Ultrafast Optics and Spectroscopy
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Lecture - 21
Construction of Ultrafast Laser (Continued.)

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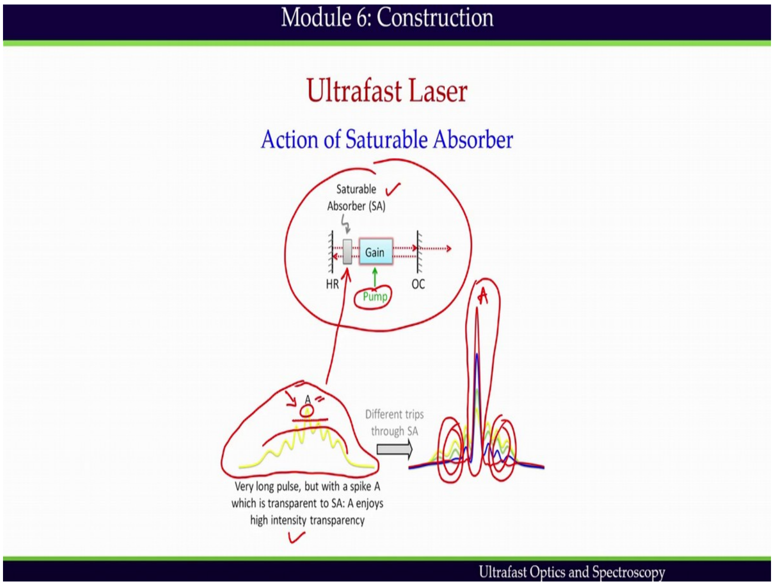

Saturable absorption is a property of any material where the absorption of light decreases saturates with increasing light intensity or in other words transmission of light increases with increasing intensity of light passing through it. At sufficiently high intensity of the input beam ground step population is depleted completely and therefore, absorption saturates and the material becomes transparent at high intensity.

It is called intensity dependent transparency. Most materials exhibit some saturable absorption, but only at very high optical intensities. Saturable absorber can distinguish a weak and a strong spike in a long pulse. Let say this is my cavity the gain medium and pumping to create inversion population inversion and then I am undergoing stimulated emission in the medium.

And at some point of time I have been able to get a very long pulse with this many spikes. What will happen the moment I have created this long pulse presence of this saturable absorber in the cavity it will distinguish the weak spikes and a strong spike. Due to it is intensity dependent transparency it will transmit a strong spike and absorb a weak one. In laser cavity a long pulse can be generated with weak and strong spikes when modes are not really in phase.

Therefore, saturable absorber can select strong spike by transmitting them. If a saturable absorber is placed in the laser cavity it will transmit only those modes which are in phase and responsible for creation of the strong spike A. All other modes which are not in phase are suppressed because they are creating their contributing to these weak spikes this idea is shown here. In the first round trip creates the laser cavity creates a broad pulse with many spikes the one which is shown here.

And in the next trip because the spike having intensity higher than a threshold value above this threshold value only saturable absorber will start working, will start transmitting the beam. That is why this portion of the beam this portion of the pulse will be transmitted and the moment it is transmitted it will be intensified in the second round trip by another stimulated emission and gradually this portion of the pulse will be suppressed. The saturable absorber acts like a in phase mode selector the saturable absorber acts like an in phase mode selector which helps long term modes in the laser cavity.

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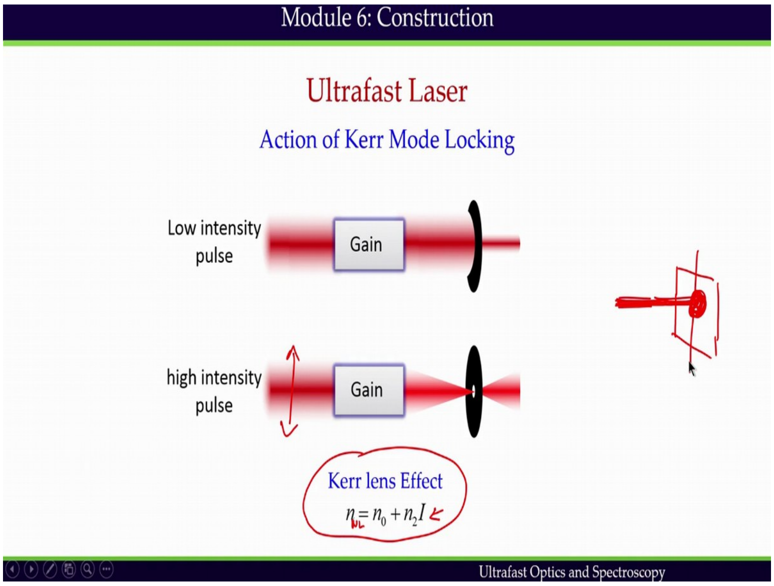

Similar to saturable absorber in which absorption varies with intensity mode locking can also be achieved using Kerr effect in which medium refractive index varies with intensity. We have already studied optical Kerr effect which shows that refractive index that is non-linear refractive index depends on the intensity profile.

And we know that due to tm mode intensity as Kerr effect may arise in the laser can medium itself additional optical element like saturable absorber is not required for mode locking and this is why mode locking this kind of mode locking is called self mode locking. Self mode locking mechanism is very easy to obtain and frequently used for building ultrafast laser oscillator. In this case the laser gain medium not only lasers, but also locks the mode by Kerr effect.

So, what does it do? According to Kerr effect the refractive index of a medium varies with intensity and that is why the medium does not feel a homogenous refractive index as it passes through as the beam passes through the medium. That is why a beam a Gaussian beam does not feel a homogenous refractive index as it passes through the medium.

Because it is intensity varies along the perpendicular axis of the propagation direction. So, this intensity variation is shown here it can be varied like this way I have a beam proper gain along this way. So, if I place one piece of paper then intensity will vary along this way.

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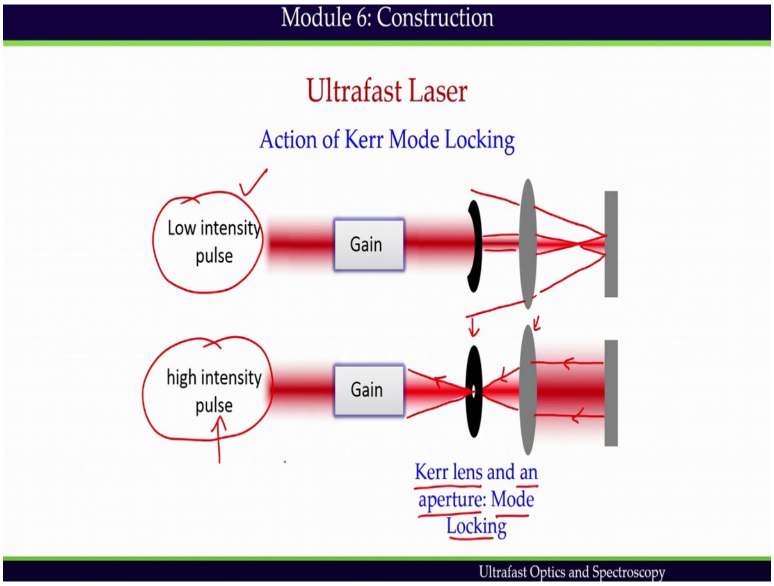

Now, Kerr effects become prominent for modes which are in phase due to the resultant high intensity. If I have in phase frequency components they will produce higher intensity and that can be focused due to optical Kerr effect and if we use an aperture and a lens then what might happen if we compare low intensity pulse and high intensity pulses.

Then this focusing occurs because of the optical Kerr effect. This is present only for high intensity pulses high intensity pulses are created by those modes which are in phase. And then after passing through this aperture it will be it will make a parallel beam it will come back again along the same direction and it will be sustained in the cavity.

But think of low intensity pulse where frequency components are not locked, their modes are not locked and that is why we do not see this lensing effect in the end this lens will focus the beam here. And slowly after the reflection it will start diverging the beam when it will start diverging the beam it will go out of the cavity. So, this arrangement this Kerr lens and an aperture can lock the modes which are in phase by selecting them or allowing them to sustain in the cavity. Is mode locking enough to generate ultrafast pulse?

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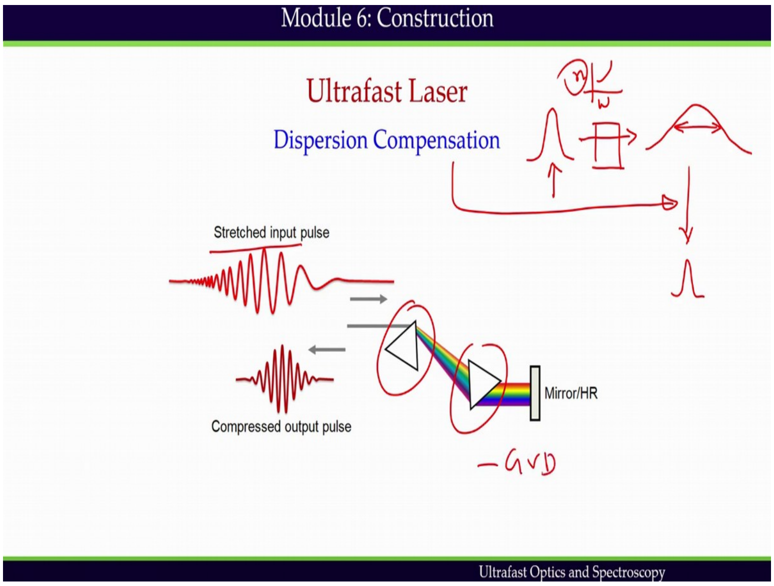

So, the first thing we will we have to learn here is that we need many frequency components. Then we have to learn that all frequency component will not sustain in the cavity there are some frequency components which will sustain in the cavity and those frequency components are called longitudinal modes. But in spite of having many longitudinal modes we need mode locking technique to produce an ultrafast pulse and the last component which we need is the dispersion compensation.

Previously we have mentioned that when a pulse even if I have a short pulse, but when it is propagates through a medium every medium is dispersive. That means refractive index changes as a function of increases as a function of frequency. So, all the frequency components which has constructed this pulse will experienced different refractive index different velocity that is why they will be stressed and the moment we have stressed it I need to have in order to produce a short pulse I need to have a mechanism.

And that is called dispersion compensation to create the short pulse to get the recompress the brought pulse again to the short pulse. And we have seen that angular dispersion is very useful given by prism. So, this is the pair prism we have used we can use to compress a stretched pulse by introducing negative GVD.

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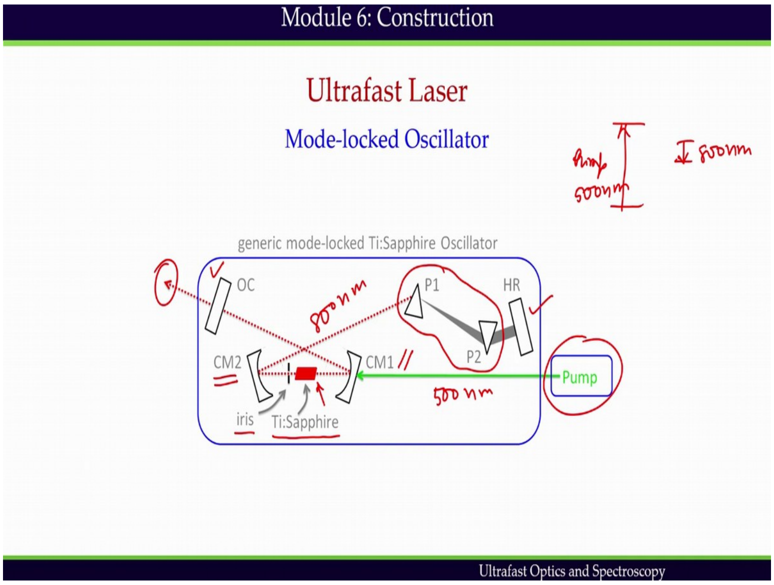

So, we are done now we have all the optical elements which we need to construct an ultrafast laser. We have this gain medium Ti sapphire gain medium, we have optical cavity composed of these two mirrors CM 1 and CM 2 and we have output coupler less than 100 percent reflectivity, this is the output of the beam.

Dispersion compensator composed of two prisms and high reflector which is giving 100 percent reflectivity and mode locking element which is which includes iris and Ti sapphire. It is self mode locking and a pump source this kind of laser system is called oscillator, Ti sapphire crystal is pumped by the output of the continuous wave argon laser or direct pump frequency doubled yoke laser.

The CW light is focused into the Ti sapphire crystal collinear with the laser cavity itself. CM 1 is the dichoric mirror which is transparent at 500 nano-meters and reflects the emission wavelength of Ti sapphire which is 800 nano-meters. So, within this cavity we have 800 nano meter and pump is 500 nano meter that we can understand from four level system.

We have pump which is 500 nano meter higher frequency and stimulated emission will occur at lower frequency which is 800 nano meter. Mode locking here is achieved through the optical Kerr effect is called self mode locking. The generated 800 nanometer light passes through a prism pair and gets reflected by the end mirror then returns along the same path. So, that it can pass out of the cavity through the output coupler two prisms P 1 and P 2 compensate for the dispersion of the group velocity inside the cavity.

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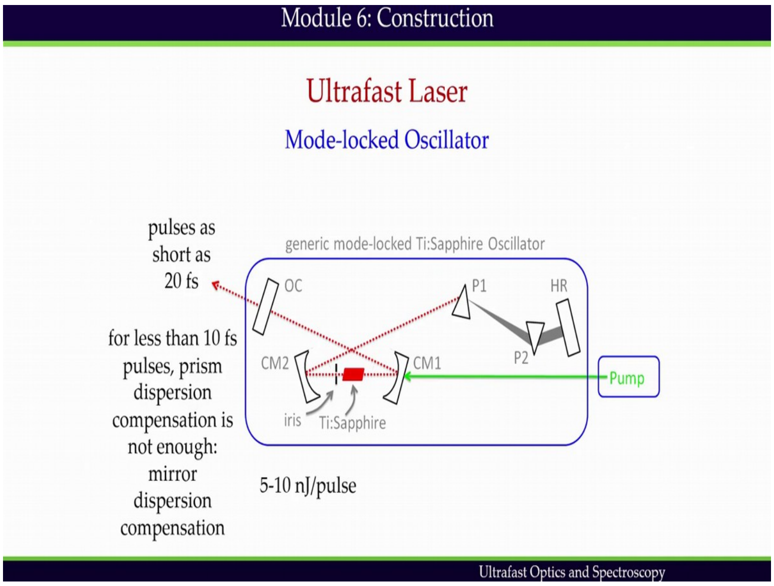

Employing self mode lock tisapphire laser oscillator as depicted here one can generate pulses as short as 20 femtosecond with excellent stability. To generate pulses less than 10 femtosecond duration the prism dispersion compensation is not enough in that case mirror dispersion compensation is an is efficient way to generate ultrafast pulses as short as less than 7 femtosecond. Typical output energy of the mode lock oscillator is 5 to 10 nano Joule per pulse.

In many applications of ultrafast laser spectroscopy this energy may be enough, but what about if we need more energy then we have to amplify it. We will stop here and we will meet again for the same module.