Ultrafast Processes in Chemistry

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Module No # 08
Lecture No # 36
Regenerative Amplifier in our Lab

Alright with so much of discussion about the evolution of oscillator evolution of amplifier what has happen in the past? What has happened what is going to happen in the future? Let us now see what is happening in the present in our lab? So in this module which hopefully it is going to be shorter than usual we will talk about what is there in the lab in?

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Well inside this box this is the one box amplifier the name is Libra HE and is from coherent this is what we have in our lab it is input well we will talk about input later it is output is 4 milli joule pules 800 nanometer model wavelength at 1 kilo hertz. So this is literally a black box fortunately it is a black box whose lids you can take off. So it is not a black box figuratively.

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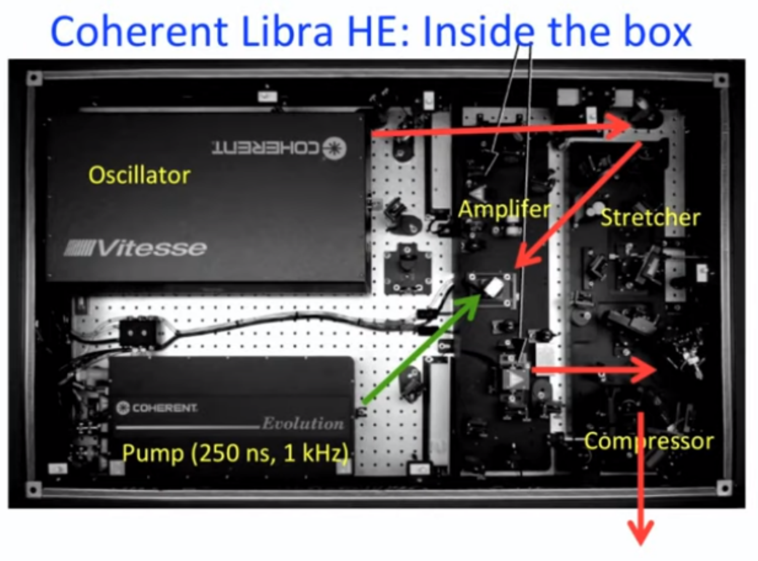

So if you take a lid off and look from the top this is what you see that the box actually contains more boxes. The first one is the oscillator in our case we have a Vitesse oscillator from coherent now this once again is a compact titanium sapphire oscillator. In this laser there are 2 parts this side the side where Vitesse is written that is where we have this diode pump solid state laser which pumps the Ti sapphire laser which is on this side and this is a very compact design very pretty much like the MaiTai laser from spectra physics that we had shown when we had visited our lab.

This one gives the 80 megahertz output at 800 nanometer and the pulse energy is nano joule right then this here is the amplifier. As you know the amplifier has to be pumped by another laser typically Nd:YAG or Nd:YLF laser with some 100 200 nanosecond full width of maximum this is what it is this I made a mistake here the pump laser is ND:YLF the name is evaluation from coherent but the full width half max is 150 nanosecond in this case not 250 nanosecond.

And this laser operates at 1 kilo hertz that is what it determines the repetition rate of the regenerative amplifier okay. And then we have also discussed that before the seed can go into the amplifier it must be streched the stretcher is here and the output of the regen is really a chirped pulse amplified but chirped pulse it has to be compressed this is where the compressor is. So it is really a very compact design and that is why in case the alignment goes wrong for some reason usually it if does not in case it goes wrong then to get the alignment back is not an easy task.

So schematically this is what happens the pump laser creates the excited state population in the titanium sapphire crystal inside the amplifier the output oscillator is stretched and the stretched seed pulse is fed into it into the titanium sapphire inside the regen output of regen goes into compressor and after compression we get the un-chirped narrow pulse that we want to work with. Now this is the schematic but what will try to do in the next 10 15 minutes or so is that we will try to get at least a rough idea about the light paths inside this system okay. The figures that I have used here are all taken from the user manual of Libra HE.

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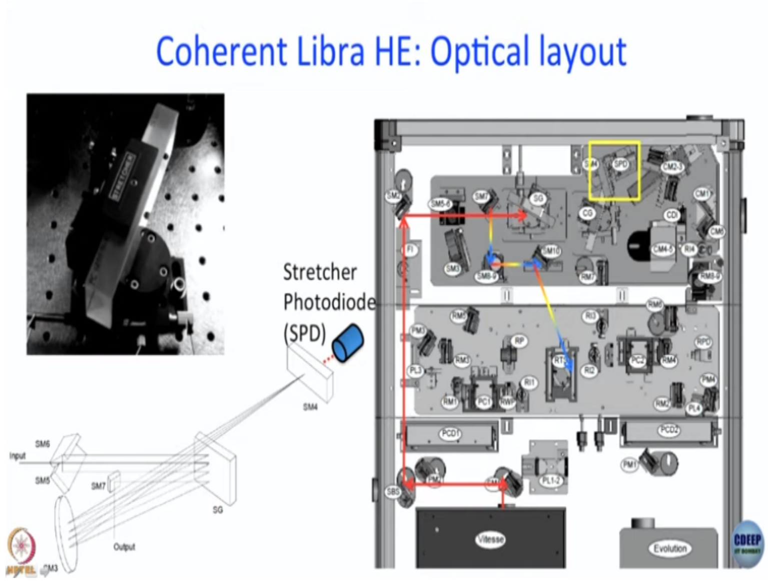

So this is another way of looking at it what you saw earlier was a photograph this is a schematic well this is what it is this is the first thing that happens was that too fast? Output of the Ti sapphire laser hits SM1 now here the naming is systematic SM means a mirror in the stretcher 1 means the mirror that comes first 2 means the mirrors comes afterwards so on and hence so forth. So as you see this one is SM1 this is SBS what could SBS be? It is a stretcher beam splitter in our case we do not really take the beam out but here in this laser there is an option small amount of the beam can actually come out of this port.

See you can take it out and use it for some other application the limitation is that you cannot tune it when it is inside when the oscillator is used along with the compressor when it is not a good idea to keep changing the wave length because there has to be an exact match between the seed and the light within the regen. So comes out hits SM1, SBS, SM2 and then goes to the stretcher grating like this okay. And this here what the grating is looks like alright.

Now what happens inside the grating we have discussed it already in a previous module so we will not repeat but one thing that we need is this is the input comes to the grating that is what we have shown here using the red light. Can you see what I have drawn can you see this lines can you see the red line? Okay so that red line comes in hit the grating then it hits this big circular concave mirrors several times SM3 post to SM4 does several round trips and finally from SM7 the output is obtained that chirped output okay.

Where is SM7 here do you see this is SM7 right so from SM7 but before that I want to say something what is this? SPD S for stretcher what is PD? No, PD polarizer would only a P in fact here is a P here see RP that is regen polarizer but this is SPD photo diode. As we have said earlier it is very important to time the event right so how will you time the events? The way it is done is by using different photo diodes in different places or by taking synchronic electrical outputs.

In this case what happens is there is photo diodes stretcher photo diodes SPD behind the stretcher mirror 4 okay. And even though this are high reflectors is there not really 100% reflectors even if 99% is reflectors and 1% gilts through that is enough for photodiode. So this photo diode captures the bleed through of SM4 and that output of the photodiode is used for timing the events alright.

Now let us come back to the light so we said that we were at SM7 from SM7 the chirped beam goes to SM8, SM9 it is basically a periscopic arrangement like this. Comes in here goes up and goes in this direction goes where to SM10 that is the last mirror in the stretcher. From SM10 where does it go now what should happen stretching is done right what was the red beam now is chirped where should it go now?

It should go into the regen how does it go into the regen you have seen so many designs now the first one that we discussed in lot of detail in one of the previous modules was one where the output of this stretcher went and hit the Ti sapphire crystal in the regen is not it and that being the brewster angle reflected it. So that is what happens here as well okay so regen goes and hits here can you read what is written here RTS what is that? Regen Ti sapphire T for titanium S for Sapphire R for regenerative amplifier.

And then of course you understand that it will reflected until go into the cavity fine but let us leave that for the moment I will show you how it goes into the cavity but before that let us first establish what the path of light is within the regen okay right. So as you understand the revolution is the laser that is pumped for the regen what do you have in front of it? This is a mirror right what you see here is a mirror photograph of which is taken from the top and we are not going to go to the lab and open up the amplifier because I am little scared to do that.

We do not do it unless it is absolutely necessary so this is what we want to do in detail so see this what is written here PM1 and now I think we have getting the hang of the nomenclature M would be mirror 1 would be number 1 first what is P? Pump that is very simple so there is pump mirror one the first mirror that the pump beam hits. After that it comes this wave actually do you see what this is PL12 so this is you can if required you can increase or decrease the size of the beam it is sort of like a telescope okay.

You take 2 lenses of different focal length okay and place them side by side so that they focal the focal points match what will happen you have this beam let us see this is where the focus is the beam gets focused and then it is captured by this lens here if the focal length of this second lens is smaller do you agree that the beam will go from a broader waist to smaller waist we must say like this it has been focused here and then it goes out like this now the cross sectional will be only this much is not it? So that is what is there L1 and 2 then it comes to PM2 then we have another one PL3 L is lens then PM3 let us go one by one.

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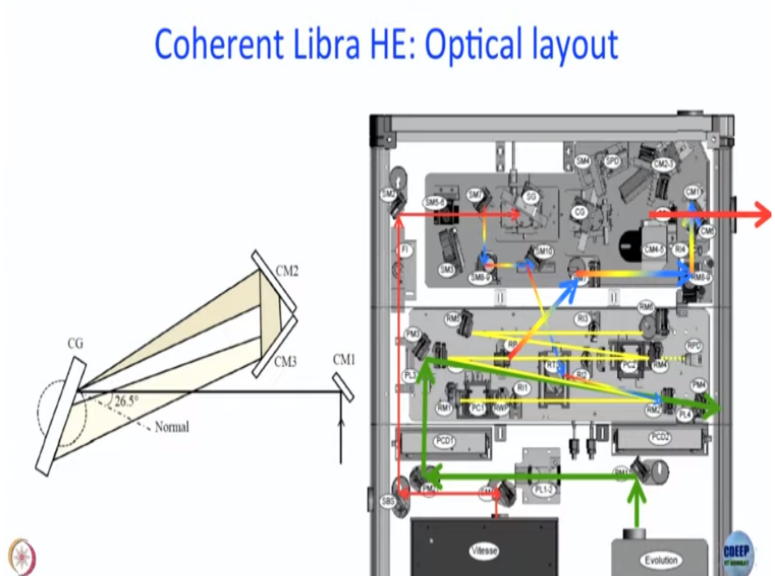

So PM1 first hit then it has gone to PM2 PM1 PM2 then from PM2 it goes through PL3 to PM3 from PM3 it goes straight through the Ti sapphire rod and while doing that it goes through one of these mirrors since it will covered I want you to read the name what is this? RM3 is a again dichroic mirror it allows green light to go through it going to reflect red light completely. So it goes straight okay then it is done so pumping of the regen is done.

Now let us see what the path of light from the regen well within the regen is we are not talking about the seed we are just talking about the regen as a self-standing laser okay what is the path this is a path. So CPM1 sorry RM1 what is RM1 this one what do you have after that PC1 what would PCB Pockel cell first pockel cell and here you have PC2 the second pockel cell and now we know why we have pockel cells in the cavity switch in and switch out.

This here is the pockel cell driver means the electronics that well okay tell the pockel cell to work or not to work basically gives the voltage to pockel cell okay that is of course not in the pockel cell driver cannot be in the path of the light it so pain okay. So from PM1 through the pockel cell and it did not read something here what is this what is that? Yes regen wave plate so you can turn the polarization as required.

So from RM1 it goes to RM2 from RM2 it goes to RM3 remember that was RM3 and when it goes through RM3 then RM2 to RM3 is though the Tisaf. So if you look carefully do you see the cross over between the green beam light and the yellow light because the pump cannot be co-axial with the cavity then it can be problem perhaps. So a little bit of angle is there so it crosses it goes to PM3 then from PM3 it goes to PM4 now what am I saying RM.

From RM3 regen R for regen P is for Pump from RM2 it goes to RM3 through the Ti sapphire crystal and by the way the Ti sapphire crystal is at an angle we will come to that later. Then from RM3 what is there after this what is RP? I told you regen polarizer so it goes through the regen polarizer through the pockel cell the second pockel cell to RM4 okay. From RM4 it goes to RM5 right so now it looks like W kind of thing so in the double U no the longer be double U is something more than double U, triple U, quadruple U something like that okay.

From RM5 it goes to RM6 and that is the end of the cavity regen cavity okay this is the cavity now defined RM1 to RM6 folded several times and the light passes through different optical elements it has to pursue the gain medium of course but it also passes through this pockel cell half wave plate polarizer okay and the polarizer that is there also at an angle that becomes important that little later. Now before going further now can you guess where the seed goes the seed has come from SM10 and it has hit the regen Ti sapphire crystal.

From there where will it go? To help you I can put it like this is how the Ti sapphire is and the seed come like this in which direction will it go definitely something like this. So what happens is this another lead through and this regen photo diode as well RPD so that is the most important thing that is what you see on the oscilloscope but now coming back to the original discussion. So this is where did you see the seed goes from Ti sapphire crystal to RM2 alright. And then here alignment becomes very important because the path from the Ti sapphire laser RTS to RM2 has to be exactly coincidental exactly the same as the path of the self-sustaining beam inside the laser.

Otherwise it will not be able to do the round trip are you clear so the self-sustained laser the yellow lines that we have drawn that sort of defines the path and your seed chirped seed must travel back and forth along that path that is how it does a round trips. So it is essentially the same thing that we had discussed earlier the same figure that is there in the laser spectroscopy book the difference is there for simplicity sake a straight cavity was shown here the cavity is folded because if you fold the cavity you save a lot of space are you clear any question can I go ahead great.

So one thing that I was taken a little unaware of because I forgot about is this through the RM4 mirror there is bleed means 0.5% 1% of light getting through the mirror that is enough it is captured by this RPD the photo diode inside the regen cavity and we see the output we are going to discuss what we see alright. Now it is doing round trips now you want to switch it out what how will you do it? Pockel cell 1 has switched it in and you know the sequence of even switched it in turned off whatever not turned off in this case.

Now if you want to switch it out then pockel cell 2 as to go on and then from where will it get reflected what is the polarizing optic after pockel cell 2. Look at the yellow line this is pockel cell 2 it comes here while coming back PC2 turned on or maybe while going PC2 gets turned on 45 degrees rotation coming back 45 degree rotation comes straight where regen polarizer. So this polarizer is actually at a 45 degree angle or well not 45 some angle polarizer is not like so this is the direction of the beam polarizer is not like this it is like this right.

So as long as the polarization of the light is such that it will go through there is no problem so it is like this. The moment you turn the polarization by 90 degrees it will now go off like this clear. So this is what happens from regen polarizer it goes to what is this called regen mirror 7 okay it is still called regen mirror it is not gone into the amplifier sorry compressor yet. Then it goes to regen mirror 8, 9 see what happens is the heights may not be matched the height at which the optics are well in stretcher and in the compressor and in the regen they might be different.

So when you want to change height I think now we are familiar with it we have to use something like a periscopic arrangement right. So it goes to these mirrors and then it hits CM1 what is CM1? Compressor mirror 1 now the compressor starts and we have already discussed what happens inside the compressor it gets compressed the amplifier chirped beam and it goes out in our case it goes out in this direction.

In some cases if you want the light to go out from here you need to have another mirror here this is CM6 we do not use CM6 it is not in place so CM6 is there then the light would go out in this direction it all depends on how you want your experiment to be okay? In our case it comes out of this port and that is your 1 kilo hertz amplified 4 milli joule un-chirped 70 femtosecond beam alright.

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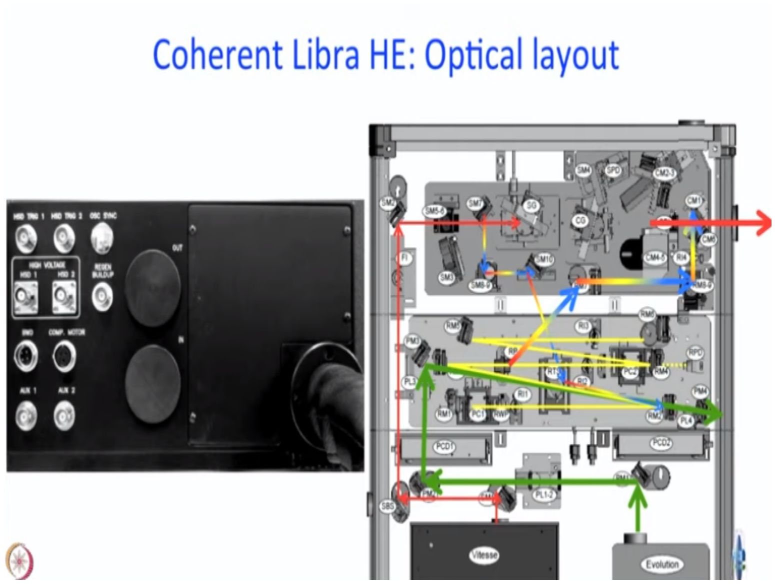

Now if you look at the so as we have said earlier also it is not just about light is got a lot to do with electronics time electronics to be more precise. And you have seen that we use photodiodes to monitor the beam in different places of this contraption right and outputs are all here okay. From here you have to use the signals appropriately to give delays that are required to sustain amplified operation.

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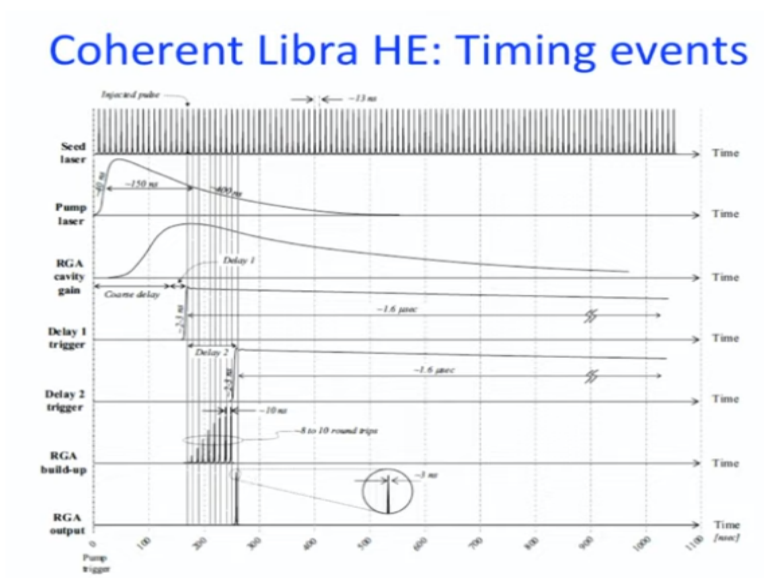

So we have discussed this once already but still let us look at the figure that is there in the user's manual. To start with can you read whatever is written here? I just copy paste it from the manual okay. So first of all you have something like that is looks like a comb right that is your output of the oscillator 80 megahertz so the pulses are very close. Next what happens is you pump the amplifier right this is the laser pulse of the pump laser 150 nanosecond.

So what you want to do really is that? You want to wait until this time because in this regen more or less the intensity of pump is same. In fact I will go 1 step further I will show you the gain as we discussed in one of the previous modules the gain trails a little bit tight and purse the little bit longer as well. See in this region it is not horizontal of course but the change in gain is not so much this is the regionn where you want to do the amplification this is the time regime in which you want to do amplification.

So what you do is you introduce this delay 1 look at the output of the laser you see this delay 1 delay 2 and all that this is delay 1 right. So now well we do not have to go into post delay fine delay all that this is where the amplification begins. So delay 1 is given to start amplification delay 2 is given to switch the pulse out right and then this is what we had discussed early do you see this is what you see on the oscilloscope do not you?

Buildup of the regen the seed wing amplified in the regen and then more or less near the maximum switch it out and then you do not see the remaining part. And this is the pulse that is switched in okay that concludes our discussion of oscillators and amplifiers it is been quite a long journey but I hope that now the black box is no longer so black to us at least it has become a grey box right. Still do not want to play around and change things inside but even then you operate unless we know what is the meaning what the meaning of this delay 1 delay 2 is we can make mistakes.

So it is important to know what is going on here so I will of course not for the remote audience but for in house people I recommend that you read the manual and follow up on this you do not have to read everything because you do not really do everything you do not install the grating and all everyday but you should know what is what you should know the sequence of events you should understand how it is working okay. We stop here today in the next module we hope to talk about the next step.

The amplifier gives you a single wavelength 800 nanometer in this case of course it is as it is own bandwidth where it is not tunable. If I want you in a variety then I want to use something called an optical parametric amplifier. The problem of discussing optical parametric amplification is that it is a non-linear optical process. So ideally we should talk about it only after we have performed a significant discussion of non-linear optics but there are 2 problems to that first of all I am not really a non-linear optic person secondly to do a thorough discussion non-linear optics that would require long time.

So we will see what we will do perhaps we will discuss non-linear optics without derivation only the functional part that we need and we will see whether we can go ahead and talk about optical parametric amplification as we will see a most of the time we want to do collinear amplification. But then in for some applications it is better to have a non-collinear amplification. So you do not want to use an OPA as such we want to use what is called as NOPA non-linear OPD.

So in the next 2 or 3 modules we hope that we are going to talk about OPA first with reference to the TOPAS system that we have in our lab and then what I really want to do is there is a this nice discussion of NOPA in review written by not a review they have built one and professor Umapathy in current science few years ago maybe we will try and discuss that okay so here we close the discussion on amplifiers.