Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

Course Title
Optical Communications

Week – X
Module-II
Optical amplifiers-II

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Hello and welcome to moke on optical communications. We will continue the discussion of optical amplifiers, we will look at couple of aspects that make RBM doped fibers not very ideal when you would actually expect it to be your ideal amplifier okay.

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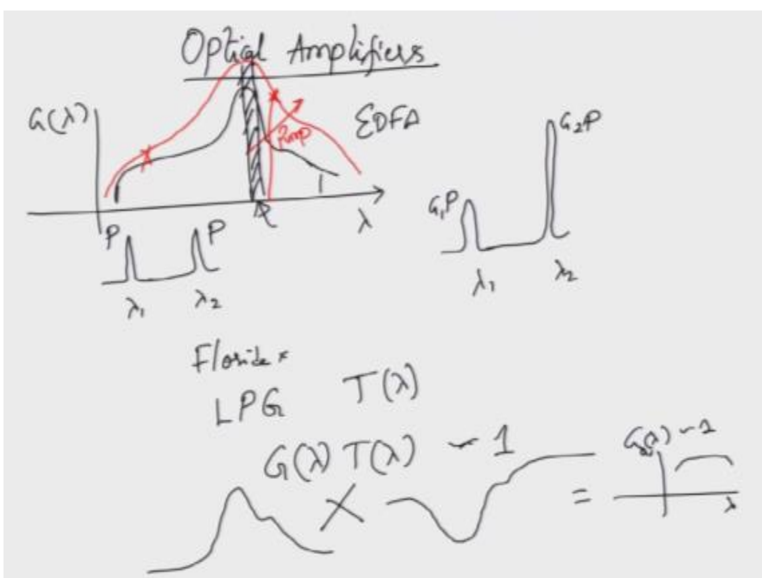

The first thing is if you were to look at the gain of the RBM doped fiber amplifier so you are looking at an RBM doped fiber amplifier, you would actually expect a very flat gain. So over its operating wavelength you would expect it to have a flat gain. Why is this flat gain important? Let us assume that you actually come in with the input signal actually happens to be two wavelengths okay, one wavelength at some λ1 and the other one at λ2.

But the power of λ1 is P1 power of λ2 is P2 and we have assumed in this particular case that P2 is higher than P1, of course information is sitting in this two wavelengths, these are the two carriers with which you are coming in. If you had a flat gain RBM doped fiber then the output would exactly be G times P1 for the wavelength λ1 and then you had G times P2 for the wavelength λ2.

However, because RBM doped fiber amplifier gain actually depends on the wavelength it turns out that, the gain that you are going to get for P1 will be different than the gain that you are going to get for wavelength λ2. And in case this gain happens to be muc and h larger than this particular gain it might so happen then that this fellow will eat up all the gain of the RBM doped fiber amplifier, whatever that it could give and then the available gain for other wavelengths would be very small okay.

This is the problem that is very, very pronounced in a semiconductor optical amplifier. In semiconductor optical amplifier this actually happens leading to in fact loss of a certain signal okay, instead of a gain your actual signal might simply disappear because one of the signals occupies the entire gain, that problem is not so severe in RBM doped fiber amplifier, but it still leads to a little bit of a problem in the sense not a little bit and the problem in the sense that signals which are at different wavelengths experience different gains okay.

So you cannot really assume that all the wavelengths that are coming in will be amplified with the same gain. The situation becomes little worse when you actually come in with two different wavelengths having equal powers okay. So if you come in with a λ1 at a certain power P and λ2 also at a certain power P and you have certain other component after the RBM doped fiber, but the output signal that you are going to get will be G1 times P for λ1 and then G2 times P for λ2.

So notice that although at the input side both λ1 and λ2 had equal powers okay, the output powers are not really equal. So you really want a certain flat gain so that this large changes in the or the fluctuation in the wave length powers are to be avoided unfortunately RBBM dope fiber does not provide a flat gain rather what it provides is a gain that is function of wave length so you want to look at the gain function somewhere around 1522 1600 closely we would see that the gain function goes something like this.

And the situation becomes slightly more verse okay so here this should have actually gone to slightly on to the longer side so any I am not actually drawing the exact curve out here put this what would typically happen the gain curve would actually start to change as the pump power starts to increase so the gain is not just the function of the wave length gain is also become the function of the pump power.

So because of this problem what will happen is the gain at different wave lengths are exactly the same okay and if you have to put this amplifier to make laser then if you do not control the frequency of the laser that is coming out then much of the laser happens in this particular wave length so if you go to construct a mode lock laser using an erbium dope fiber this is something that you are going to see it would mostly lays in this particular window which is around 1550 to 1560.

Okay so this gain not being flat is an important problem and there are solutions for that one solution would be replace the silica fiber with a different fiber such as a fluoride fiber okay there are solutions available with this one but these are not widely used rather we use hat is called as long period grating if you remember the discussion on the optical devices a long period grating was device which actually couple the modes of a core and a cladding, okay.

What was the way what was the reason why we used a long period grating or atleast I mention that we use long period gratings was the gain equalization for a erbium doped fiber it is possible to fabricate a long period grating whose transmission spectrum say T(λ).

We be in such a way that G(λ) coming from the erbium doped fiber and T(λ) coming from the long period grating together can be made to be uniform which means that if the erbium doped fiber gain is non flat and then as a certain spectral distribution that would look like this, okay. You can actually make a long period grating with a spectrum that would be kind of inverse to this, okay I probably I have not capture this correctly.

Such that their products actually will give rise to more or less flat spectrum, okay flat gain spectrum so gain will essentially overall gain G overall will be more or less equal to 1 for this particular thing so such a major use of a long period grating that commercial erbium doped fiber amplifiers operating over this wavelength.

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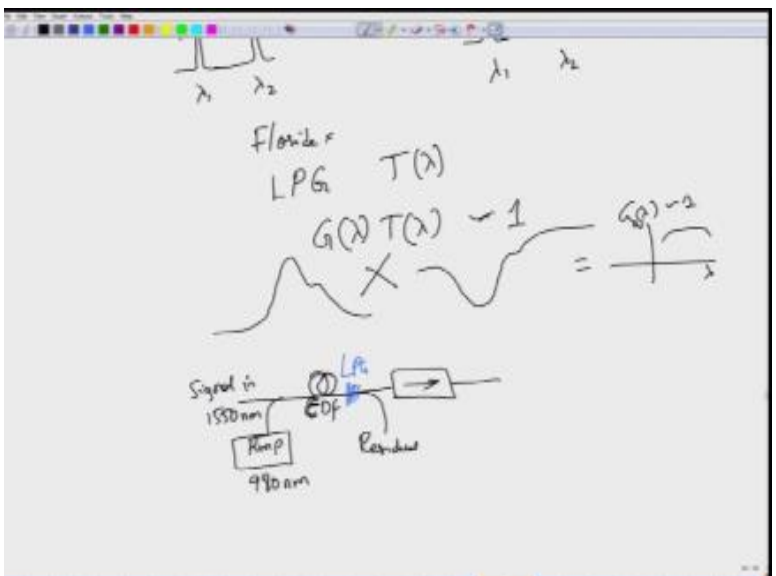

Actually come with a LPG integrated to that so you have a fiber then you also have an LPG and then you have additional components that go into the fiber, if you look at a commercial erbium doped fiber amplifier what you actually see is you need a pump coupler okay and you need a pump, what is the wavelength of the pump that is normally used, 980nm you have a signal that is coming in which is at around 1550nm and this could go into the fiber, okay.

So this is your erbium doped fiber but not the entire pump would be utilized some part of the pump might still be available to you so that forms the residual pump and after this you normally put in an isolator if you want to make an equalizer then you also put in a long period grating up at this point, okay. And then you also put one more erbium doped fiber just to symmetries the whole thing, but this is essentially what you are going to see in a commercial erbium doped fiber amplifier for broad band application, okay.

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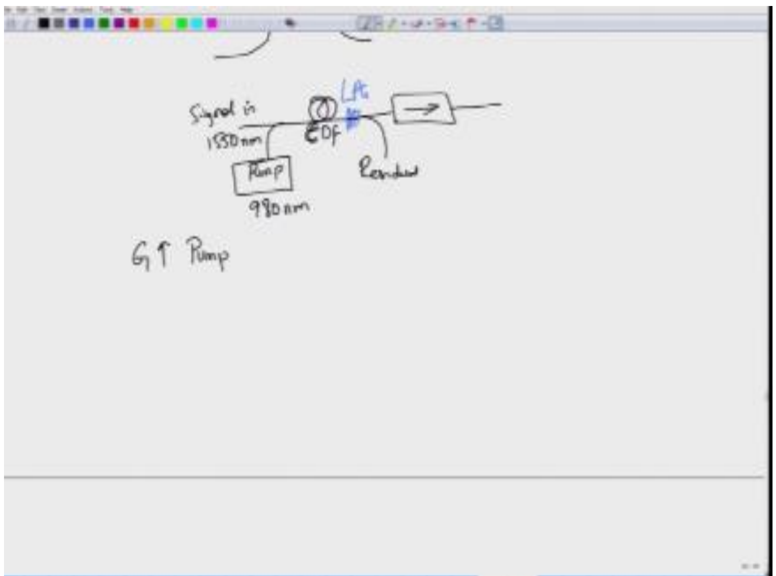

There are couple of things on which the gain depends, we have already seen that the gain kind of increases with the pump power that is input, right so however can it possible that I can just keep on increasing the pump power so that the gain keeps on increasing unfortunately, no. the reason who I does not happen is because a larger number of the pump photons coming in means that these signals are getting excited, okay.

However, they will also start to decrease back, okay so there is sort of a saturation that really happens when you start putting in large amount of pump power. The saturation is even more pronounced when you actually have a signal to this, okay.

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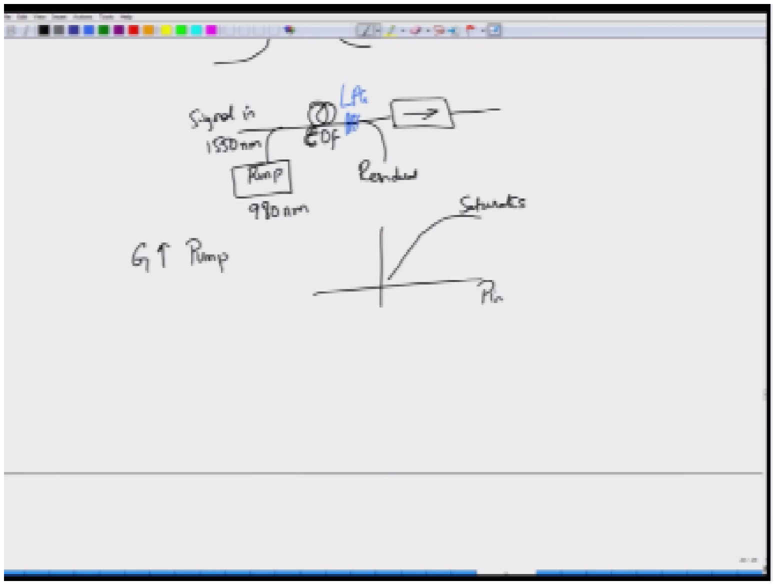

Initially the gain of the signal starts to increase and then the gain starts to saturate, okay the gain basically saturates with the increasing input power why is that so well, initially when the input power is here and then you have created a population inversion then there is chance for these input photons the signal photons to see a larger population inversion and then stimulate the emission process.

However, a large number of photons that are coming in will also start to deplete the population inversion faster, remember these are dynamic, okay. So that is varying with time so a larger number of optical photons coming in will start to deplete the population inversion and the gain is basically a function of how much the population inversion is there or you know has been created that population inversion as it drops the gain also starts to drop.

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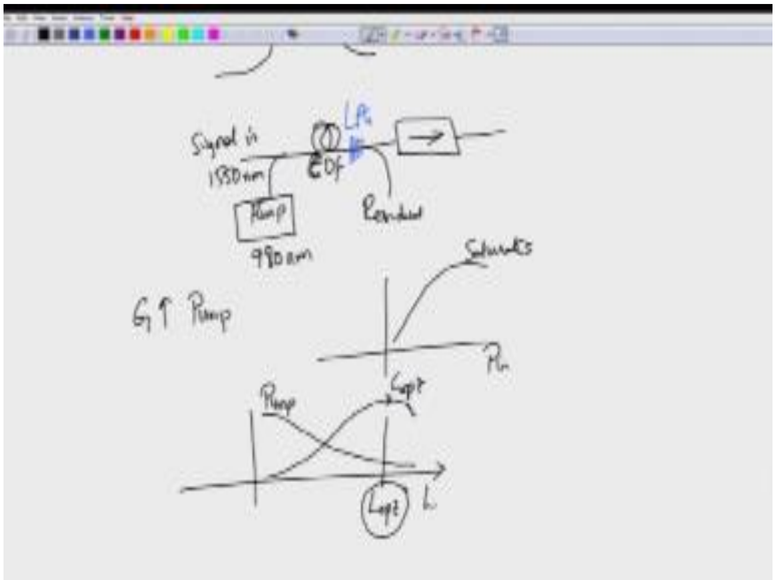

In addition the gain actually decreases and you know starts to decrease reaches a certain maximum value certain optimum value for a certain optimum length of the fiber, okay so if you start increasing the length of the erbium doped fiber then the gain initially begins to increase and then after a certain value which is optimal length the gain starts to decrease again the reason being that is the gain start increase the pump power that you have applied will start to decrease okay.

So as the pump power decreases there is not sufficient population inversion which means that the gain actually starts to drop so when you are creating a commercial erbium dock fiber amplifier or utilizing the erbium dock fiber for any purposes it is more or less recommended. That you work with the optimum length okay at the optimum length the gain of the fiber amplifier is maximum.

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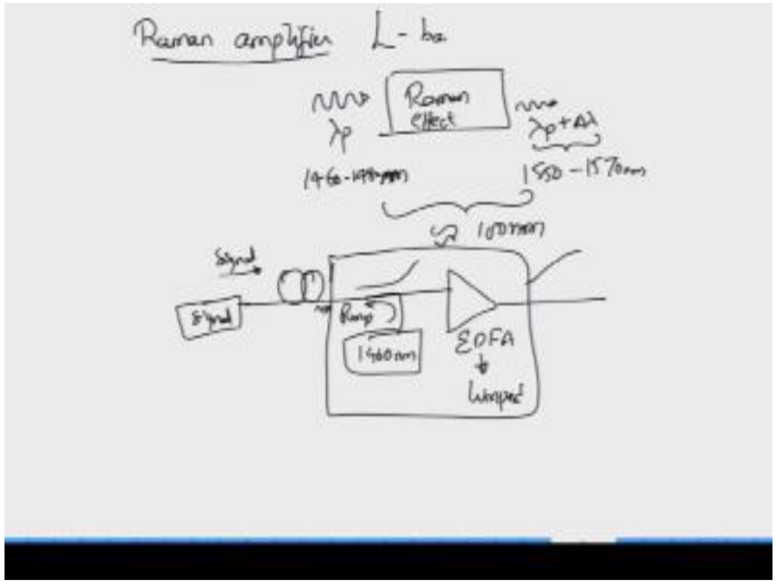

So these are some point about erbium dock fiber amplifier in optical communication recently we have started utilizing another based amplifier called as Raman amplifier the basic idea of a Raman amplifier is very simple suppose I take a photon of some wave length λ p and then I have a medium which has you know which is capable as generating Raman effect okay what is Raman effect.

Well this input photon generates another photon at a wave length which is a certain wave length higher so which is called as the stock shifted photon okay so this is called as the stock shifted photon and in optical fibers you can see the effect when λ p is around 1416 to 41 nm okay the corresponding stock shifted photon which is kind of amplified version will actually be around 1550 or other 1560 to 1570 nm okay there is almost approximately about 100nm difference.

So you have a shorter pump power and then that would result in a stocks wave which is at a larger wave length or a longer wave length okay how is this actually useful for us well before you put in a span you actually have a erbium dock fiber amplifier correct now to this erbium dock fiber amplifier just before that you can actually take in this 1416nm pump okay and then connect this pump on to the fiber notice that this would act as a pump, starts to interact with the signal that is coming in from this side, okay.

So here is where your signal is coming in from, but as this signals starts to talk to the pump the pump is propagating backward and starts to amplifies the signal. So you actually have a certain amplified signal coming in which then can be further amplified with respected EDFA but the advantage here is that EDFA can be reduced, the gain required for the EDFA can be reduced, and the pump can be remotely used right? So this Raman amplifier is actually a distributed amplifier, as we would say, this is called as the lumped amplifier, because you have to put it at a particular point.

And then compare to the span length this rbm dope fiber length which is around 20 to 40 meters typically is very small, compare to the Raman amplifier whose lengths are typically in dense of kilo meters, okay. Raman amplifier is normally combined with the rbm dope amplifier, because Raman by itself is not used for optical amplification purposes, the reason for that is as the pump power increases, okay there is a back scattered power called as the ray lay scattering, okay.

So this ray lay scattering limits up to what pump power I can actually used, what is the maximum pump power that I can use for the Raman amplification process? Okay in addition to this any fluctuation in the pump power is actually felt instantaneously on to the signal as well, because of the very fast response of Raman Effect.

Whereas this response time is in mille seconds where as for Raman's it is nano seconds, whereas for rbm fiber amplifier it is in mille seconds, therefore any fluctuations in the pump power is not typically altering and creating some problems in the rmb doped fiber amplifier, okay so this is about Raman amplifier which is one of the newer technologies, typically made to work in L band, the long wavelength band which is around 1600 and beyond that.

In addition to semiconductor amplifier I'm not going to cover that in detail, except I will mention couple of drawbacks of semiconductor optical amplifier. That gain in polarization dependent, semiconductor optical amplifiers have a very high amount of cross stock between the wavelengths.

However this high cross talk is actually quite useful, you can actually use this as a wavelength convertor, you can use this as a wavelength convertor to convert from one wavelength to another convertor. These days SOA based optical, you know logic convertors or header recognition kind of units is being implemented, these are all made possible because of the fast response time of the semiconductor optical amplifier.

A large bandwidth compared to erbium doped fibers, SOS can amplify signal from 1300 to 1600 nm, basically because they utilize semiconductor material which are transparent to light in this entire region. These are quiet broadband, the problem is they are gaining polarization dependent and they have a high amount of cross talk, therefore the they are not widely used a erbium doped fiber ion amplifier for communication amplification purposes, but they are widely used in optical signal processing, many optical signal processing elements. Actually use a semi conductor optical amplifier, the construction SOA is very similar to the double hetero structure laser diode that we actually talked about.

The pump is from the current and the pump is the transverse direction, everything that we talked about the lasers actually holds for semi conductor optical amplifiers as well. In the next module we will discuss the noise processes that are associated with optical amplifier and then talk about the improvement that an optical amplifier such as erbium doped fiber amplifier provides to the signal or provides to the performance of the systems in optical communication systems. Thank you very much.

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