Industrial Instrumentation
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Lecture - 28
Optoelectronic Sensor – I

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Welcome to the lesson 28 of industrial instrumentation, in this particular lessons we will study optoelectronic sensor. In fact, the optoelectronic sensors, I have divided in the 2 lessons in the electronic sensor 1 and optoelectronic sensor 2. In the optoelectronic sensor 1, we will look at this various types of photo resistors then photodiodes photo transistors, we will cover very brief. And all this things also, some brief introduction to fiber optics, because as you know there are as a day's going on. So, there are lot of fiber optics senses coming up and we should discuss that details in the lesson 29. But in basic introduction to the fiber optic sensor also will be fibre optics techniques transmission techniques. And all this things will be covered in this particular lesson that is the second I mean, later part of this the lesson 28.

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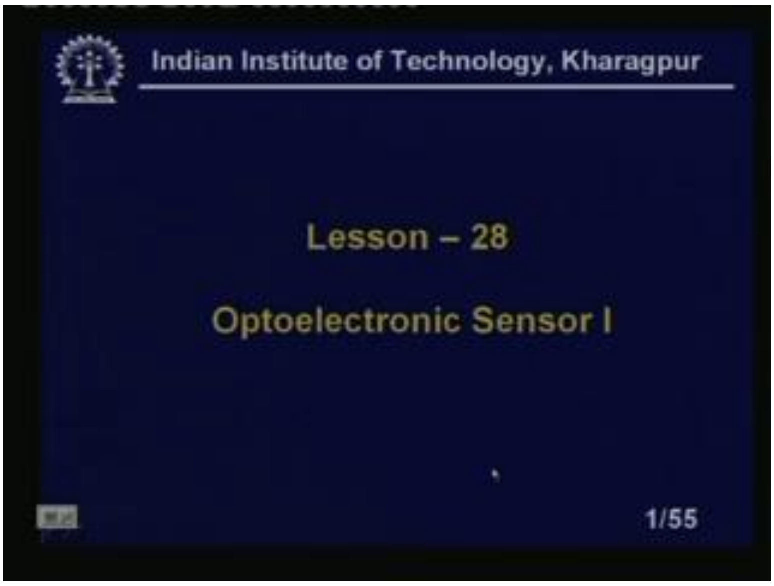

Let us look at optoelectronic sensor 1.

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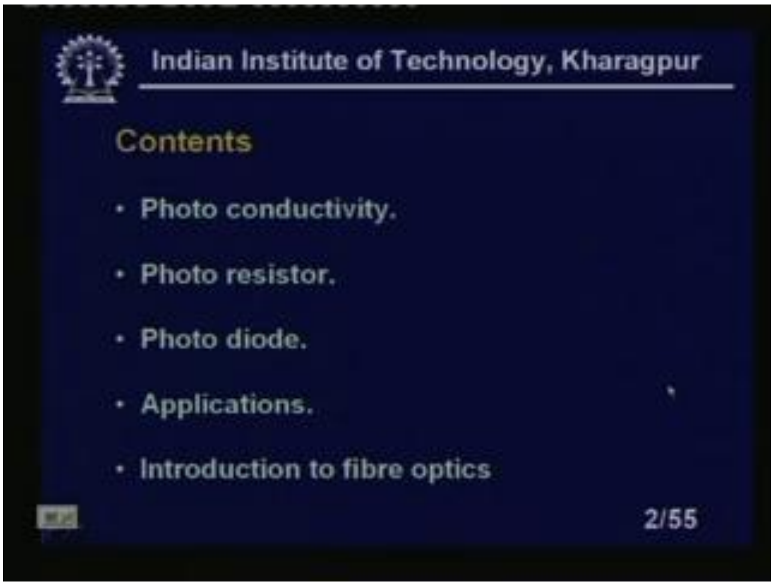

Contents are photo conductivity, we will consider here photo conductivity. Based on that, in the photo resistors or light depended resistors has been developed and which is used is extensively in instrumentation. So, that we will cover in the photo basic principle of the photo conductivity, then on based on this what are the different photo resistors? We have developed I mean, engineers and scientist developed that we will discuss right. Then we have photo resistor, photo diode then and applications. We will look at some of the application typical application; that means, how we can utilize make some measurements? Basic measurements; there are various applications of this photo diodes per. So, far as the instrumentation is concerns in context to instrumentation, we will take 2 examples and see how this photo diodes are utilized to make that above measurements. Also we will cover the introduction to fibre optics we will discuss the fibre optics in details and fibre text, fibre optics sensors in lesson 29 for basic principles of the fibre optics will be covered in the lesson 28.

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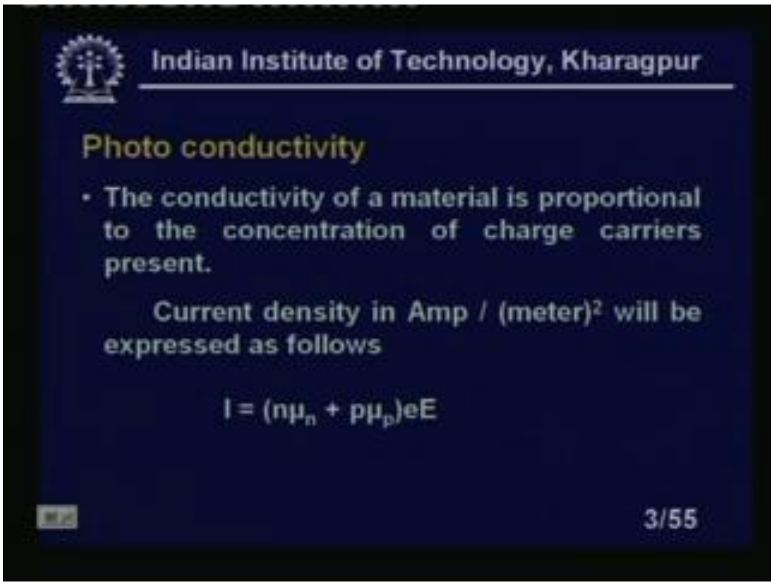

Photo conductivity; what is photo conductivity? The conductivity of a material is proportional to the concentration of charge carriers present right. You know conductivity s basically depends on the charge carriers in the case of metals. We have some fixed amount of charge carriers, which is thermally generators? In the case of I mean, semi conductor devices, these can be varied depending on incident light. So, which will change the resistance; obviously, the photo current also will change. The current density in amperes per meter square will be expressed as follows, I equal to n mu n plus p mu p e multiplied by E.

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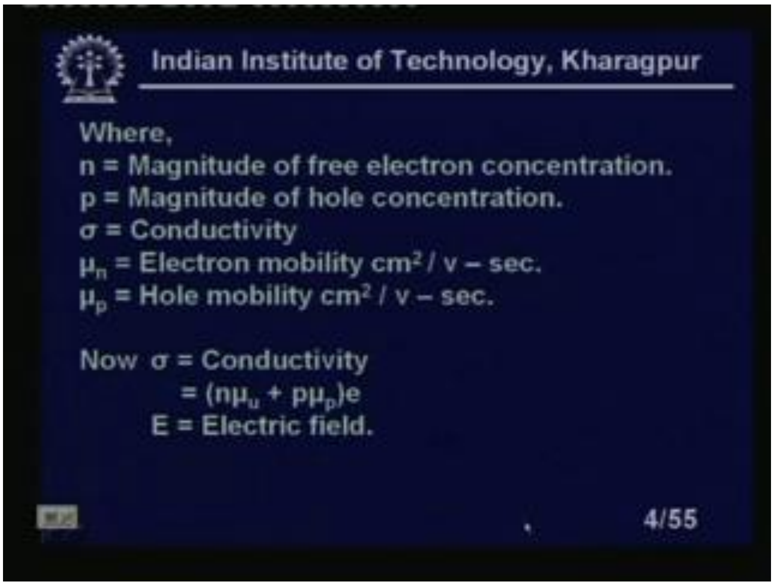

Where n is the magnitude of free electron concentration, p is the magnitude of hole concentration, sigma is the conductivity, mu n is the electron mobility in centimeter square of an by volt second and mu P is a hole mobility in centimeter square per volt second. Now, sigma conductivity will be given by n mu n this is mu n this is mu n p plus mu p multiplied by e, where e is the electronic charge E is electric field.

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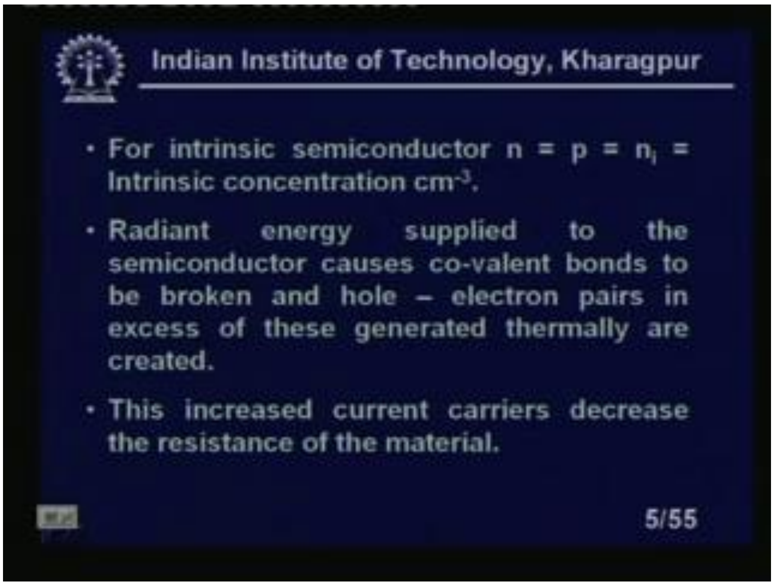

For intrinsic semiconductor, that is semi conductor without, any impurity. We call it intrinsic semi conductor in the case of; that means, with without any doping. Once you dope, what will happen that the number of hole electrons will change. Now, if you dope with the p type impurity number of hole will increase, if you dope with the n type impurity the number of electron will increase right. So, for intrinsic semiconductor n equal to p equal to ni which is called a intrinsic concentration, when the semi conductor is doped we call it extrinsic semiconductor right. In that case np cannot be same, because it depends on the, what types of dopings? In may be in the case of I mean, travel and impurity. What will happen? That you'll find that the hole will increase number of hole concentration will increase so on and so forth.

Radiant energy supplied to the semiconductor causes, covalent bonds to be broken and the hole electron pairs in excess of these generated thermally, are created excuse me. This increased current carriers, decrease the resistance of the material, whenever the light falls is increased there is increase of charge carriers. In fact, what will happen? Where is as you know there is in a metal ((Refer Time: 05:56)) forbidden energy. So, some metal I mean, some electrons will cross that forbidden energy gap and come to the conduction level. So, which will contribute to the change of concentration of the charge carriers?

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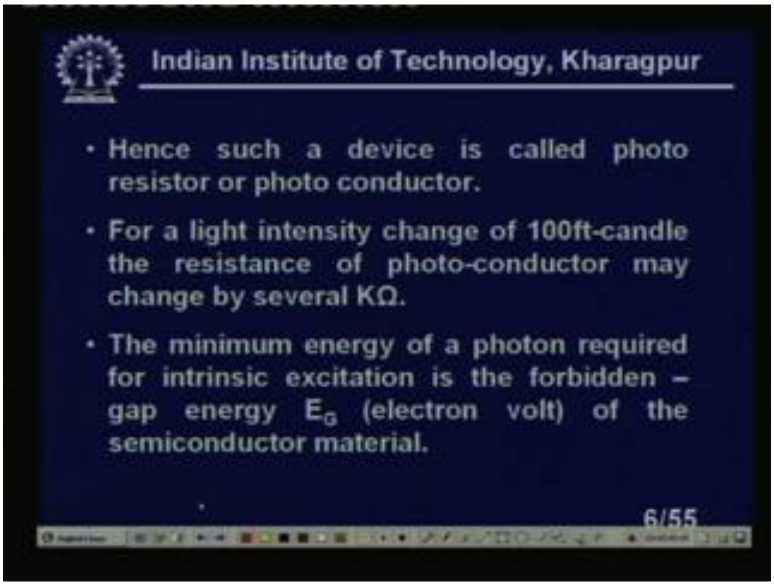

Hence such a device is called a photo resistor or photo conductor, clear? For a light intensity change of 100 foot candle the resistance of photo conductor may change by several kilo ohm, right. The minimum energy of photon required for intrinsic excitation is the forbidden gap energy. Now, electron volt, which is in electron volt of the semiconductor material, if you remember when it appears to be like this one.

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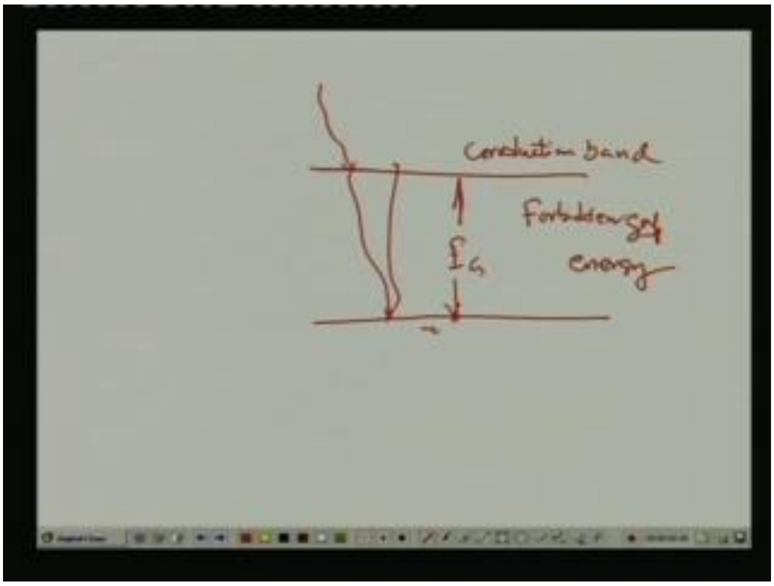

I have a conduction band. So, when the light falls, which is comes here, some of the electron; this is the forbidden gap energy EG. So, these energy these amount of energy must stored so that the electron will come to the conduction band. This is the conduction band and this is our forbidden gap energy, right.

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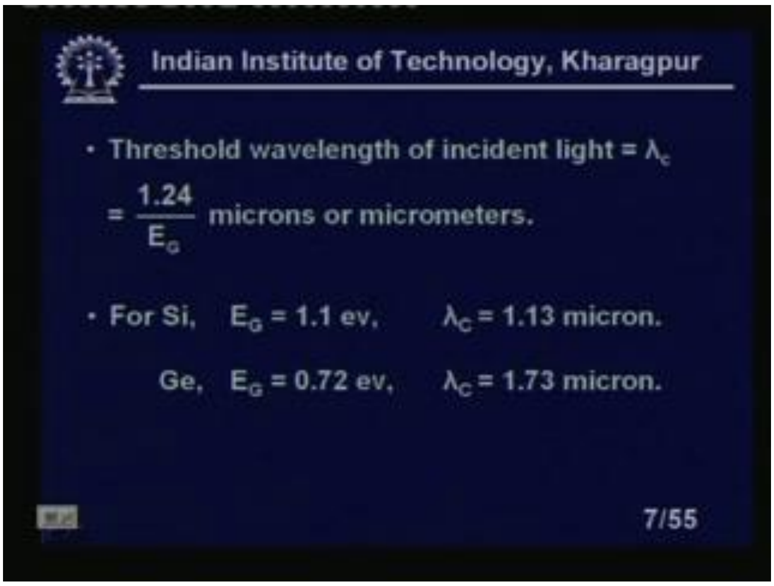

Now, threshold wavelength of incident light; that means, the light which will be sufficient to generate the excess carriers in excess to the thermal energy is given by a 1.2 4 by EG in microns or micrometers. For Silicon EG is equal to 1.1 electron volt for lambda c equal to 1.13 micron and for germanium EG equal to 7.2 electron volt points 7 2 electron volt. Which will give you lambda c are the of that, because this is necessary, because you have to first note the what the incidence light will be make this incidence frequent of the incidence light, which will you must I mean, must fall on a semiconductor devices photoelectric devices. So, that the electron excess electrons or excess carriers will be created right.

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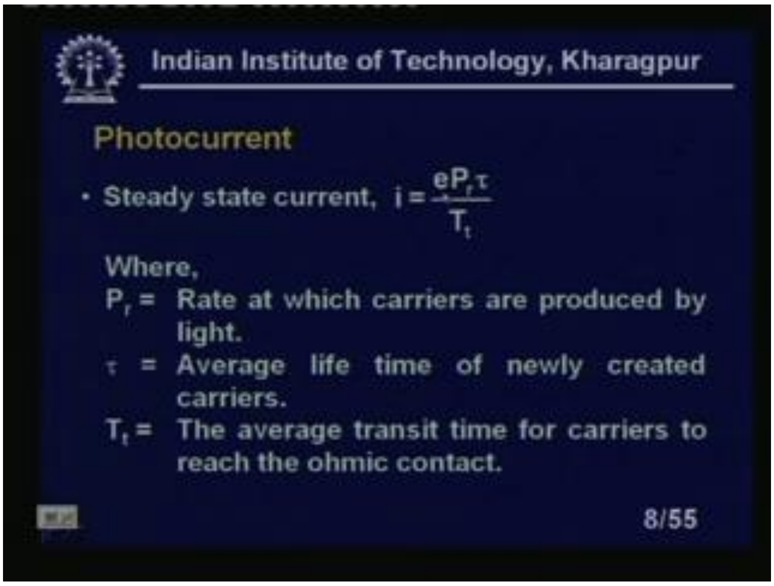

Photo current; now, steady state current is given by I equal to e multiplied by Pr into tau upon T subscript small t. What are this regions i is the steady state current in a photo resistors or photo conductor where Pr is a rate? At which the carriers are produced by light rate? At which the carriers are produced by light, because if the light falls strong light falls more numbers of carriers will be generated which is in excess of the thermally generated carriers. Tau is the average life time of newly created carriers, because you see that, whenever the hole electron pair is generated, there is the chance of recombination.

So, this the average light time, because once it is recombined that current cannot to be detected at the output. T subscript small t is the average transit time for carriers to reach the ohmic contact. Because any semi conducted devices, I must collect the current at the outside. So, that it must reach that carriers, must reach the ohmic conduct. So, that it will pass through, some ammeters and some deductible, current will be observed and e is a electronic charge e is an electronic charger.

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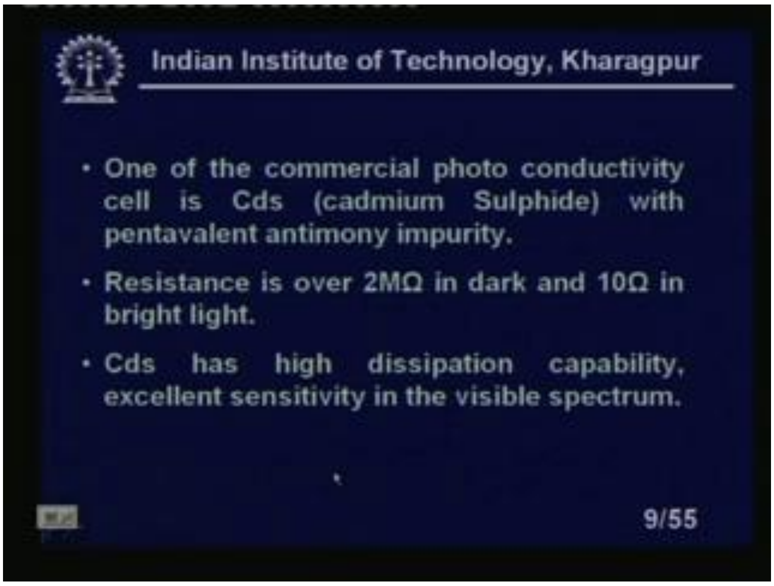

Now, one of the commercial photo conductivity cell is cadmium sulphide, one of the most widely used photo conductivity cell or photo resistor or LDR. Whatever the name, you call is light depended resistors or photo resistors or photo conductivity cell. It basically same; that means, ((Refer Time: 10:08)) made of cadmium sulphide with the pentavalent antimony impurity. Impurity must be there, otherwise in cannot be pentavalent impurity are basically, the charge carriers will be here the electron right since it is pentavalent. The resistance is over 2 mega ohm in dark and 10 ohm in the bright light right. It looks like this, it looks like this, if I take a.

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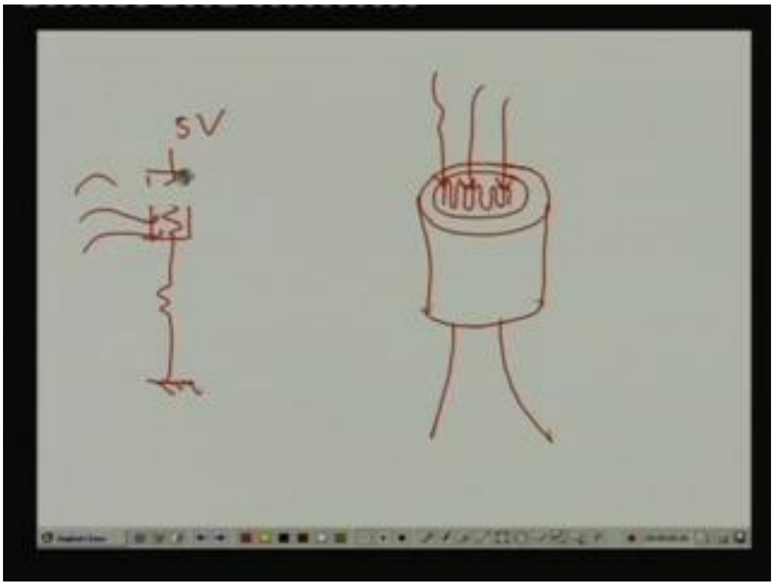

So, it is looks like this, I mean if you look at the encapsulation, I will draw a little bigger 2 leads are coming up and there by transparent plastic cover on the top. Unlike the other semi conducted devices and we can you can see this photo resistors inside right. So, light should fall on this 1, if you bring it to the sun light, you will find immediately, the resistance. We measure the resistance across this 2 immediately, it will reduce right that resistance, you can make several circuits by which I can. Suppose if I have a circuit like, this 1 I have a I am giving a voltage of suppose 5 volt and this is my photo resistors, this is my photo resistors. So, light is falling on this, so what will happen? So, the charge current will change. So, I can do in other way, you can we can take I mean, I can do it in other way; I can take a new slide there is no problem. So, it will go so let me take the pencil, let me take a new. So, it looks like this.

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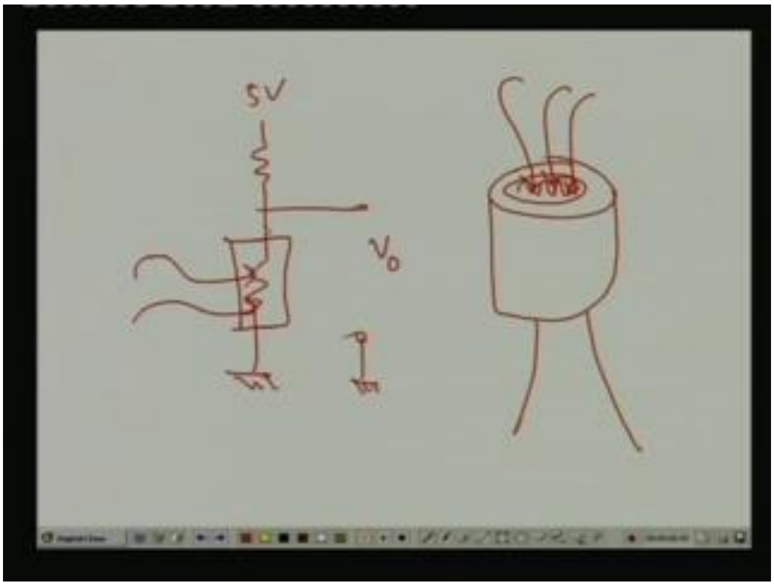

I can take a right. So, I am giving a 5 volt here, and this is my photo resistors light is falling on this looks likes as I told you earlier its capsulations. So, it is looks like this 2 leads are coming up, you can see the photo resistor here. Lights are falling on this right and this voltage; obviously, what will and if the light falls, you will find that this voltage will change right. So, if I measure, because this resistance will change. So, this voltage Vo across this will also change.

So, this Vo can be utilized for making so many sensors or switches also right I can use it as a switch also these photo resistors, clear? Because this voltage will change as a light falls on this in dark. It is very large resistance around 2 mega ohm in a bright light, it is very less 20 ohm clear. In fact, the dark it should be very, very, very high it should be infinite, but there is always a dark current, because there will be always some electron hole electron pair in the in the which is thermally generated. So, we there will be a some current right. So, resistance is over 2 mega ohm in dark and 10 ohm 10 to 20 ohm in bright light cadmium sulphide has a high dissipation capability excellent sensitivity in the visible spectrum.

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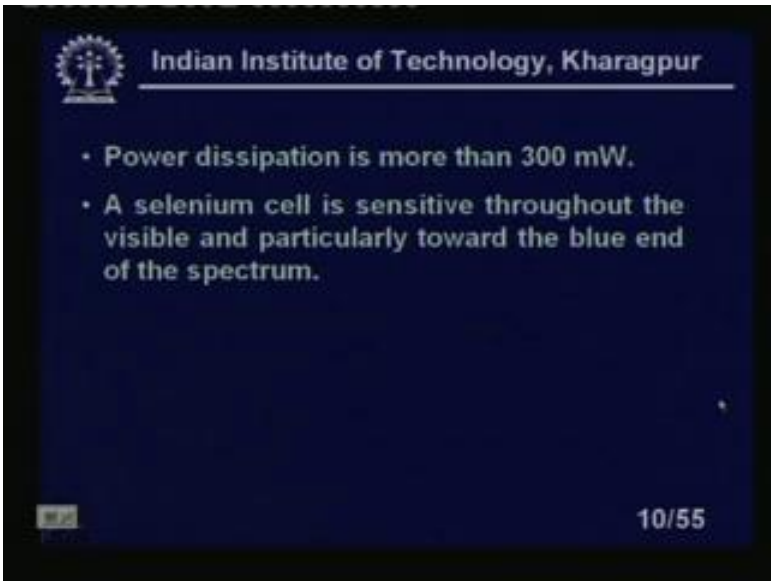

Power dissipation is more than 300 milli watt and a selenium cell. Selenium is also used as a photo resistor; selenium cell is sensitive throughout the visible and particularly, towards the blue end of the spectrum right.

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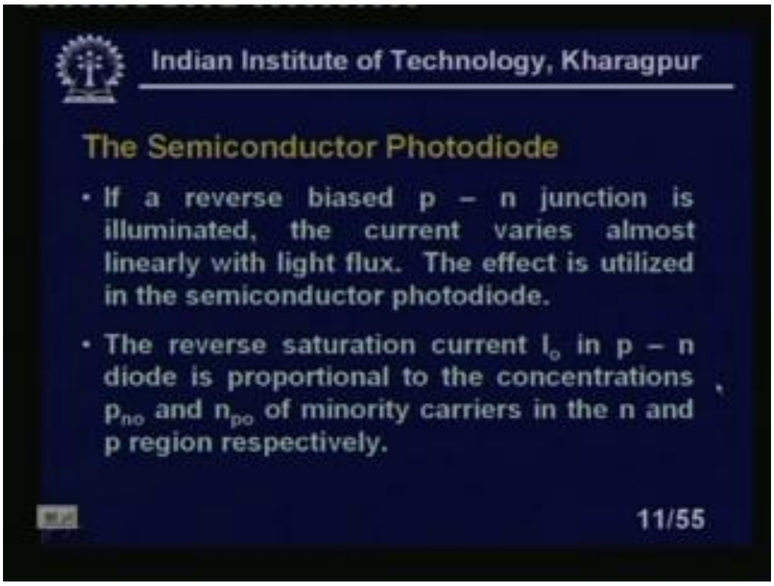

Now, semiconductor photodiode now, we talk about only the photo resistors so; that means, I have some means, that the light dependence resistors. We are calling also it, I mean, also as a light dependence resistors, but more applications in instrumentation. You will find is that is in the semi conductor photodiode photodiode and phototransistor is almost same in case of phototransistor. I will get some amplification, but the time constraint is large. Whereas, in the case of photodiode current is small, but the time constraint is small. If a reverse biased p n junction is illuminated the current varies almost linearly, with the light flux the effect is utilized in the semiconductor photodiode right this effect is utilized in the semi conductor photo diode. The reverse saturation current Io in pn diode is proportional to the concentrations pno and npo of minority, carriers in the n and p region respectively

If you have a reverse biased photodiode then in that case ((Refer Time: 15:26)) there is no minority carriers. So, the only the sorry majority, carriers will not play the current, because only the minority carriers will play key role to have a current because in all semi conduct. It does not matters, if it is p type semi conductors the hole is the majority carriers and the electronic minority carriers. In n type semi conductor electron is the majority carriers and the hole is the minority carriers. So, if it is reverse biased then what will happen that the reverse saturation current Io in Pn diode is proportional to the concentrations of pno and npo minority carriers and n and p type region. You see the pno, we are calling the minority carriers in n type region and npo is a electron, which is as semantically as p region respectively.

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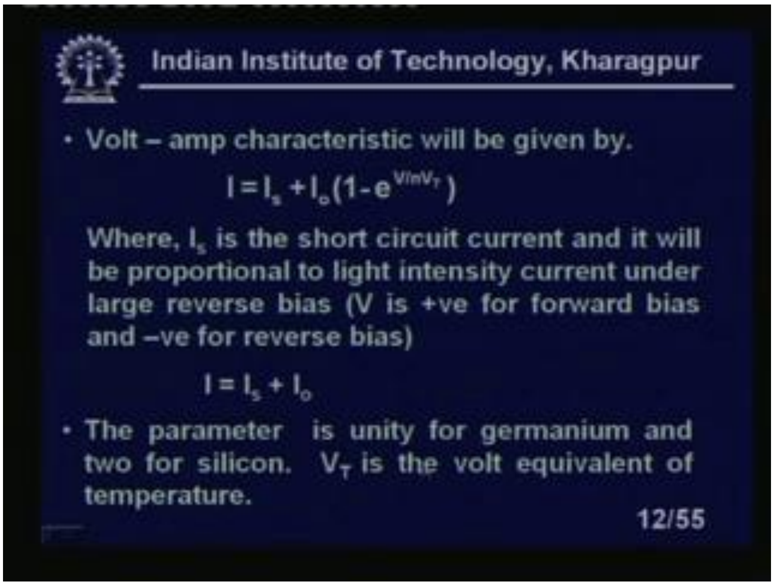

The volt ampere characteristic will be given by I equal to Is plus Io 1 minus 1 minus e exponential to the power V by eta Vt. Please note this is eta, this is eta right, this is not n this is eta like this 1. Where Is the short circuit current and it will be proportional to the light intensity, current under the large reverse bias V is positive for forward bias and V is negative for the reverse bias right. Now, for the ((Refer Time: 16:55)) bias is large then obviously, what will happen? This part will be very, very small it is not it. Is the reverse bias is very large the reverse bias is large. So, what will happen? If is reverse bias is large then what will happen?

You will find you see that this will be negative. So, this is V is very large then what will happens? So, this will be almost negligible. And only it will be I equal to Is plus Io where Is is the short circuit current and it will be proportional to the light intensity current. And large reverse bias V is positive for forward bias and negative for reverse bias. The parameters eta I should write here, eta is unity for germanium and 2 for silicon, this eta this not n please note eta the parameter eta is unity for germanium and 2 for silicon and Vt is the volt equivalent of temperatures right.

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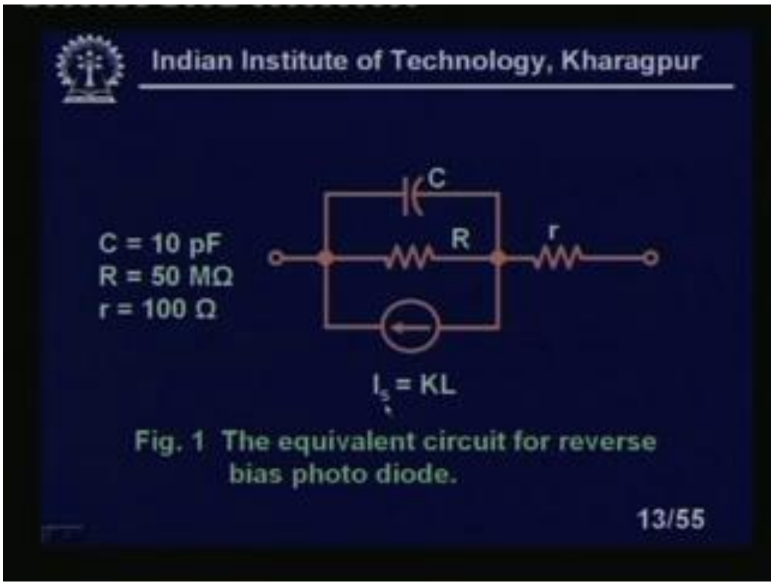

This is a equivalent circuit of a reverse bias photo diode. You see these, we have one capacitance, we have a current generator here C is equal to 10 pico farad P is I mean R is quite large 50 mega ohm and there is a small resistance r equal to only 100 ohm. So, is that saturation current is equal to K into L, what is K?

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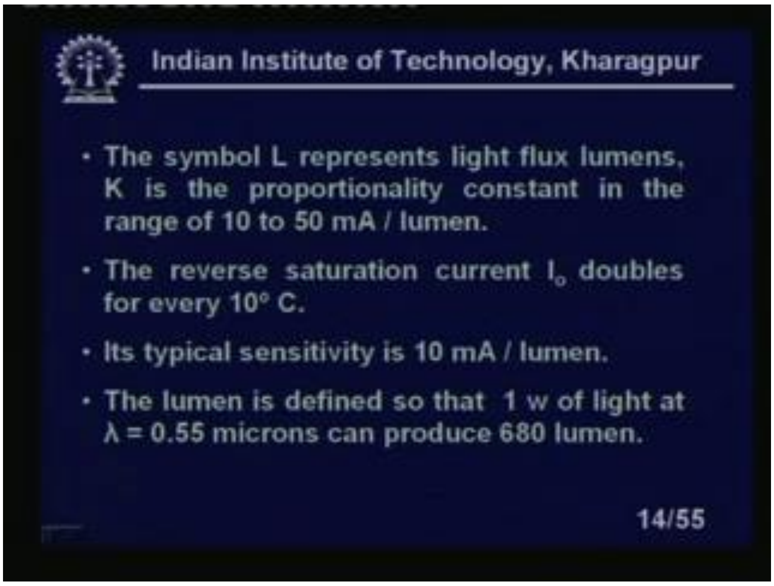

We will see the symbol L represents the light, light flux in lumens you see the Is equal to KL the symbol L represents the light flux in lumens. And k is the proportionality, constant in a range of 10 to 50 milli ampere per lumen, clear and the reverse saturation current Io doubles for every 10 degree centigrade reverse saturation current. We have seen also this 1 equal to 4 reverse saturation current Io doubles for every 10 degree centigrade and its typical sensitivity is 10 milli ampere per lumen, right. The lumen actually, is defined as a 1 watt of light at lambda equal to 0.55 micron can produce 680 lumen. These are standard for lumens that mean a 1 watt of light at lambda equal to 0.55 micron can produce 680 lumens.

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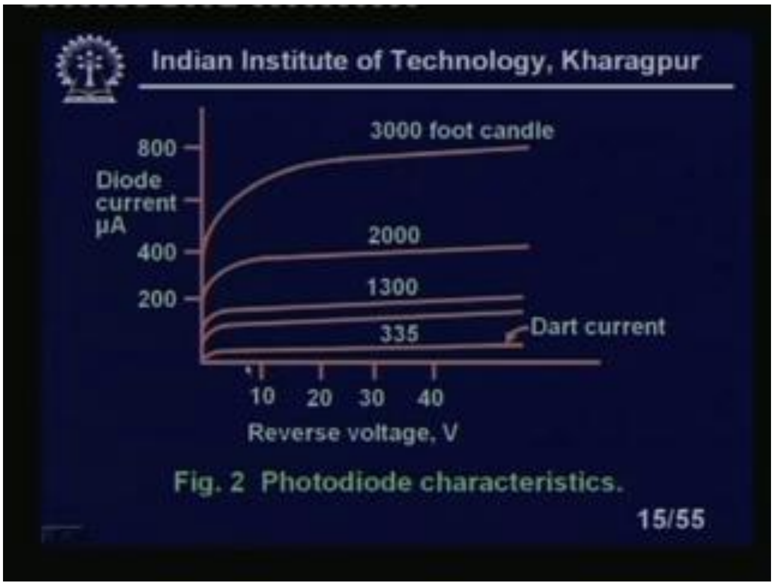

Now, you see this photodiode characteristics, we have drawn here. This diode current in micro ampere and this the reverse voltage, as we increase the reverse voltage, we will find that, there is saturation. And this incident light, which is given in foot candle right, this incident light in foot candle 3000 foot candle, 2000 foot candle, 1300 foot candle 335 foot candle. This one and there is the dark current even, if you do not I mean, throw any light on the photo. I mean, diode this basically, you are falling, you are sending a light to the junctions of the photodiode please remember right pn junctions. So, in the pn junctions, you are sending you are throwing the light. So, these are dark right this reverse bias photodiode characteristics reverse voltage V. And this diode current as you can see that, if we increase the light; obviously, the diode current also in getting increased.

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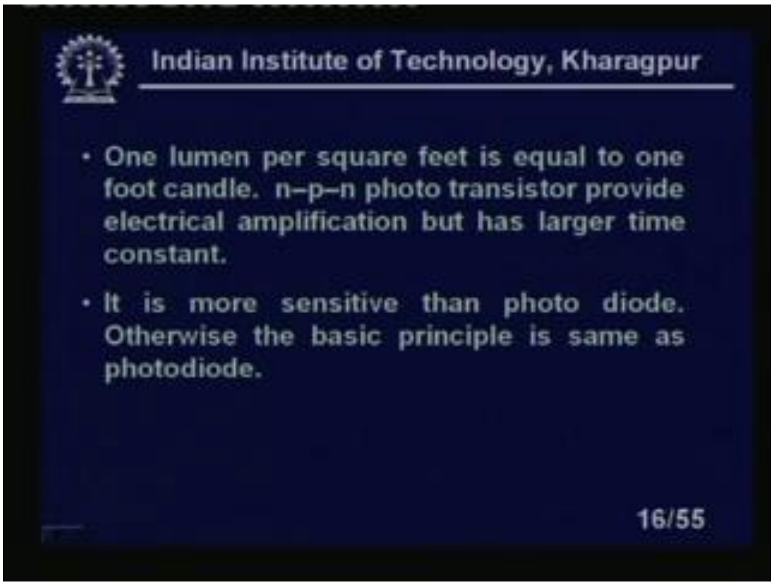

One lumen per square feet is equal to 1 foot candle 1lumen per square feet is called the 1 foot candle n-p-n photo transistor provide electrical amplification, but has a larger time constant. So, you actually, you will find at this photo diode is basically, a diode, but you will find that it is a it is put in a plastic in capitulation. So, that the light can fall on the pn junction pn junction it is more sensitive, than the photo diode; otherwise basic principle is same as a photodiode. If it is more sensitive large current, you will get, because you will get some amplifications resin inherent to any transistor characteristics. Suppose if the base ammeter, we I mean throw some lights; obviously, at the collectors. We will get a large current with amplifications, that is the only advantage, but time constant is large.

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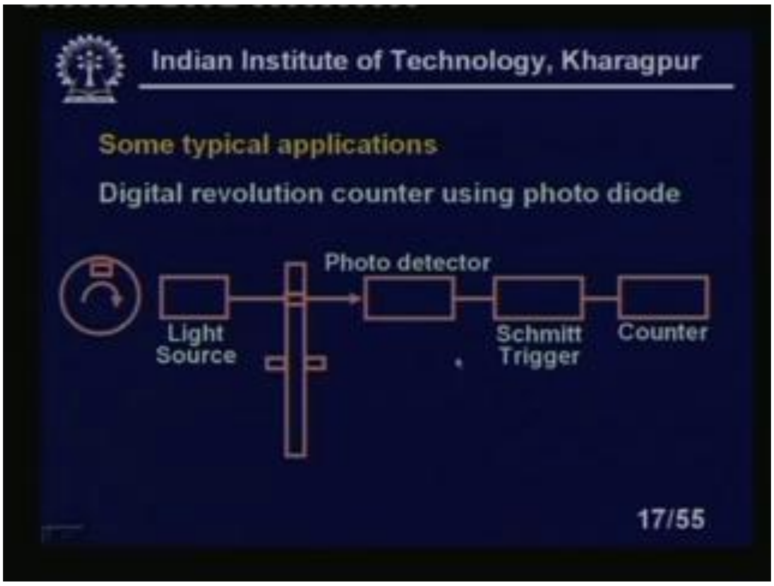

Some typical applications of this photodiodes let us look at some typical applications. Now, this is a scheme, which we have shown that a detail evolution counter using photodiode, how a digital evolution counters? We can make using the photodiode, you see here. So, I have a light source, light source is coming here, this a disk when this light source light emitting diode. Then this hole on the disk this circular disk and the photo detector, which is photodiode comes in a 1 line, then only some light are found will fall on this line light will fall on this photo detector otherwise not. So, you see if it rotates, if this disk rotate as a there is a shaft and the disk rotates, for each rotations. I will get a pulse here, at the output of the photo detector now, this type of pulse as you know this type of pulse will very irregular shape, right.

So, this pulse will be very irregular shape, this pulse will be very irregular shape. So, you must sent through, Schmitt trigger through, which is called a pulse shaper to give a regular shape pulse and then to a counter. So, as the speed of this disk increases number of count number of count per second or per minute will also increase right. So, I can make a direct rpm meters or a revolution per minute meter by these types of scheme. We have some other electronic circuitry, but this is a some applications of the photo diodes. There are numerous applications, with that is not much concerns, with the instrumentation or measurements, that is I am not discussing automatic opening of the doors. And all these things you know automatic switching on the street lights in many countries you see that there is no person to switch on the street lights. So, what they do?

There is a photo diodes sensitive switches they have. So, what will happen? That when the light I mean, the sunlight goes down.

So, automatically, the, this photo diode will be activated, and is will turn on the switches of the all the street lights. So, there are some and that above many applications are there especially, in a in countries like a Europe. You will find when the tramps and trains are going usually, to save the power; they do not turn on the lights inside the bus or tramps. So, whenever the tramps or bus are going inside a tunnels so; obviously, the light is less all the lights, inside the tramps or bus should switch on. So, those are photo sensitive, but there is not much of the instrumentation there some measurement techniques. We are discussing; that means, some revolution counters, we are using now, we have developed using the photo diode, let us look at how it works.

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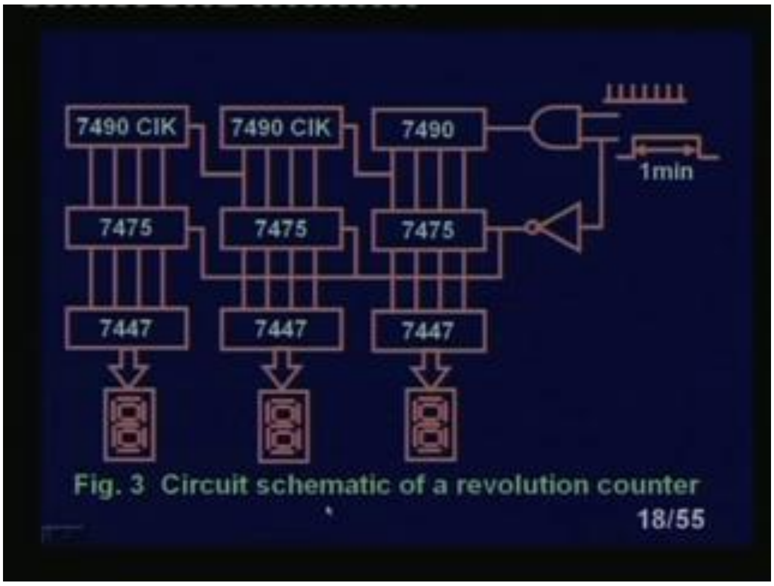

Fig. 3 Circuit schematic of a revolution counter

So, you see this is our circuit schematic of the revolution counter. Here you see that we have a 7490 decade counter most significant bit of the 7490 is going as a clock. Here is a clock which is coming from the n gate again; the most significant bit of the 7490 is going to the clock of the next 7490, clear? So, is the decade counter, it will start from 0 is the decade counter, it will start from 0. And it come up to 9 then again, comes to the 0. So, its 10 different states of modulated counter, it will start from 0 count up to 9 then again, come to 0 right like that. Now, how it works? You see this is 7475 is basically, D latch 4 bit D latch flip flop. You know the D latch is basically, a device which is basically, a master slip flip flop. But it will latch to the previous state, until unless new clock comes right.

Whenever a clock cycle ((Refer Time: 25:06)) whatever the whatever, you have at the. So, sometimes we call the data latch flip flop, that is it is we call D flip flop or data latch flip flop. Data latch flip flop means, whatever the previous signals we have. So, it will go it will stick to that until unless a new signals comes, new state comes, either it may be 0 or one it will go back to that is it will go to that is particular state. When the when the now, is basically, when a clock pulse comes at the tailing edge of a clock pulse in the case of master shift. Obviously, it should activate at the tailing edge of the clock pulse. So, it will go to the state, if it is one is at the input of the D flip flop this basically, JK flip flop. You know this basically, JK flip flop the data which I want to transmit that, data is directly, coming to the j input and data and the and the k input is whatever the j. Whatever the data input is coming in a j inputs, we are passing through a inverter and coming to the k input right.

So, automatically, what will happen? See if it is 1 is coming, so in the j input is getting 1 and k input is getting 0 and if the 1 is 0 is coming, j input is getting 0 and the k input is getting 1 see it is important. So, what will happen? Under the clock pulse if it is a master ((Refer Time: 26:20)) to the trailing edge clock it will trailing edge clock activated. So, what will happen? That that inter change will occur at the trailing edge and you whatever the data input you have either 1 or 0 it will stick to that right. Now, 7475 is such as data flip flop with the 4 bit data latch flip flop seven four 7475 is the 4 bit data latch flip flop it is a 4 bit. So, what will happen? You see it is very interesting, you see I have in the AND gate inputs. We have a clock pulse, high frequency clock pulse right and you see here.

Now, this clock pulse is coming from, where it is coming from? That photodiode, depending on the number of speed depending on the speed of the disk, number of clock pulse per minute will also increase right. So, what we are doing here? You see that in 1 input of the AND gates, I am giving this clock pulse and other inputs; I am giving a 1 a pulse, where the mark is 1 minute. Then it will have something and then again it will come. So, it is only 1 minute width it is repeating pulse obviously. Now, what will happen? You see, so this whenever this is high. So, it will activated and the the counter will start to count from 0 right.

Now, you see what will happen? During that time this is inverted here. So, 7475 will not be activated. So, counter is going on counting now, what will happen? At the trailing edge of this clock pulse, when the 1 minute is over. So, this pulse will go down and no more it will it will no more, this output from the photodiode can enter the 7490 7490 will stop counting during, that time when this is low, this will be activated, because it is inverted what does it mean? So, whatever they have counted. So, long that 2 7475, it will it will come to the ((Refer Time: 28:29)) coder and then to the display unit clear?

We have a 7 segment display. So, we will introduce display unit now, during that time you see what will happen? This duration I can make very small, I can make 1 minute then 1 second and again 1 minute at time pass I can make it clear. So, during that again, what will happen? Whenever this pulse is off, next clock this, whatever the data, we have at the end of the 1 minute. That will hold for the next until unless, next clock pulse comes, that is a reason it is called data latch flip flop. So, what will happen again? Again it will start to count. So, for 1 minute, so after this when this falls it will stop counting same for 9 0 will no more count anything. So, one this falls, this will be activated, because this will be 1. So, whatever that data, we have it is output of the 7490 in a 4 bit, that will come to the 7475. So, previously it will latch to the I mean previous values.

So, then it will come to the display and it will ((Refer Time: 29:35)) coder right, this way it will work. So, this you can see this 1 application, even though I mean, this photodiodes I mean, as a very small part. But the, until unless you have photodiode this system will not work you see. So, I will light source, when the light source which is rotating in a very high speed and since photodiode has a very, very small time constant. So, small amount of whenever, even it is speeds at a very high speed it does not matter, it will detect each and every poles. Whenever, this photo detector this hole and the light source comes in one line. So, it will make 1 pulse and this pulse is to be shaped through, Schmitt trigger then it is coming to the counter clear?

This is our scheme, this very interesting scheme that is will be activated for 1 minute will count for. So, whatever the reading, we are getting here, it will be directly in revolutions per minute, is not it? Because we have made the width of 1 minute, mark to space mark will be for 1 minutes space might be for 1 second it does not matter. So, during 1 second, what will happen? Again until unless this 1 minutes comes at the end of the 1 minutes these data whatever the data there that will be displaced automatically, that will remain in the same whole position clear?

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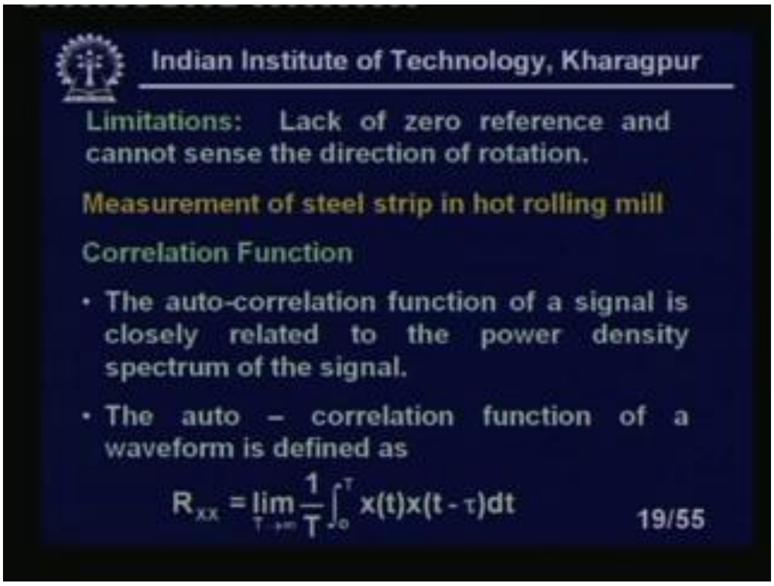

Now, limitations it has limitations, lack of 0 references and it cannot sense the directions, of the rotations. Whether it is I mean disk is rotating in the clockwise, directions or anti clock wise directions. It cannot sense for that reasons, I have to we have different we have seen that, we needs some phases, it modulation to have a that type of sensing. Measurement of steel strip in hot rolling mill, this another I mean, scheme by how the photo diodes can be utilized to make a, because in the hot rolling mill, it is very difficult it is. So, hot temperature is, so high it is very difficult to measure the thickness of the, because thickness measurement of the rolling sheet is also very important accordingly, I can use the feedback poles, so that the we can put more pressure on the roles. So, that it should be thinner or the remove the pressure.

So, that it should come to the proper thickness right. So, we in context of that, we will see that the photodiodes, because a hot rolling mill in the hot surface will work as a photo diode photo, I mean light emitting diode. Now, the question comes, we need little bit of mathematics; that means that auto correlation and the cross correlation functions that will be discussed. Now, you see the correlation function the auto correlation function of a signal is closely, related to the power density spectrum of the signal. The auto correlation function of waveform is defined as Rxx limit T tends to infinity 1 upon T t to 0 xt xt minus tau into dt.

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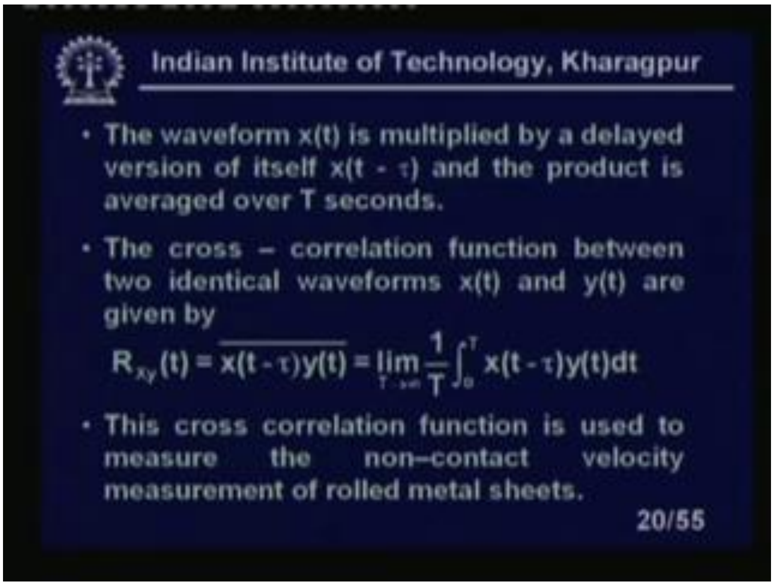

The waveform xt is multiplied by a delayed version of itself, xt minus tau and the product is averaged over T seconds, the waveform xt is multiplied by delayed versions of itself xt minus tau. The produce is average over T seconds, if it is multiplied by the same signal delayed by some time, we call auto correlation function. Now, let us look at the cross correlation, the cross correlation function, between the 2 identical waveforms xt and yt are given by Rxy t xt minus tau yt average. Which is limit t tends to infinity 1 upon T t to 0 xt minus tau yt in to dt right. The cross correlation function is used to measure the non contact velocity measurement of rolled metal sheets, non ((Refer Time: 32:23)) type of techniques. So, non contact with out of the velocity of the rolling sheet, right. So, the velocity is most importance thickness is there, but the velocity is most important, because it why it is important? Because in the hot rolling mill, if it is not I mean, if you do not put in the quail form when it is steel hot that will create problem right. So, that reason…

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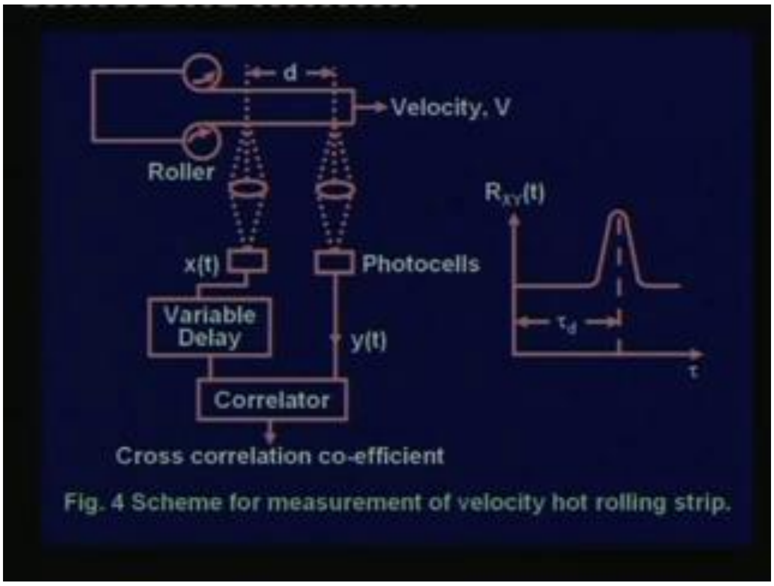

This is a scheme for measurements of velocity of hot rolling strip, you can see here. So, we have a hot rolling strip here you can see ((Refer Time: 33:57)) is coming. So, it is coming through a roll and the thickness is getting reduced like this 1. This is a thickness and this velocity should be as, I told you this velocity is to be maintained, because until and unless it is hot you cannot put in a quail form right. So, that is the reason the velocity is important, we have a roller here these two's are called the rollers. Now, see it is since it is hot, so it will work as a source light source, we have a collimator lens these 2 are the collimator lens.

So, light will be come and it will focus and will form the photocell. We have the 2 photo cells here, 1 photocell is here, 1 photocell there. We have a variable delay here; we are assuming these 2 signals are I mean, same type of signals. But that it is not the exactly, same signals it is coming from the 2 different sources. So, we have to make the correlation functions of this 2 signals, this is the correlators, which is make the cross correlation of the 2 signals, which is coming yt and xt and the cross correlation coefficients we have getting at here.

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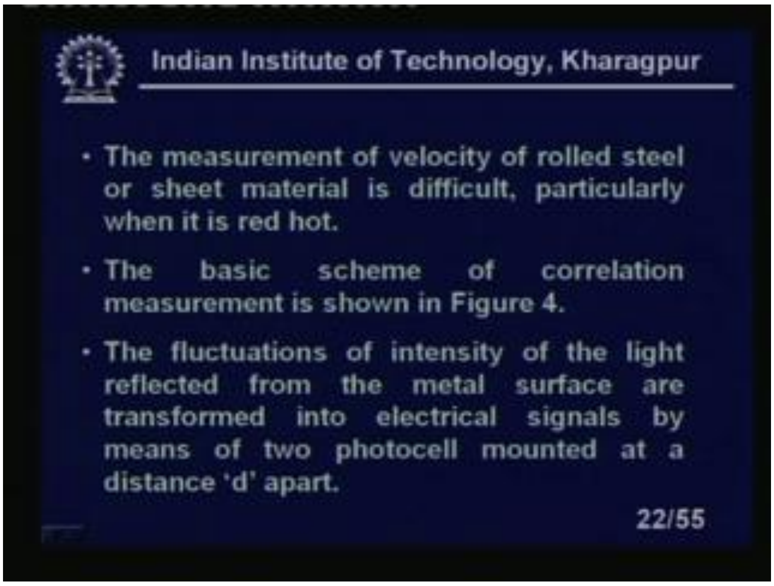

The measurement of velocity of rolled steel of sheet material is difficult, particularly, when it is red hot. The basic scheme of the correlation measurement is shown in figure 4 which have already shown. The fluctuations of intensity of the light reflected from the metal surface. Are transformed in to electrical signals by means of 2 photocells mounted at a distance d apart.

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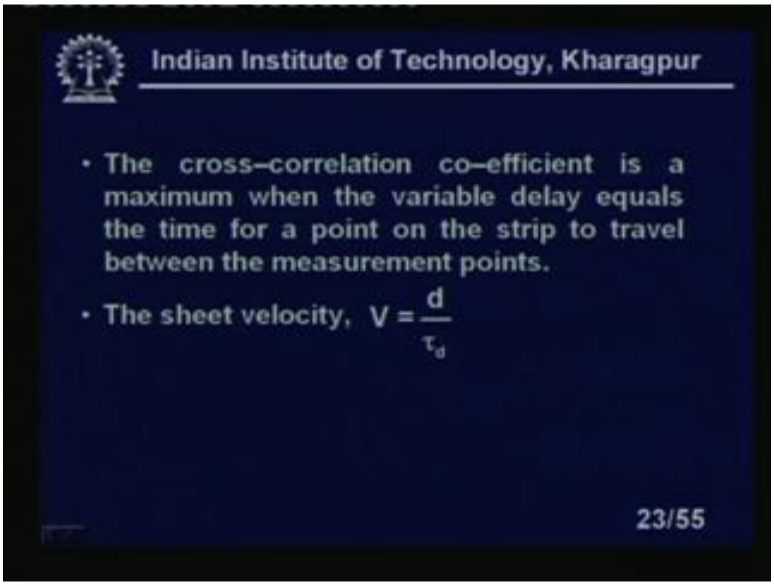

Let us look at yes the cross correlation coefficient is a maximum, when the variable delay equals the time equals the time for a point on the strip to travel, between the measurement points. There are 2 measurement points, so the cross correlation coefficient is maximum, when the variable delay equals the time for the point on the strip to travel the between the measurement point. So, let us look at, you see this is the measurement point, when this variable delay equals the time for time to travel the same points of these to these, I will get that peak output of the cross correlation coefficient. So, let us look at that the cross correlation coefficient is maximum, when the variable delay equals the time for a point on the strip to travel between the measurement points. Now, the sheet velocity will be small d divided by tau d, because what will do?

Actually, you see here actually, I will vary the delay. So, whenever I will vary the delay. Whenever I will get the peak, I will measure this tau d right. So, tau d, so the d divided by tau d will give the give us the, because this is the cross correlation coefficient is the correlation co efficient. So, d divided by tau d will give me the velocity of the roll steel. Now, let us come to the, I mean this with this I come to the end of this 1; that means, that the optical sense. I mean, the photo electric and photo conductivity sensor photo diodes let us, come to the introduction to the fibre optic transmission systems. Because we in the lesson 29 will covered the fiber optic sensor, because it otherwise it will very huge. So, I will cover some of this in this lesson 28.

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Fibre optics is the technology of using light to transmit information, light has a number of advantage over electricity, as a medium for transmitting information. It is immune to corruption by neighbouring electromagnetic fields 2 light source, can go parallely 2 cables can go parallel. Whether there it is very difficult to put cables 2 parallely, because there is a curve, there may chance of cross talk, right. It is immune to the corruption by the neighbouring electromagnetic fields attenuation in the all electrical circuit. There is attenuations here, in this case attenuation over a given transmitted distance is much less and it is also intrinsically, safe and since it is light.

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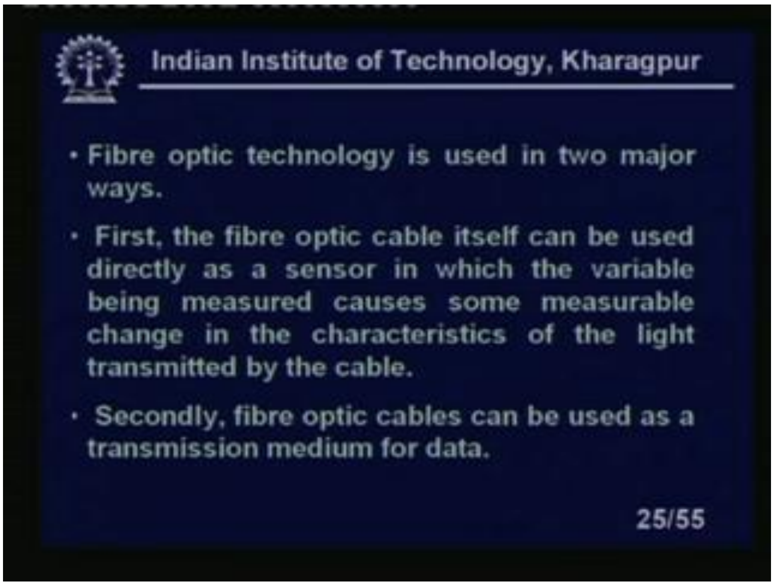

So, there is no ((Refer Time: 38:08)) as such. Fibre optic technology is used in 2 major ways, first the fibre optic cable itself can be used directly as a sensor, in which the variable being measured causes, some measurable change in the characteristics of the light transmitted by the cable. Secondly, the fibre optic cable can be used as a transmission medium for data.

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The later use of the fibre optic cables for transmitting information can be further divided into 3 separate areas of application. First relatively short fibre optic cables are used as part of the various instruments to transmit light from the conventional sensors to a more conventional, convenient location for processing often in situations where space is very short at the point of measurement.

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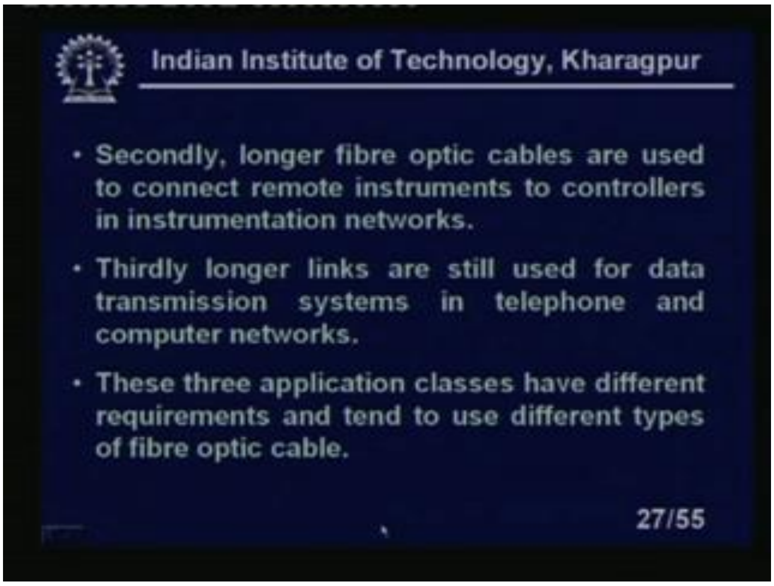

Secondly longer fibre optic cables are used to connect remote instruments to controller in instrumentation networks. Longer fibre optic cables are used to connect the remote instruments to controllers in instrumentation networks, because ultimately, that signal is to be transmitted to the controllers right. So, transmission electrically, so the transmission the electrical transmission there is lot of problems. So, we can switch to the fibre optic senses. Thirdly longer links are still used for data transmission systems in telephones and computers networks. We are not much interested, we will not neither we will cover that in this server in more details right. That is in the communication part these three application classes have different requirements and tend to use different types of fibre optic cables.

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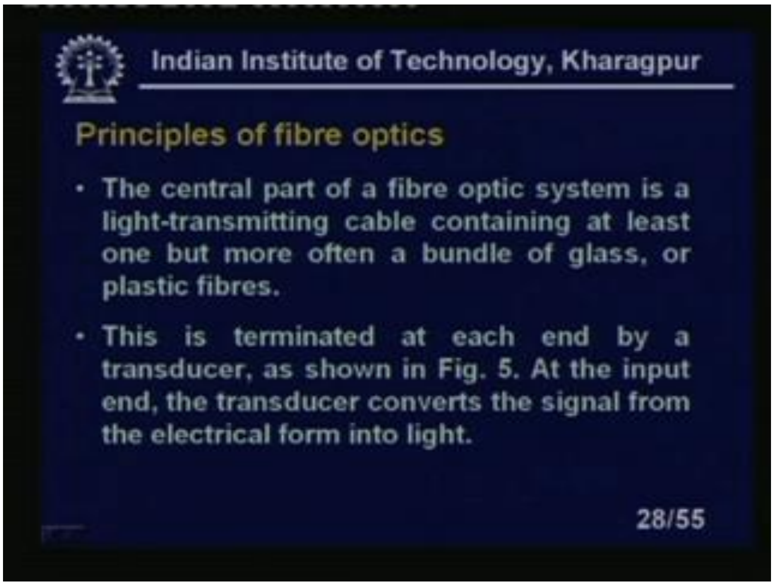

Principle of fibre optics; the central part of a fibre optic system is a light transmitting cable containing at least 1, but more often a bundle of glass or plastic fibres. This is terminated at each end by a transducer as shown in figure 5 at the input end. The transducer converts the signal from the electrical from into light, right.

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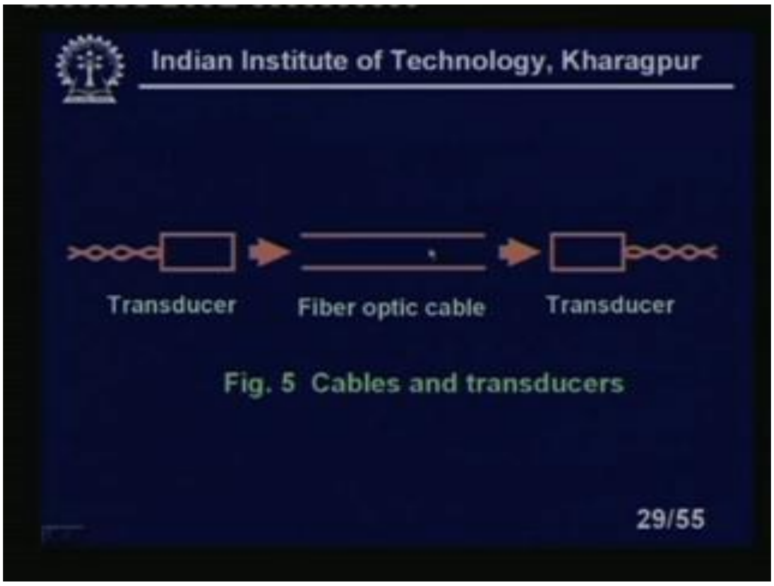

This is you see, I have a transducers which is electrical signal is coming from the left hand side. It is coming the light, light is getting launched through this fiber optic cable and basically, we will see this fiber optic cables we cannot light can transmit. It can go in a curved path, we know from our childhood light never goes in a curved path. But you will see using the total internal reflections in the fiber optic cables, light can travel in the curved path also right. So, at the transducers we will get light again, suppose this is our LED, LED light emitting diodes. It is launched though this one and these is a, we have a photodiode or pi n diode. So, I will get the electrical outputs, so the electrical to electrical, I will get at the 2 ends whereas in the medium, it is only light are taking them our data or information.

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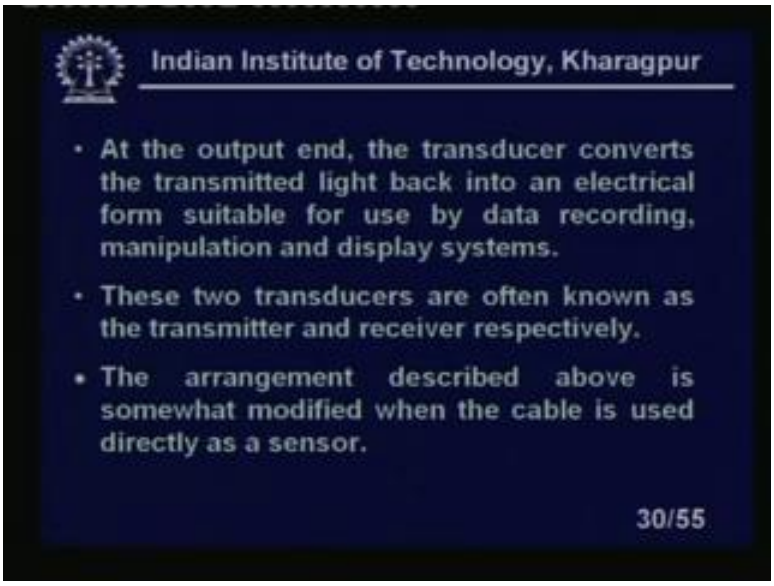

At the output end the transducer converts, the transmitted light back into electrical form, suitable for use by data recording manipulation and display systems. So, we have a data recordings, we have it conversion, whatever you like you can do once it is in electrical form. These 2 transducers are often known as the transmitter and receiver respectively, what is the transmitter? That we have seen which one is transmitter, this is our transmit this also transducers, But we are calling it, transmitter and these are we are calling it, receiver since it is receiving signals.

We are transmitting the signals through this LED, where the, that signal the photo diode or pi diode we are calling it receiver. In that case sorry, these two transducers are often known as the transmitter. And receiver respectively, and the arrangement described above is somewhat, modified when the cable is used directly as a sensor. You will find in some cases, we will use a cable as cables as a sensor, we will modulate the light which is going through this 1. So, it will be slight different in that above application.

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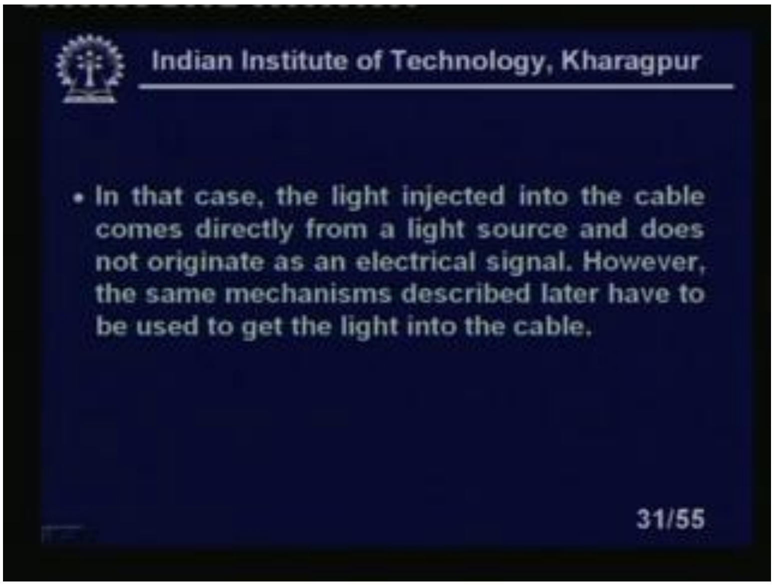

In that case, the light injected into the cables comes directly, from a light source and does not originate does not originate as an electrical signal. However, the same mechanisms described, later have to be used to get the light in to the cable.

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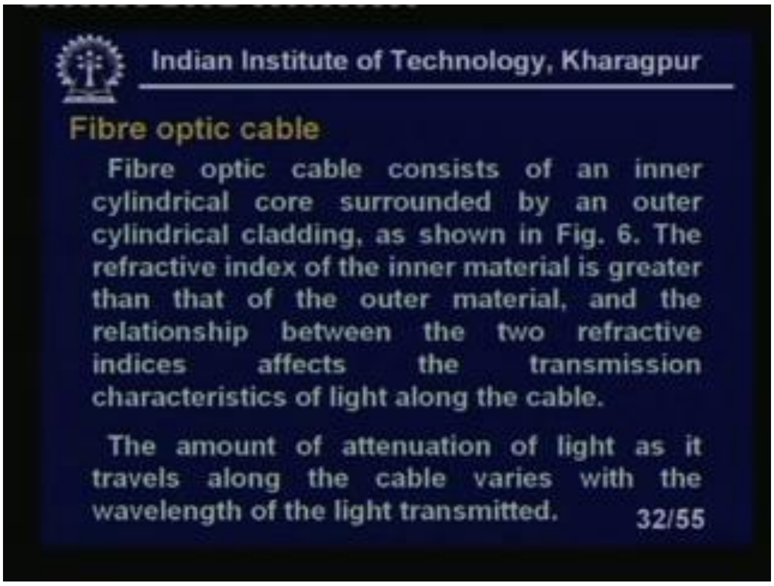

Fibre optic cable fibre optic cable consists, of an inner cylinder core surrounded by an outer cylindrical cladding as shown in figure 6. What is that figure 6? Let us look at a little far it went.

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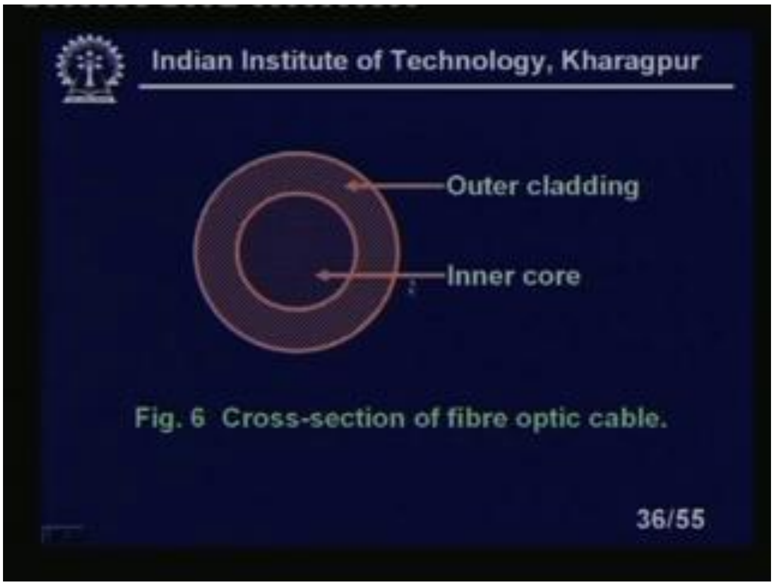

So, we have a inner core, we have outer cladding then jacket and all these things the refractive index of this one. Then only you will get a total internal reflection, please note refractive index of the this of 1 the inner core will be higher than the refractive index of the outer cladding clear, this is always; otherwise you would not get the total internal reflection. Fiber optic cable consists of the inner cylindrical core surrounded by an outer cylinder, cladding as shown in figures 6, which I have shown the refractive index of the inner material is greater than, that of the outer material and the relationship, between the 2 refractive indices affect the transmission characteristics of light along the cable.

The amount of attenuations of light, as it travels along the cable varies with the wave length of the light transmitted. This is very important, we have seen that the, we have find to out optimum, wavelength of light optimum colour of the light which will give us, the minimum attenuation that is important otherwise, you have to use a repeater though. I am saying that the loss is less, but there is a loss usually, which is describing ((Refer Time: 44:08)) per kilometer something like that. So, what will happen? As it is less repeated otherwise again, I have to convert that, signal to at what at the repeated station? I have to convert that signal in the current electrical domain, again through led to transmit that signal.

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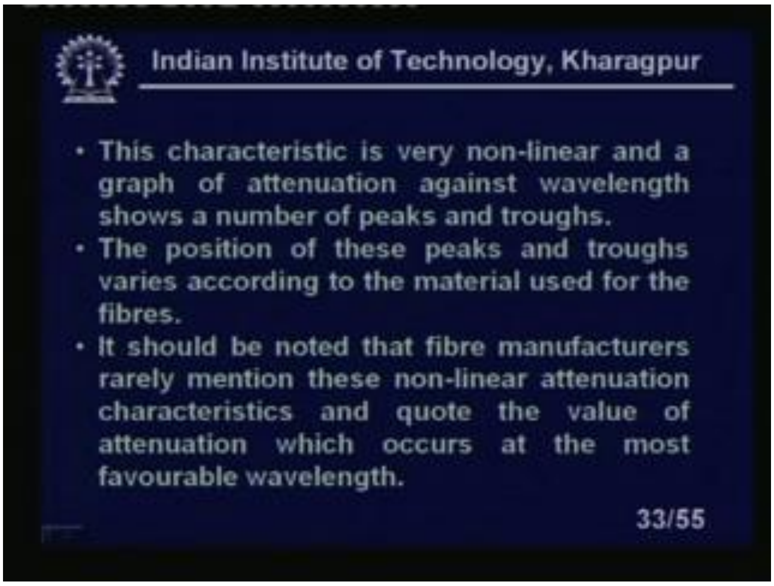

This characteristics is very non-linear and a graph of attenuation, against the wavelength shows a number of peaks and troughs the position of these peaks. And troughs varies according to the material used for the fibres, it should be noted that the fibre manufactures, rarely mention these non-linear attenuation characteristics. And quote the value of attenuation, which occurs at the most favorable wavelength.

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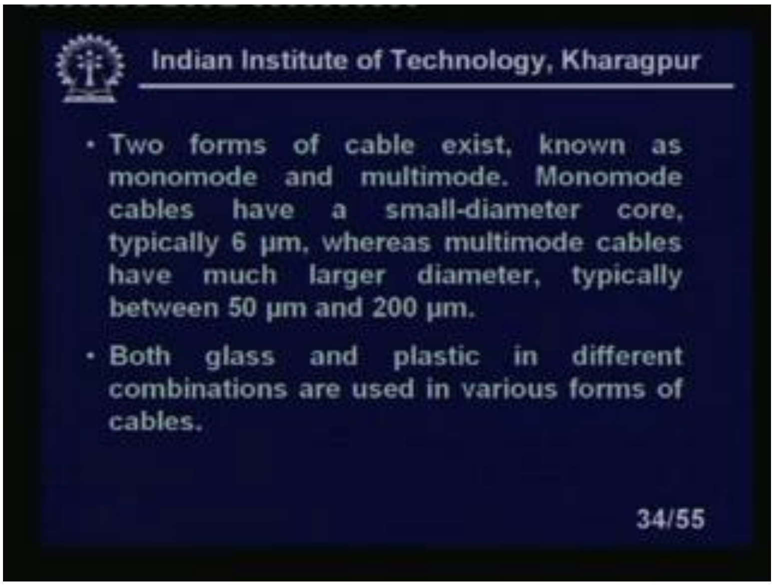

The 2 forms of cable exist, known as monomode and multimode, we have a monomode fibre. Monomode has some I mean, monomode has a I mean, launching the light in the monomode fibre is very difficult. Because it is, we have to use a very directional light in the case of laser whereas, in the case of multimode fibre. I can use ordinary light led, that is very I mean, that is saves a lots of cost. Monomode cables have a smaller diameter core typically, 6 micron, whereas the multimode cables have much larger diameter. Typically, between 15 micron and 200 micron both glass and the plastic in different combinations are used in various forms of cables. We can use glass or plastic.

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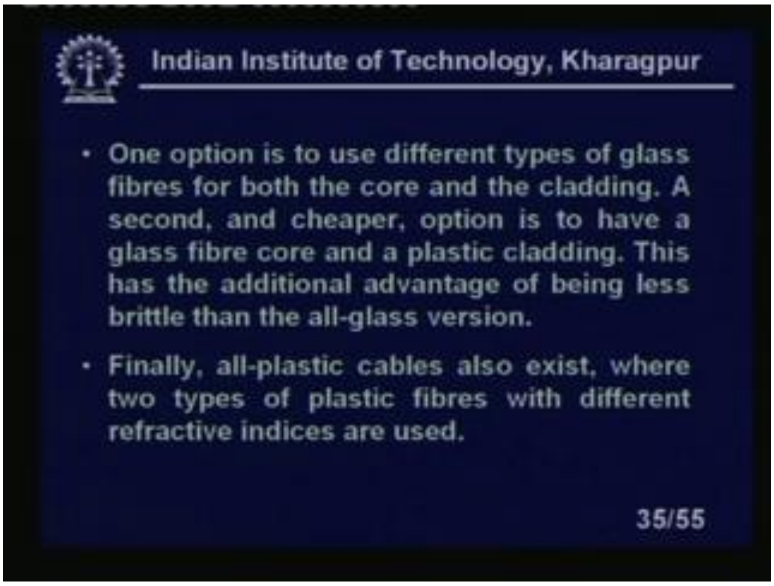

One option is to use different types of glass fibres for both the core and the cladding. You can use both the glass for the, but; obviously, of different RI refractive, index for the core and cladding is second the cheaper option is to have a glass fibre core. Which has a higher refractive index and the plastic cladding, which has a less RI value refractive index, value this has a additional advantage of being less brittle than the all glass version. So; obviously, if we use the plastic it will have, because ultimately, you see the mechanical strength is also very important. If it is made of full glass, it is very difficult to hold, it I mean it is very difficult to its very prone to the breaking. So, if we use a plastic cladding; obviously, your chances of I mean survival is better.

Finally, all plastic cables also exist also 2 types of plastics where is the different refractive indices? But they have a larger losses. So, that is the reason all plastic cables is not very popular till now. This already, I have shown you inner cross section of the fibre optic cable, inner core this might be all glass this might be glass. This is can be glass whereas, this can be glass and this can be a plastic. Obviously, the refractive index this 1 whether it is glass or plastic it does not matter; obviously, it should be higher than, this one or it can be using all plastic, but all plastic this attenuation is large. So, that is another problem that all plastic fibre optics cable.

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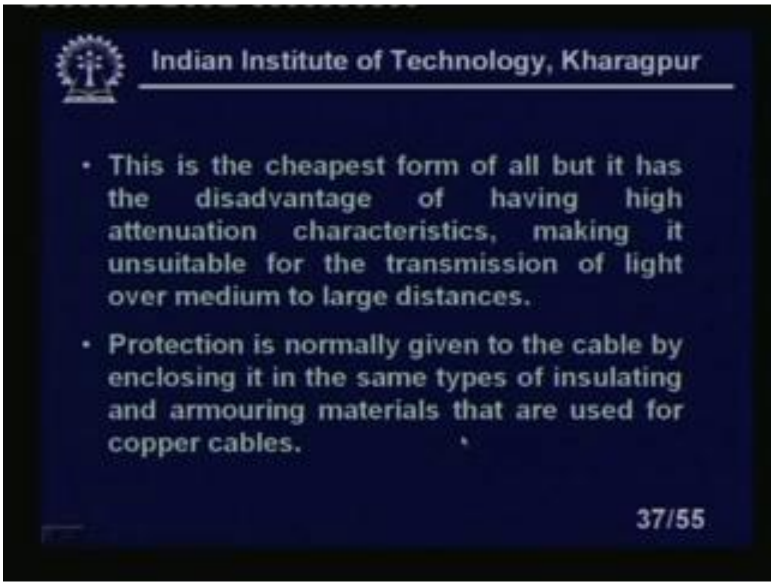

This is the cheapest form of all, but it has a disadvantage of having high attenuation characteristics making it, unsuitable for the transmission of light over a medium to larger distances for a shorter distance. Suppose I am using as a sensor pressure, sensor load sensor that type of case not a problem, but if is used for a transmission only. So, it is a not very suitable for using the plastic, all plastic fibre optic cables. Protection is normally, given to the cable by enclosing the same time of insulating and armouring materials. So, they have a outside plastic, I mean we have a like we have the electrical cable that type of protection. We will give protection is normally, given to then cable by enclosing. It in the same types of insulating and armouring the material, that are used for copper cables as in the case of copper cables, we have a several, because this will give you mechanical strength also.

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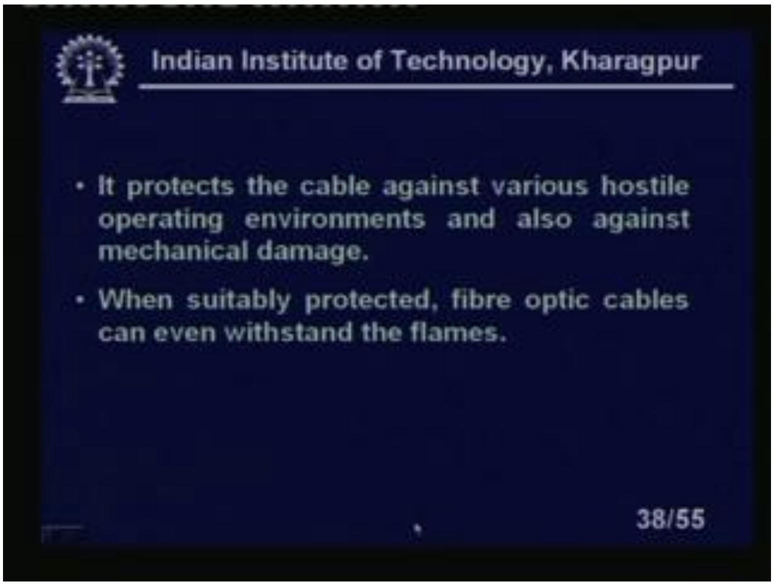

It protects the cable against various hostile operating environments also against, mechanical damage. So, mechanical damage, so that it will give you this, protections will give you that type of things, when suitably protected the fibre optic cables can even with stand the flames, if you engulfed by the flames fibre optic cables. If we have observed that, the fibre optic cables can survive it is impossible, the cases of the copper cable and all those things.

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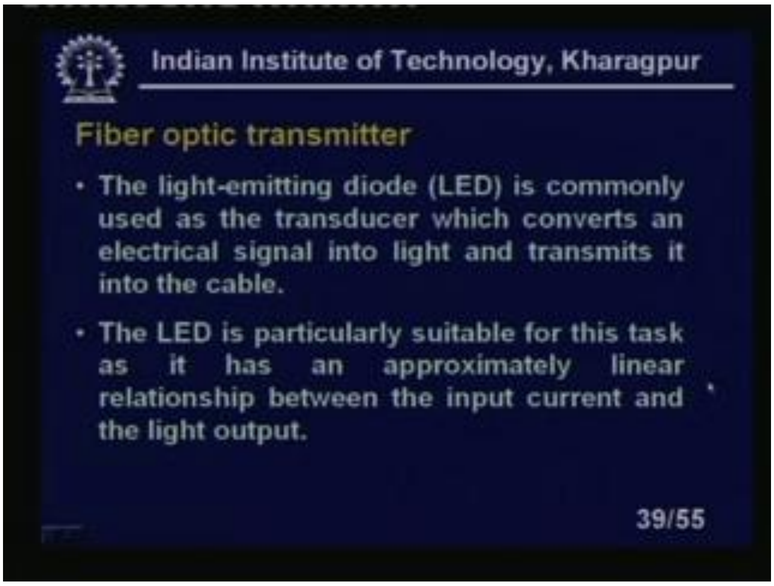

Fibre optic transmitter, let us come the light emitting diode LED is commonly, used as a the transmitter which converts, usually light is used for multimode fibre at the monomode fibre. We have to use laser please note because the light should be very well directional. In fact, you will find the launching the light in a fibre optic cable is a very very difficult task we have a lot of connectors and all those thing. So, we if we some other or some way or the other that is simplified that that gives you lot of advantage lot of flexibility while using the fibre optic cable, which converts an electrical signal into light and transmits it into the cable the LED is particularly suitable for this task at it has an approximately linear relationship between the input current and the light output. So, the input current and light output is very much I mean this linear relationship is there we have seen that the diode has the I mean that type of advantages.

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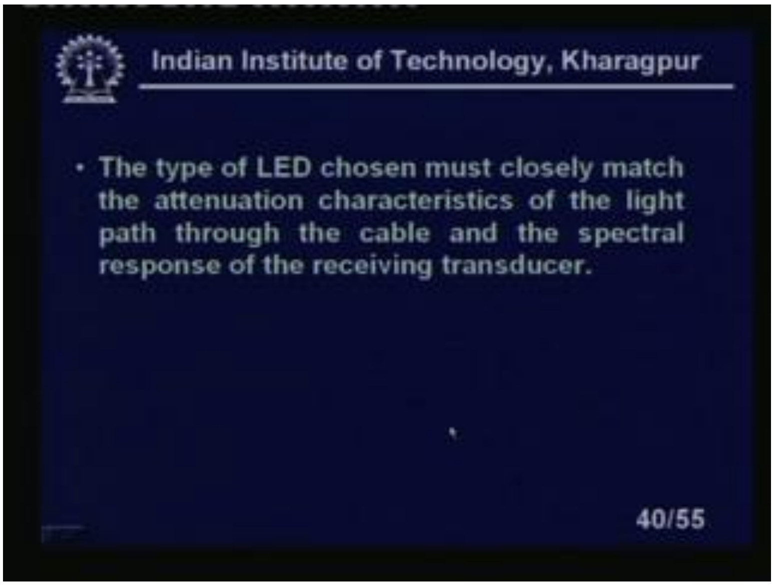

The type of LED chosen must closely match the attenuation characteristics of the light path through the cable and the spectral response of the receiving transducers. Because receiving transducers also should have same characteristics or the, cannot convert that light signal to the electrical signal that is one to one characteristics should be there. That means, as I told you linear characteristic amount of light falls and the current it is a it is a linearly variable. So, that should be a at the receiver end amount of current amount of light falls. That is at the case of receiver end in the case of transmitting end amount of current should be directly proportional to the amount of light which is going to launch to the fibre optic cable. An important characteristic of the transmitter is the proportion of its power, which is coupled in to the fibre optic cable. This is more important than the absolute output power.

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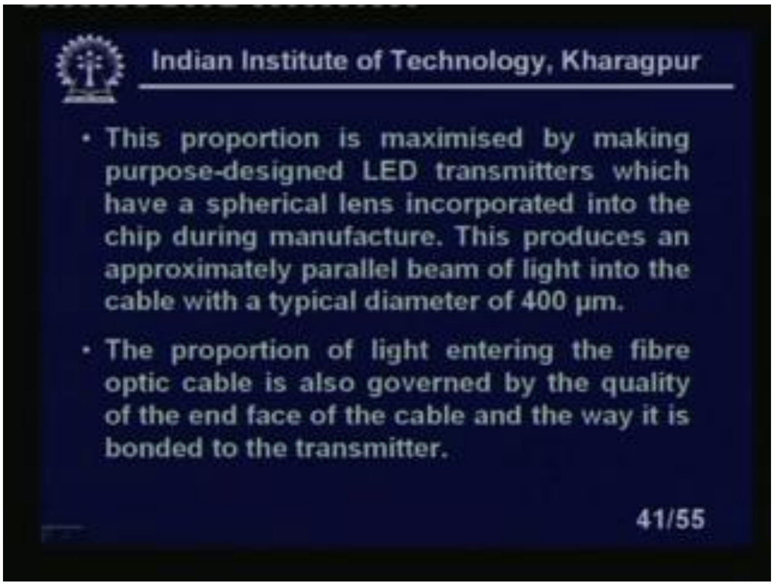

This proportion is maximised by making the purpose purposefully designed LED light emitting diode transmitters which have a spherical lens incorporated. So, that it is like I mean if you put a a source at the focal point of a lens then what will happen the light which is coming out of the lens will be the parallel. So, that is very much in necessary. So, this produces approximately parallel beam you see whatever I said this produces a what is the this proposition is maximised by making the purpose designed LED transmitters which have a spherical lens incorporated into the chip during manufacture.

This produces an approximately parallel beam of light into the cable with a typical diameter of 400 micron right? The proportion of light entering the fibre optic cable is also governed by the quality of the end face of the cable and the way it is bounded bounded in the transmitter. So, this is a very difficult task as I told you it should be very much well polished if there is a little misalignment. So, the light cannot be launched through the fibre optic cable this intensity of light will be sufficient. Otherwise you need a repeated very I mean after a short distance in the case of transmission.

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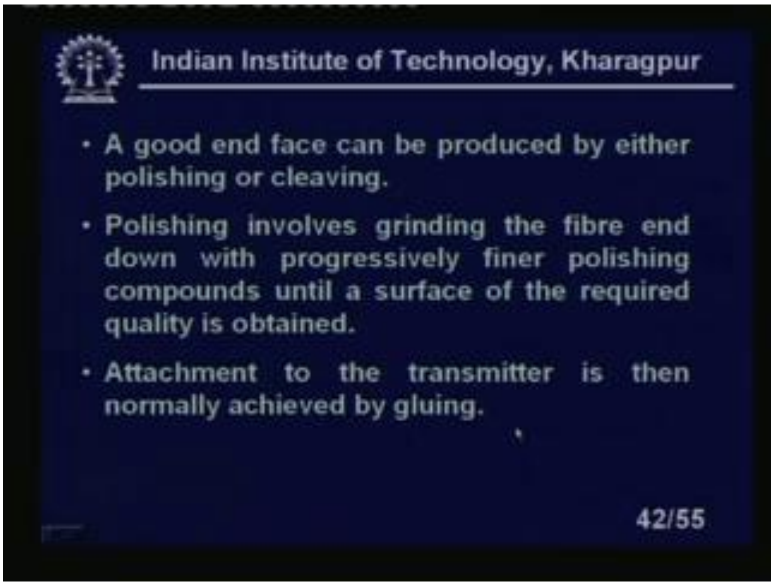

Instrumentation that is not very much necessary. A good end face can be produced by either polishing or cleaving in face end face of the fibre should be very much polished. Polishing involves grinding the fibre end down with a progressively finer polishing compounds until a surface of the required quality is obtained. So, the end will be perfectly polished is this means this end will be perfectly polished. Because you see I have I have a cable I have a cable and we have a its I have a cable and I have a transmitter here.

So, whenever it is connected to that cable this transmitter this light cannot be launched if this end surface of the cable is very rough. So, that should be very much polished. So, we are using grinding technique and cleaving technique. So, through that it will be very much polished and light can be easily transmitted through this one this light source as I told you it is a spherical lens. So, that the light which is coming off from the suppose the source is here it is falling on the spherical lens and which is from the lens when it is going out it is going all parallel lines of lines of lights . So, that we will launch through the fibre optic cables attachment to the transmitter is then normally achieved by the gluing.

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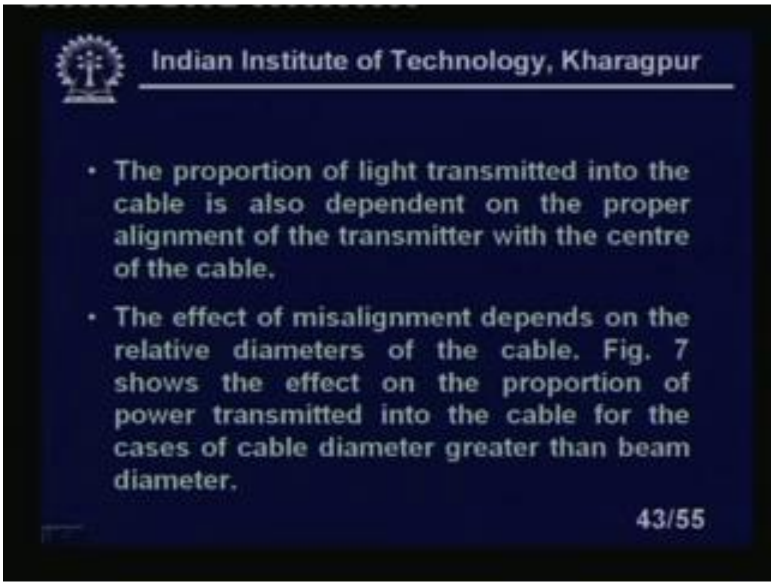

The proportion of the light transmitted into the cable is also dependent on the proper alignment of the transmitter with the center of the cable right. The effect of the misalignment depends on the relative diameter of the cable. And figure 7 shows the effect on the proportion of power transmitted into the cable for the cases of cable diameter greater than the beam diameter.

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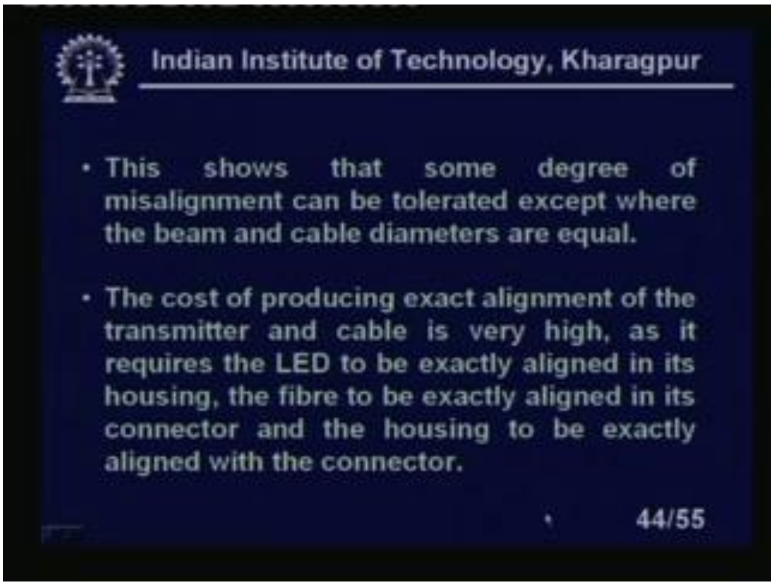

You see this shows that the some degree of misalignment can be tolerated except where the beam and the cable diameters are equal. The cost of producing exact alignment of the transmitter and the cable is very high as it requires the LED to be exactly aligned in its housing, and the fibre be exactly aligned in its connector and the housing to be exactly aligned with the connector.

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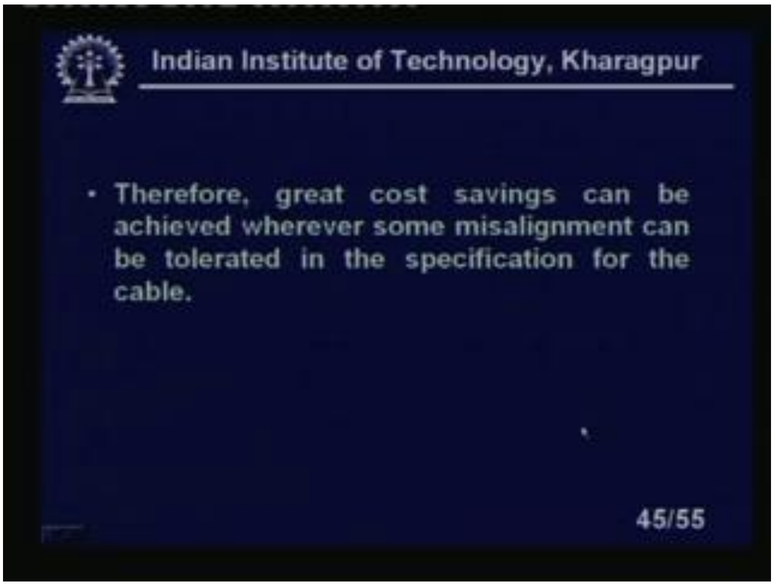

Therefore the great cost savings can be achieve wherever some misalignment can be tolerated. That is the reason multimode fibre is always preferred over the monomode fibre is little misalignment will not affect much.

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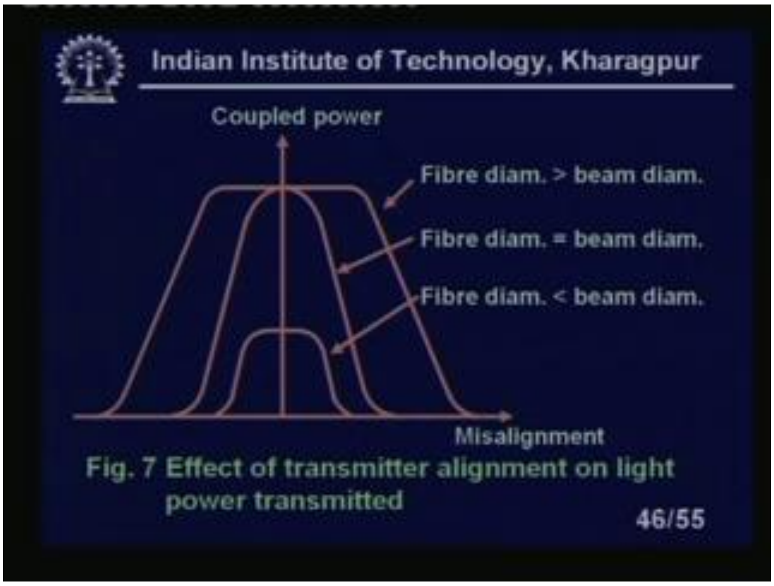

You see this is that we talked about effect of transmission here see the fiber diameter is the more than the beam diameter. We can see that how much tolerances misalignments we can I mean aligned that is multimode fibre has a always the more diameter is more right. So, that is the advantaging whereas, the fibre diameters is equal to beam diameter and fibre diameter is less than beam diameters whenever this is less it is more we have a miss a small amount of misalignment. So, only will be tolerated.

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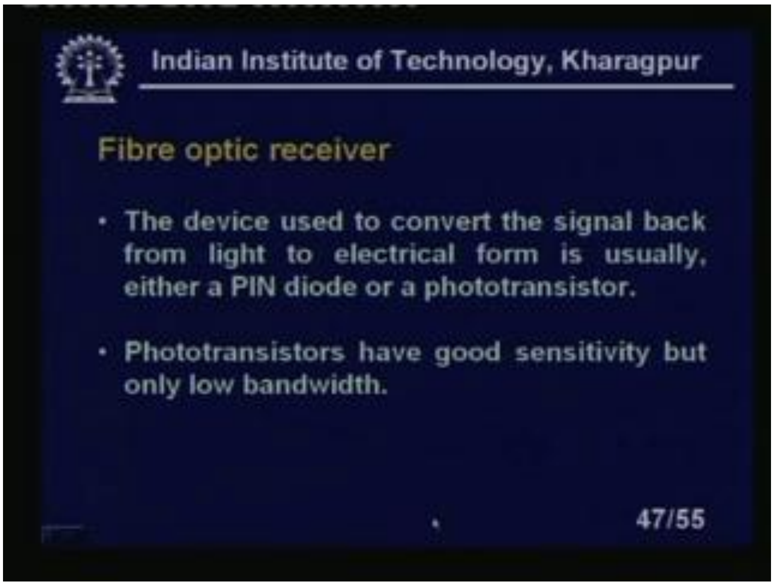

Fibre optic receivers device used to convert the signal back from light to the electrical form is usually either a PIN diode or a phototransistors right. Photo PIN diode is more popular use. Phototransistors have good sensitivity, but only low band width the bandwidth of the photo transistors is very small.

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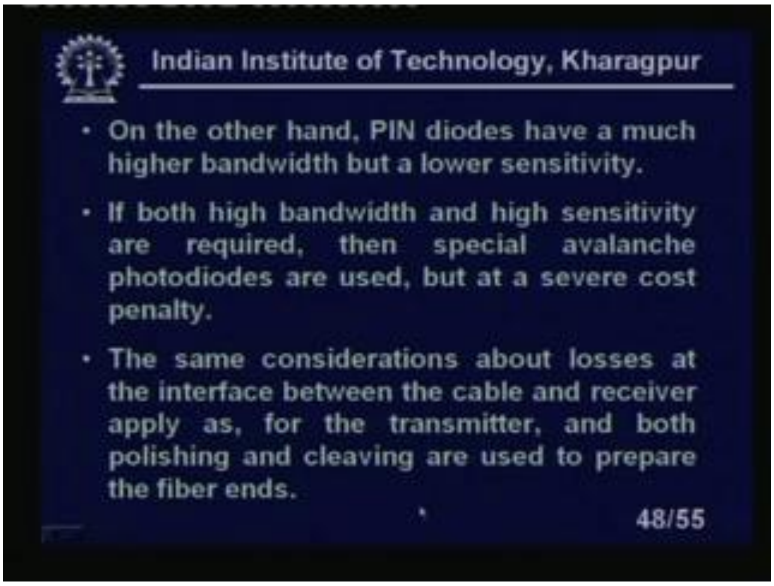

On the other hand, PIN diodes have much higher bandwidth, but has a lower sensitivity we need a amplification obvious that is not a problems. So, we can have a amplifier. In both high bandwidth and high sensitivity are required then the special avalanche photodiodes are used. But at a severe cost the same considerations about losses at the interface between the cable and receiver apply as for the transmitter and both polishing and the cleaving are used to prepare the fiber ends.

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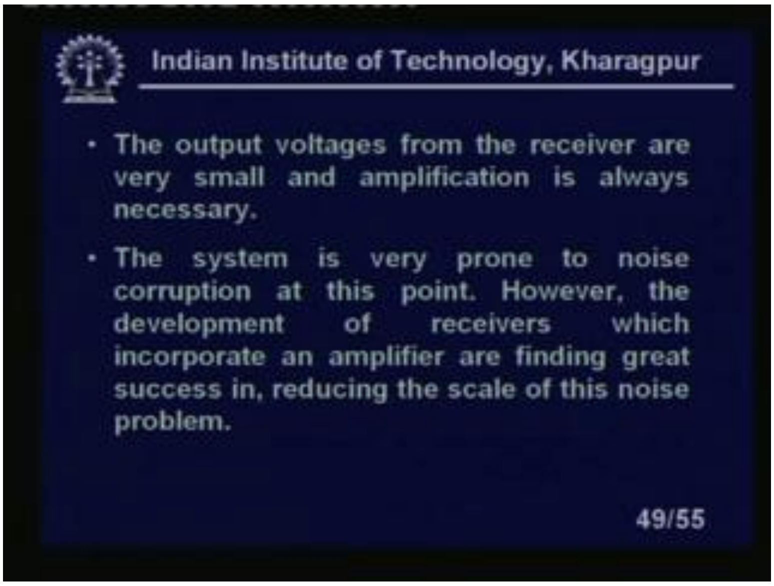

The output voltages from the receivers are very small and the amplification is always necessary, right. That is I told you I mean I can I can use a PIN diode, if I use a PIN diode I. need further amplifications, but that is a advantage which we were getting, because it has a larger bandwidth right. The system is very prone to noise corruption as I even though I am telling this is not corrupted by any interfering noise or any electrical noise. But the noise will come at the transmitting and the receiving end, because there is a position there is a where it is signals optical signals compact to electrical signals again.

So, noises sources have introduce then even though if a fibre optic cables are going on and over there are many crises cross of the other electrical cable. So, the any spikes in the electrical cable does not I mean effect the information which are getting transmitted to the fibre optic cable. System is very prone to noise corruption at this point; however, the development of receivers which incorporate an amplifier are finding great success in reducing the scale of this noise problem.

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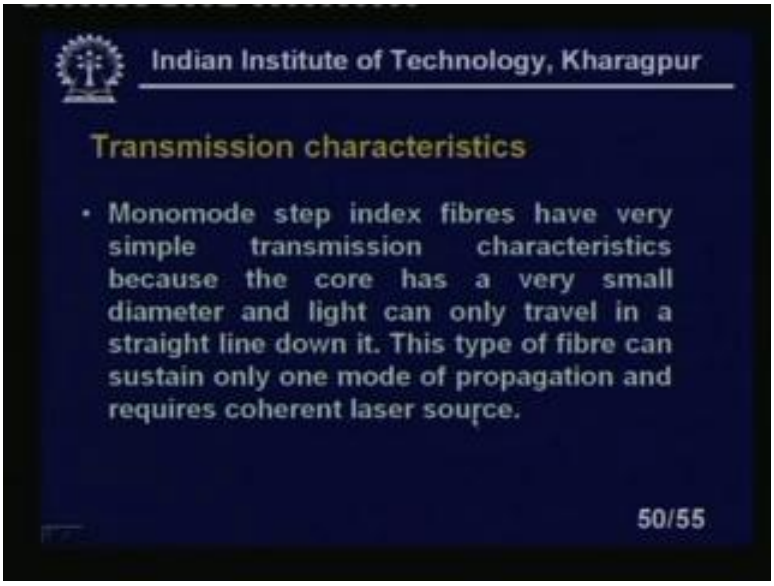

Transmission characteristics: Let us look at the monomode step index fibre have very simple transmission characteristics, because the core has a very small diameter the light can only travel in a straight line down it? This types of fibre can be sustain only one mode of propagation and equivalents requires coherent laser source that is a problem, because light will be transmitted in straight line.

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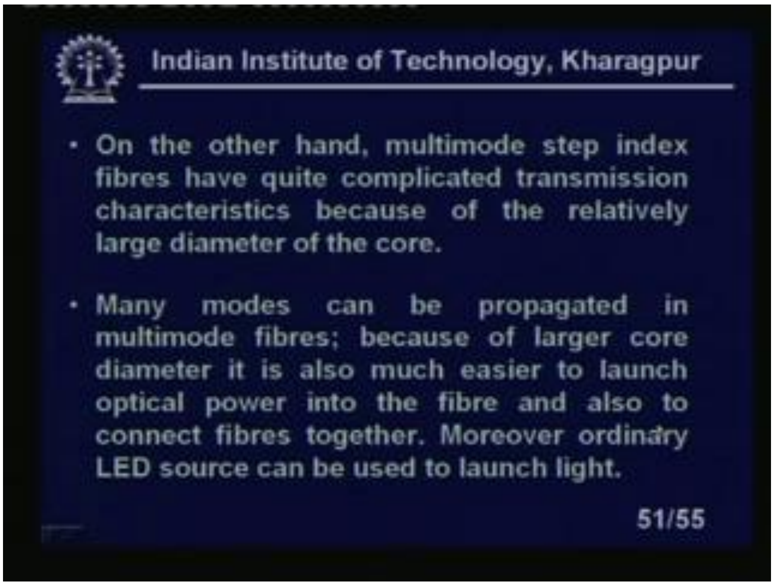

On the other hand multimode step index fibers have quite complicated transmission characteristics, because of the relatively large diameter of the core. Many modes can be propagated in the multimode fibres because of the larger core diameter. It is also much easier to launch optical power into the fibre also that connect the fibres together 2 fibre can be easily connected by together. Moreover ordinary LED source can be used to launch light that is most important I do not need laser.

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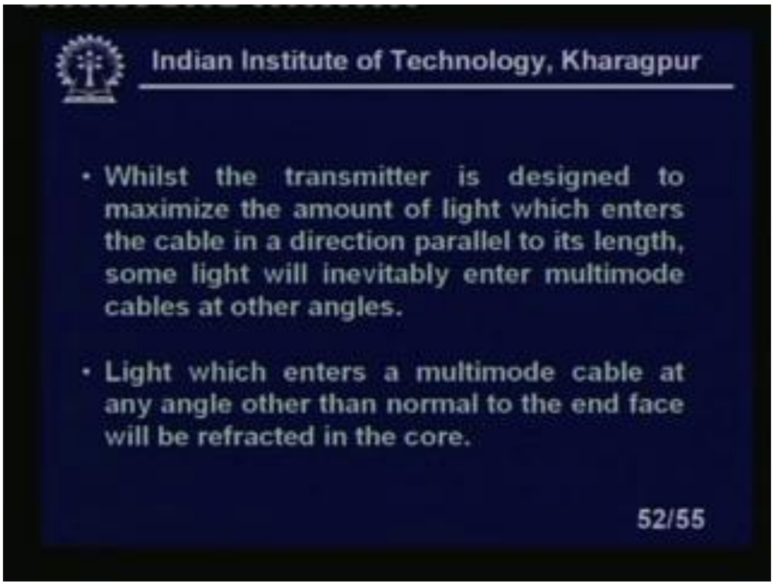

Whilst the transmitter is designed to maximize the amount of light, which enters the cable in a direction parallel to its length some light will only will inevitably enter multimode cables at the other angels which is quite obvious. And it is going to total internal refraction at coming to the end one end. Light which enters a multimode cable at any angle other than the normal to the end face will be refracted in the core right.

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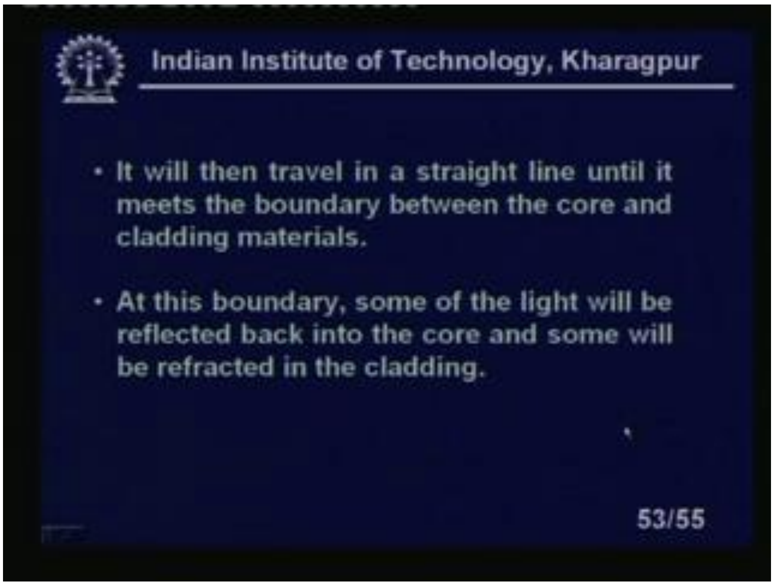

It will then travel in a straight line until it meets the boundary between the core and cladding materials. At this boundary some of the light will be reflected back into the core and some will be refracted in to the cladding, right.

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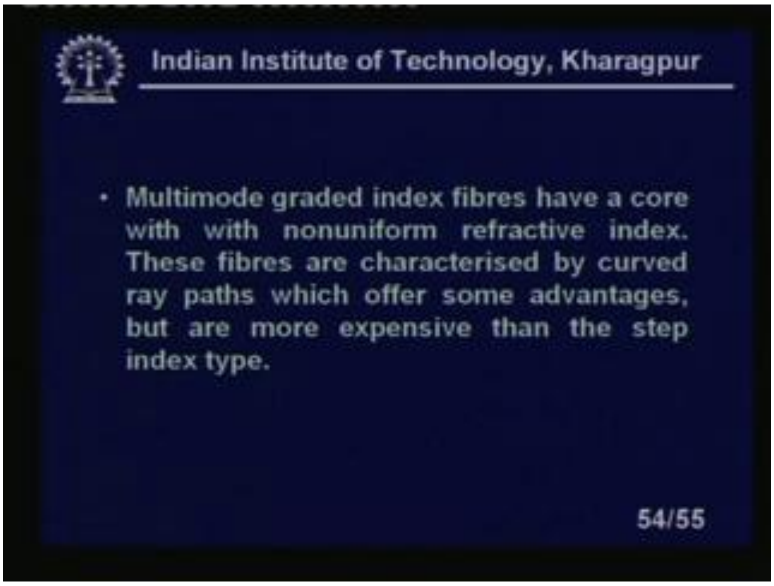

Now, multimode graded index fibres is also there where the I think we talked about the step index fibre. Both in the case of I mean your monomode and multimode fibre basically this is only graded index there is the of the index refractive, index of the change abrupt change of the refractive index of the hum refractive index of the material of the core of the fibre and also the cladding. Whereas in the case of graded index fibre, what we will find that the the core itself is made of a material where the it is changing slowly slowly. So, that the light can go in a core in curved path itself there, right? So, multimode graded index fibres have a core with with nonuniform refractive index. These fibres are characterized by the curved ray paths, which offer some advantages, but are more expensive than the step index type.

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So, you will find the next day in the, I mean in the lesson 29 we will covered this in more details. Because the, what is the base principle, what should be incident light? All these things and then we will go to the some fibre optic based sensors. With this we come to the end of the lesson 28 of industrial instrumentation.