Physics of Linear and Non-Linear Optical Waveguides
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Module - 02
Basic Fiber Optics
Lecture - 08
Fiber Loss, dB Units, Dispersion

So, hello student to the course of Physics of Linear and Non-linear Optical Waveguides. So, today we will going to have lecture 8, and in lecture 8 we will going to discuss about the Fiber loss in dB units and another concept called Dispersion, which is a very very important concept in waveguide propagation.

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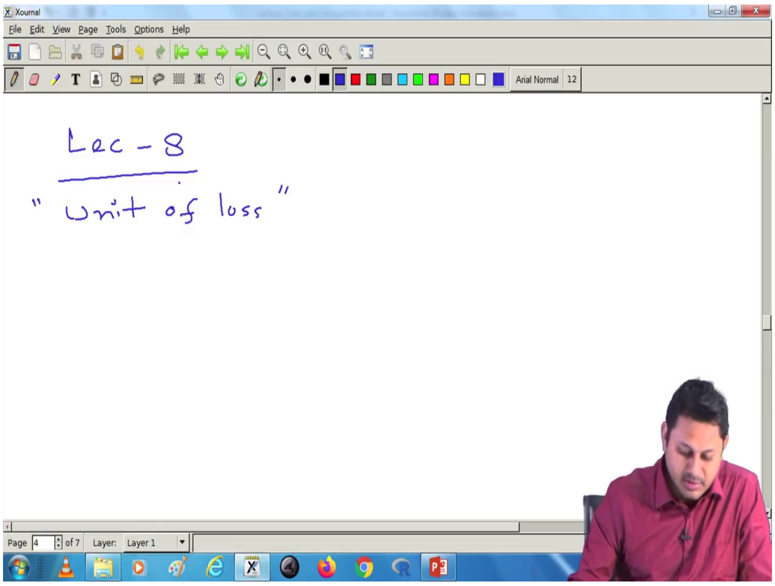

So with this note, let us directly go to, so we have this is lecture 8 ok. So, the in the previous class we discuss about the loss and we mentioned that there are many way through which the loss can be incorporated in a waveguide propagation and it can be calculated and there is a specific unit for that. So today we will going to understand, what is the unit through which one can define a loss.

So, to the topic is you need to know unit of loss. So there is a specific unit for it, dB or dB per kilometer etcetera. So, there is a measurement of loss, so that we will going to discuss.

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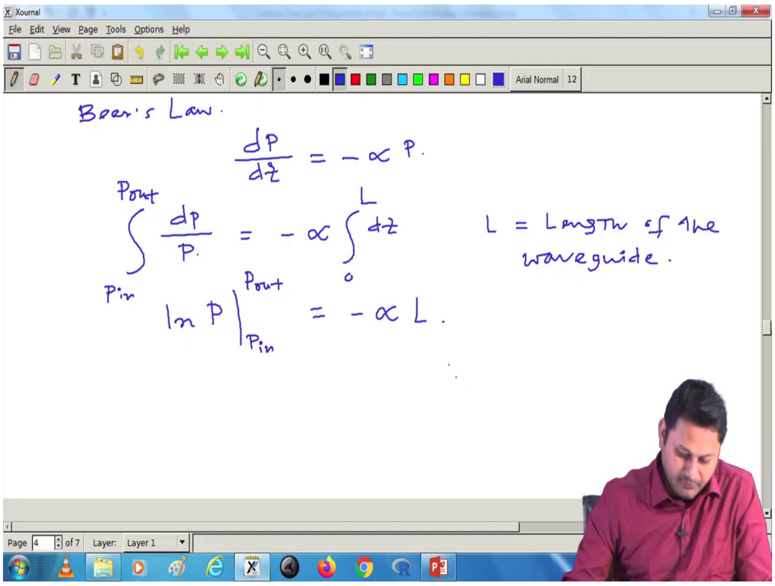

So, let us start with our well known Beer Lamberts Law or simply Beers Law. And in Beers Law, we know that the rate of change of power during the propagation, if there is some loss is defined by this differential equation. It will be proportional to the power and there is something called loss coefficient. So, alpha is a loss coefficient. So, this is the; this is the law we know.

Now, if I want to find out this alpha in terms of this P, one can readily find that by integrating this quantity; this is P in. So, this quantity is minus of alpha integration of d z. So, at z equal to 0, I have P in at z equal to say some L; length L I have P out. So, I have the input and output power in my hand and L is a length of the waveguide. In this case, fiber. So, ln of P by putting the boundaries value P in and P out will be equal to minus of alpha of L.

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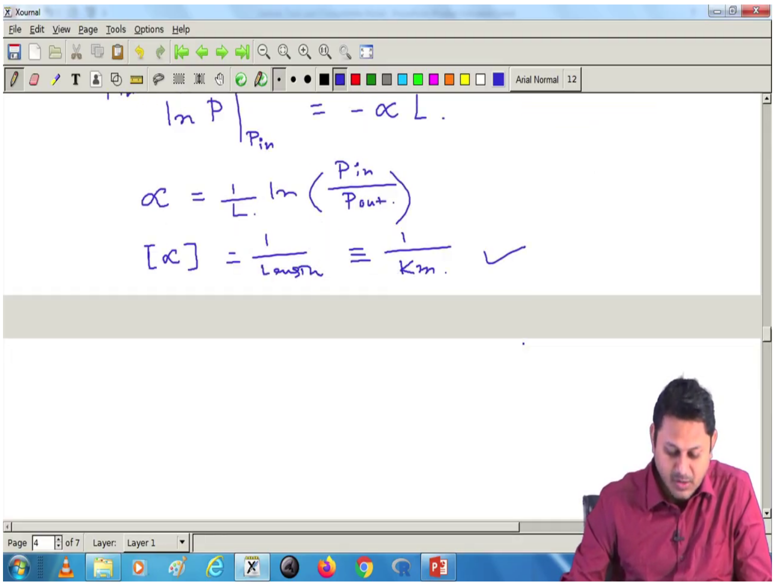

So alpha is simply then, which is we call loss coefficient. Is simply, 1 divided by L ln P in divided by P out. By just changing P in and P out we just remove this minus sign here. So, if I find out the unit of alpha, then it should be simply 1 divided by length or 1 divided by say in kilometer, normally we use in terms of kilometer because the fiber, the waveguide length or the fiber length is normally in kilometer range, so kilometer.

So, 1 by kilometer should be the unit of the loss coefficient alpha. But, we use another kind of unit in fiber optics which we call dB unit.

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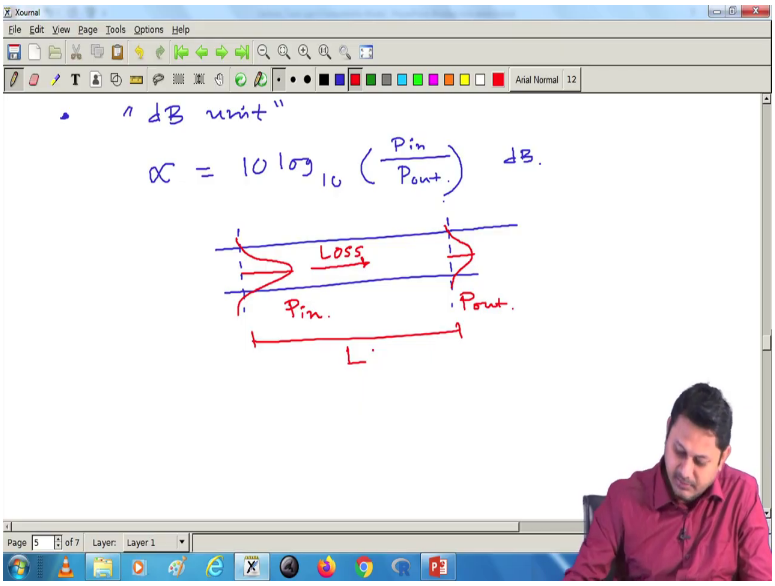

And, by definition alpha is equal to 10 log 10 in dv unit. If I define alpha in dv unit then basically, this is the measurement I have in the right hand side; P in divided by P out in dB unit. This is the dB image.

So, I have the input power, I have the output power. So, this is the waveguide I have and like before I have the initial structure. So, here I have this value; the power, say peak power. I have some value P in this is the power of initial power of this mode and it is now propagating through the fiber. And, on the output at the output the value of this amplitude is reduced because of the loss.

So, I have some loss here, during the propagation. And value on the output P output is reduced, whatever the value I have it will going to reduce. Now, if I calculate these two input and output value and put this in the equation, then whatever the loss I have, this value alpha will be termed as that dB amount of loss.

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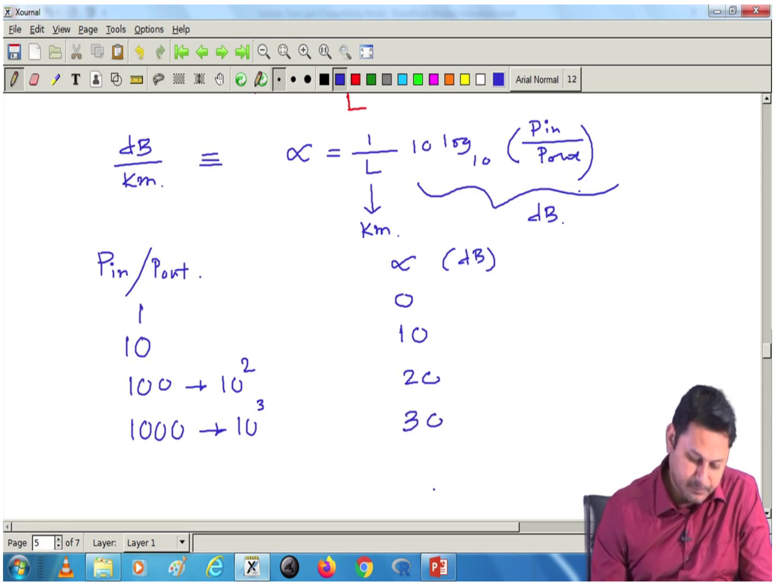

Now, also we need to include this length along which this loss is there. If this is L, this length is L, then I can simply write a unit dB per kilometer; that means, per unit length, what is the amount of loss one can expect. And it should be alpha equal to 1 divided by that length, then 10 log base 10 P in divided by P out.

So, this is the strategy to find out what is the value of alpha in dB per kilometer unit. So this unit, this portion gives me the value in dB and this L is measured in kilometer. So, overall I can have the value of alpha in terms of unit dB per kilometer.

I can chart it, what is the value; because it is in 10 base. So, I can see what is so, if I have P in P out ratio that is argument of this log 10 base and alpha in dB, if I calculate say unit length. So, when it is 1; that means, input and output power level is same, I should have 0 loss. So, here you can see this value is 0 in terms of dB.

If the ratio of P input and P output is 10; that means, the output is reduced as a factor of 10, then in dB it is 10 as well. If it is 10 to the power say 100, which is 10 to the power 2 then the value in the dB unit is 20. If it is 1000, which is 10 to the power 3, the value in dB unit is 30 and so on.

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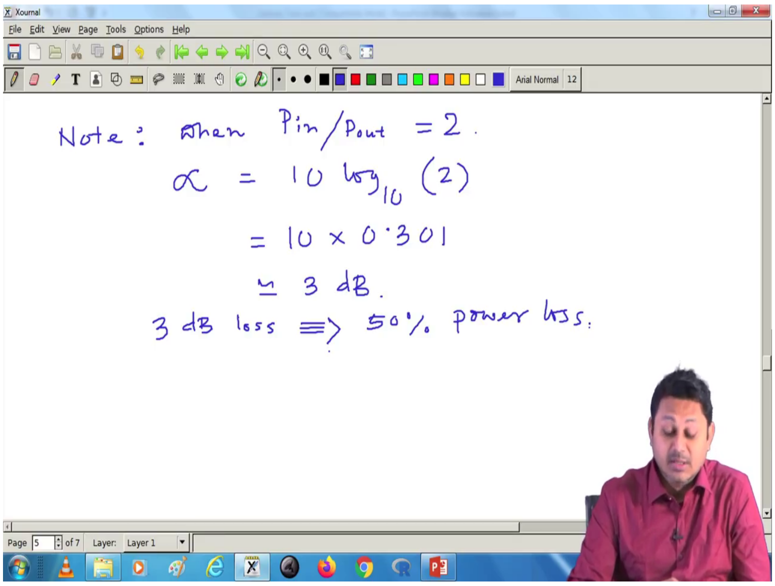

Now, note; when P in divided by P out is 2; that means, the power is reduced to half; the power is reduced to half, then the value of alpha is equal to 10 of log of 10 divided by, P in and P out is 2, so I write it at 2, this value is 10 into roughly this value is 0.301; so it is nearly equal to 3 d 3 dB.

So, in many cases this 3 dB value is used and basically it measures the 50 percent of the loss. That measures 3 dB loss means; when I say it is 3 dB loss, I eventually mean this 50 percent power loss. So, I launch a power and when this it is propagating in the waveguide, through the waveguide then there is a reduction of the power, and if the power is reduced 50 percent then the value of the alpha comes out to be 3 dB in dB unit.

So, that in many ah cases it is used. Another kind of unit also one can one can find in fiber optics communication systems, so which is called dBm unit.

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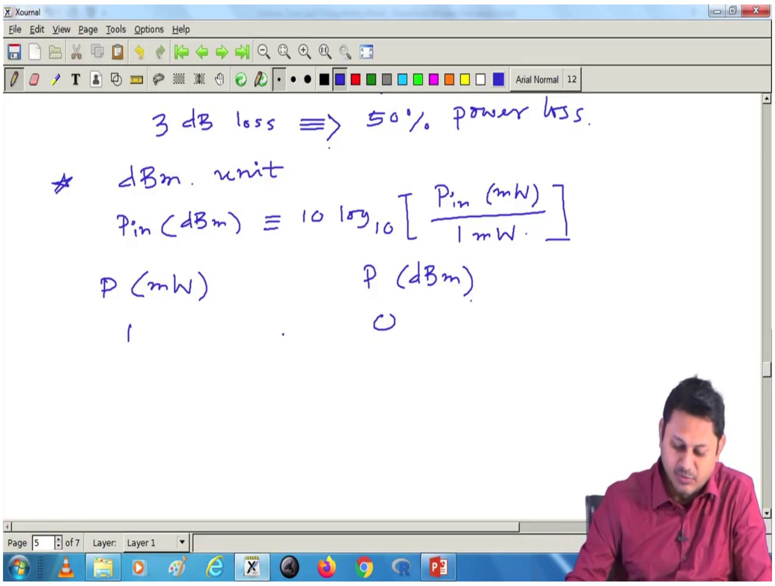

So, it is also defined in this way; P in dBm unit is eventually 10 log 10; then P in some milli Watt unit reference by 1 milli Watt. This is the reference. So I write the milliwatt unit in terms of dBm unit with this definition.

So, this is a definition through which I can convert this milli Watt unit to dB unit. So, also I can make a chart and have an idea that P in milli Watt and P in dBm; I just start putting the value and readily I get the result. So, 1 it should be 0. So, 1 milli Watt P in terms of 1 milli Watt in dBm it is a 0. This value is 0.

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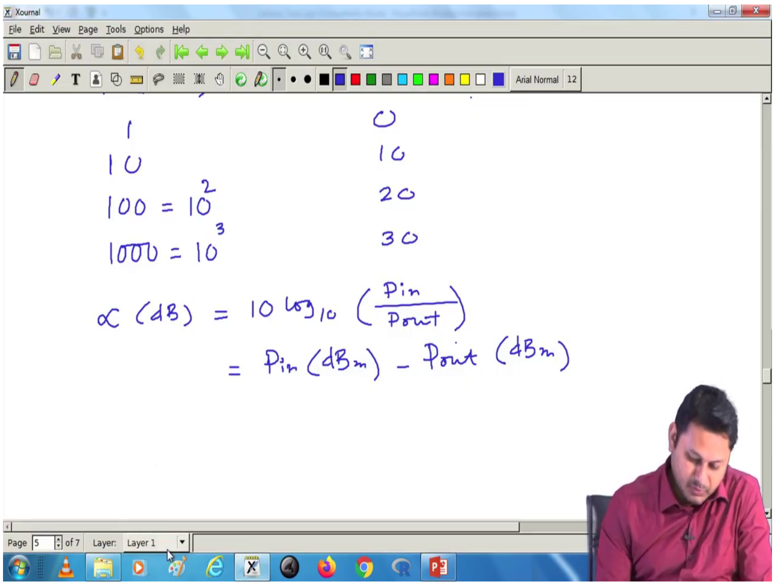

10 milli Watt this value is 10. 100 which is equal to 10 to the power 2 milli Watt, this value is 20 dBm. 1000 which is 10 to the power of 3, this value is 30 dBm and so on.

So, alpha can also be represented in terms of; I mean, knowing this dBm alpha I can write, in dB is equal to 10 log 10 P in divided by P out, and now if I if I reduce this to dBm unit, I can write it as P in dBm unit minus P out in dBm unit.

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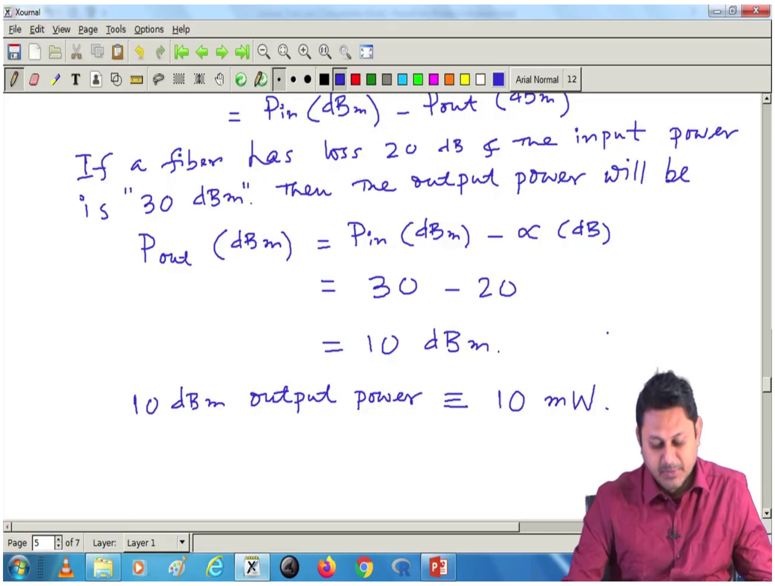

So; that means, what is the meaning of that? That if a fiber or a waveguide, if a optical fiber has loss 20 dB and the input power is say "30 dBm", in dBm unit in input power is represent in dB dBm unit, then the output power is output power is output power will be; what should be the output power? P output in dBm unit should be using this formula whatever the recipe we have; P in dBm minus alpha which is represented in dB unit.

So this quantity is 30 and alpha is 20 given, so we have 10 dBm. So, at the output at the output I have 10 dBm power. So, 10 dBm power means the output I have 10 dBm power means 10 dBm output power is equivalent to, here we have a chart, so you can make a chart. So, here 10 dBm is equivalent to 10 milli Watt.

So, eventually I have 10 milli Watt power at the output whereas, in the input I have 30 dBm. So, 30 dBm means in the input actually I have 10 to the power 3 milli Watt; that means, I launch 1 watt power and during the propagation there is a loss and at the output I am getting 10 milli Watt of the power and this loss is 20 dB. When the loss is 20 dB I have 10 milli Watt.

Well, this is roughly the way one can represent the loss in the fiber in dB units. Now, we will going to start a new characteristics, a very very important characteristics I mentioned the beginning of the class and this characteristics or this property is called the dispersion it is called the dispersion.

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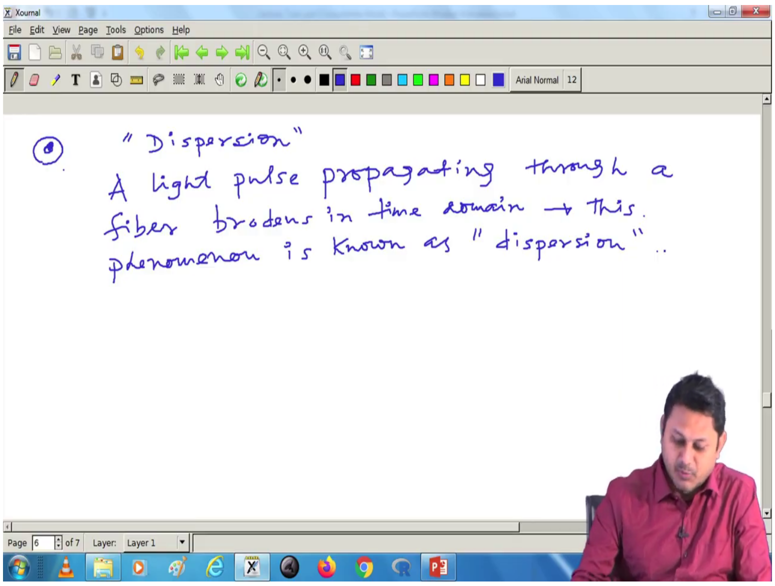

Very very important parameter. Loss is also very very important characteristics of a fiber. Dispersion is also equally important for long distance communications. And how one should have an idea about the dispersion, what is the physics behind dispersion, that we will going to discuss in detail in this course. A light so, what is the dispersion? So, a light pulse propagating through a light pulse propagating through a fiber broadens in time domain. So this phenomena is roughly known as dispersion.

Anyway, we already have an idea about the dispersion when we launch a white light in the dispersive medium; like a prism and then we find that there is a separation of lights.

That means, when the light is propagating inside the medium, like prism which we call the dispersive medium; the velocity of the light is not same for all the wavelengths, that is why there is a separation between the rays and we have the spectra as a output. In; however, in optical fiber when a light is propagating then it propagating the form of pulses.

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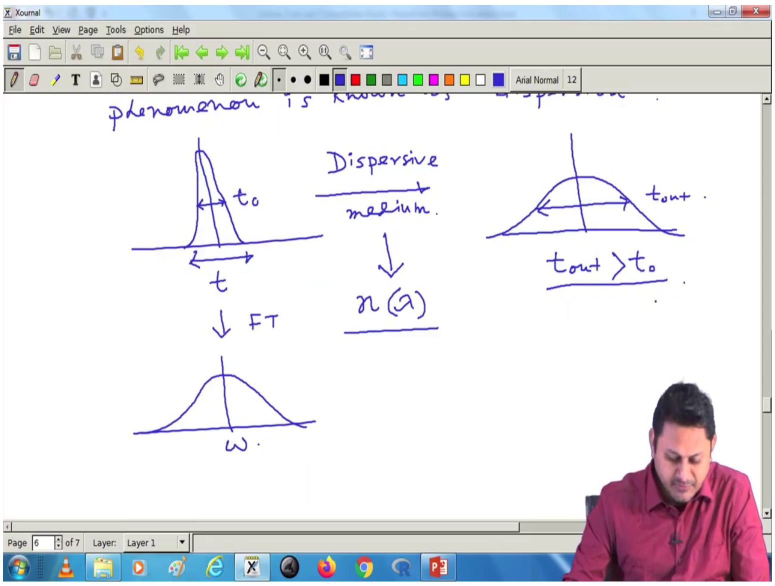

So, if this is the pulse, this is in time domain, this is the pulse. If I make a Fourier transform of that then I should have a frequency distribution of that. This is in omega. And a frequency distribution of that thing.

Now, when it is propagating when it is propagating in a dispersive medium, different frequency component can propagate in a different speed, different group velocity, because the refractive index, when we have a dispersive medium that essentially means the refractive index is a function of lambda or frequency; which we know that refractive index is a function of frequency. Then as a result, at the output we have a spectral broad a temporal broadening like this.

So, if at the initial with is t 0, suppose it is a Gaussian kind of optical pulse, this is also a Gaussian kind of optical pulse. But here, we have a pulse with t out where t out is greater than t 0 and this is because of the dispersion.

Well, with this very very rough idea we can divide this dispersion phenomena into two major parts;- one is called intermodal dispersion.

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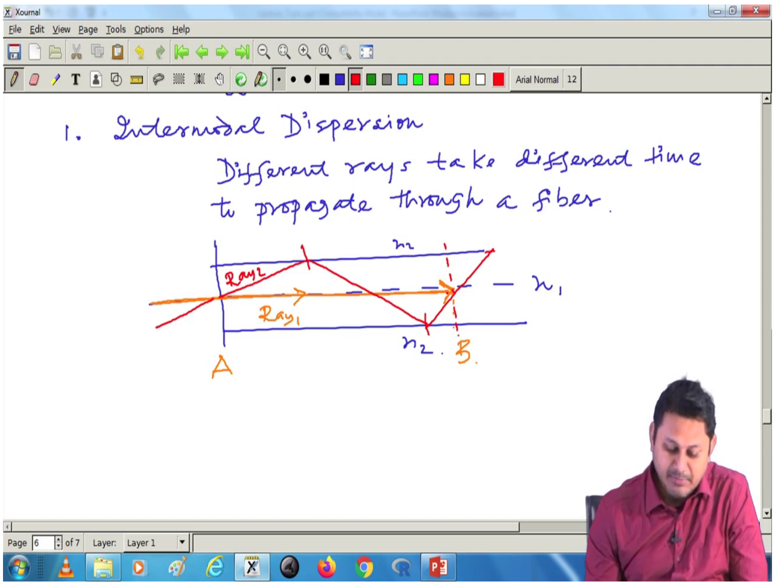

One can understand this is a intermodal dispersion in the ray picture like; different ray take different time different rays take different time to propagate through propagate through of a fiber. This is called intermodal dispersion. So, I very simple example, one can suppose this is a cross sectional view of a fiber effective index n 1 n 2 n 2. So, I can consider two rays. So, one ray is passing through like this. I launch the ray is passing through the core axis like this.

Now, once this is once this is passing through this co axis it will take some time to go from point A to point B. And another ray one can consider which is passing through the system like this. Also, this ray, if it is ray 1, I can write it as ray 2. So ray 1 and ray 2 should have different time to reach this same point B, whatever the point I have here B. So, there is a time, definitely there is a time delay between two rays.

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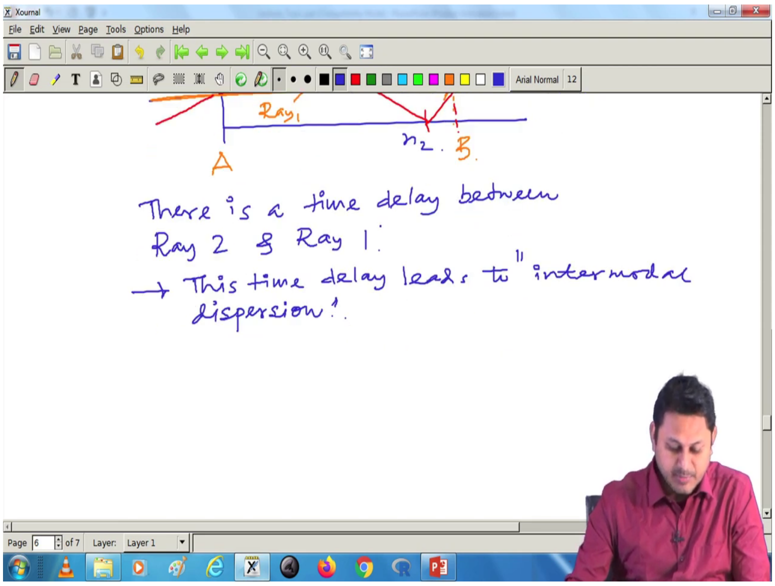

So, there is a time delay between Ray 2 and Ray 1. And, this time delay leads to this time delay leads to intermodal dispersion. Apart from intermodal dispersion we have another kind of dispersion.

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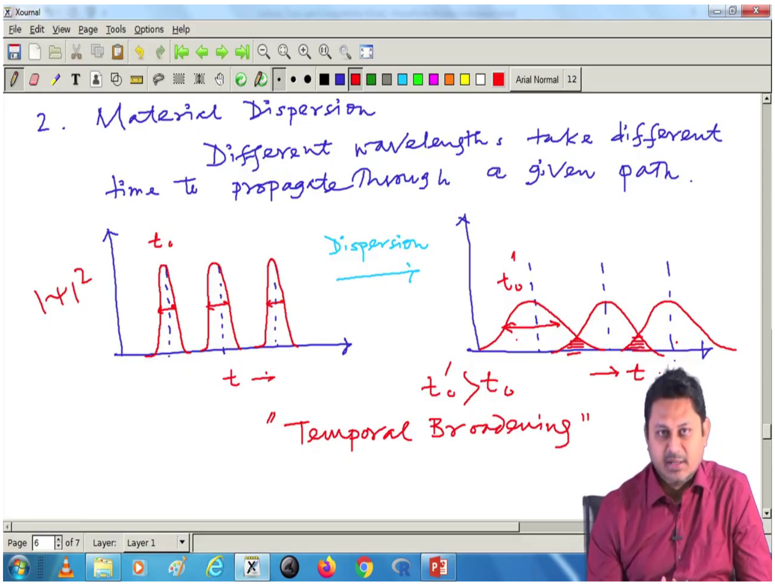

Let me define this which is called material dispersion. So, in material dispersion already I mention that different wavelengths take different time to propagate through a given path.

So, different wavelength are taking different time to propagate a given path, and as a result what happened is this which we called what is why it is important you can understand that it will going to experience some kind of temporal broadening and that will affect the transmission quality heavily.

Suppose, we have some input pulses like beats. In the propagation these beats are very very important. This is 1 this is 2 and this is 3. So, 3 pulses are propagating containing the information in the form of beats. And now these widths, so this is say mode of psi square where psi is a field and this is time t and this widths are t 0 all the cases.

Now, it is passing through now it is passing through a dispersive medium, some dispersion will take place this dispersion so some dispersion will take place. And when this dispersion take places when this dispersion takes place, then what happen? There will be a temporal broadening of that like this. The same wave now are having a broader temporal.

So, this is a t 0 prime, where t 0 prime is greater than t 0 this is again in time domain, so we have a temporal broadening. And when we have a temporal broadening, you can see some overlapping is happening here. So, it will going to affect the transmission quality. So, how it will going to affect the transmission quality and how we calculate the intermodal and material dispersion that we will going to learn in the future classes.

So, today we do not have much time. So, I like to finish here. So thank you for your attention. In the next class we will going to calculate the inter how to calculate the inter model dispersion.

So, thank you and see you in the next class.