Laser: Fundamentals and Applications
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Lecture - 19
Passive Q-switching, Mode-Locking

Welcome back. So, we were discussing about the you know Q switching phenomena particularly we were discussing about how we can use a pockel cell and form a q switch. So, let us start from the place, where we stopped last time.

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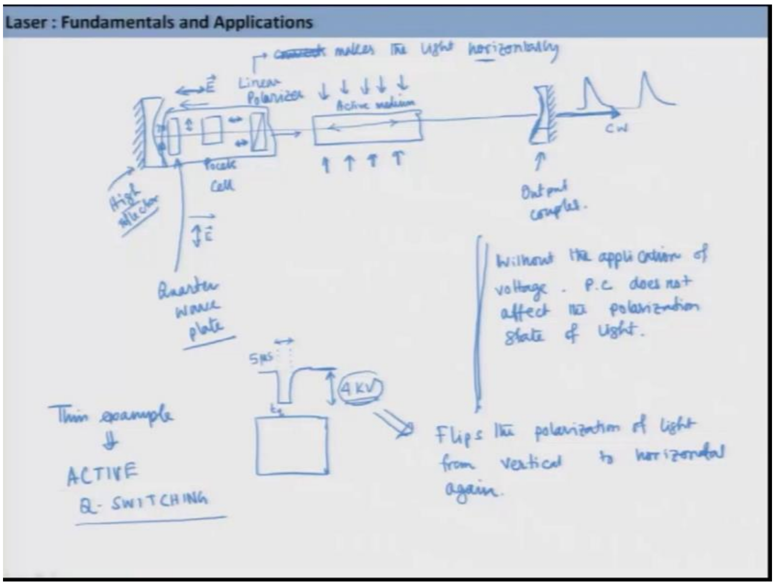

So we said that we applied 4 k V voltage for very short duration time that is 5 microsecond, and this particular amount of voltage, you know it causes what it does it flips the polarization of light from vertical to horizontal again. I said again why because it was initially horizontal. So, here this is horizontal and it goes through this one this is circularly polarized light and this is another circularly polarized light is coming through and then when it passes through this one, this becomes vertical and this guy over here when I applied this amount of voltage it rotates plane of the polarization by 90 degree again, and this becomes again this. So, it allows and this is possible only when I apply the voltage by a particular amount which in this particular case I am telling 4 kilo volt. And this number that I am taking is generally used in nd yag laser, which is q switch nd yag laser this is just for your information all right.

So, now in this case I will allow the beam now to pass through the active medium again and I will depopulate the you know active medium totally to get output; and my time period for which this pockel cell is you know on. So, when I say pockel cell is on; that means, essentially I have low loss. So, at that you know condition I will have round trips taking place and a huge number of photon will start coming out from this output coupler, and how will it look like? So, at this time, this is say when that q switch is being started. So, t q said 0 time. So, I will get like this, and as time will pass by. So, more and four photon will go, because more and more depopulation will take place. So, after sometime there will be no more photons in the excited state. So, there will be no more light coming out. So, it will casually decay like this ok.

So, again the same thing will happen and I will get another pulse. So, it will form a pulse train. So, the repetition rate will depend on few things. So, first I know that in case of Q switching I need to allow the population inversion to take place, while there is no photon in the cavity. Now if I use a flash lamp to create the population inversion, then it will depend a lot on the flash lamp and normally in nd yag laser since I was talking about certain parameters for nd yag laser only.

So, for an nd yag laser it takes for the flash lamp to you know create a sufficient population inversion, it takes almost two hundred microsecond for the flash lamp. So, after 200 microsecond I can turn on the q switch, and then allow it to be on for 5 microsecond and then again closes and you know wait for you know 200 microsecond and in that way. So, I can get ultimately a very you know large amount of photons as a pulsed and one this is very important here that this this switch that we are using which consist of this 3 optic pockel cell linear polarizer and quarter wave plate.

So, this be synchronized with the flash lamp. So, then only we can get a proper pulsed output from the laser having high energy. So, this in this particular case what we are doing, we are actively modulating the quality of the cavity controlling quality of the cavity getting pulsed output. So, this q switch is actually being modulated by us from outside; without us manipulating it, it is not going to give me desired output correct. So, this particular type of Q switching is known as active q switching. So, this example talks about active Q switching and for that matter the previous one that we talked about which is using rotating mirror that one will also an active q switching. So, the moment I am talking about active Q switching there is a possibility that there is a passive mode passive q switching. So, actually there is a technique called passive q switching. So, let us have look at that.

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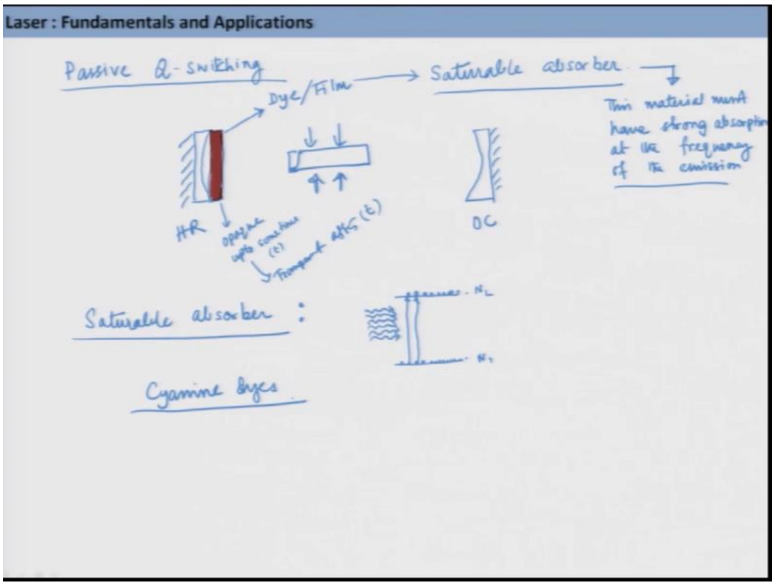

So passive Q switching which means that this principle will remain same, what we are going to do? We are going to create a switch which does not need us once you place it, it can work on his own that is what a passive Q switching means and the same thing will be applied when we will talking about other type of pulsing techniques that is mode locking. So, there also we will have active and passive mode locking. So, what is done in case of passive q switching? So, this one is probably the simplest arrangement.

So, you take one as high reflector and then output coupler active medium do not worry but these things anymore then what you do? You put material right here. So, this can be just a solution fill in a you know transparent container. So, so this one is it can be anything it can be a dye, it can be some you know film so, but it should have certain properties. So, what are the properties? So, that you know if this particular material should be saturable absorber. So, this dye must be a saturable absorber. So, the immediate question is what is a saturable absorber let me tell you briefly. So, saturable absorber. So, you are all familiar with the term saturation. So, now, I have no problem in describing this one.

So, this is a kind of material where if you keep on increasing the intensity of light falling on it, then after some time it will saturate so, that means, it cannot absorb any further. So, you can imagine this like a condition like if you have say this two state and then there are several molecules here this is very strongly absorbing sample. So, one particular criteria for this particular material here is that, it must absorb the particular wavelength that is being emitted by our active medium. So, this is one very important aspect without this this will not work. So, this material must have strong absorption at the frequency or wavelength of the emission, this emission is the emission which ultimately creates the laser.

So, what will happen? So, the moment I put light this dye will go here, it will be here now if more and more photon comes so; that means, it will create more and more populations. So, the moment there are huge amount of light coming in then it will highly populate. So, let us look at this situation, I excide the active medium is in my pump it will create population inversion, and it will have some spontaneous emission and because of the spontaneous emission there will be some stimulated emission. So, along with spontaneous emission this stimulated emission will also go in different direction. So, there will be light coming toward this material correct toward my saturable absorber; which absorbs that particular light be the spontaneous emission or to stimulated emission both have the same frequency.

Now, at the beginning when you know start pumping, numbers of photons are as I give some more time more population inversion is created, more number of photons coming and heating this absorber. So, after sometime there are so much of population inversion created that the amount of spontaneous emission is sufficient to saturate the level; that means, the population of these two states are now equal. So, into an n 1 they are equal the moment they are equal then the rate of absorption and emission same there correct. So, the probability of transition forward transition or upward transition or downward transition they are same. So, essentially what will happen at that condition of saturation, if I send in light will just simply pass through before that light is getting absorbed; that means, this particular dye is essentially opaque; up to sometime t say up to t. After this time t I will have enough photons that can actually make this satural absorption or turn this absorption transparent after time t.

So, before this time t my cavity was losing; because this saturable absorber it was not allowing the light to heat the high reflector. After time t now this guy is allowing the light to go and heat the high reflector and also coming back. So, this is what we want.

We first created loss and now all on a sudden we open the gate. So, light can travels through the active medium back and forth between h r and output coupler. So, I generate gain and I get light output till the time population inversion existed. Once all the molecules are depopulated again like in the previous case, it will repeat the whole you know absorption thing again, and again it will open up at a certain time. So, this is very similar to the previous to you know pulse Q switching method that we discussed ok.

So, here this dye which is a saturable absorber is acting just like a switch, and it is switching the quality of the cavity from low quality to high quality, depending on the number of photon or the intensity of light that is heating it. And the intensity of light that it heating this saturable absorber, it depends on the time because time is needed to create large population inversion and therefore, large amount of photons in terms of mostly spontaneous emission coming and heating this absorber.

So, this mode of Q switching is known as is a passive Q switching why because we are not doing anything we all we are doing we are taking this dye if we are talking about dye or whatever the material is, we are putting in front of this high reflector and then we are just watching from outside we are not doing anything we do not have to modulate anything. So, this is kind of self-modulate. So, this is what is passive q switching. So, there are you know several different types of a saturable absorber. So, I will name one essentially this is some kind of cyanine dyes, which are you know very routinely used to create this Q switching passive Q switching because they can act like a saturable absorber alright. So, I think this is pretty much about the Q switching part, I tried to be as elaborate as possible you know so that you understand this concept very clearly.

Now, before I move over to the next topic I will retreat another important point, that the cavity dumping and Q switching both of them are pulsing technique and both of them can give decent high energy pulsed output of similar kind of time skill. So, in the case of nanosecond, in case of cavity dumping there are certain advantages that it can still give you know nanosecond pulses, even when the repetition rate is very high which is little difficult for the Q switching is quite easy to understand, if you think about it you need to give quite a bit of time to the active medium so that the population inversion is created. So, just 5 minutes back I talked about active q switching, there I said like it takes 200 microseconds for the flash lamp to built enough population. So, that is quite you know large time, and then it will you know it will q switch will work and it will form the pulse.

Now, many times people get confused with the concept of cavity dumping and q switching, because at the end you will fill like both of them are you know emptying the cavity at some point of time, and after that you know once all the lights are out as a pulse there is nothing inside the cavity.

Then what is the essential difference I am sure that by now you have understood what is a difference still I will say it again in case of cavity dumping, you do not block the oscillation within the cavity round trips are always going on you are storing the energy inside the cavity. And at the end you are dumping all the energy out this is cavity dumping. Contrastingly in case of Q switching you block the oscillation, you do not allow the cavity to function as a resonator it is not working as a optical resonator because the you know high reflector part of the cavity, is nonfunctional there because light is not reaching there you are blocking it somehow.

So, the moment you are blocking you are you know actually adding to the loss of the cavity. So, there is no photon build up within the cavity, but you know photon is actually doing its job in form of pump photon and creating population inversion. So, energy is getting store in the active medium in cavity dumping energy store, in the cavity in Q switching the you know energy storing the active medium and once you remove the source of loss. So, you switch from lossy to a gains mode you allow the you know excited states to depopulate getting a pulse output. So, there is clear cut difference between cavity dumping and Q switching in the way we you know this two processes are defined.

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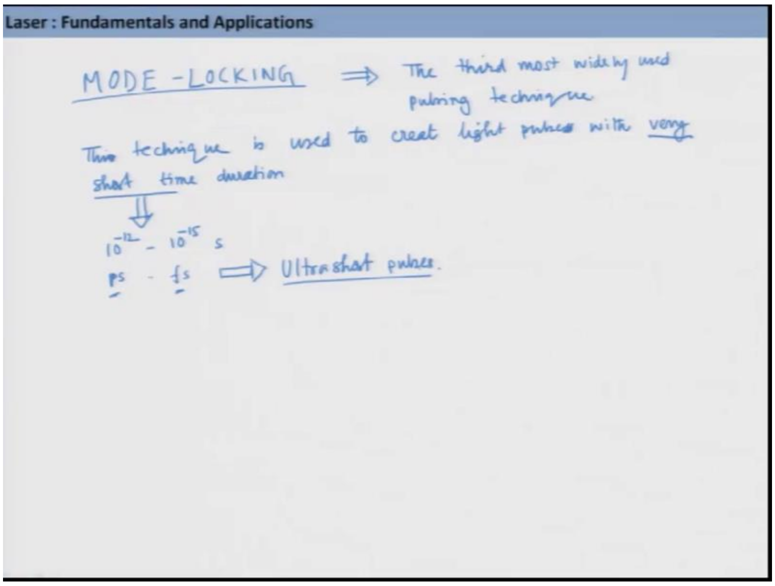

So, now, we will talk about the other technique that is used to create pulsed output. So, yes we are talking about mode locking. So, this cavity dumping and Q switching are the you know mostly used pulsing technique and the third most widely used technique is mode locking. So, this is the third most pulsing technique. So, why do I need another technique we already have to and within those two we have active we have passive different modes of pulsing techniques. Now this particular mode of this particular way of forming laser pulses is needed, because this technique can give raise to really, really small time duration pulse. So, mode locking this technique is used to create light pulses with very short time duration.

So, when say very short how much it is. So, very short it can be typically in the order of 10 per minus 12 to even 10 per minus 15 second; that means, from picosecond to femtosecond. So, these are really short and these are known as Ultrashort pulses. Now the question is why do we need ultrashort pulses, why do we use ultrashort pulses. So, the you know this ultrashort pulses find you know there application mostly in chemistry and biology and in certain cases some physics problems. So, in case of chemistry you have chemical reactions that can take place in a very short time scale which is in the order of say picosecond or femtosecond a breaking of a bond. So, if I need to know how a bond is being broken, what is the dynamics of this bond breaking? I need to have you know just like you know any camera speed here if I can you know shine light with very short time period; I can take the pictures of the processes that are happening at that time scale.

So, that is the need of ultrashort pulses in case of chemical reaction; similarly in biology you need you know ultrashort pulses to understand several phenomena starting like you know photosynthesis and so on. So, we need ultrashort pulses and this particular mode locking technique is the way out by which we can create this ultrashort pulses. So, we will talk about this particular technique in detail in the following class, where we will also learned how to you know estimate in the you know real cases, what will be the pulse with a for a given you know configuration of a laser. So, we will see you tomorrow again.

Thank you very much for your attention.