Laser: Fundamentals and Applications
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Lecture – 17
Q-switching

Welcome back today is the second day of this week. So, yesterday we looked at the pulsing techniques. Particularly we started with the cavity dumping. So, what do we said that in cavity dumping, what do you do you store the energy within the cavity and in a short period of time you dump it outside, you get a pulse laser output. So, we showed that in practice we used in acoustic modulator. So, we modulate it and as a function of this modulation we get pulsed output. So, how would you know pulses pulse patterns will look like the temporal profile. So, the temporal profile for cavity dump output. So, cavity dump output will generally have a sinusoidal temporal output pattern ok.

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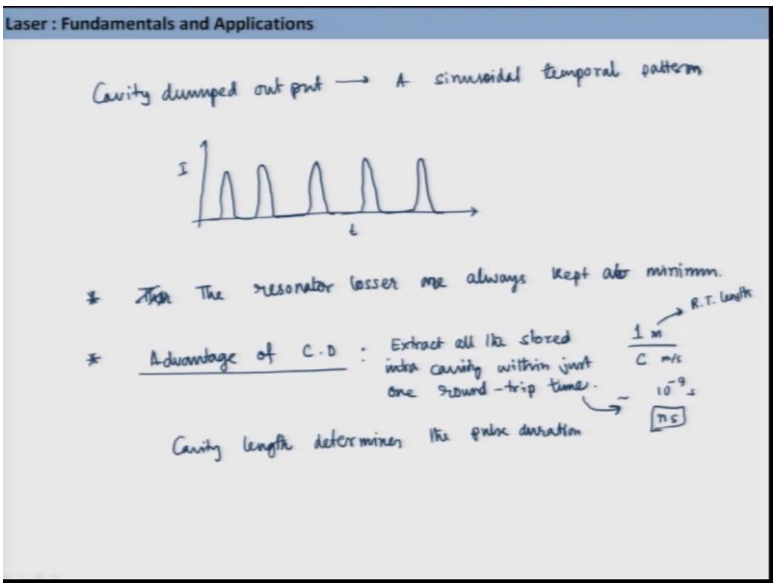

So, essentially if you look at the intensity as a function of time it will look like. So, they are of same intensity and it is like a sinusoidal profile. Now few things which I should mention regarding the cavity dumping process is first place there is you know all the time in a cavity dumping process the resonator losses a kept at minimum. So, the resonator losses are always kept at minimum. We have already seen like if you have more gain over loss then only you will have a output, and in this case so, so what you

have to do you have to increase the gain and minimize the loss. And in the cavity dumping process losses are minimum because we are taking care of the 2 mirrors for all the mirrors that we are using they are you know having 100 percent reflectivity. So, no light is being escaped from the cavity the less probability of escaping from the cavity for the light essential stimulated photons lesses the loss. Lesses the loss means highest the output power.

So, this is one important aspect. And another important characteristic or for that matter I can say an advantage of this cavity dumping process is you have seen that you know you can switch all the stored photon in the cavity can be dumped by just one round trip time, why? Because in the last class we have shown right.

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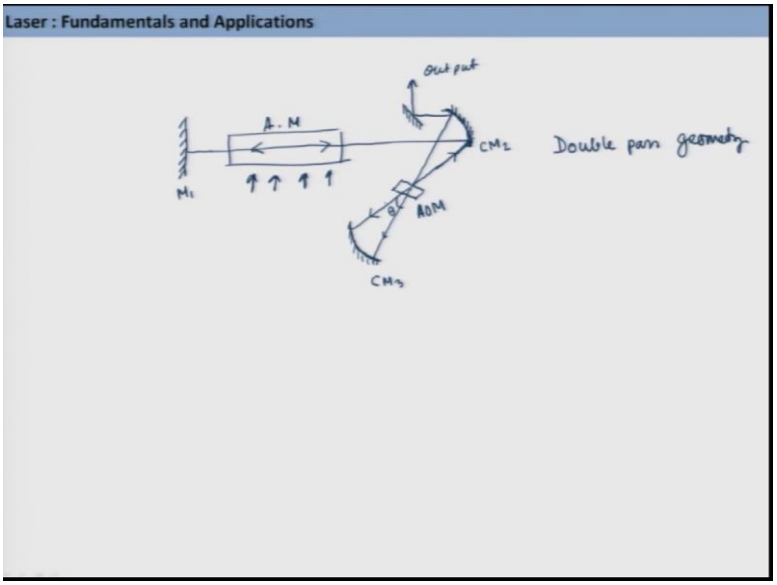

So, if we can just go back and have a look at this. So, the moment this process happens that is this is this guy is coming in this direction all the lights from here is just coming in one direction and then it goes out. So, this is an UV direction process. So, all time that we that we require is that one round trip time maximum by then all the stored photons will be out of the cavity.

Now, what is one round trip time? So, a cavity size you know given a normal cavity size we can have like say one meter is the round tip distance suppose. So, in one meter how much how much time it takes for light to travel one meter we can easily figure it out right.

So, essentially so here let us do it. So, one meter divided by c. So, which is essentially 10 power minus 9 second. So, that is nanosecond, So in the order of few nanosecond. So, within this much time we can empty the cavity totally. And this is the greatest advantage of cavity dumping technique.

Now, you may you know wonder like you know why that be. So, important it is important because it is not only the you know energy or I mean the amount of energy or the power. Or the you know pulse duration that is important, but also how many times the pulses are coming in a second that is a repetition right that is also important. So, for various reasons people would like to have high reputation rate laser. So, if you have high reputational rate laser, if you need that and if you still you know one to have short pulse high energy then this is the way to go. Because within nanosecond this is all the lights stored in that cavity out.

So, if I just you know see what actually determines the pulse with, the answer is the cavity length right. So, cavity length determines more or less the pulse duration. So, here let me just write down explicitly. So, advantage of cavity dumping is that it can you know extract all the stored intra cavity photon, intra cavity photon means whatever the photons are there in the cavity within just one round trip time right. And that time is essentially roughly this one correct. So, one meter is suppose round trip time round trip length and c is the velocity that is meter per second. And you get this much amount of time for releasing on the photon. So, in case of high reputation rate lasers also you can get high pick energy and short pulse duration, which we will see in case of q switching may not be that easy. Q switching is another pulsing technique that we will look at next ok.

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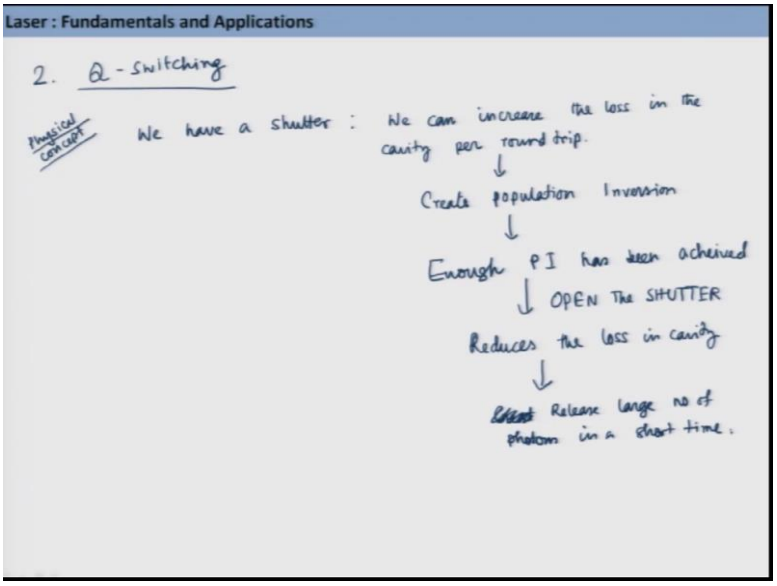

So now let us look at other technique that is the second one that we want to look at q switching. Now if we want to talk about this q switching first let us talk in physical terms. So, in physical terms the reasoning behind this particular method of pulsing or achieving pulsed operation can be shown here. So, let us see what it is. So, if you have a shutter. So, suppose we have a shutter.

So, this is the physical concept behind this q switching. So, we have a shutter such that we can increase the loss in the cavity, increase the loss per round trip So that you know why do I do that I reduce the loss; that means, I am you know not allowing the round trip to be complete. So, we are not essentially creating or storing energy in the cavity because we are using some shutter which is blocking the light to go and hit both the mirrors. So, there is no creation of energy within the cavity by increasing the amount of loss.

But when this is happening that is we are increasing the loss by using the shutter at the same time my pump is on. So, what I am doing essentially I am creating population inversion. So, I am storing energy within my active medium. So, this is in contrast to what we have learnt in case of cavity dumping. So, you make sure that you understand this point very clearly. In cavity dumping we store the energy within the cavity, we allow the round trip to through active medium. Here in case of q switching we use a shutter to close the gate So that the light cannot move back and forth between this mirror end mirrors and thereby causing huge loss, while this loss is taking place per round trip

pumps are putting the molecules more and more in the excited state, creating more and more population inversion high degree of population inversion all right. So, so this will allow create population inversion, because I am not allowing the light to the excited molecules to come down.

So my shutter is you know blocking the light through make the round trip for a certain period time. Now how much is the time period? This is the time period by which the amount of spontaneous emission is very negligible. So, thereby I am not really losing my you know population at the excited state. So, which time this population grows and I achieve very high degree of population. And when I feel that enough population inversion has been achieved, or enough PI has been achieved, then I will remove my shutter from that place that is I open the shutter you open the shutter. What will happen? It will now reduce the loss, because shutter was initially blocking the beam to propagate in the cavity. Now I am making the shutter open.

So now, the beam can propagate through the cavity so; that means, I am reducing the loss. So, this process reduces the loss in cavity, rather it is increasing the gain. So now, the moment I open the shutter the photons are moving back and forth between 2 n mirrors and what happens by just few you know round trips the already created population inversion will give rise to a very large amount of stimulated photon that will come out as a function of time until the total population inversion is reversed.

So this will create or this will release large number of photons in a short time. So, this is the basic physical concept behind the q switching operation. So, let me just tell it briefly again. First you block the beam within the cavity. So, that it cannot move back and forth between these 2 mirrors creating loss in the mean time the population inversion is being created. So, once enough population inversion is being created you open the gate.

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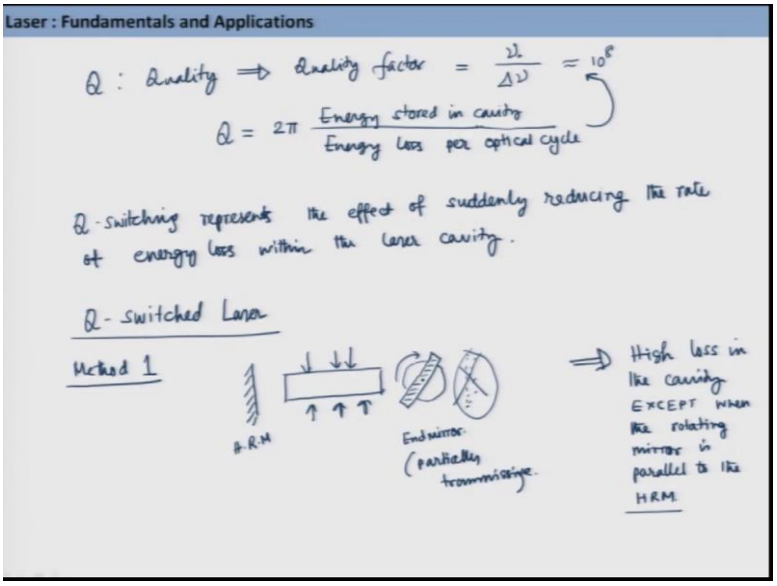

So, the light now can move back and forth between these 2 mirrors and population inversion gets reversed by giving a burst of photons that is what my q switching is. So, why this name q switching cames. So, there are 2 things q and switching. So, q the first term it refers to quality. If I be very specific this is related to the quality factor. So, we have already learnt what quality factor is in one of the previous classes in some other you know context.

So, what was the quality factor we saw that quality factor is the emission frequency divided by the spectral width. And this can be very high for certain raiser and we said this is good potential to be used in high resolution spectroscopy. Now this definition of quality factor came from the expression of quality factor q which is given by this energy stored in the cavity divided by energy loss per optical cycle. So, essentially this from here we get this definition. So, what does this mean? This means that the q switching. So, this is this is related to quality the first term q. And another is switching meaning that we are switching between different qualities. So, what does that actually mean? So that means, following. So, q switching represents the effect of suddenly reducing the rate of energy loss within the laser cavity. So, first the quality of the laser cavity is reduced and that is what we just said. And in the next step we increase the quality.

So, when we talk about reducing the quality; that means, we increase the loss. Higher is the loss lower is the quality correct. So, they are inversely proportional in some way. So,

in q switching what we do we first reduce the quality of the cavity by increasing the loss and in the next step we reduce the loss by increasing the quality. So, we switch between these 2 ends of quality. So, low to high quality. So, what we need to do for that to achieve laser output pulse laser output using this mechanism. So, this is you know the principle that we would like to follow because this seems duable. So, while we are reducing the quality of the cavity the pump should you know build up enough population and pump should actually exceed spontaneous emission we just stated few minutes ago right. So, during this you know creation of population inversion the spontaneous emission has to be quite minimum. So, my pumping process has to be extremely efficient I should not allow the you know excited molecules to come down by spontaneous emission. We have to keep bombarding with the pump photon So that I achieve a high degree of population high degree of population inversion maintain it and achieve more ok.

So, in the next step after your population inversion is created, I have to switch the qualities right. And this switching time will give me the desired with or duration of the pulse that come out. So, this duration of the switching has to be short, short enough. If it is long then there are so many problems associated to with that. So, if time permits then we will discuss about those things. So now, first let us look at you know what are the methods that one can use to get a q switch laser. So, the laser where this q switching techniques used to get pulse output is called q switched lasers q switched laser. So many q switch lasers are available this is one of the you know most popular pulsing techniques that people used and q switch lasers are probably the most used laser for example, like you know q switched nd yag laser in the webeye pour laser or you know even the ruby laser they all they all used q switching.

Now, let us look at the you know methods. So, method for creating q switched pulse output. So, how we can do that is as follows. So, first you have an in mirror you have an active medium. So, this is like you know as usual. Now there is no you know mirror on the other side I have not shown that intentionally because in this system there is no permanent period on the other side. So, the in normal cases I have this one, but in the present case I do not have such mirror. Instead what we have is a mirror which is you know say let me show this one this is a mirror. So, this is a high reflecting mirror high reflecting mirror, this is another high reflecting mirror ok.

So, you must be wondering now that you are using you know sorry this one let me correct this one. So, this one will be. So, this is a an end mirror. So, this will be this part will be partially transmittable. So, whenever I say end mirror what we mean is this mirror is partially transmissive. So, partially transmissive. So now, let me complete what I have saying. So, this mirror is placed on a rotating mount. So, essentially this can rotate. So, I have one mirror here I have my active medium and on the side instead of having a fixed mirror parallel to this one I have something which can rotate. So, it can just rotate in the plane or in this plane does not matter. So, while this rotation is being executed by this mirror? There will be one time when these 2 are parallel correct.

So, if it is rotating in this way then at some point of time they will be parallel. So, the way I have shown here at this moment they are parallel just like any normal laser cavity. Except this particular incident all the time I actually have great loss in the cavity because my this mirror is not parallel. So, this is some pointing that some other direction right.

So, this cannot form a cavity where the light will move back and forth between those 2. Only in one particular orientation it will be and that will come at a particular time. So, this rotating mirror essentially is inducing a high degree of loss in the cavity. So, creates high loss in the cavity, except when the mirror or the rotating end mirror is parallel to the high reflecting mirror well understood. So, when this rotating mirror is not parallel to this one what is happening the population inversion is being created more and more and more and more. And when this after making the full revolution mirror again comes back to the parallel position that time it completes the cavity and minimize it is loss. And that moment all the excited molecules will come down and then it goes out from the output coupler, you get a pulsed output.

This mirror can be rotated quite fast and that will define like you know how many times it will give you this pulse output. So, it can you know having high speed as say like 500 at p m and you get a decent pulsed output. So, this is kind of you know proof of the concept that I can get pulsed output by switching the quality of a cavity from low to high, first lowering the quality increasing the loss and then increasing the quality by minimizing the loss. And thereby you can create a pulsed output. So, there are other available techniques for a creating q switch pulse laser and we will talk about that tomorrow.

Thank you very much.