Laser: Fundamentals and Applications
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Lecture-16
Cavity Dumping

Hello and welcome this is the 4th week of this course and today is the first class. So, we will discuss about something called pulsing technique today.

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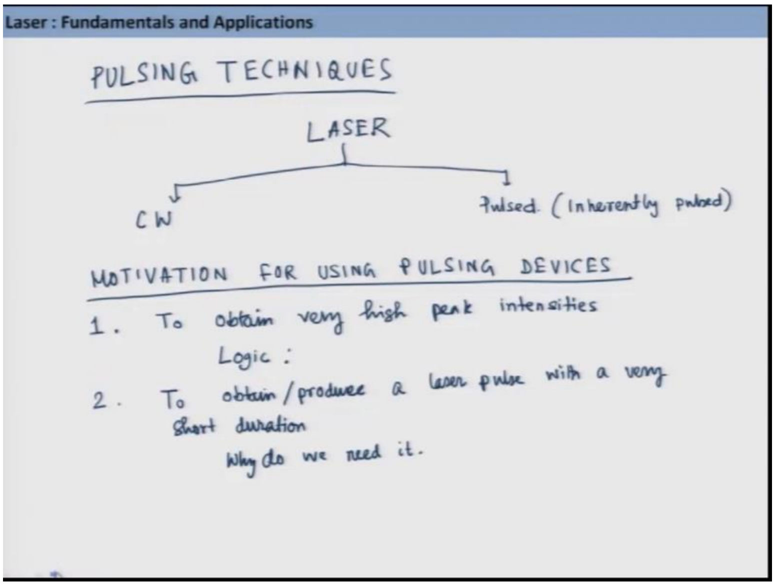

So, we are going to talk about pulsing techniques. Now in previous classes we have looked at several possible systems that can give raise to laser the action, 2 level system you have seen and then we have seen 3 level system and beyond. And while discussing about this you know different systems we figured out that certain system can give laser operation in a continuous way fashion. Or in short c w, where the laser light will always be there as a function of time right.

And there are another class of lasers which will be operated inherently in pulsed mode. So, in laser can be classified into 2, one is continuous wave and another is pulsed. So, this pulsed laser can be also inherent. Like we talked about you know ruby laser we have seen that it will be pulsed in nature intrinsically you do not have to do anything from outside. So, given that there are inherently pulsed laser available still people use pulsing device that is a device which can you know give you a pulsed output from a laser beat a continuous wave or a inherently pulsed laser shows. So, why people use this pulse device? There are several reasons why in come on practice people use these pulsing devices there are you know so, motivation for using pulsing devices ok.

So, what is the first motivation? The first motivation is of course, to obtain a very high big intensity. So, for the time being we will take it at as it is. So, one motivation is to obtain very high pick intensity. Now what is a logic behind you know such a motivation? If we can stop the emission from a laser output for certain duration time and then all in sudden if I allow all the intensities developed inside the laser cavity to come out then what I will get I will get a huge amount of energy. So, that is exactly what we talked about under this first motivation. So, the time over which the light will come out that could be very short because what I am doing? I am doing I am allowing a laser cavity to you know develop a high you know very large number of photons, and then I am already sudden allowing that to you know come out before that I am not allowing it to come out some way.

The second thing is that whether I have continuous wave or I have a pulsed inherently pulsed laser system I can still get a shorter pulse duration. So, second motivation is to obtain or produce laser pulse with a very short duration. So, again why we need it? So, there are several processes in nature, which you know take place in a very short time skill. For example, like in photosynthesis the light is absorption by the you know plants essentially they have some light harvesting system which consist of chlorophyll and all and so on. So, those molecules in a plant takes a photons and then drives the energy from one part to another part and then ultimately you know it stores in another form of energy. So, this process takes very short period of time. Now if you have to find out what is happening at that short time skill you need a light shores which also has that short time pulse. Similarly if you are exciting a molecule to a an exited state and you want to know how or you know what it is doing at the exited state, and in what are the processes through which this excited state molecule is coming down to the ground state. So, this process is happening in a short time period. It can be a nanosecond it can be a pico second it can be femto second. So, if I have to prove those events that are possibly happening over there I need to have a very short pulse.

So, thereby we aim to produce such short pulses using some pulsing techniques. So, these are the 2 motivations one is to create high intensity light second is to get very short pulse light.

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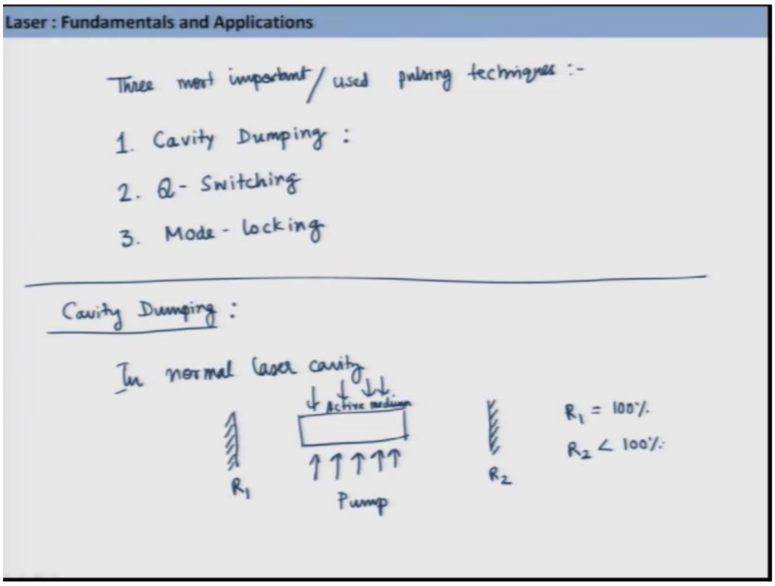

So, let us now have a look at the existing pulsing techniques. So, there are 3 most important and used pulsing techniques. And what are they? So, let us look at 1 by one the first technique is known as cavity dumping. The second is known as Q switching many of these terms you are hearing probably for the first time. So, nothing to worry we will talk about those things. And the third is mode locking. So, these 3 are the main 3 pulsing techniques and these are most widely used. So, we will start looking at these different techniques one by one. So, let us start first with cavity dumping ok.

So, what is cavity dumping? Let us write down it here again. So, always the name suggest something. So, here also if you look at the name it is called cavity dumping from this name itself you can figure out it means that at a particular time possibly all the energy stored within the resonated cavity of laser is being dumped outside. So, the moment we are dumping it; that means, it is coming to our end right we can use that. So, let us have a look at the details of this process this technique cavity dumping.

So, how it is dump? So, let us first look it in much simpler way how we can achieve this. So, normally when you talk about a laser cavity what do we have. So, in normal laser cavity say for example, we consider continuous wave. So, what we have we have 2 mirrors they can be flat they can be concave and you have and active medium right. So, this is fine active medium and you have the light source that essentially pumps the molecules within the active medium to the respective lasers from where it can emit to produce laser. So, you exit them from the light source which is which we call pump. And what is what are conditions imposed on mirrors? That is they will have reflectivities are R 1 R 2 such that R 1 is 100 percent reflective, while R 2 is less that 100 percent reflective; that means, partially transmissive, that is the counts sip of normal laser cavity.

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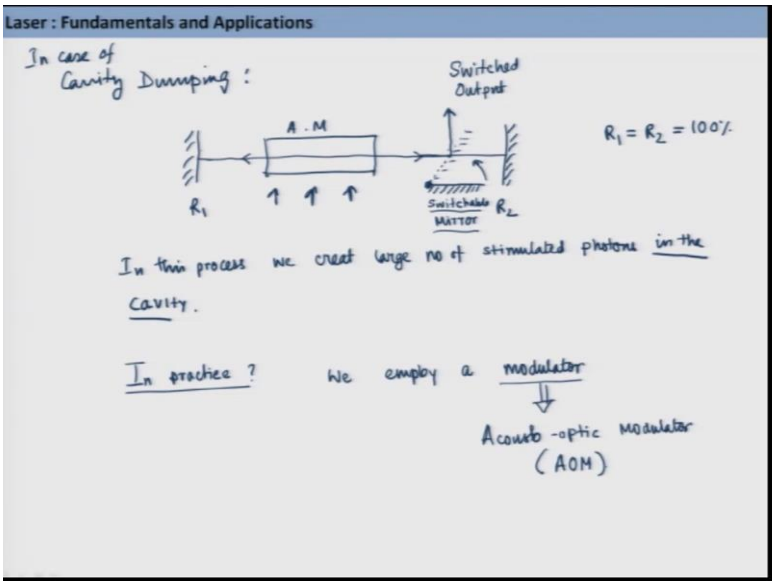

Now, what do we do in case of cavity dumping? So, in case of cavity dumping, So again in case of cavity dumping what we do we keep the structure same. Only thing is that we change the characteristics of the 2 mirrors which forwards the cavity. So, here what we do we essentially have everything same like there are 2 mirrors you have the active medium. So, I am writing in short active medium you have the pump on. Now here when you look at the reflectivities you have to make sure that both R 1 and R 2 are completely reflective; that means, R 1 and R 2 are you know 100 percent. So, that then reflectivities are 100 percent.

So, what do we get in this case? We create a laser unit cavity where when the population inversion occurs and the spontaneous emission triggers a stimulated emission. This stimulated emitted stimulated photons can go back and forth between these 2 highly reflecting mirrors correct. So, they are making round trips and with every round trip they are creating more and more photons, with time. So, as soon as with turn on the pump. So, as soon as we turn on the pump there are population inversion and which after sometime you know creates us you know spontaneous emission and stimulated emission and there are more and more stimulated in propagating along the access of the cavity, but it cannot come out.

So, what we are doing in this case. So, in this process we create large number of photons inside the inside the cavity. So, we create large number of stimulated photons in the cavity please mark my word in the cavity. Why you will understand very soon, but this is clear that I am allowing the round trip to take place. So, the photons have forming and they are moving back up forth moving the end periods. So, I can say that there are energy developing within the cavity and this is being stored there. Still now I did not allow any light to come out. So, it over the time the energy is increasing and increasing and increasing and it is being stored there.

It is as if you have an overhead take in your house and you are putting in water you know, from somewhere using some pipe you are putting it. So, more and more and more and more water is coming out, but you are not turing on any tap. Then suppose you have a big tap attached to your tank and you open it within a very short period of time all the water stored over the time will cush out and it will empty the tank. And again you close this tap again filled the water and again open the tap you repeat this process. So, this is pretty much we are going to do when we are going to use this process cavity dumping.

So now we have stored enough energy, so what? But we have to allow the light to come out at some point of time then only we can you know use it right. So, how we can do that? For example, suppose I have a mirror, extremely highly reflecting mirror. So, this mirror if it is such that this is clamped somewhere here on an access. So, as if the mirror is lying this plane and this can be moved this can be switched. So, this is the direction by which lights are propagating in the cavity. And I have a mirror right here and this is you know clamped in such a way that I can switch from here to here. Now if I if I have stored enough energy if I fill that I have stored enough energy.

Now let me switch this guy into a position like this. So, this is the new position of my mirror. What will happen? This light which is coming from this direction it will now be reflected off this mirror. And this is my output and this output I actually switched correct. So, I can call it as a switched output. And this is as I said is a switchable mirror. So, this is the fundamental concept of cavity dumping process. First I stored enough photon. I stored a huge you know energy inside the cavity. I do not block the round trip of the photon. So, every time the photon passes through active medium it created more and more photon; with time energy increases within the cavity not on the active medium.

So, here every time population inversion takes place I am allowing it to come down to the ground state emitting photon. And that emitting photon is you know going back and forbidden this mirror. So, emitting photons stimulated photons and not going anywhere. So, with time number of stimulated photons are increasing. So, thereby I am storing the energy in the cavity, I am putting stress on this one again and again. Because at a latest stage this will help you differentiating this cavity dumping process with another process per say q switching, which very often people get confused with. So, the moment I bring in a way bring in a you know say mirror here in the beam path.

So, what will happen all the stored energy will now go out. This will be pretty fast process because I have stored the energy in the cavity. So, all the stored energy after getting reflected here, it will now turned back and come and hit here and then in a single short it goes out. So, what I get I get is a pulse I get a pulse which is short and I have quite large amount of energy. So, I hope this mix your idea about cavity dumping quite clear.

Now, how do we do it in practice? So, in practice how do we do the cavity dumping? So, what we do in practice we employ a modulator. You can immediately understand right here in case of in this first case we consider switch will mirror. So, we switch in back and forth and get pulsed output, instead if off doing this mechanical process if we can do something say electrical. So, and then I can modulate this turning on the cavity. So, I open the cavity. So, that laser pulse comes out then the life will be not easier. So, what kind of modulator do we use? We use acousto optic modulator, which is known as AOM in short. So, what do we do here? Before doing anything let me tell you little bit about acousto optic Modulator So that you can understand this process much better.

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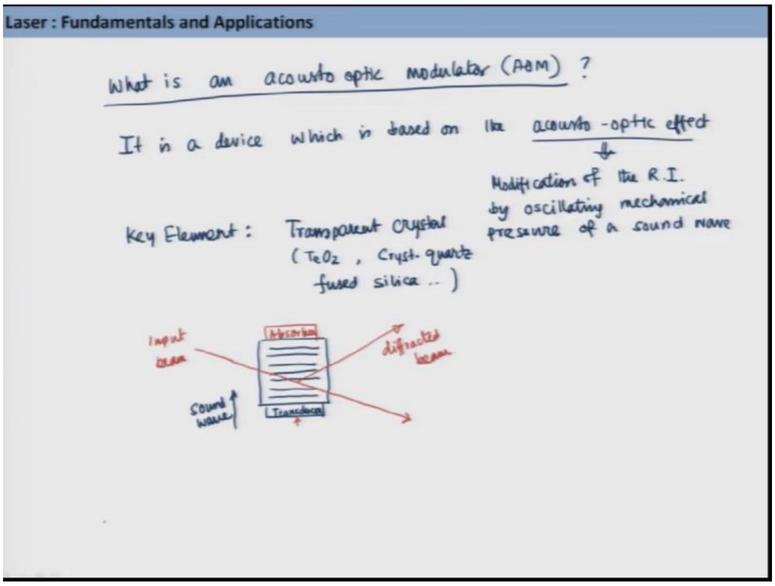

So, what is an acousto optic modulator? So, that is my next thing right. So, acousto optic modulator right. So, an acousto optic modulator is a device ok.

So, first place it is a device which is based on acousto optic effect. So now, the natural question is what is the acousto optic effect and how we are going to use this. So, acousto optic effect is nothing but modification of the reflective index by from oscillating mechanical pressure of a sound wave. So, all it does is when we put some you know mechanical pressure on that creating a sound wave to propagate trough this device it changes the refractive index. So, it is behaves in a by refrainment way. Now the light propagation through a medium is strongly dependent on the refractive index of the medium right. Now let us look at inside this acousto optic modulator. So, which is essentially what are the key element? So, the key element in a in a in an acousto optic modulator is some crystal which has to be transparent because we need to same light through it. So, it has to be transparent through it. So, we need to have transparent crystal such as te o 2 or say crystalline quartz or fused silica etcetera.

So, such crystals when you apply some mechanical pressure, how do you do it? So, let us have a look at it. So, if you have a crystal of this material. So, suppose this is my crystal. And then I put a transducer a transducer. So, essentially peso electric transducer. So, what it will do? It will apply pressure right. And that will create sound wave through this, and that will propagate here in this passion. So, this is the direction of sound wave propagation. Now suppose I have not done anything, I have not use this transducer and I send in light. So, this is my input beam. So, this is my input beam now when I use pressure from this direction is in the peso electric device, the sound wave will propagate along this access and there will be an absorber. So, absorber which will absorb that sound wave ok.

So, during this motion of this sound waves through the crystal it will create a grading structure and that will change right. So, the moment it changes the light will be diffracted in a different reaction. So, this is my diffracted right, this is my diffracted beam. So, this much I know about acousto optic modulator I take a crystal you the peso electric modulator put pressure there create sound wave which will alter the reflective index in medium which will force this one this crystal to act like a grading to my input beam which was just passing through this now will scatter. So, it will scatter in a different direction. So, I can modulate the direction of the beam propagation using this acousto optic modulator that is much I know. And I can modulate the direction of the beam propagation by applying some external pressure using peso electric device.

So, essentially ii can do it by you know using sound wave also. So, by sound wave we will dictate how much the beam will deflect. Now let us come back to our original discussion that how I will get the cavity dump laser using this acousto optic modulator because that is what people do it in practice.

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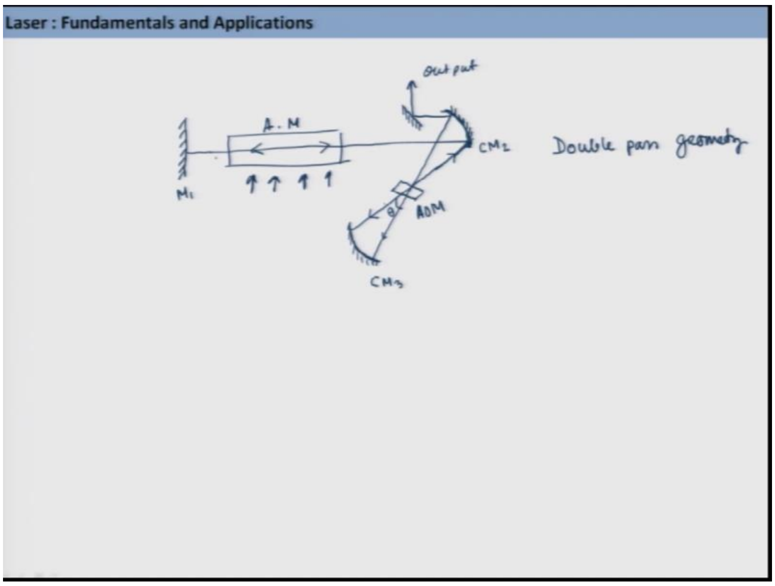

So now, let us try to look at that. So, what is done here you have a mirror here, you have active medium as usual active medium you have the pumps all as usual. Now on this side we will have concave mirror. So, this is a concave mirror. So, the light after this emission is emission has taken place from the an active medium, light will go light will be created and it will bounce off from this first mirror say let us call this one as M 1 and then I have this mirror which is a concave mirror and I call is as a CM 2 this will reflect the beam. So, here I will put another concave mirror which let me call as CM 3.

Now, what is happening here? The light is moving back and forth between this concave mirrors are arranged in such a way that beam will be just tracing back it is path. So, it will form again a cavity a resonated cavity. So, I have the light moving back and forth through active medium and here essentially if I be very specific I will show this direction and again it will go back in this direction. Now here is what we do. Here we put this acousto optic modulator which is I said is a crystal. So, this is my acousto optic modulator. Now at a given time when lot of energy has been stored already I will apply sound wave here. And then the magic happens it goes here it deflects by some angle theta light goes here and then it goes to the same direction it goes and hits here get reflected. Now here if I again use an extremely high reflector that is high reflecting mirror this will take the beam out of the cavity. So, within a very short time, initially we do not send a sound wave there. As such this acousto optic modulator will be transparent to the beam. So, the beam will go you know as such go through as such, and then I come up with this sound wave I modulate the refractive index of this crystal within this acousto optic modulator which creates the diffraction of the beam allowing the beam to move away from it is path. And once it is moves away then it is not part of the cavity, but it goes out of the cavity. So, all the radiation that is created here will come here go and then reflected of out of this laser. So, this is my output ok.

So, this is what is done in this particular geometry you can see this is like you know is double pass geometry, this is good to know. So, it is going coming here again going then coming back. So, this acoustic wave is helping me to create ultimately a short pulse of light by dumping the whole energy stored within the cavity. So, in this process may be we are quite out of time today. So, we will start from here and continue in the next class. So, see you in the next class.

Thank you very much.