
OPA in our lab: TOPAS C (part 3)

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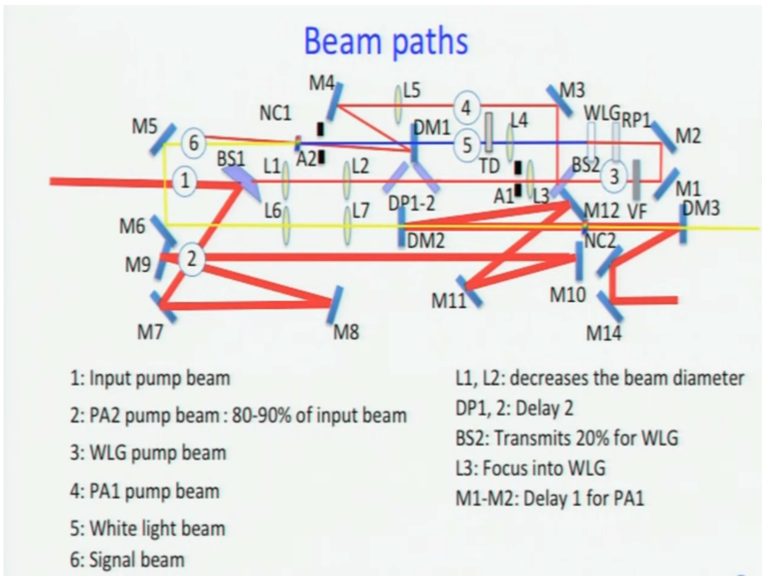

So this module to hope to complete our discussion of an actual optical parametric amplifier the one we use in our lab. We have this is where we are this is where we go to until the last module. To recap quickly we have this input beam hitting beams splitter 1 80 to 90% of which is reflected on to M7. Remaining part of it goes straight using L1 and L2 pairs of lenses which constitute a telescope.

The beam diameter is reduced then it goes to a couple of plates almost at Brewster angle but whose tilt can be controlled to bring in some delay in the path. Then after that it goes to aperture A1 on to L3 which is the focusing lens and immediately afterwards there is another beam separator BS2 which transmits about 20% reflects about 80%. The transmitted 20% of the beam remember converging beam goes on to M1, M2 and after this polarization being rotated by RP1 of wave plate it gets focused on a sapphire plate denoted WLG here.

And that is where white light generation takes place. We have not shown the white light generation the path of the white light yet ok. What we have shown is path 2 that is PA2 pump beam and now we showed well even PA2 pump beam we have shown only the beginning and then we have shown the white light pump beam WLG pump beam path 3. And then what we said is the 80% of light that is deflected by BS2 hits M3 that is path 4 that is PA1 pump beam preamplifier pump beam.

And remember this is a focusing beam so it is collected by L5 which surfed collimated. Then the collimated beam hits M4 then dichroic mirror 1 and as we discussed in the previous module this dichroic mirror is essentially a short pass filter. So it reflects the 800 nanometer light and as you see later it transmits the white light and then this 800 nanometer light goes through an aperture A2 and this nonlinear crystal NC1.

Where it took some trouble to make this NC1 crystal rainbow color I do not know whether it is very obvious in the projection is it? Ok good ok and then it is dumped. Why it is essential see generally when we talk about white light generation or second harmonic generation some frequency generation we always focus the beam right. In this case why is it that PA1 pump beam is being collimated before being incident on NC1.

You agree with me that this PA1 pump beam is collimated because they are using a lens L5 to collimated. Why are we not focusing? And what is the purpose of NC1? What will you do in NC1? We are going to do optical parametric amplification right. This white light will fall on it and we are going to choose the condition by which we are going to amplify one of the colors. That is what to that is the role of NC1 that is the hint.

Why is the pump beam not focused on NC1? Yes if you focus the pump beam then there is always a danger of getting second harmonic generation. And remember second harmonic generation is more probable process second harmonic will actually have a stronger intensity. Of course it will come at a different a tilt but it is very easy to get confused. In fact if you read the manual it says clearly there should be no second harmonic generation at NC1. Do not proceed further if there is second harmonic generation at NCI that means you are doing it wrong ok.

That is why you cannot focus the pump beam on NC1 it is very essential that it is collimated right so that is one thing. Then now it is time to finally show you the path of the white light ok path of the white light is not very difficult to understand here because the WLG pump is path 3 it has been focused by L3 onto this WLG which is the white light generator type this sapphire crystal ok. So naturally it will go straight. Since I cannot draw white line on a white background, I have shown it using blue ok.

So this blue line denotes the white light ok. But there are a couple of things that with better discuss before going further ahead. One thing we have talked about already in the previous module is what is the role for L4? How do you generate white light? L3 focuses this pump beam on to the sapphire crystal right. So after the sapphire crystal this pump beam going to be diverging and white light will also be diverging.

So as you said in the last module role of L4 is to capture the diverging beam and make in collimated ok. That is why you need L4 then we have something strange here. After L4 there is something called TD. What it is TD? Well in the manual I also could not find what T is but D is a diffuser. Diffuser means suppose you take some tracing paper and make light go through it. If it is very intense light it will go through right.

But it will get a little diffuse. So what a diffuse does and now finally we are going to answer the question why it is ok to use and maybe when desirable diffuse lenses is what diffuser does is it diffuses of course. But many of diffusion is it bring in some chirp in the white light ok. You understand in diffuser this refractive index will be higher right and the difference in refractive indices of red light and blue light will be different more different.

So it bring in a chirp and since you are consciously putting in a diffuser to bring in a chirp anyway it is fine to use lenses. If anything it will help bringing in a chirp. Generally we like to think chirp is bad right. Thus why you will always try to compensate for chirp but the issue is chirp is good as well as you saw right chirp pulse amplification is what allows us to get higher energy out of the laser right noble prize last year.

So sometimes you can use chirp to your advantage as well. And here the good thing that can happen if you bring in chirp is what are you trying to do? What is the ultimate goal? To amplify one color ok one central wavelength right. So if you want to do that there are several waves you can do in which you can do it. One is which keeps on changing the tilt of the NC1 because that is where the amplification will take place. But it will also help if red light comes first blue light comes later or the other way around.

Then what you can do is we can also have a controlling in time because after all do not forget that this light that is coming in, in this direction in path 4 the pump for optical parametric amplification the preamplifier what kind of light it is it? It is a pulse light right, this pulse light. So if you have a chirped pulse over 2 picosecond of 3 picosecond and you have this 50 femtosecond pulse going in right this is the 50 femtosecond pulse x axis time of course or maybe I will just draw it.

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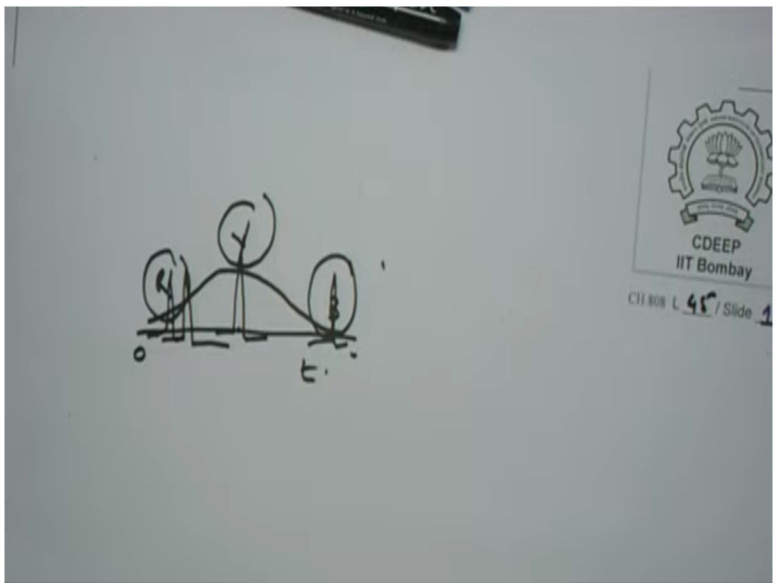

So what I am trying to say is this is your white light in time but let us say this is blue this is yellow this is red right. So in earlier time it is more blue actually it is other way round this is early time this is 0 this is more right. Early time it is red intermediate time it is predominant yellow later time it is predominantly blue. And then you have this femtosecond pulse coming in, if it comes in at this time because you have 2 different path lengths light, we have studied this femtosecond optical gating we have studied pump probes.

So we know that change the delay and that is how we do all our experiments in here. Here also what is happening is if you have the path lengths in such a way that the femtosecond pulse arrives here then it is going to amplify yellow light. If it arrives here then it will preferable amplify red light. If it comes here it will preferably amplify blue light ok. So delay is a second parameter that comes in right. That can give a efficient optical parametric amplification understood.

That is why we are taking about the delay 1 and delay 2 ok. So remember moving M1, M2 forward backward that is delay 1. Tilting DP1, DP2 that is delay 2. By doing all that what are you doing essentially? You are changing the when you change this one delay 2 that will affect both actually right. And when you change M1, M2 what will which path will be affected white light or the pump. So essentially moving that spectrum forward or backward ok and thereby you are choosing the optimal wavelength that can be amplified provided you said the NC1 crystal at the right wavelength ok and chirp is not the problem.

First of all here you see chirp is an advantage secondly remember your amplifying only one color only one modal wavelength right that takes care of the chirp. You do not have to compensate later on. If you want to you can still put in prism pulses prism pair later on it is not required because out of this chirp pulse which is spread over 2 picosecond or something you are actually choosing one color as a central wavelength and you are amplifying it ok.

Everything else is not even considered. So chirp is forgotten the moment you do optical parametric amplification ok. That is why it is ok to use lenses may be desirable that is why there is no need to use prism pairs later on unless you have some very special application ok. And this is where the smartness of the design comes in where you put in at diffuser where you bring in chirp alright. So once again if you by mistake you remove that diffuser or replace it by something else you might not get the desirable results alright.

So this is what happens. So this blue light blue line is your white light that comes in straight goes through the dichroic mirror DM1 and remember what we said earlier we have made a mistake while saying it earlier. But actually it goes in non-collinear in a non collinear fashion. Why does it going in a non collinear fashion? Because the white light goes in like this if pump goes in the little different angle then you can just dump it. You do not have worry about the pump anymore right.

If there are collinear then the signal will travel in same duration. Then you have to worry about cutting out the pump. But if they are non collinear this is pump, this is the direction of white light, this will be direction of your signal as well right. So you do not worry about the pump any more just dump it. Are you clear so far? Ok. So from a NC1 you get the signal the wavelength that you desire ok.

So what will where will it go? It will go straight to M5 then to M6 I have drawn it little badly M6 and M9 seem to be connected and then it will go straight right. That will show you the path. Signal M5, M6 then again you collimate it little bit. Here collimation is required because it is going through this nonlinear crystal some amount of focusing defocusing will come in ok. And then it goes to another dichroic mirror on to NC2. Why dichroic mirror why NC2?

Now you can understand dichroic mirror because that is what is going to be used to bring in this thick beam path 2 PA2 pump. And why NC2 that is where your final amplification will take place. So what have we done at NC1? We have generated some signal of moderate intensity moderated amount of amplification is taken place. In the second phase second stage power amplifier PA2 that is where first of all your signal is stronger than it was in white light.

Secondly you are going to pump using a much more energy ok. That is where your final amplification takes place alright. So this is the path of the this number 4 no this is number 6 signal beam of course it will go straight later on and now finally let me show you path 2 which we have only started at the beginning of the discussion but did not go further. Can you guess where path which path this will follow.

I should have broken a little bit ok but let see if I can just follow it and show you. So of course if you just follow the number of mirror you can sort of understand. So first of all from the beam splitter remember 80% of the total input hits M7 its directed to M8 these are all highly refractive mirror. From M8 to M9, M9 to M10, M10 to M11, M11 to M12 I am not named one of the optics here later on 13 I think.

And then from M12 it goes and hits the dielectric the dichroic mirror. Remember the dichroic mirror is the short pass mirror or long pass mirror? Short pass, short pass filter. So it is going to reflect this pump beam and the alignment has to be such that after hitting DM2 the path of the pump beam is exactly coincident collinear with the path of the signal beam because in the second stage amplification we use collinear geometry alright.

What is the need of so many mirrors? Why do we need so many mirrors? I mean after M8 or what was the need of M8 M9? If I just want to go here I could have sent it from M7 to M12 from M12 it could have gone to DM2 it were be perfectly possible to align. Why do we use so many mirrors? Path lengths has to be match remember. Path lengths have to match temporal overlap is important otherwise nothing will take place.

All this mirror what will do is it will give you the suppose the path lengths is something like 2 meter or 1 meter. It does not make sense for you to put a mirror on a 1 meter long stage right it is better to fixed mirror folded cavity kind of thing and more or less make up to 1 meter up to the nearest millimeter and rest of it you use you make up using translation stage. That is what is done ok. Then the signal so what happens in the second stage PA2 or amplifier 2 is that the pump and the signal travel in the same direction.

Then there coincident on NC2 that is where the final amplification take place ok. How will this this amplification take place? What you have to do in NC2? First of all some mirror has to be moved that is there and secondly their angle has to be tuned. All this is done using software using computer controlling. You can do it by hand but initially when alignment is done it is done by hand.

After that the computer is trained that this is the setting for this wavelength and all and then there is algorithm that is sort of tell the computer that if this is the setting for say 700 nanometer then change the setting to this and you will get 600 nanometer sort of something like that. Now then what you have is you have DM3? What is DM3? Dielectric mirror 3 again it transmits the signal reflects the pump.

So DM3 reflect it to I have not written the name of this mirror there is no place this is M13 to M14 and M14 finally guides the pump beam out. And through DM3 you get the signal coming out. You have 2 outputs of TOPAS one is signal, and one is pump. And what you could do is? You could do crystals after this to generate second harmonic, third harmonic, forth harmonic if possible and this is what it gives us so much of tunability ok.

So finally we have completed the discussion of the entire beam path. So but well not quite couple of more this that I want to show you is this. Now what you should do is? You should take this picture go to TOPAS, if a TOPAS is available then compare and see because what I have drawn here is just schematic. Your mirrors actually do not look like this.

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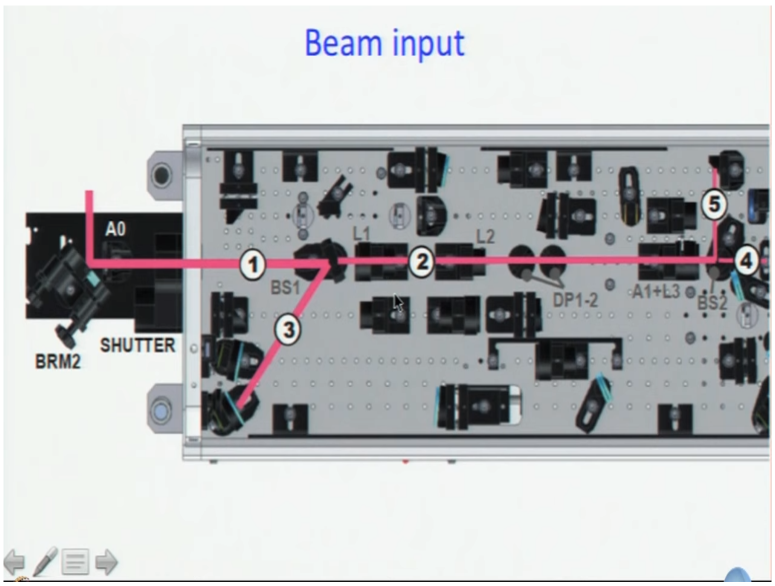

So here you can see this is the beam input pathway. It comes in like this is what the beams splitter looks like from the top this is a second mirror and then you go straight this is L1 this is L2. These lenses are actually mounted on cylinders and in principle you can move them back and forth you should not unless it everything is broken and you have to and you know how to fix it.

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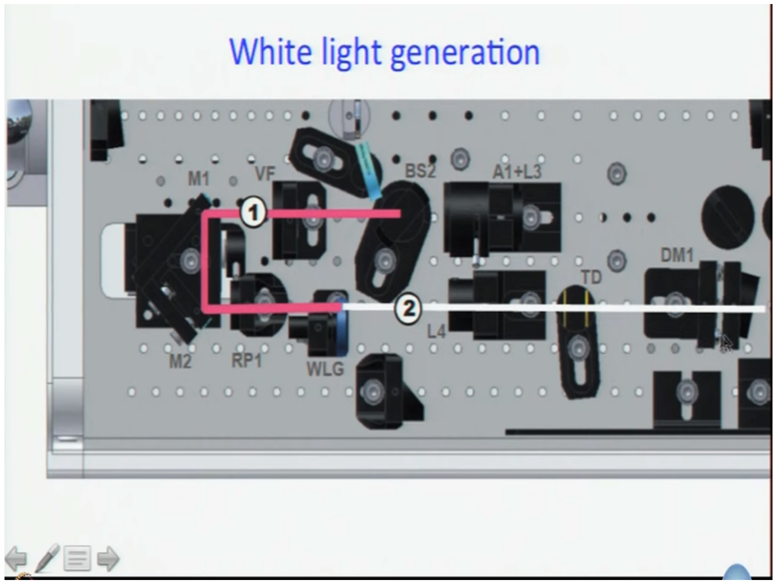

Next this is the white light generation stage so remember what we had in white light generation stage. We had RP1 so this is the pump coming in right. This number 1 2 in this diagrams are not always the same as numbers 1 2 that we used in our master diagram. So this is the pumps that comes in you see this is the M1 from the top this is M2 and what you can hopefully see is that you are looking from the top right. So this is the mirror as you see it from the top this is the mirror you see it on the top. This square thing you see at the bottom that is the plate on which these 2 mirrors are mounted.

And this thing sticking out from here that is the motor ok so M1 and M2 together can be move back and forth lead to refractor that is your delay 1. And then this is the half wave plate this is where white light generation takes place and white light goes out. This here is the diffuser and this is the dichroic mirror.

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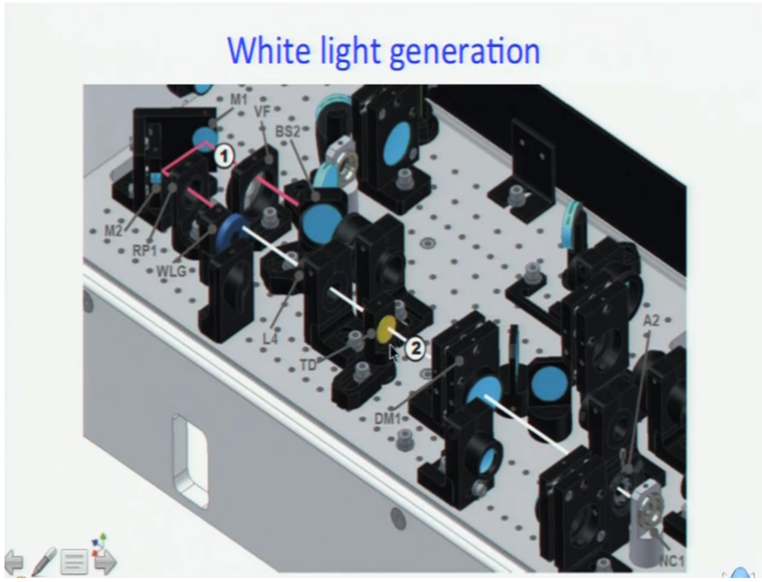

This is the view from the top and this is your isometric diagram. This is a good simulation of what it looks like except colors may or may not be exactly like this they are right. The mirror are have similar color are they transparent ok. So this is what it is this is the diffuser and it goes straight. Now, so one thing that one needs to make very careful about as you discussed earlier is the quality of white light. So if you hold a card in front of M4 you will get to see what the white light looks like.

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And this is an example this is couple of example of good white light and bad light ok. Good white light is well symmetry is beauty right. So good white light is beautiful symmetric bad white light is asymmetric so this kind of situation is encountered if your pump power is too high. So if you get white light like this what do you have to do remember the variable filter. You have to move the variable filter little bit so that more OD is used.

So cut down on the pump and white light should get fixed. We generally do not play around with the lenses in this case because as you understand if you move L3 not only is the white generation pathway affected. The preamplifier path is also affected ok and that would bring in too much of your alignment. So it is better to use the variable filter that does that is something that does not change in to too many parameters.

But if you have white light like this that is absolutely unsatisfactory. You put pumping in too much putting in too much power too good is no good decrease ok that why we need it. And you should be able to get back white light like this.

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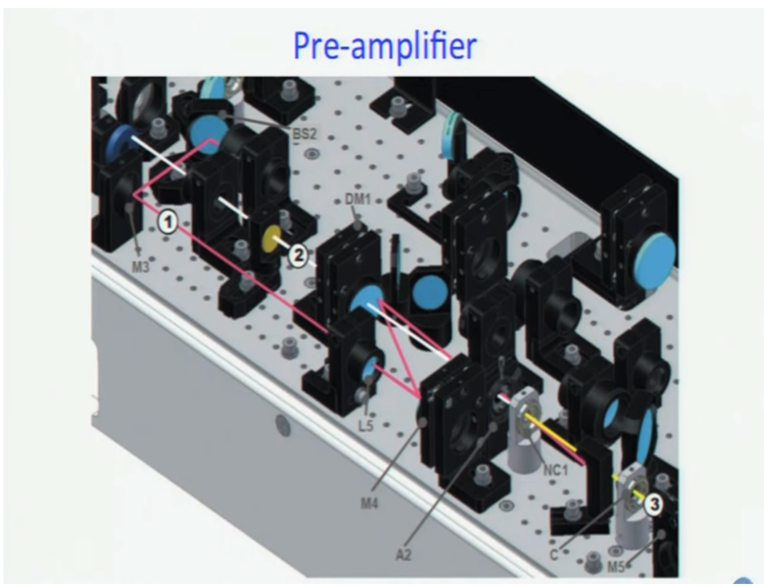

Moving on this is the isometric view of preamplifier once again if you have seen TOPAS you will be able to compare the optics and know which is which?

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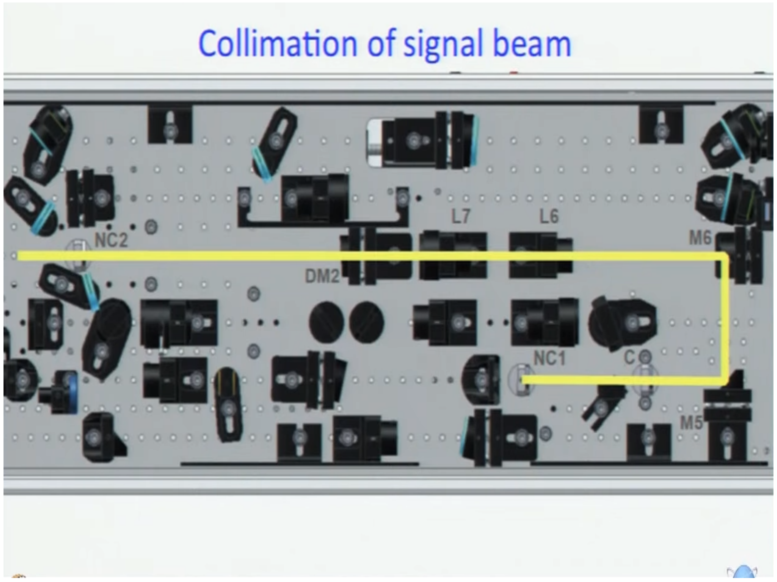

This is how you see collimation of the signal beam L6 L7.

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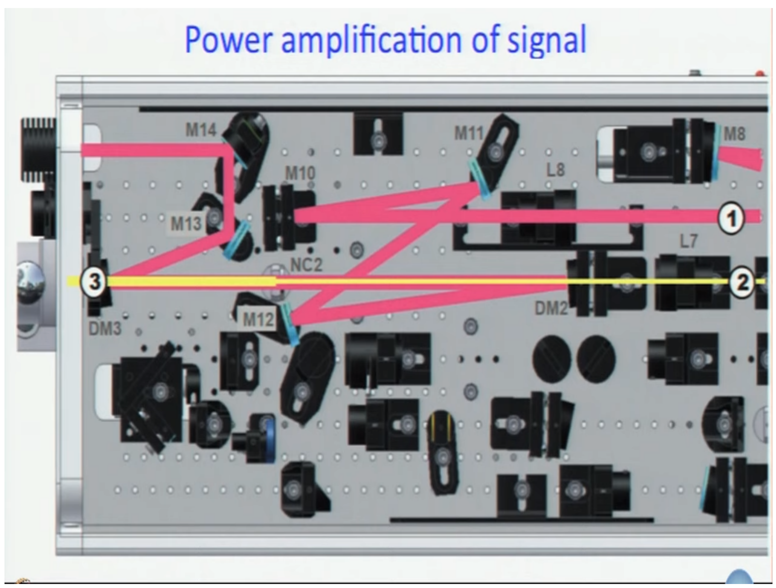

And this is how power amplification of the signal takes place. So the reason why I am even showing this picture is that please go back and have a look and identify the optics. Then only we will understand what is going on inside ok. That brings us to the end of this 3 module long discussion in TOPAS. Hopefully we all have a working knowledge of this instrument now.

So and also it has been a longer than expected duration of discussion of just instrument. So in the next few modules what we will do is we will present some seminal experiments using pump probe and femtosecond up conversion. And then we will go on to discuss some other techniques things that we do not do in our lab. But things that are quite common nowadays and we should know about it.

Depending on how much time you have at the end we want to discuss 2 dimensional spectroscopy electronic and vibrational and we want to discuss if possible terahertz spectroscopy. I do not know whether we will able to get that far. But if you are in the business of ultrafast spectroscopy it makes sense to know those techniques. Otherwise you will read paper and not understand anything right.

So that is what we will try to do and while doing that we have to come back to the instruments once again a little bit not this much. But we will need to learn certain aspects that we will do. Another experiment that I really want to talk about is stimulated Raman kind of experiment. That is not very difficult to understand once you know pump probe ok. So break here today and next few semesters will be of little different flavor.