Advanced Optical Communications

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Lecture No. # 27
EDFA

In the last lecture, we talked about wavelength division multiplexed systems; that means on a fiber, you put multiple optical carriers; each carrying highest possible data rate and by that essentially we can increase the capacity of a optical communication channel. We saw that the optical fiber has a very large bandwidth, typically of the order of about 30 terahertz; whereas, if we use only one optical channel, then effectively only 10 gigahertz bandwidth is utilized; so the fiber is highly underutilized. So, either we could exploit this bandwidth of the fiber in time domain by generating signals, which are very narrow in time or we can exploit this bandwidth in the frequency domain.

And we saw that generation of the signal in time domain is extremely difficult, because we require the optical pulses typically of the duration femtoseconds. But exploitation of this bandwidth in the frequency domain is more easier, and that is what essentially led to the systems what are called the wavelength division multiplexed systems or WDM systems. Then we saw that for WDM systems, we require various components, and one of the very important components for long distance communication is an optical amplifier.

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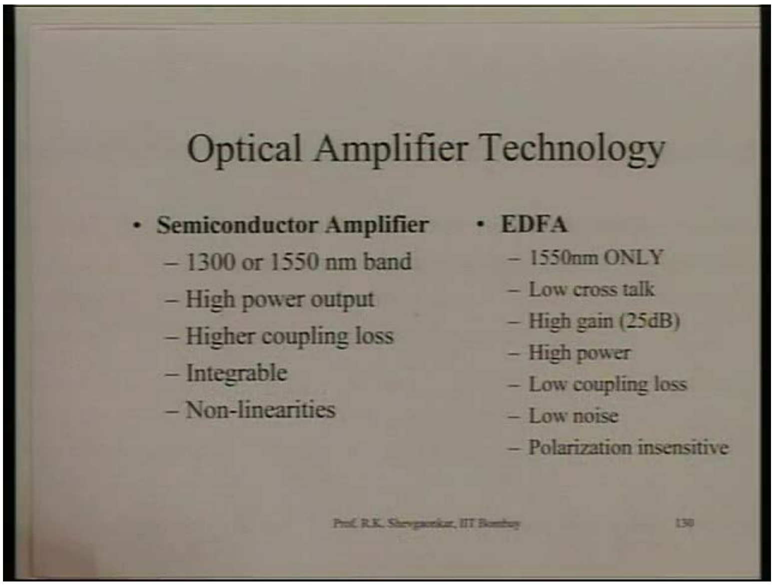

So, let us today, we had a comparative things that if you consider now the amplifiers, which can amplify the signals directly at optical frequencies, then either we can have an amplifier, which is semiconductor amplifier is like a laser or we can have an amplifier which is fiber based and the most commonly used amplifier is the erbium doped fiber amplifier. And then we saw the characteristics of this that it has many advantages over the semiconductor amplifier. And especially since this amplifier is fiber based, it has very low coupling loss compared to the semiconductor amplifier and also it gives you good gain. It can handle high power, low cross talk and so on. So, in this lecture essentially, we talk about the characteristics of the EDFA functioning of EDFA.

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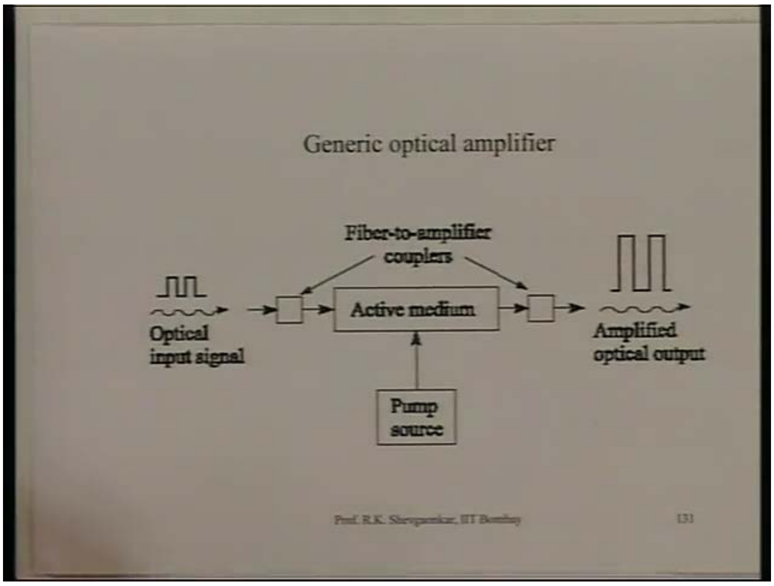

So, inside this erbium doped fiber amplifier also, the principle is same that we have a medium which can generate amplification. So, we call that medium as the active medium and then we pump this medium; so that, the medium is excited. And then if you put a optical signal which has a frequency equal to the energy difference of the two energy bands of the medium, then the signal gets amplified, because of the stimulated process. So, basically even this system is same as the laser system. Only thing is now the medium which we are talking about is the optical fiber.

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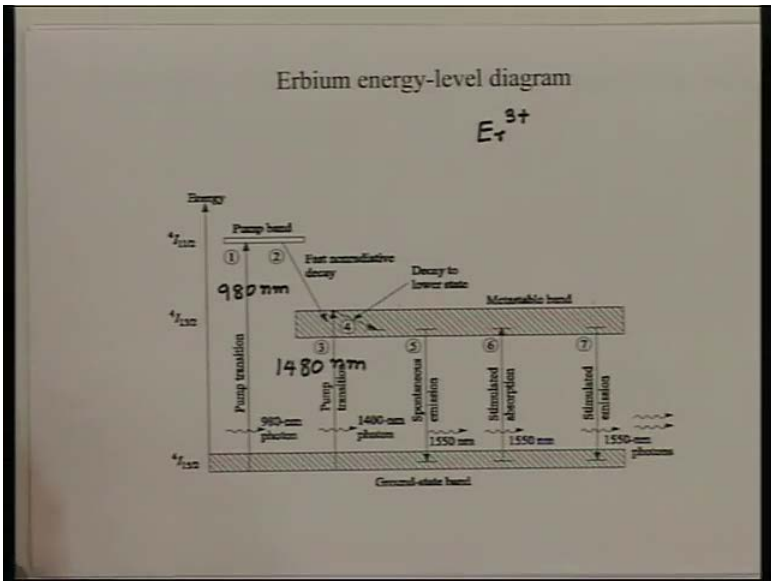

So, if we take a normal fiber and dope the core of this optical fiber with the atoms of erbium, then we get the energy levels inside the core of the optical fiber which look like this. And as we saw that either we can pump from this level to this level, which corresponds to a wavelength of 980 nanometer so this is 980 nanometer or we can pump from this level to the top of this level, which is 1480 nanometer. So, this material erbium doped glass can be pumped either at 980 nanometer or it can be pumped at at 1480 nanometer. And then we saw that once the material is excited, then you can have downward transition which could be because of natural process, which is the spontaneous emission.

So, this will appear like a incoherent emission coming out. Nothing to do with what signal is incident on this and that process we call as the spontaneous emission from the material. And since this has nothing to do with the signal, this will appear like noise in the output of this amplifier. So, we will talk about this little later. Then we have a process which is the stimulated process and also some absorption process. So, if I consider the transfer of electron between these two energy levels, then either we can have a process which is downward which is spontaneous or we can have absorption of the energy of photon.

And we can have a stimulated process, which is responsible for optical amplification. So, if we pump the material at 1480 nanometer, then essentially the emission spectrum and the absorption spectrum are partly overlapped. Essentially, we are going to supply the energy corresponding to the upper level of this band and then the stimulated emission will correspond to the lower level of this band and the ground state. We have also seen that since these two spectra are overlapping, essentially filtering of this pump on the other side becomes rather difficult. So, 980 pump is the one which is rather preferred for pumping the erbium doped glass.

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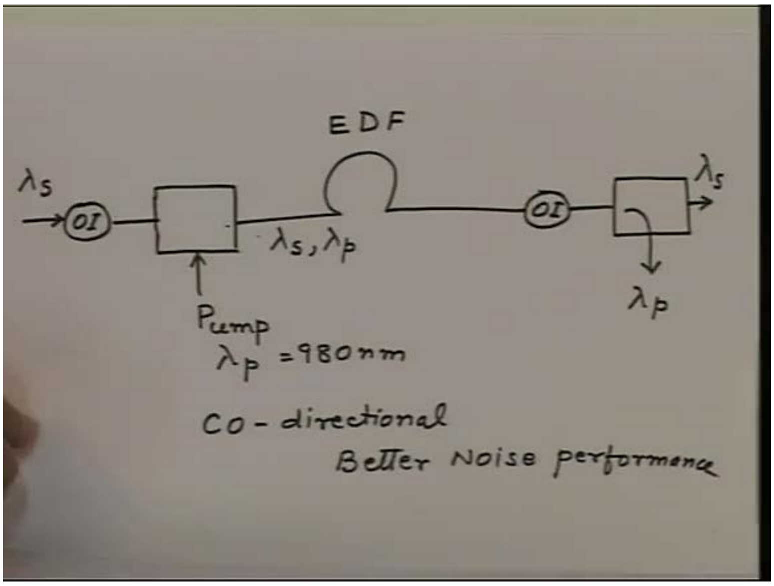

So, now the process is very simple. We have a erbium doped fiber which we call as EDF and then we have to pump this. So, we have here a wavelength combiner. So, here we supply the signal which is pumped. So, let us say this is pumped at lambda p and this will be let us say at 980 nanometer and then if we get the signal which is to be amplified, we combine in this combiner. So, the pump and signal together will travel inside this EDF and on the other side, we get the amplified version. Also some pump will be remaining, when the signal is amplified. So, we require some kind of a separator which will take the pump out and the amplified signal will come out.

So, now essentially after the signal and pump are combined by this combiner, then automatically the signal gets amplified inside this. And a small length of fiber of few tens of meters can give you a gain as large as something like 20 to 30 dB. Now, since we are having a medium here which is amplifying and the gain on this amplifier is very large, even a small reflection because of any deformations in the fiber or something may have a feedback. And since the gain is very large, there is a good possibility that this signal which is feedback because of small reflections. It may put this whole device in to oscillation and that is the reason we put what is called an optical isolator.

So, we provide a device here which is optical isolator and also we put a device here which is optical isolator and then you put the signal, which is the lambda s. So, optical isolator essentially is a device in which the signal can propagate only in one direction. So, signal can go only from this to this. But whatever reflected signal comes this way, it cannot propagate through this. So, if you are having some reflecting elements in this direction or here, then the signal will not get feedback into this amplifier. So, you get something here; again you have a wavelength demultiplexer. So, your pump lambda p comes out and you get here a lambda s, which is amplified.

So, essentially what we have done here? We have combined the signal and the pump by using this wavelength multiplexer and lambda s and lambda p have travelled together inside the EDF and we get the amplification of the signal. Now, the interaction of the pump photon and the signal photon does not depend upon the way these two are travelling with respect to each other. So, even if the signal photon and the pump photon were travelling in the opposite direction, even then the interaction between these two will take place and the signal will get amplified. So, now there are two possibilities.

Either we can pump (( )) pump which will propagate along with the signal and signal will get amplified. But in this case, as we can see that we have to separate out the pump and if you are having let us say pump which is 1480, then you require very good filters. So, that these two wavelengths are separated out. Contradict to this; suppose we had put the signal this way; but the pump was supplied in the backward direction, then also the amplification would take place. And also in the pump is travelling in the backward direction, separation of this would be rather rather easier. So, this one scheme is called the co-directional scheme and this essentially provides a better noise performance.

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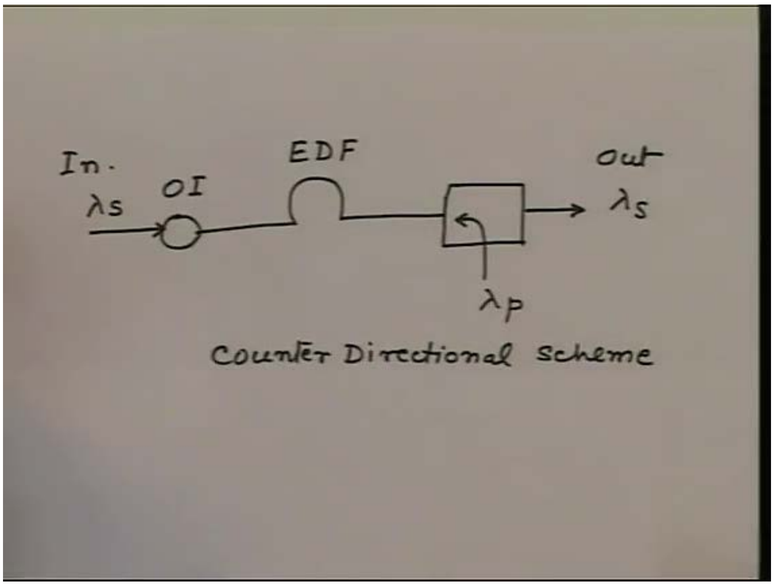

The other scheme which is opposite of this that we have this EDF and we put the signal from this direction; this is your optical isolator. I put the signal this side, which is lambda s and the pump is supplied in the opposite direction. So, pump is combined this way; this is lambda p and you get the amplified signal, which is lambda s. So, this is the output; this is the input and this is EDF. This one we call as the counter directional scheme. So, the signal and the pump they travel in the opposite direction inside the EDF and the power get transferred from the pump to the signal and signal gets amplified. The third possibility is the combination of this scheme and the co-propagating scheme.

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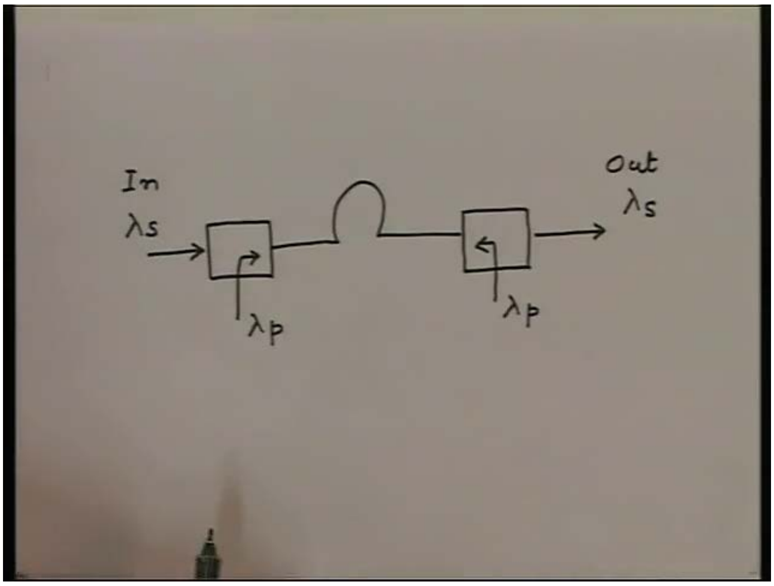

So, we may have a combination of these two which is this. So, we have one coupler, where pump is combined, lambda p. We have another here; pump is supplied backwards, lambda p and this is the signal, which is lambda s. This is input and we get the output from here, which is the amplifier. So, in practice, you see various possibilities for pumping this medium. We can have the co-directional pumping or we can have a counter-directional pumping or we can have a combination of the two and each one has some advantage over the other.

You also seen now that, if we do not put any signal inside the amplifier, then because of the band diagram we create population inversion. (Refer Slide Time: 03:54) And now you have got the electrons accumulated in this region, which will make downward transition. And so since now there is no signal present here, there will be downward transition which will be because of the spontaneous emission. So, we will get the output signal, which will have a spectrum corresponding to essentially the broadening of these bands. Say we mentioned here, these bands are not very sharp and because of that, you get a sort of a broadband signal generated by this amplifier, which we call as the spontaneous noise.

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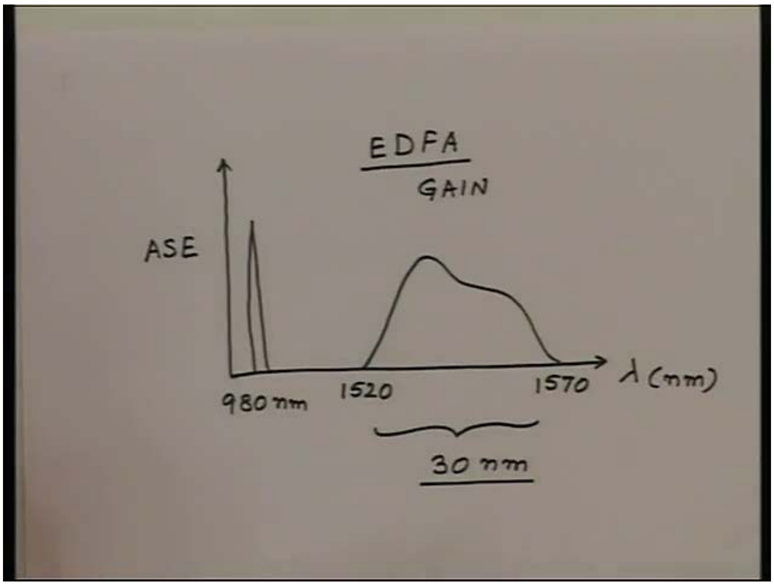

So, if you look at the spectrum what we call as the ASE spectrum. It will typically look like that. This is wavelength and this is ASE; so is amplified stimulated emission. So, typically a spectrum looks something like that. So, here let us say the wavelength is about 1520 nanometer and goes up to 1570 nanometer and the pumping will be done somewhere here, which will be at 1980 nanometer. So, this will correspond to 980 nanometer. So, in the absence of the signal, we get a very broad band signal typically of a width of about 30 nanometer. But if you have signal, then essentially this is defining the gain profile also of the amplifier. Say if you put the wavelength corresponding to this, it will give me higher gain.

If you put here, the gain will be little lesser; if you put here, the gain will be lesser and so on. So, what that means is that the EDFA essentially gives the broadband amplification typically over a band of about 30 nanometer effectively. So, this is the EDFA gain. So, if we use now the standard ITU grid which we saw yesterday that every 0.8 nanometer, you have to put one wavelength. Essentially, 30 nanometer divided by 0.8 about 40 channels can be accommodated in this window of EDFA and all these 40 channels can be simultaneously amplified inside the EDFA. So, essentially we do not require separation of the optical carriers. In a long link, we can just put an amplifier which is EDF and all the 40 channels which will be lying within this band; they will be simultaneously amplified.

Ofcourse, there is a concern that now you are having a gain, which is varying as a function of wavelength. So, those wavelengths which will correspond to this region will see more amplification and these channels will see less amplification. So, after certain number of amplifiers in the chain, this power in these channels would be much more compared to this. So, we require some kind of a mechanism, which will flatten this gain and will create an amplifier for which the gain is practically constant over this width of 30 nanometer. So, that is one of the aspects of EDFA design; how do we make the flat gain optical amplifiers. But it appears at this point of time that if we have a EDF which essentially is the piece of erbium doped optical fiber pumped with an appropriate wavelength 980 nanometer or 1480 nanometer, we can amplify about 40 optical carriers in one shot.

And that is a very interesting device that now we and also cost effective because just one amplifier is enough to amplify these large number of optical channels. And that is the reason the EDFA has become one of the very important components of a long haul optical communication system. Now, as the signal power increases, (Refer Slide Time: 03:54) the input signal power increases. We have a certain pump power which is going to create the population inversion. But as the signal power increases, essentially what happens is that now more and more electrons are pulled down. So, the optical power output power increases and as the output power increases, the population inversion which is created start depleting.

So, as the signal propagates inside the optical fiber or the EDF erbium doped optical fiber, initially the gain is very large; because there is a large population inversion which is available. But as the signal starts growing inside the optical amplifier, the population inversion starts filling sharp of the requirement and then essentially the gain of the optical amplifier starts dropping. So, typically then if we look at the characteristic of the optical amplifier, that the gain of the optical amplifier depends upon the input signal power. So, if you take the very low optical powers minus 50 60 dBm, the gain is rather large. But as the optical power increases, then the gain starts dropping.

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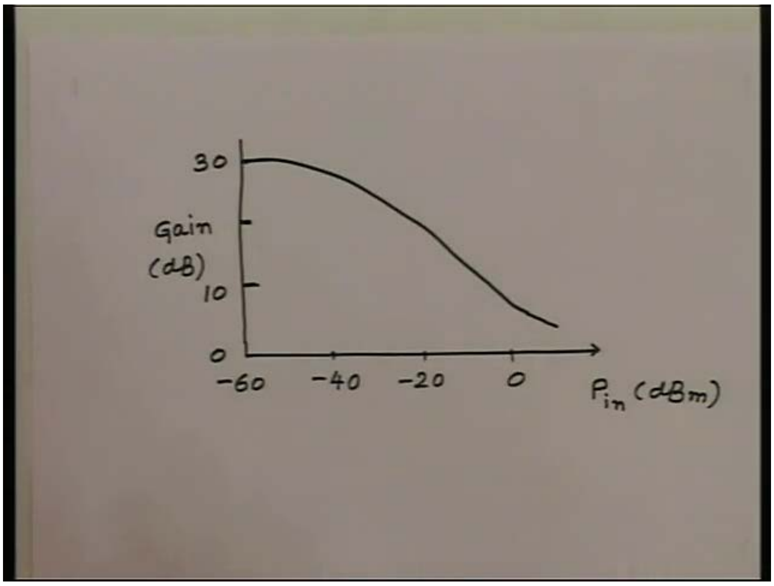

So, if you look at the typical characteristic of optical amplifier gain, it will look typically like this. So, this is the P in is the signal input power and you have here gain in dB's and let us say we put the power; this is minus 60; this is in dBm; minus 40, minus 20, 0. So, if you go to low optical powers, the gain could be as large as about 30 dB and this is 20, 10 and this is 0. So, a typical profile which we will get will look something like that. So, for a optical power input power as low as minus 60 dBm, the EDFA will have a gain of about 30 dB. But as the power reaches to about minus 20 dBm, the gain would have dropped to about 10 dB and by the time the power reaches to about 0 dBm.

Then practically, the gain has gone to 0 dB; that means there will be no amplification of the signal. So, this characteristic which you are getting for the optical amplifier essentially is that the power which is supplied by the pump now is not adequate; because as the signal grows inside the optical amplifier, it starts demanding more and more population inversion. So, you can now write the equation for the powers of the signal and the pump and essentially, we can write this from the conservation of the photons. So, we are saying that the certain number of photons, which were transported to give you the population inversion. Out of this, the power is transferred to the signal photons. Power was first carried to the upper level and then power was essentially extracted from the system in the signal photon, which is amplified.

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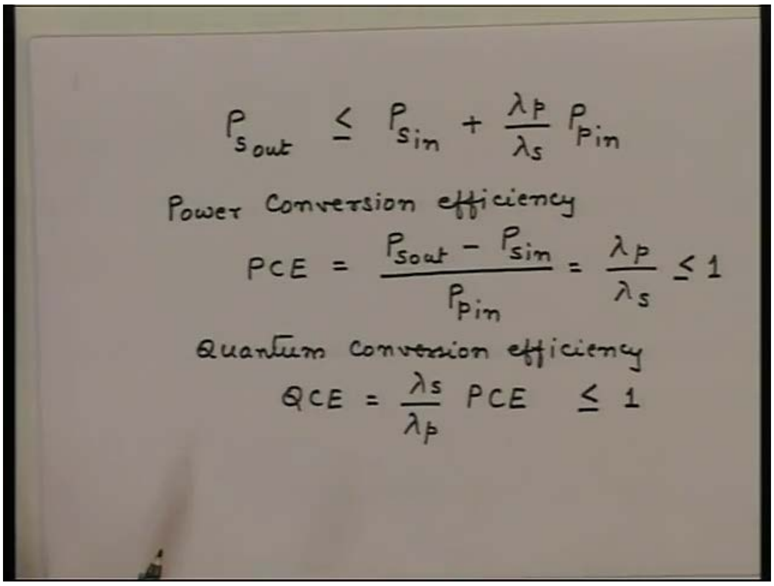

So, we can write down now the equation, which is the signal photon at the out which we get that will be less than or equal to the signal power which we have put in the input plus lambda p upon lambda s the pump power, which is supplied to the system. We get this ratio here lambda p upon lambda s; because essentially we are talking about here the photons, which are the energy divided by the energy of the photon. So, that is the quantity essentially we are having here and that is the (( )) that is the reason this quantity essentially is a expression of that the total number of output photons in the signal will be less than or equal to the original signal photons plus the pump photons.

Now, the quantity which is of interest would be the power conversion efficiency, the certain power we have put in to the pump. How much power actually we could extract from this in to the signal? So, we have parameter for the amplifier what is called the power conversion efficiency, (No audio from 25:26 to 25:36) PCE that is equal to the signal output power minus the signal input power. That is the power which essentially should have been supplied by the pump power. But every pump photon is not converted in to the signal photon. So, that is the essentially the efficiency we are talking about. So, this is pump input and this quantity will be equal to lambda p upon lambda s.

So, P s out minus P s in divided by P in that is this quantity and since this quantity is less than or equal to 1, now the quantity which you are having here. So, we have this power conversion efficiency, which is essentially P s out minus P s in divided by this P pump in and that quantity is lambda p divide by lambda s and as we have seen from our spectrum that this quantity here. (Refer Slide Time: 15:31) This is the wavelength, which is lambda p and that is the wavelength which you are going to get, which is lambda s. So, this quantity is always less than or equal to 1. Now, the power conversion efficiency now since it is the ratio of lambda p and lambda s, it actually does not tell you same number as like the quantum efficiency; because now it depends upon the wavelengths relative wavelength, which are used.

So, more useful quantity which we have used earlier for the like a laser or for the detectors, we can define the quantum efficiency or quantum conversion efficiency QCE; that is equal to lambda s upon lambda p into this quantity, which is the power conversion efficiency which is PCE. So, this quantity is 1 and since now we have taken this factor out essentially from here, we have multiplied this quantity lambda s upon lambda p. This quantity essentially is telling you the photon conversion efficiency same as what we have seen earlier for the photo detector or in terms of the LEDs and so on.

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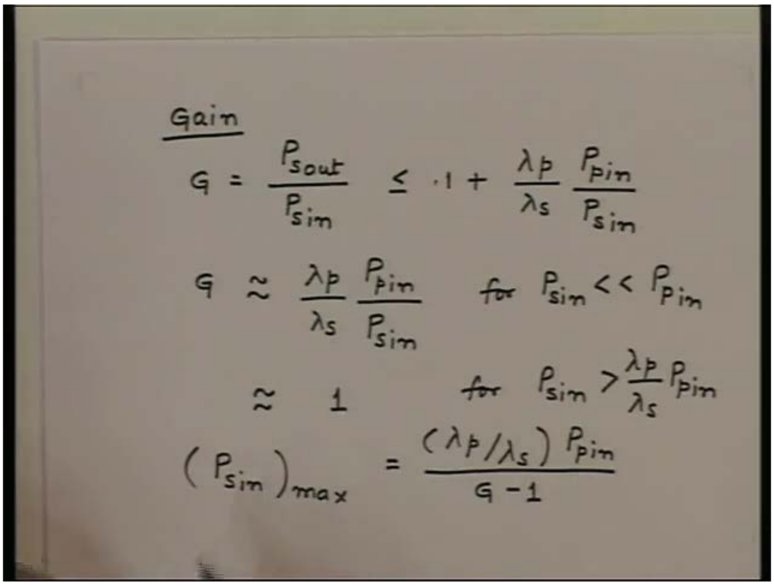

Then one can define the important parameter for the amplifier, which is for the gain. So, we can have a gain for this amplifier and that is nothing but the signal power in the output divided by the signal power in the input. So, this quantity is less than or equal to 1 plus lambda p upon lambda s into P pump input divided by P signal input. So, what we see now that when P signal is much much smaller compared to P pump; that time we have a gain this quantity is large and then we have the gain, which essentially is given by this parameter. So, we can say that this gain is approximately equal to lambda p upon lambda s P pump input divided by P signal input; for P s in is much much smaller compared to P pump in.

And this quantity will become approximately this, when this quantity becomes larger or comparable to this quantity. Say if you take a another situation where the signal are now is larger compared to the pump, that time this factor will be very very small and the gain essentially will go to 0 or 1 or 0 dB. So, this will be approximately equal to 1 for P signal in greater than this quantity, which is lambda p upon lambda s P pump in. So, essentially what we are saying is that for a specific gain of the amplifier and the pump input power, the signal input power should not exceed beyond certain length.

Infact if we look at these two quantities here, that is the characteristic which we drew here (Refer Slide Time: 21:18) which is saying that when we are having the signal power which is very very small, we have a large gain. So, this is the quantity which corresponds to this number here; whereas, when the signal power becomes large, you get the gain which is almost equal to 1. So, this function essentially tells us the signal power increases, for a given pump power we have a reduction in the gain and that is what essentially this curve is telling you. So, then one can say that for a desired gain and for a given pump power, there is a maximum power which should be given to this amplifier.

So, there is maximum value of the signal input, which can give you the desired gain and that essentially we can get from inverting this relation. So, we have a signal power input the maximum value of this; this is equal to lambda p upon lambda s pump power divided by G minus 1. So, essentially we have taken this expression; taken this one on this side and you find out what is the maximum value of this required; so that, I can get the desired gain G. If the power signal power increases beyond this value, then the amplifier gain will be less than this quantity G. So, therefore for a given amplifier and for a given pump, you have a maximum optical power input power which the amplifier can handle.

And beyond that, essentially with the gain of the amplifier will starts dropping. Now, if I take a optical link; if you put an amplifier just next to the transmitter where signal power is large, practically the optical amplifier will not do anything though it may add some noise. Whereas, when the signal is attenuated to a significantly low value that time you put an amplifier, then you get amplification in the signal. So, we see later that as we are having a long length, we will put the amplifier at locations where signal is attenuated to a low value (Refer Slide Time: 15:31) and then you get the appropriate amplification by putting the amplifier there.

So, this you get essentially is some kind of a saturation effect, which is taking place inside the amplifier. Also one can note from here that when you are having now this spectrum of the signal which we saw, this is the signal which is going to grow rapidly inside the amplifier and this signal will see less gain. But as the power in the signal increases, the gain of this amplifier will reduce for these wavelengths. So, essentially we are having some kind of a complex phenomenon now; that initially these are the wavelengths which were start increasing rapidly. But as the power in that increases, then the gain for these wavelength reduces and so on. The gain of the amplifier also depends upon the length of the EDF.

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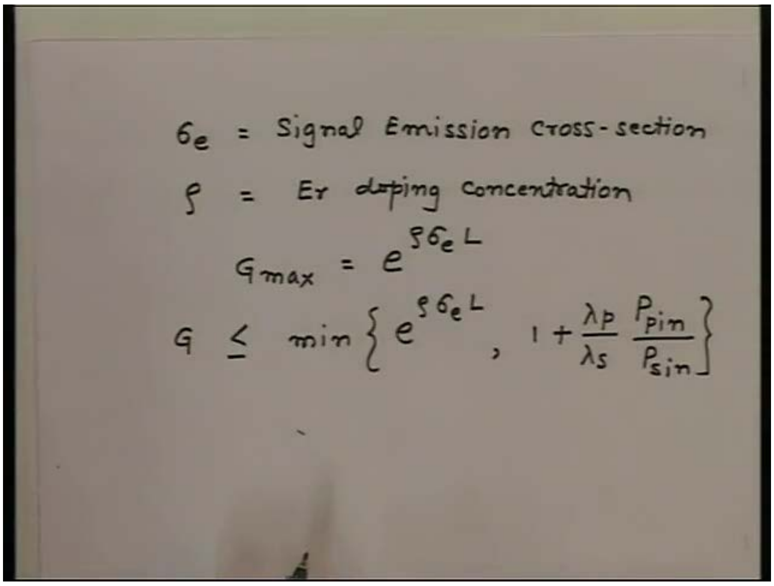

So, if we say that we are having what is called the signal emission cross section for the EDF and let us denote that quantity by sigma e. So, these is signal emission cross section and let us say we have a parameter called rho, which gives the erbium doping concentration inside the core. The maximum gain which the amplifier can give G max; that is e to the power rho sigma e into L. Now, the gain actually depends upon now two things. One is the saturation effect which we saw inside this, which which is because of this (Refer Slide Time: 28:54) this quantity.

So, as the power starts growing, essentially the gain will start dropping. So, Ii have now the two things. One is this factor which is showing you the gain, which is going as the length is increasing. But as the signal starts growing, then the saturation effect starts come in to picture and because of that, the gain drops again. So, we can have the gain, which is less than or equal to minimum of the two. One is this quantity, which is e to the power rho sigma e into L and the other one which is because of the saturation effect, which is 1 plus lambda p by lambda s P p in divided by P s in.

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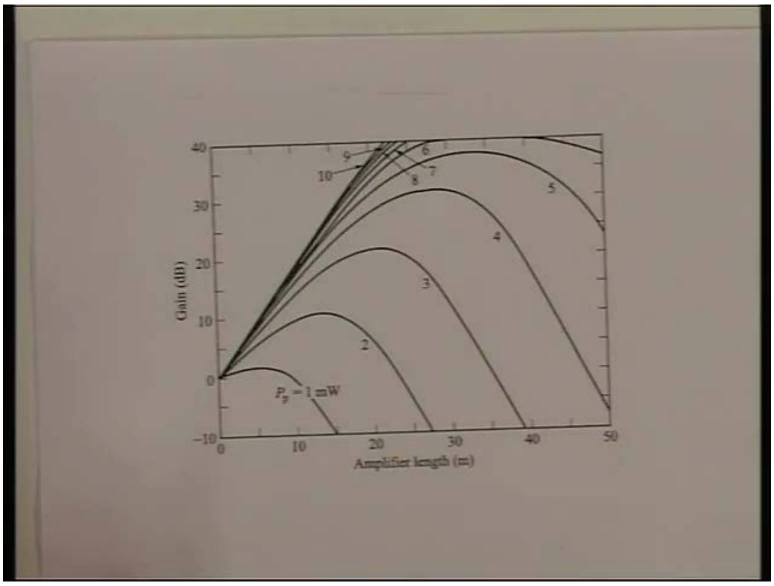

So, if you take this gain in plot now as a function of length, a typical gain characteristic of the EDF would look like that. So, what is shown here? We have a amplifier length, EDF length and this is the gain of the amplifier, which is given in dB's and these are the curves for different pump powers. Say, if you have 1 milliwatt pump power, you will get a maximum gain which should be very close to 0 dB. And if we go to 2 milliwatt, the gain would go of the order of about 10 dB and like that, if I go on increasing the pump power, ofcourse the gain would increase. But for every pump power, there is a maximum gain which is possible and beyond that, again the power will start dropping or the gain will starts reducing.

So, for given erbium concentration inside the fiber and the pump power, there is a optimum length for the amplifier. If you put the length more than that, then we will not see the gain in the amplifier; because internally signal would have grown to certain value. But again, the gain will start dropping and we will not get any advantage. If you put the length smaller than that optimum length, again the gain will not be sufficient. So, infact we have to put the EDF length appropriate, the optimum length which would correspond to the maximum value here. And typically, this length then would lie in the range of about 20 to 40 meters. So, we see here the maximum is lying about minus 30 dB kind of gain about 30 meter of the amplifier length would give me that gain.

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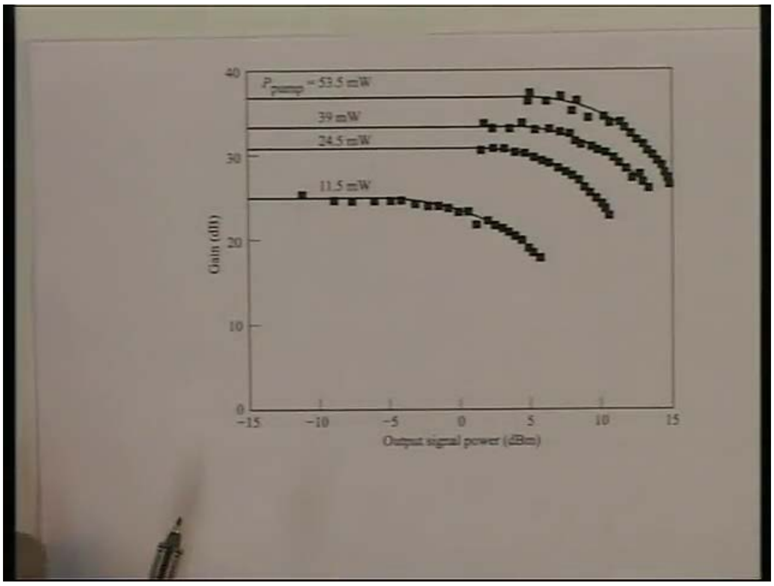

Here the characteristic which shows the gain saturation for the optical signal. So, this is the input optical power and this is the gain. Again as the pump power changes, these are different values for the pump. Here the pump is 11.5 milliwatt; here is 254 milliwatt, 39 milliwatts, 53 milliwatts and these are the input signal power minus 15 dBm, minus 10 dBm, minus 5, 0, plus 5, 10 and so on. Say we are talking about the pump power, which are reasonably large. So, the gain saturation starts coming in to picture beyond about 0 dBm power. Say, here a typical gain is of the order of about 30 dB and up to 0 dBm, the gain is practically constant and as you go beyond that, then slowly the gain start dropping because of the gain saturation effect.

So, EDFA has this characteristic that it shows the gain saturation inside the amplifier and also it shows reduction in the gain, beyond the certain optimum length of EDF and these things should be taken in to consideration, when we design the EDF. The another aspect of the EDF is the noise which is generated inside the EDF. Infact, whenever we talk about an amplifier, there is always a noise associated with the amplifier. There is no amplifier in the world which can give you only amplification without adding any noise and EDFA is no exception to that. So, in this case also, we get amplification of the signal.

But at the same time, we have reduction in the signal to noise ratio and as we saw from where the noise is coming, the noise essentially coming because of the spontaneous emission inside the EDF. So, when we are having a population inversion in the absence of even signal photon, the electrons would make downward transition and in that process, they would give the emission out and the spectrum of this would be same as that ASE, if the broadband spectrum about 30 nanometer width. So, you get now the noise typically of the bandwidth of about 30 to 40 nanometer and this is the noise which will get added to the signal, when the signal comes out of this. So, then one can define the parameter for the ASE or what is called the amplitude spontaneous emission noise.

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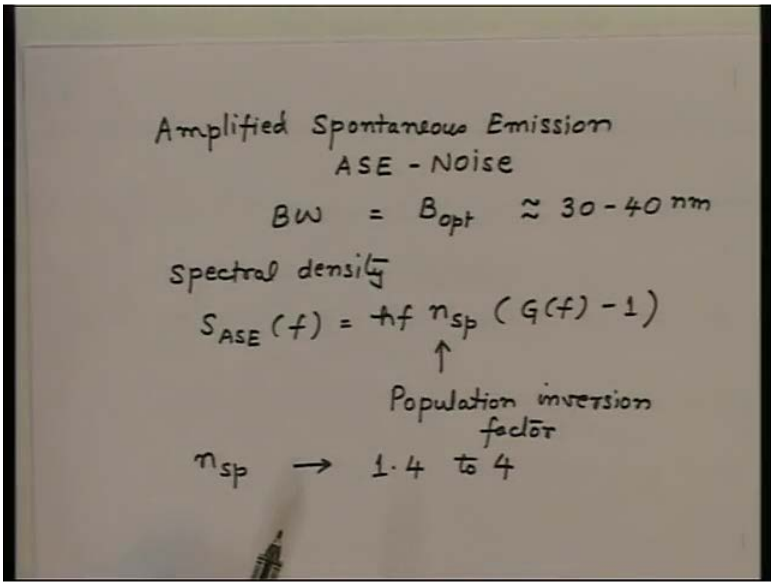

We can write down the spectral density. So, if we take this amplified spontaneous emission noise, so we call this as ASE noise; the typical spectrum for this will be… Bandwidth for this let us call it some B optical. This is typically of the order of about 30 to 40 nanometer. We can define now the spectrum; assuming that the spectrum is practically constant in this band without worrying about the small variation which we have. So, we can get a spectral density of the ASE noise. Let us say that is S ASE as a function of frequency that will be h into f, where f is the frequency of the photon; n sp gain of the amplifier which is a function of frequency minus 1; where this quantity is what is called the spontaneous emission factor or population inversion factor. (No audio from 44:50 to 45:03)

Typically, this value would lie between 1.4 and 4 somewhere between for typical EDF 4 to 4 and this will depend upon the wavelength and the pumping rate. So, more population inversion you create, essentially you are going to get more downward transition. So, you can get essentially the population inversion factor enhancement. But typically for the kind of pumping we are talking about, with this now parameter would lie in the range of 1.4 to 4. So, essentially where one can get the amplified spontaneous emission noise or ASE noise and this also depends upon which way the amplify this pump. Infact, why we talk about two different schemes? One is co-propagating and counter-propagating. Because the ASE contribution is different in two cases and that is what essentially is shown here.

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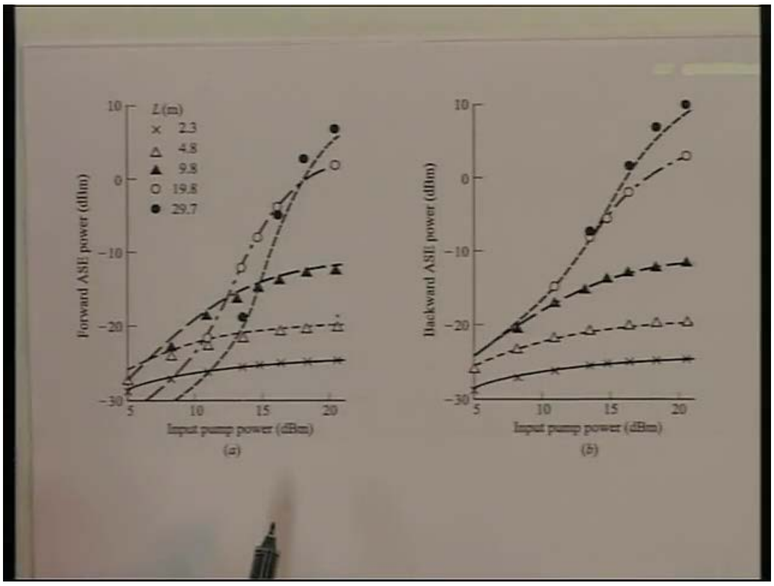

That as the function of the input power in dBm, we have here the ASE in dBm and this offer two schemes. This is for the forward scheme and this is for the backward scheme. So, in this case, the signal and the pump they are travelling in the same direction and in this case, the signal and the pump they are travelling in the opposite direction and these are the different lengths for the EDF. So, let us say if we consider this typical data which is about 30 meter of the EDF length, these are the points which are representing that and this is the thing for the backward propagation. So, this gives you essentially the relative difference between the ASE, which will be created in the forward scheme and the backward scheme.

Now, what does the ASE do further? When the signal goes and reaches to the detector, the originally the ASE is a noise which is the broadband noise, which is generated inside the EDF and it reaches to the detector. Now, detector essentially is a square low device. So, as we have seen inside a photo detector, we have the photocurrent which is proportional to the optical power. But now the photons which are going to be generated inside the EDF, they will be added with the signal and the signal and the noise photons together are going to fall on the detector.

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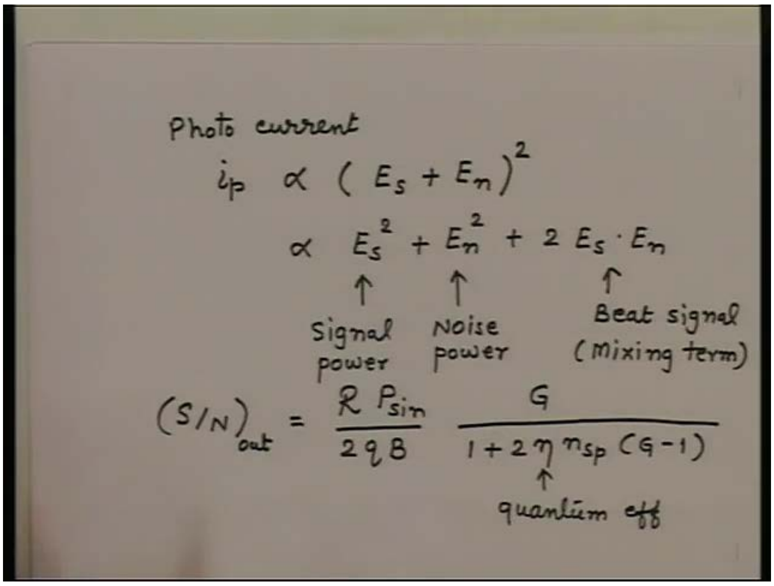

So, now in this case if you ask what the photocurrent which is going to flow, we will get the photocurrent in the detector. Let us say, this is i p that will be proportional to the total power. But now since we are now combining this noise and the signal, essentially the fields of the signal and the noise will get added. So, you will see the photocurrent will be proportional to the signal field electric field plus the noise electric field, which is because of ASE and the square of this. So, in the absence of this noise, you have the photocurrent which is proportional to E signal square, which is the power in the signal. But now we have this i p proportional to sum of the electric fields of the signal and the noise.

So, therefore this is proportional to E s square plus E n square plus 2 times E s dot E n. So, this is nothing but your signal power. This is the noise power in the ASE. But we have got now additional term which looks like noise; because we have a product here which is with respect to E n. But its amplitude is not as low as this; because this quantity is multiplied by this E s. So, it becomes proportional to this quantity signal; this is what is called the beat signal or the mixing term. So, the output power which we are going to get now actually is because of the signal power and also the noise, which is going to contribute it because of the ASE. And in this case, now we are going to get the ASE which will be also depending upon the signal; because the photo detector essentially does some kind of a mixing of these two.

So, then if we calculate now the total noise, which is going to be present and now I have a noise which is the shot noise, thermal noise and also the noise, which is created because of this term. If we put all together, then we can write down the signal to noise ratio of this amplifier and that will be given by R is the responsivity of the detector P signal input divided by 2 q B, where q is the charge; B is the bandwidth of the receiver multiplied by G upon 1 plus 2 eta n sp into G minus 1. This is same as the like quantum efficiency of the detector and this term you already defined. So, essentially I have got a signal to noise ratio at the output of this amplifier, which would look like that. Now, this quantity is nothing but the signal to noise ratio, which we would get at the input or in the absence of this amplifier.

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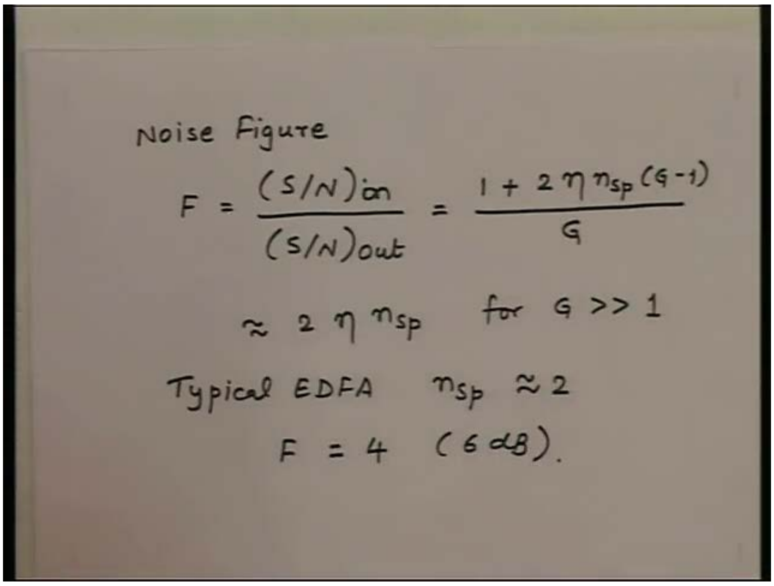

So, then one can define the noise figure for this amplifier, which is the signal to noise ratio at the output divided by the signal to noise ratio at the input. And that will be noise figure F, which is S bar N at the input divided by S bar N at the output and that will be nothing but this quantity here 1 plus 2 eta n sp G minus 1 upon G. So, this is approximately equal to 2 times eta n sp for G much much greater than 1 and typical

EDFA has n sp is of the order of about 2. So, you get a noise figure for the amplifier, which is equal to 4 or about 6 dB.

So, what we have done in this lecture? We have essentially seen the various characteristics of the erbium doped fiber amplifier. We saw that for this amplifier, there is a gain saturation effect; there is optimum length for getting the maximum gain from the amplifier and then there is also the ASE amplified stimulated emission noise; this essentially affects the signal to noise ratio performance. So, the EDFA like any other amplifier increases the signal level. But there is always deterioration in the signal to noise ratio and a typical EDFA would have a noise figure of 4 or 6 dB; that means signal to noise ratio will deteriorate by a factor of 4.