Ultrafast Processes in Chemistry
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Lecture No. 32
Pulse Stretcher/Compressor: Single Grating

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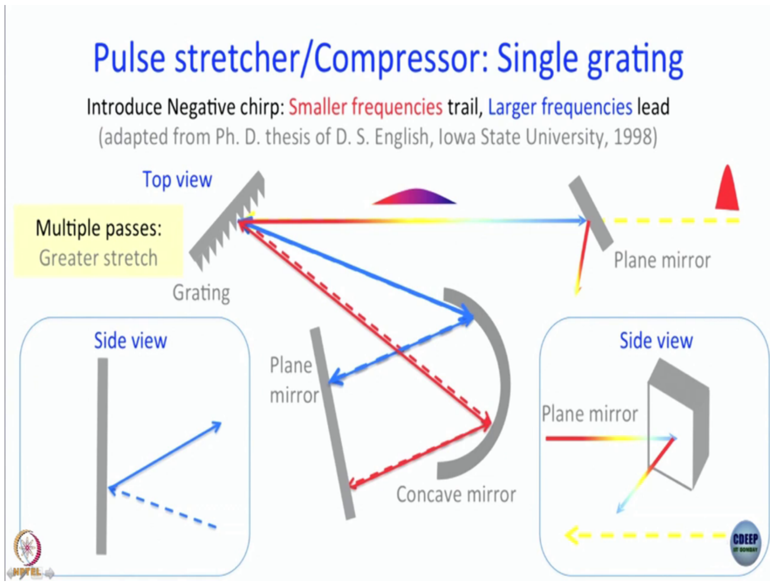

So, this is where we are stop our discussion, how do you stretch a pulse and so far we have discussed the simplest possible geometry using a single grating couple of plain mirrors and a concave mirror. And we had said that if you want a greater stretch a greater chirp, then you need multiple passes more often than not, as it discussed if you really want a 200 picosecond pulse the path difference would better be something like 6 centimeters. Either your stretcher will be very big, which you do not want or you have to do multiple passes by so that the effective path travel is much more.

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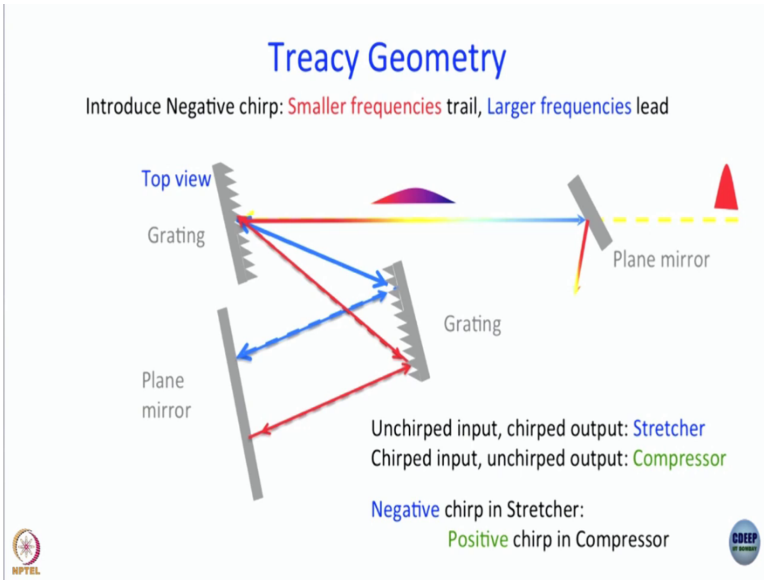

So, that leads us to a little more complicated geometries. This geometry is called Treacy Geometry, which I am not very sure what the correct pronunciation of Treacy is, but then let is just call it that so, here what you have is you do not have one grating rather you have 2 parallel gratings and I have not animated this slide, but you can see right it comes in similar kind of separation takes place.

And then it comes here comes in now the path has increased a little bit. And again, by Treacy geometry, you can make not only a pulse stretcher, but also pulse compressor. In fact, in the laser that I used as a poster, this was the geometry for the compressor. The earlier geometry was the one for a stretcher. Now more components you have in a system more parameters you have that you can control and get an accurate match but more complicated it also becomes.

Next, let us look at we already said this but let is say it again. So, if you put in an unchirped pulse, unchirped input in any of these geometries then you get a chirped output and you get a stretcher, put in a chirped input the output is, unchirped then you get a compressor provided it the chirped that was there in the original pulse is exactly compensated this perhaps eighth time have said it in the last module and the present one, but this is something that we should never forget.

So, if you were a negative chirped stretcher, generally you want to give a positive chirped compressor and vice versa. So, different people prefer different things some think it is better to a positive chirped in the stretcher, negative chirped in the stretcher, some feel it is the other way around. So it is completely dependent on what you want to do.

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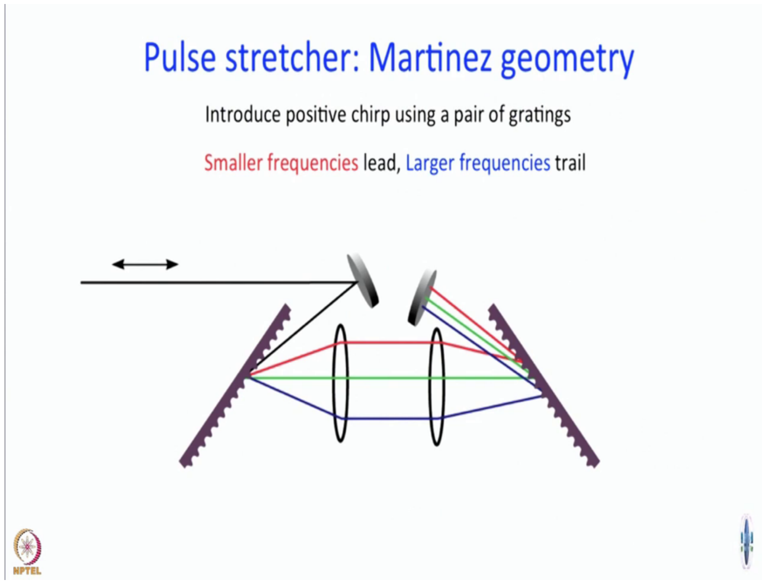

Next move on to another geometry, which is known to be quite a good one it is quite popular, it is called Martinez geometry. In martinez geometry once again you have 2 gratings but unlike in Treacy geometry, the gratings are not parallel. If you produce them, they would make an acute angle. And another thing that is very important is Martinez introduced telescope between the 2 gratings it is not as if this geometry is not used actually you get a good amount of stretching using this.

But can you tell me what could be a possible problem Martinez geometry? Using lenses. So you are making a short pulse travel through a lens. So that itself introduces some chirp. So the question is, are you using good lenses or not? If you use very good quality lenses in the telescope, then actually Martinez geometry works fine. But one needs to be careful about that it is not such a big problem, because in any case you want to stretch.

So, I am sure you did not want to use it in a compressor. But in a stretcher, this works and in fact, Martinez had shown that the efficiency of this geometry is quite good. And one difference between the earlier geometries that we had discussed and this one is that here in Martinez geometry, you end up introducing a positive chirp. The gratings are facing are almost acute angle. Next let us move on to something that is a little more complicated and this complicated arrangement is called an offner triplet.

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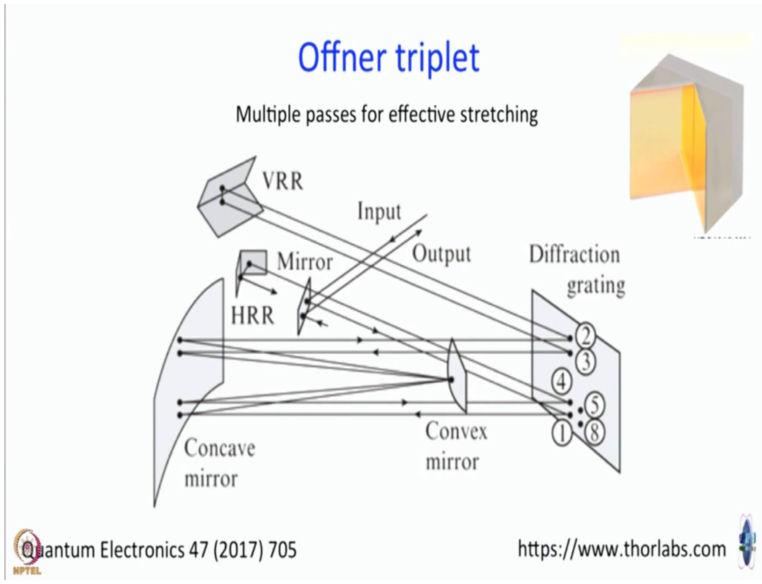

This is one slide that I should have animated, but it would have been too much of work as well. So, I did not so, let us see if you can understand what is going on here what do we have here, unlike the other geometries, this looks like a more complicated arrangement because first of all, you have a plane mirror. Then, you have a grating after the grating, your concave mirror followed by a convex mirror followed by HRR.

Does anybody know what HRR could mean? Well, there is a VRR. So H and V would mean horizontal and vertical respectively. These are called roof retro reflectors and this is what they look like. And usually these are very good because already the angle between the 2 reflecting planes is defined. So, you cannot really mess up things there it is we have something like this in the retro reflectors in our spectrometers, in our case we have 3 sides of a cube.

This is sort of a hollow cube and the coating can be different, it can be aluminum can be gold can be direct, it can be nothing. So depends on what you mean. So this is a horizontal roof reflectors and this is a vertical roof reflectors. So, what is happening the input comes hits this mirror and comes to the diffraction grating. This number one is the first part on the diffraction grating then where does it go?

It goes to the concave mirror from concave mirror to convex mirror from convex mirror back to concave mirror and from there it goes back to the diffraction grating once again to form point number 2. From here, the beam goes to a vertical retro reflector and of course, it is a vertical roof retro reflector and if it is a retroreflector, of course it has to send it back and good thing about the retroreflectors is that the incoming and outgoing waves are parallel to each other opposing directions but parallel.

So, it comes back and hits the defraction grating here at point number 3 go straight to the concave mirror from concave mirror to convex mirror then back to the concave mirror and back here in point number 4 from there it goes to the high reflectors horizontal retro reflector and then it goes out what is a need for such a complicated arrangement? Actually provided the answer already, in one of our earlier discussions, we have given you the answer what is the need of such a complicated arrangement.

Remember, we said that if you want a good amount of chirp to be introduced, then the path length would better be large here path length is large without the stretcher having to be too large, if you suppose you had only this mirror concave, this plane mirror concave mirror and grating you can understand path length would have been maybe 1 - 5th or 1 - 10th of what it is in this arrangement. So, this is basically a geometry in which a lot of passes are made.

So, that the effective path length is significantly large and you can get a good amount of chirp into this. And the reason why I give you trouble with this kind of complicated geometry is that in the laser that we use the stretcher is you can see a modification of this Offner triplet arrangement. Thankfully, it is not as complicated as what it is here but we will see what it is. But before going there, you must have noticed that we are listed references of papers there.

If you are interested to study more, all you have to do is go to these references and you will get leads to further detail about these things. And again, before moving on, I am sure you can understand how much of effort would go in to design something like this. It is not easily done. In earlier days, everybody worked with homemade lasers. Typically those lasers would be bulky. Even now for some applications you have to make your laser typically, the laser would be bulky.

Because it is difficult for us to do things that are very complicated and also did not want to do it because maintenance is an issue. But in commercial systems, the design is complicated. And nowadays at least up to this part, generally, nobody has to do anything themselves. But still it is important that you know, for all you know, somewhere sometime you might have to make your own apparatus where this understanding would come handy.

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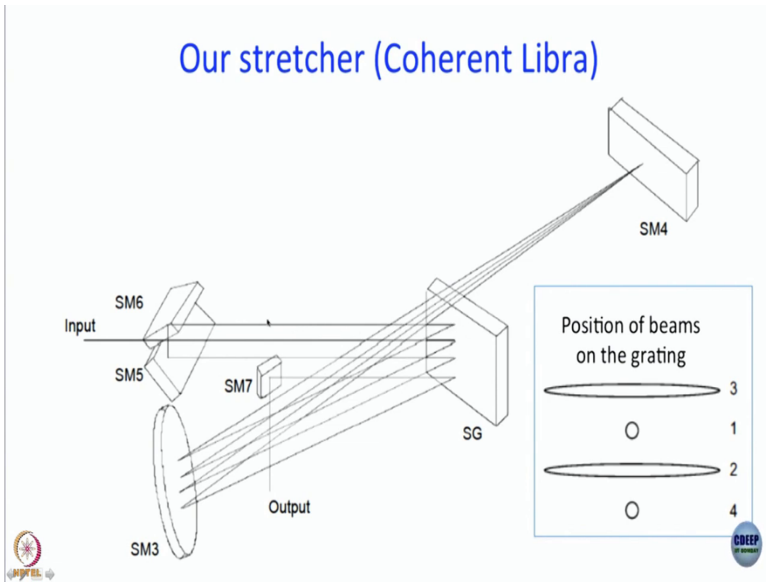

Okay with that we move on to the laser we have, a one box coherent Libra laser, Libra amplifier, we are going to talk more about the amplifier in one of the subsequent modules. But for now, let me just show you the ray diagram for a stretcher and you already see the complication. Look at the input. The trouble starts here the input goes through 2 mirrors that are like this, and this thing is important, if you ever have to align the laser yourself or if you ever have to even see whether the stretcher is working properly or not.

So, let us see what happens this here is the input comes through SM5, SM6, so in Libra User's Manual. SM means a mirror which is in the stretcher mirror. And the number would of course, indicate the sequence, so it goes through SFR it does not hit any and impinges on the grating, and it is a simple unchirped beam hitting the grating. So on the grating it looks like a spot a circular spot. We will come to this 2, 3, and 4 relative positions later.

So this is where it comes goes to SM3, which is a circular big mirror. From SM3 it goes to SM4 from SM4, it comes back to SM3 and hits the grating once again and in a correct alignment. If your alignment is perfect then this beam number 2 should hit the grating; lower than beam number one that is point number 1. point number 2 is so far it has done one hit on the grating so since it has hit the grating once it has been dispersed.

So beam number 2, which is directly below beam number 1. Spot number 2, let us say is no longer a circle you see a stripe a streak has somebody seen when this is opened up you are seeing. So this is actually a streak it is not a circle then, this is 1 this is 2 goes back here, back here then back to SM3 then it hits the grating above spot number 1 and it is still a streak. Then from here it goes to SM6 got it a little wrong.

1, 2 from SM2 it goes to SM5, SM6. Back to spot number 3 comes to SM3 goes to SM4 comes back and then when is the last time it hits the grating that disperson is gone? Because so many passes again well dipersion is still there, but you did not see a streak anymore. Once again you see a nice circular spot and that is what goes to SM7. And from there it moves out. So this is the stretcher we have in our laser where we have in our laser we will see in our amplifier.

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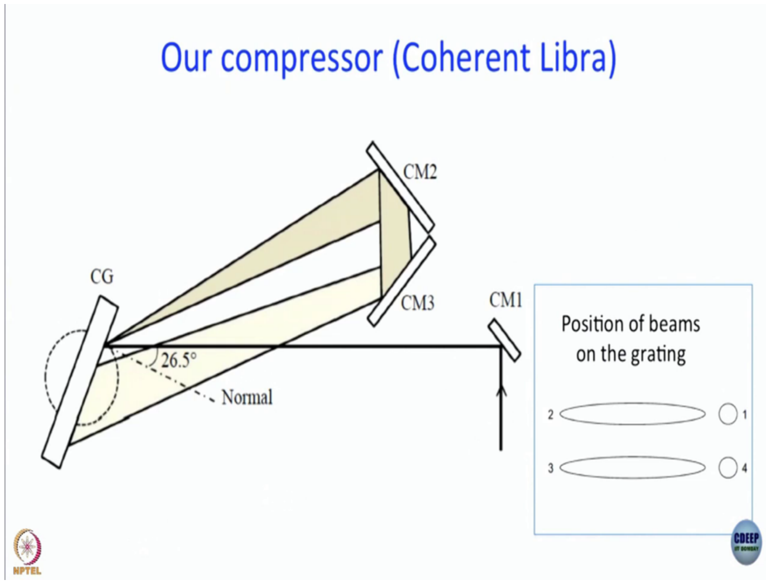

And this is the compressor once again the compressor has only one grating. Earlier I have shown you a design with 2 grating. But here since it is a one box laser everything has been made very compact. So, minimum number of optics has been used. So instead of putting another grating, what they have done is here it is perhaps not very clear about what happens here. But once again there are several passes and here you can see the relative positions of the beams 1, 2, 3 and 4, once again the first beam that goes in is circular second and third are streaks.

Fourth one is where this spatial dispersion is taken care of, but not spectral dispersion and that is beam number 4 which goes out, this is what we have. So, that almost concludes our discussion as stretcher and compresses, but then I might have given you the impression over the course of this discussion, that if you want to stretch a beam or if you want to compress a beam all that is there at your disposal is grating or prism. So, you will see in literature, designs using not gratings but prisms.

That is understandable. But that is not the only thing. In fact, what is whatever technology we have is moving towards miniaturization.

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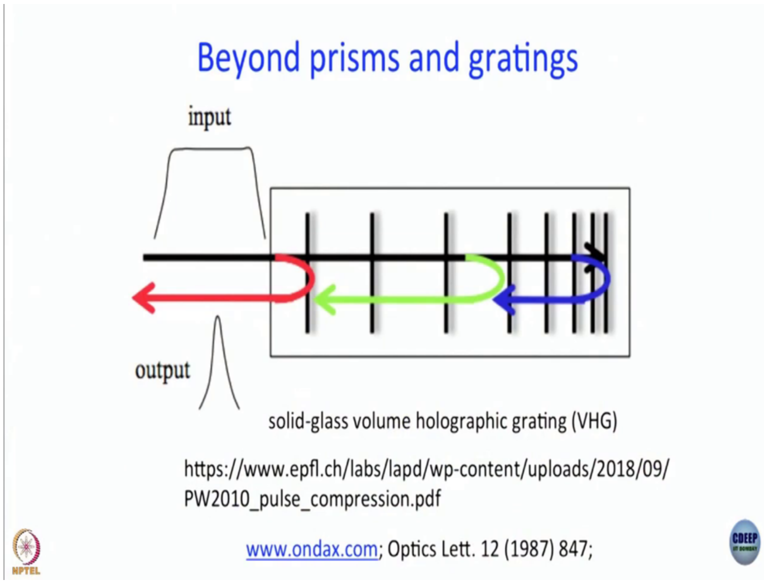

So I think the latest development in this field is something called VHG solid glass volume holographic grading. So you remember, we talked about the Bragg mirror. Bragg Mirror, where reflection is from different layers. Here also, what you have is so this is a very small device. And so far I did not know if anybody else does it there is this company called Ondax which has now been taken over by Coherent, Ondax markets this.

And the principle was no longer and in fact, when this was demonstrated long ago as well in 1987, optics lasers paper, but then now, this company has developed it and marketed as a product and it is very simple. What do you have is your optical fiber feeding the pulse into it and as what is that, what is it that we have to remember, if you are going to use optical fiber in an application like this, you better use a polarization maintaining fiber.

It is very important and in the next module we will see how we use polarization very effectively. So, typically what you have is you have this fiber going in, if it goes in through here, then there are since it is a holographic grating, there are several reflecting surfaces and different reflecting surfaces reflect different frequencies it is as simple as that. So, red gets diffracted first, followed by green followed by blue.

So, if your input was a broad pulse chirped pulse was provided, the chirp is such that the red trails and blue leads then this kind of an arrangement is going to give you compressed output. Otherwise, the sequence of reflecting mirrors has to be opposite. But the good thing here is that if you take a pair of these VHG stretcher and compressor all you have to do is put in the pulse the initial output of the oscillator unchirp pulse as you put it in here.

Let us say, then what will happen you will get a chirp pulse and you get a chirp pulse which red leads and blue follows in the compressor side, just turn it around let the beam going, from here and not from here. Then what will happen then it will get compensated. So, the same piece of optic can be used either as a stretcher or as a compressor. Depending on which is the input which is the output.

And I have not seen it, but from the pictures on the website and all it seems like something that is about this size. So, the stretcher that I used 20 years ago was about this size square. The stretcher we use now is about this maybe this and the one we are talking about here is this so, that is what advent of technology and miniaturization does, so much for pulse stretching and pulse compression. We are going to next discuss the actual amplification width of chirped pulse amplification method.