Ultrafast Processes in Chemistry
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Module No # 08
Lecture No # 44
OPA in our lab: TOPAS C (part 2)

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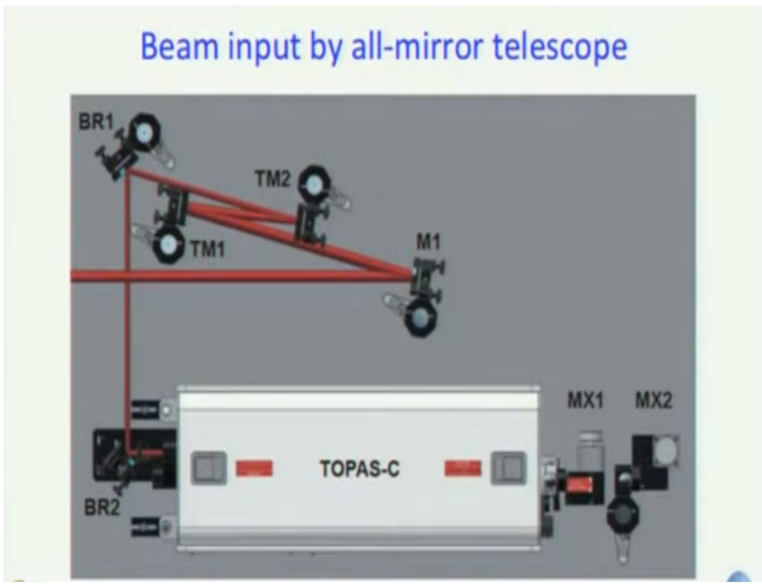

We are discussing a the optical parametric amplifier we have in a lab TOPAS C. What we have said so far is that we put in the beam the pump beam output of the part of the output of the regenerative amplifier we have using an all mirror telescope. And the reason why we need so many why do we need so many mirrors let me ask you? Yes one is path length you might have to give a particular delay because later on some other application right.

So for that a part of the beam will go somewhere else. So you need to give a path length. Secondly you need at least 2 mirrors if you want to align a beam. So as you are going to discuss we have already started in the last module we will complete in this module as we will discuss alignment is very critical in this things like this. So generally things well life is much simpler if you try and make the alignment in such a way that at least in every stage the beam is horizontal ok.

So we do all our experiments in optical table which in any case has this array of holes where you can put in screws and fix optics the holes have a second purpose they tell you which one what the vertical direction which one is horizontal direction. So if you want to make an instrument and you have to actually build something the easiest way of trying to do is it that try and make your beams go along the line of holes and to start with using a ruler make sure that the height is same. That way later on alignment becomes much easier.

And if something goes wrong you can check easily. So this steering at least this 2 steering mirror is the required to ensure that the input is straight horizontally well like this it should not be like this it should be like this right. Both this direction can be fixed easily if you have at least 2 steering mirrors.

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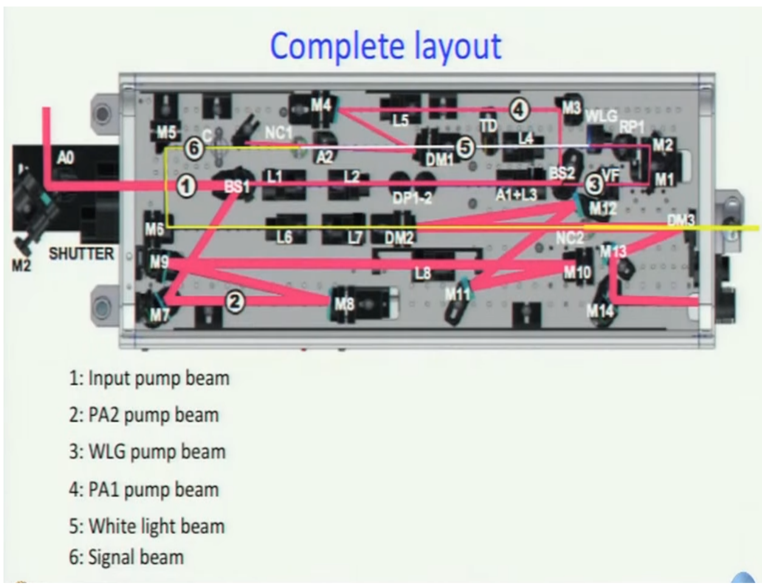

And this is what we have shown you we said that you have light coming in from the regen and using beam splitter and different optics you split it into 6 different paths. We have already discussed the first path input beam and we have started talking about the pump beam. Now in this module what we will do is we are going to talk about all the paths that are there inside our TOPAS ok. This is what we have presented already.

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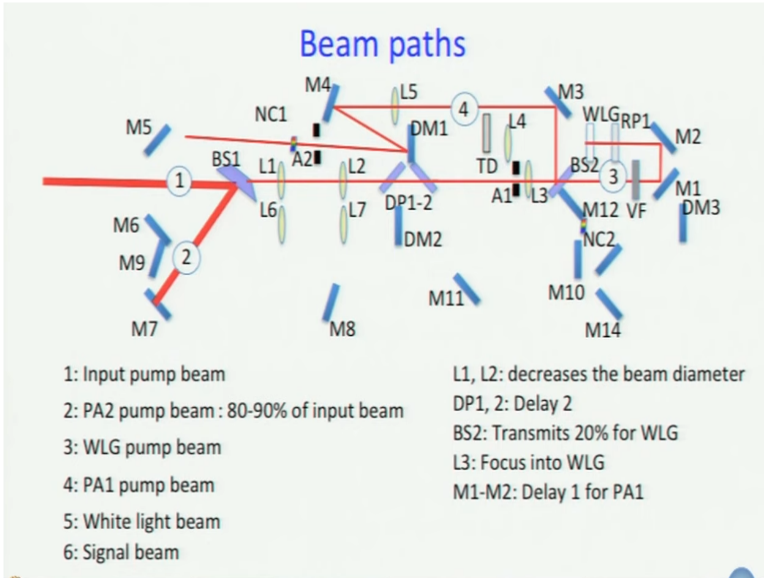

Light comes in from the regen that is path 1 input pump beam 80 to 90% of it is reflected towards M7 and we will see what happens after M7 towards the end of our discussion. The remaining path goes straight and we have said that the next piece of the optic that this transmitted beam encounters are L1 and L2 2 convex lenses they are arranged in such a way that their focal points are coincident and L1 and L2 are chosen in such a way that the focal length of L1 is longer than the focal length of L2. So that after the beam passes through this you get once again a collimated beam.

But a collimated beam of a narrower beam diameter smaller beam diameter than the input beam. You required this because later on this beam has to go through several iris's and all. A very broad beam would cause a loss of energy and inefficient amplification right. But let see what is there before we draw the path or maybe we will draw the path first. This is how it goes. Well it goes further but we stop it here because we have to discuss something right.

So first of all what we have said already is that L1 and L2 serve to decrease the beam diameter. Secondly the other 2 things that are there right after this and we are going to try to show you some isometric diagrams of this not photographs. So if you get to work on a TOPAS it should be helpful if you first go through this presentation then read the manual or read the manual along with this presentation.

Look at the asymmetric diagrams and go to TOPAS along with the manual and try to compare with the diagram to find out which optics is which. In order to run it intelligently we must know what is what? Otherwise it is baffling and if you do it blindly it is impossible to do anything with it ok right. So what is DP1 and DP2? DP1 and DP2 are 2 well I think quartz plate material is not mentioned in the manual but 2 quartz plates that are set at approximate Brewster angle.

Approximate Brewster angle because you want to maintain the polarization. Now I said approximately it is actually there are little different from Brewster angle so that the polarization are not compromised but what you can do is if you tilt this plates a little bit anyone or both together then what happens is the light going through this plates depending on how much you tilt will go through more glass or less glass right. And that would cost a change in delay.

So when you run TOPAS this delay is called delay 2 in this software that runs TOPAS. So if you change delay 2 what it means is that essentially you are tilting these plates. Why you have to change delay at all? Hold on we will come back to it. And remember we have still not answered that question why it is ok to use lenses ok. Can you make a telescope using mirrors? You can right in principle you can.

You just use concave mirror of different focal lens it is that you have to tilt them in a such a way the light that goes out ok. Otherwise if the output of these 2 mirrors keep on going keep on oscillating between each other is of no use. But why do you we use lenses will if I say ok to use lenses we will see later or why it is desirable to use lenses. We will see later on. But do not forget the moment it goes through these plates then also it is possible that you introduce some chirp. It is not an all reflective optics TOPAS ok and that is fine.

After that if you produce this line what do you get? What is the next thing? A1 is a aperture ok that is why it is drawn like this. This black little thing here the black little thing here in the middle there is a hole right. So it is something like this ok section of that would look like A1. And then you have L3. What is L3? Another lens what is the shape of the beam that goes in to L3? Collimated beam now when it goes to another lens what will happen it will get focused ok.

So why do we need to focus we will see ok. But then after that we have this BS2. BS2 is the beam splitter that transmits approximately 20% of the beam ok. Next we piece of optics along this thinks of this horizontal line ok that is the direction of the propagation of the beam as you are going to see shortly. After that we have VF. What could VF be? Can we guess? In this context what could

F be? F could be you can speak in any case you would not be hurt. If you give the wrong answer it is ok F is you are right actually filter.

F is filter and V is variable. VF is variable filter because you want to play around with the intensity of the light that goes through. Why you have to play around we will see later. Remember when the principle remember is too good is no good. You do not want to put in as much light as you can that messes up thing we will see later ok. And then you have this M1 and M2 and so on so forth ok. So let me draw the beam BS2 we have already said transmits about 20% of a white light of the WLG beam. This is your path number 3.

What is path 3? WLG pump beam that means with this beam that goes through. So how of this what could be the energy in this? You put in and say 1 milli joule ok 80% of that let us say went on along path 2. If this direction horizontal direction 20%.of 1 milli joule is how much 200 micro joule and then we are saying that this beams splitter transmits about 20%. So 20% of 200 milli joule is how much? 200 micro joules sorry. 20% of 200 micro joules is how much? 40 micro joule.

And then you have this variable filter so you can actually control. You can make it less than little 40 micro joule as well not little you can make it 0 if you want ok. So you so that is a maximum you do not want too much of light to go in. What is this beam going to do? This beam is going to generate white light ok. With experience of doing pump probe spectroscopy we know that if we use too much of light energy to generate white light or if you focus too hard then the white light quality is not good right.

It is unstable there is filamentation many things happen. That is why so that is the answer. So that is why you do not want to use too much of pump and I will show you have photograph of what happens when you use too much of pump once we are done discussing this ok. But this is your white light generating pump beam WLG pump beam goes to the aperture L1 L3 focuses it. Now see what is the role of L3 why does it have to focus? Why does the beam have to focus?

Because your white light generation is going to take place in WLG you see. This is basically a sapphire plate. To generate white light there it is not sufficient to send a collimated beam you have to focus the L3 the job of L3 is to focus the beam pump beam for white light generation on the sapphire plate ok. Can you comment on the relative focal length of say L1 L2 you know already right. L1 has to have a longer focal length than L2.

Can you compare can you comment on where L3 focal length will be should it be longer than L1 should it be shorter than L2 or should it be something in between? See this is cartoon but this is roughly to scale the way I do the cartoon is that I started with that photograph and in that I have drawn the optics. So lengths are more or less ok. So what do you think just looking at what you see here should the focal length of L3 be more than L1 less than L2 or something in between.

Actually it has to be more than L1 right because what is the separation between L1 and L2 this much. So depending on how much you want to shorten the beam maximum focal length of L1 is something like this from here to here. But look at where L3 is and look at where WLG is? It is this is the focal length of L3. So L3 is actually a long focal length lens. It is better that because you generating white light.

What happens what is the difference between focusing using a lens of long focal length and the lens of short focal length. Finally you focus and focal spot can be well your depending on what lambda is it best possible focus you get is lambda by 2. So if you use a long focal length and if you use a short focal length what is the difference? Let us say they are achromats. So one answer is chromatic aberration might depend on the focal length.

But let us say we are using achromats. Chromatic aberration does not even arise. So for long focal length the situation is something this it is called soft focusing. This is called hard focusing because it is not just the point of focus it is the volume of material though which the light is going through. If you do hard focusing then you put in more energy for the same length right. For white light generation or even second harmonic generation sometimes soft focusing is better.

You do not want to focus too hard. So this solid angle is important ok. That is why you want to use a L3 with long focal length right. So then what have we learn seen so far pump beam has been input most of it has been sent along path 2 which is going to be used for final amplification signal. Small amount of it has been transmitted and this well there is another beam splitter do not forget BS2. So far we have neglected the reflection of BS2.

But if you look at the light that is transmitted through BS2 that light is used to generate white light. It is a pump for white light generation ok. And we have discussed this path 3 thoroughly so far ok. M1 and M2 are of course a pair of mirror in fact mounted on a same platform and then there is RP1. What is RP1? Let see whether you can guess? It is a halfway plate RP means rotate polarization halfway plate.

Why do need a halfway plate? Because you want to restore the polarization the input polarization is horizontal ok input polarization for TOPAS is horizontal. For the next one next stage you need vertical polarization ok. So what this RP1 does is that it rotates the polarization to 90 degrees and each of this steps is important. Suppose by mistake you take out RP1 already you rotate RP1 so the polarization is not turned by 90 degrees. What will happen? You will not get the next stage amplification ok.

So we need to know every component alright so white light is generated ok. And what we have seen is L3 focuses into focuses this pump into the sapphire plate to get your this thing to get your white light. As you remember we talked about delay 2? The problem is that forgotten what the animation is so I am saying things before I show it you anyways. Do you remember what is delay 2? Delay 2 we said that this DP1 and DP2 that 2 plates tilt them a little bit and bring some delay.

Will that change be large or small? Naturally it is small that is why it is called delayed 2. So we are talked about delay 2 first not delay one. What is delay 1? This M1 and M2 are actually mounted on a translation stage and all these are motorized control by the computer. So you can move this M1 M2 forward or backward. So that should remind you of the retro-reflector that we use in femtosecond optical gating or pump probe for that matter right.

So it can be move forward or backward. So that is coarse right. So that is delay 1. So if you actually use TOPAS and if you try to control things by yourself then you will see that you can play around with delay 1 and you can play around with delay 2. The delay is this M1 M2 retro-reflector moving back and forth. Delay 2 is the plates tilting at some angle. So delay 1 and 2 are your so delay one is coarse delay, delay 2 is fine delay.

It is important to know this because I mean only after you have played around coarsely you want to touch trying delay right. I want to ask you the measure the length of this room what will you do? You will get a I want you to measure it to the nearest millimeter let say or even the nearest micron. So are you going to start using a Vernier caliper from this end to that end of the room no?

First you will measure with a tape right and the last bit you will perhaps measure with Vernier caliper. So it is important to not forget that delay 1 is the primary delay, coarse delay, delay 2 is the secondary delay fine delay. So we should not I mean we want to play with delay 2 only when we are close. Of course close to what that we have not said yet we will see ok. But delay 1 is the coarse delay that first has to be taken care of.

Alright now what have we done so far. We have said that we have generated white light where we have generated the white light at WLG which is a sapphire crystal right. I have not shown the white light passing the next picture animation but ok we will come back to that later. We have right now I am not showing you white light but you can guess where it will go. Where will the white light go? It will go straight and it will hit L4. What is the need of L4? It has to collimate right.

Finally you want collimated beams. With LC3 you have focus the pump beam right. So white the pump beam is going to diverge and the white light that you generate is also going to diverge. It is exactly the same as what you have been the pump probe set up ok. White light will also diverge so we have to capture it and make it collimated that is the roll of L4. We have certain things later on we will come back to it there is something more interesting later.

So see once again we are using a lens and we said it is ok to use lenses maybe 7 desirable. We will see why it is ok. Next let me show you the other path, path 4 what is path 4? PA1 pump beam. What is PA1? Power amplifier 1 or in other words the preamplifier. So of course where this BS2 we said 20% of the beam is a transmitted 80% naturally it is reflected right that is the beam that we use for the first stage amplification of signal.

So where will it go? It will go up M3 maybe I will show you M3, L5, M4, DM then goes through let us follow this path. Maybe I should have done it step by step anyway. So see 80% of this beam that is that impinges upon BS2 is reflected to M3 and this is path 4 PA1 pump beam goes straight then goes through a lens L5. What is the role of L5? Again collimation do not forget that this is also a diverging beam converging up to a point then diverging because you have used L3.

So L3 not only focuses the beam here it is also going to focus the beam somewhere here. So it is going to focus both the arms. So it is not enough to use a lens in the white light generation sight. You also have to use lens on the other side which is the pump for preamplifier. So that is L5 essentially it collimates the beam. Next the collimated beam goes and hits M4 from M4 it comes and hits DM1. What is DM1?

Nothing to do with the initials of our celebrated colleague DM here mean dichroic mirror. Dichroic mirror he is wondering who is this celebrated colleague is it is not so difficult figure ok. Dichroic mirror why do you need a dichroic mirror here? Because see white light will come from this side ok. That white light has to pass through at the same time you have to get this pump for the first stage amplification going in the same direction.

That is why you use a dichroic mirror that will reflect pump. What is pump? 800 nanometer ok and what is white light more or less ends by 800 nanometers. So this dichroic mirror is it going to be so dichroic mirror means essential filter right. Can you tell me will it be a long pass filter or short pass filter? It is reflecting 800 nanometer and it is transmitting say 400 to 800 nanometers. Well I have given you the answer. It is a short pass filter.

So dichroic mirror is essentially a short pass filter alright ok how far have we gone? So this is taking so much of time perhaps slide number 5 and we are in to the second module and we are about to break again ok. How far have we gone here? On one side we have generated white light on the other side we have generated pump that is going to selectively amplify one of the colors when is say one of the colors of course when is say one of the colors I mean modal color femtosecond pulses they have broad.

One of the colors from the white light it an next stage ok. I would have preferred to get this get it done in this stage in this module, but I do not want to rush. So we will take a break and come back we will finish this discussion in the next module.