Ultrafast Processes in Chemistry
Prof. Anindya Dutta
Department of Chemistry
Indian Institute of Technology – Bombay

Module No # 07
Lecture No # 35
Alexandrite and Fiber Lasers

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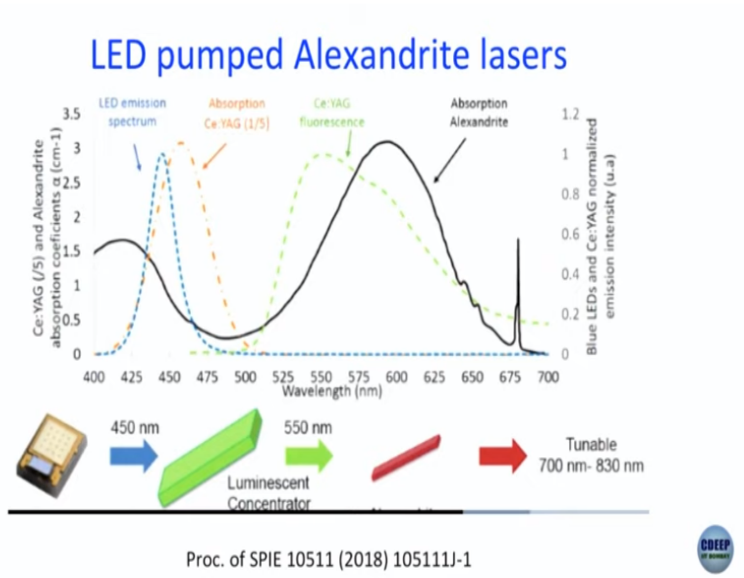

So in this hopefully short module we will talk about Alexandrite and fiber lasers so this is what we had discussed in the previous module we are introducing very new discovery, LED pumped Alexandrite lasers. And of course if you can pump with LEDs instead of diode pump solid state lasers that is beneficial in many ways including cost and ease of operation. So what we said is that we have this 450 nanometer emitting LEDs that are used to build luminescent concentrator. So let us before going further talk about what luminescent concentrators are?

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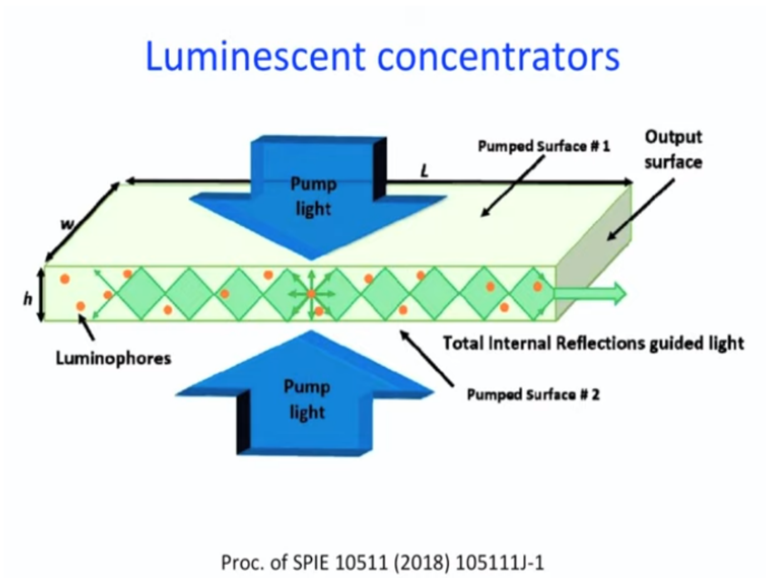

Once again this is not a very new idea this idea has been around for a long time and it is a popular research topics for materials chemist material scientist. The idea is this you have a solar cell okay in order to capture solar radiation what do you want? You want a large surface area is not it? But many times you also want to concentrate the solar cell you have captured if you think of more futuristic kind of applications we have a window right.

Let us say I want my window I have been windows in a house I want this windows to act as solar cells which means the sunlight that falls on windows I want to capture it and I want to utilize the energy how will you do it? In the conventional design of solar cells if you put panels then your window is going to become opaque right. So is that a way of having a transparent window perhaps maybe colored but transparent nevertheless but something that captures energy very efficient and that will be nice in another way as well the sunlight is completely absorbed and the energy send somewhere else then your room will remain cool okay.

That is the idea and that is what has been utilized here so the idea is this in case of solar concentration sunlight in case of the application we are talking about light from the LEDs come from this directions. So this is your concentrator so you place the LEDs here and that is where the several designs of LEDs I mean you are also seeing right Diwali is coming during Diwali people use this long screens of LEDs and all but you also at this square LEDs right

Square LEDs are convenient because if you take something like a slide let us see okay microscope slide you can place the LEDs 1 by the other right and completely cover the surface. So now imagine a situation where you have something like a glass slide well something like this on top you have LEDs facing downwards giving out light at the bottom we have LEDs facing upward. So from both sides the light from the LEDs fall on the substance of which block is slab is made off right.

Now in this slab what you have is, you have emitters which absorb the LED light and in the ideal case scenario with quantum efficiency of 1 quantum yield of 1 emits the light as well in whatever there emission ranges it okay. Then what will happen? Typically this medium in which the emitter are embedded that as a higher refractive index. So if higher refractive index is here lower refractive index here then what will happen?

Many times when light is emitted it is going to undergo total internal reflection right so that is what is shown here you see this squares what it means is at the junction you have an emitter or may here you have an emitter. Emitted lights hits this wall then here so it goes in a zigzag fashion until it can go out from the site understand what I am saying. So if total internal reflection is 100% this never 100% the design is very critical here but in this case any case you are covering the surfaces by LEDs.

So if no emitted light is allowed to go out from this direction and let us say in this side I have polished so it is act as mirror then what will happen? The only place from which the light can come out is this phase okay so you have directional emission is once again a very important topic of the research that as been going on for a last 7, 8 years. Lakowicz which among others has done a lot of work there in our own city in Bihar Sharmishta datta works in that direction okay have you understood what is going on here?

So this is the very efficient way of concentrating the light is being captured on this surface and that surface and it is again emitted from much smaller surface so naturally it gets concentrated right. So that is what is used to deliver a high dosage of light to anything that you keep on this side that thus this is how a concentrator works are we clear? And different people try different things organometallic complexes organic molecules nanoparticles that is these thing are different choices for the emitters and what is the substrate going to be that is another question.

Because ideally what you want is you want quantum efficiency of 1 the emitter should be such that it emits with quantum efficiency of 1 and also total internal reflection should be these thing like if only 10% like its total internal reflector then it is of no use okay this is how luminescent concentrator works. The reason why I wanted to digress and talk about that is that this is really an important topic of current research anyway not only for people working in optics but more so for chemist.

Most of the time chemist are working on it like this okay now let us come back so now you know what this is luminescent concentrator. Now where we let emit it will emit in the region where the active component Ce:YAG emits and that is this big fat emission spectrum as we have said in the last module this emission spectrum as very strong overlap with the absorption of Alexandrite. So if you place it correctly and we will see so how it is placed Alexandrite will you can transfer all this energy to Alexandrite.

And then the emission of Alexandrite is stimulated emission for Alexandrite is what is used to make the laser remember. The laser we are going to talk about right now is not a pulse laser CW laser.

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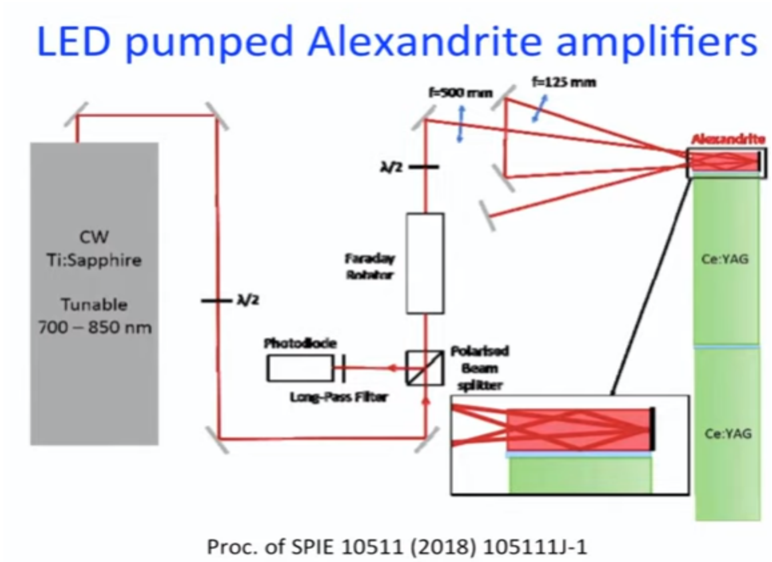

In fact this application that is shown in this diagram there this Alexandrite laser is used not as an oscillator but as an amplifier. And since it is a an early report the Ti sapphire laser that is used as an oscillator you can use Alexandrite as oscillator as well for sure it is there or it will come very soon. So you take the light out of this continuous wave Ti sapphire laser and then see this design maybe see this one at the bottom.

So this green thing is your luminescent concentrator okay I miss a little will all the light come out from one direction that is where the Alexandrite rod is placed it is a very beautiful design and the dimensions are such that the Alexandrite rod completely covers that end so whatever light comes out of this luminescent concentrator has to be used to pump that alexandrite crystal that is there Alexandrite rod that is there so that is really nice design.

Then it has been shown that it act as an oscillator of course but here it is acting as an amplifier what kind of amplifier? Multi-pass amplifier so you see this so light goes in reflected here comes here goes out and then it this a mirror gets send back this way it goes many passes until it goes out after amplification okay this system is not there in the market but maybe when you set up your independent labs you are going use things like this. And I hope you understand that this also would lead to a significant amount of miniaturization compression of size okay.

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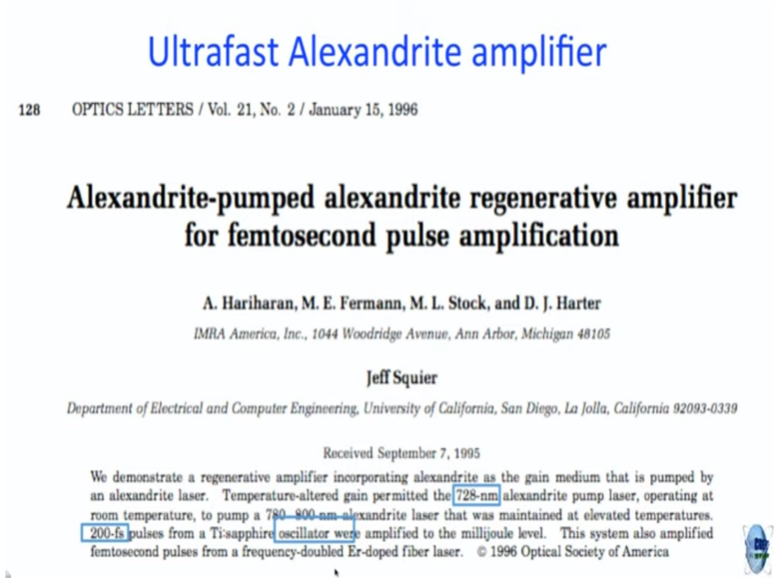

Now that being said let us not go home with impression that to cannot make ultrafast amplifiers with Alexandrite in fact you can and as early as 1996 there have been reports one again you see Squiers name here. Squier has done lot of work in this direction so there what they did is 200 femtosecond pulses from Ti sapphire oscillator that amplified to milli joule level okay and then did the last line if you can this system also amplified femtosecond pulses from a frequency doubled Erbium doped fiber laser. So that is the other kind of laser we want to talk about we will get that.

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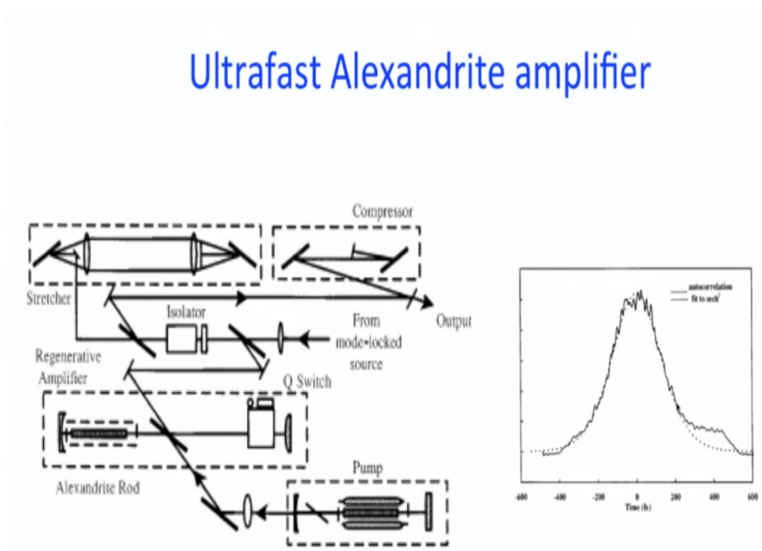

This is the design you have Ti sapphire laser as the source it is not even shown here you have a stretcher you have a compressor here optical isolator is separates the incoming and outgoing beam and here you see this pump laser is also Alexandrite diode pumped Alexandrite laser. So it is DPSS and the Alexandrite rod is used as the gain medium in the amplifier okay and here you can see the lot of auto correlation stress auto correlation trace and that is I think if I remember correctly 300 femtosecond or so okay.

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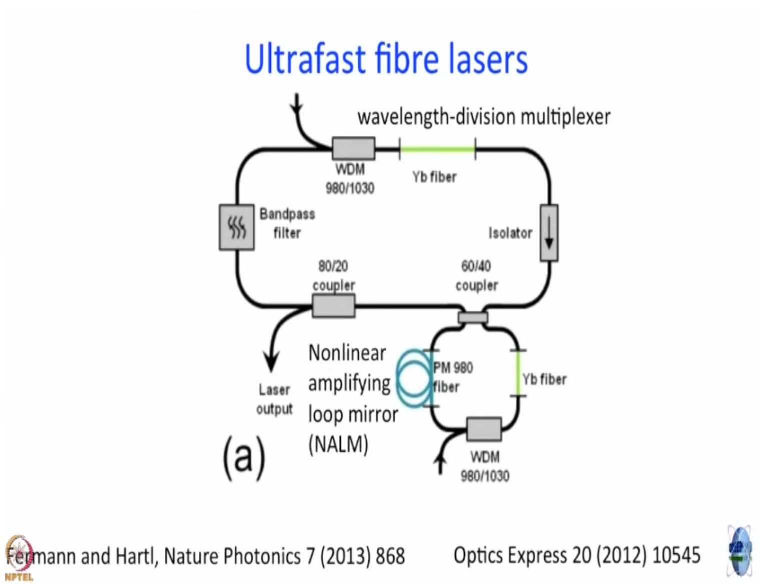

Now so that is what we wanted to say about Alexandrite another class of lasers which has actually been marketed for a significant amount of time now is ultrafast fiber lasers. You will not do a very thorough discussion but at least to get an idea about it you can read this review in nature photonics by Fermann and Hartl. You might have noticed that Fermann also feature in the 1996 paper on Alexandrite lasers. Now ultrafast fiber lasers are marketed by I think 40 companies now.

So it is not as uncommon as Alexandrite even a Alexandrite is not so uncommon but ultrafast fiber lasers are catching up bit time and one reason why you might want to use ultrafast fiber lasers is that it is first of all they are compact. You have a say 10 foot long fiber not 10 foot let us you have a 30 feet long fiber do you need a table that is 30 feet long to keep it right you can just quail it and keep it in a small box or even leave it on a table provided you do not people in the lab who are going to go and hit it with the hammer or something right.

That is why it is very simple and also in the last 20 years I would say it is connecting fiber's maintaining polarization fibers slicing fiber all this has become very easy. Now a days you can buy reasonably cheap accessories with which you can make all sorts of combinations of fibers. So ultrafast fiber lasers are actually coming up in a big way now in this laser you usually have 2 kinds of fiber's one is you need an optical medium for that you have a small stretch of fiber usually you can have the entire fiber like that does not matter but usually you have a small stretch of fiber that is doped with something like an lanthanide ion that is your gain medium.

And then you have polarization maintaining fiber that makes up the cavity okay I will show you 1 design there are many and this design is again from the 2012 paper and you will see the moment we go into fiber lasers our line of thinking is a continuation of what we have done so far for free space lasers but new things start coming in. So here in this figure itself do you see the active media do you see the gain medium you want in different color Yb fiber that is a gain medium doped fiber.

Rest of it is just simple polarization maintaining fiber so this fiber what is in 2 stages then you see where the difference comes first of all this gain medium fiber gain medium is pumped by 980 nanometer light and here you see there is a combination it is like railways tracks like one coming in and joining the other one. This coupler that brings in a different wave length of like is called as

WDM wavelength division multiplexer it can also be used to divide paths of 2 fiber of 2 kinds of light okay.

The pump light comes in and then pumps this fiber and initially you gets CW operation then isolator and all we do not want to talk about that. Here we see there is 60 40 coupler means 60% of light goes straight still CW 40% of the light enters this small loop what is there in the small loop it is sort of like it is amplification and this is not amplification maybe this is where mode locking takes place in the smaller loop.

Once again you have a pump 980 nanometer comes in and 1030 nanometer is the radiation the frequency of the well wavelength of the light that you get out from this layer again you have this Yb fiber it is pumped by this and then you get the output of this coming in here and in this loop you place mode locking element. The mode locking element that has been used here is called NALM non-linear amplifying loop mirror but I understand better right I do not know so much about fibers I understand better if I replace this by something like what we have discussed saturable absorption meter.

Remember saturable absorption meters was your bragg mirror where light goes in and comes out and when that happens mode locking is achieved because only light that is in phase survives everything else is eliminated and then we said that you put a quantum well in the in front you get a passive mode lock. So you can put in something like that so mode lock light comes and joins the loop here.

And here you have 80 20 coupler 20% goes out 80% goes back in the loop this way it is so you see the philosophy is the same but with some additional components okay. And there are other designs as well so this is more or less what fiber laser how a fiber laser works?

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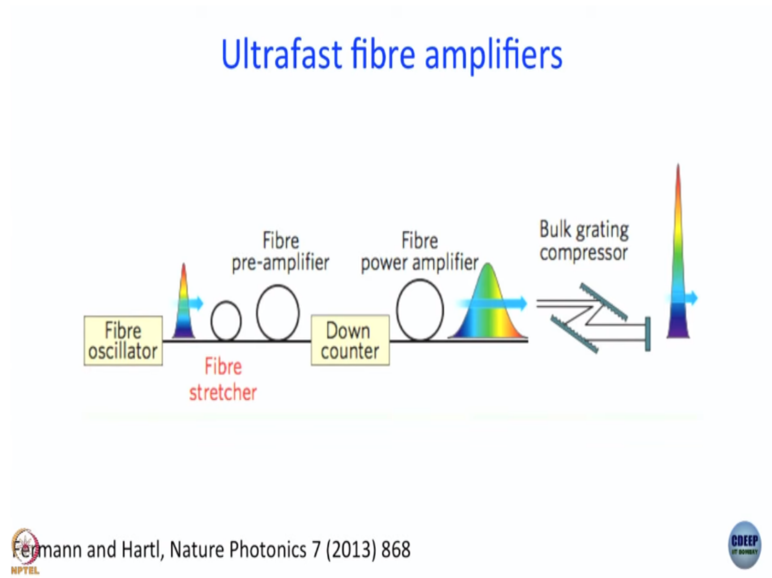

And then just to complete the discussion without going into too much of detail you can in principle make can amplifier out of it and in fact all fiber amplifiers are marketed already by several companies. Now one thing that is very much there is at generally these optical fibers with which cases have been made so far they all work very well in IR. Most of this fiber was made first of all for optical for this optical communication I remember sometime you do not have internet because somebody has hack the fiber underground.

So that is the telecommunication is why optical fiber become important so here also most of the laser have been built upon similar same fibers. So usually you get an IR laser and then it has to a sufficiently high power so that you can get second harmonic third harmonic forth harmonic to get visible light or if possible UV light. In this design that you are shown all this is fiber but then to get a short pulse you have to use a bulk grating compressor.

So do not think that we have achieved a situation where it can be fiber and nothing else it is there but if you want good performance many times it is a combination of optical fibers and more conventional component like gratings or prism pairs. So ultrafast fiber lasers are coming up big time and well companies market them of course I would like to see them replaced Ti sapphire completely that has not happened so far.

But if it happens as we have discussed already there are several advantages perhaps you do not even need a very clean lab. If optical fibers rule the roast one thing that I should say is this here there is an issue with using an optical fibers if you want to make an ultrafast laser can somebody tell me what it is? What do we have in the optical fiber? Is it free space then is solid right something like glass yes dispersion is very major problem.

So that is why you do not see a stretcher anywhere when you use an optical fiber your; the pulse is stretched anyway stretching is not a problem so you have to compress it compression is the more important thing that is why see for compression they have used A grating not so easy to do it otherwise. So it is on the face of it might seem to be a disadvantage because it get stressed but as we know. If you going to do chirped pulse amplification we have to stretch the pulse anyway.

So actually it turns to be not such a bad thing after all okay so what we have done in this module and the last one is a very preliminary discusson of ultrafast lasers in one case CW laser beyond Ti sapphire this is not even the beginning if you want to really learn about this systems there is no dearth of papers of dearth of manuals no dearth of materials on the web be my guest but purpose of the course is most of the discussion here and then we are going to next talk about what we have in our lab.