Optical Engineering
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Lecture – 42
Applications of Optical Engineering

Good morning. So, we have actually come to the last lecture of this course. Next week you will give your presentations. So, I am going to try to squeeze in two applications today. Let us see how that goes. I wanted to look at the CD DVD system, because that is one system, we started the course with. And then we encountered it every now and then in different forms.

So, it is kind of a summary to look at it again and I hope when we look at it now, things will be so much more clearer to you than they were at the start of the course.

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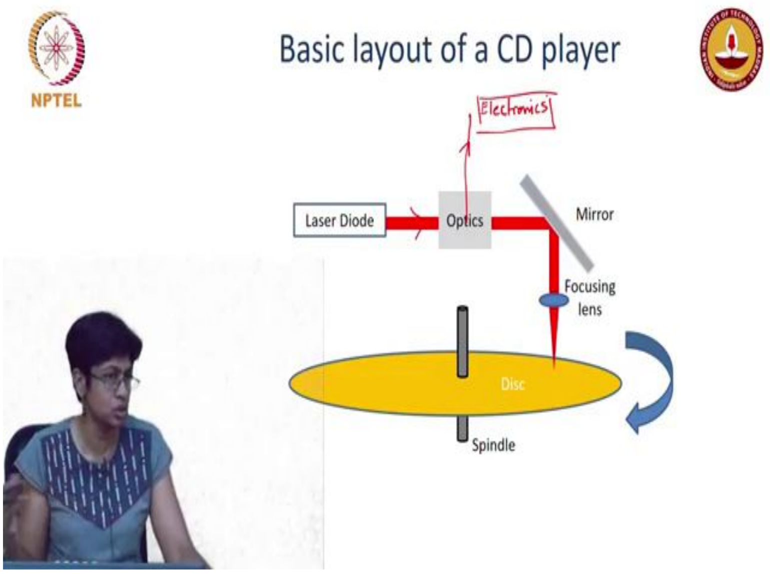

So, you might have seen this picture earlier. This is a very basic layout of the optics of a CD player. Of course, there is a lot more to it than the optics. But the basic idea is you have a light source and you send light onto a disc. And the disc stores information, it is spinning. And this there as motors which will move this beam or move somehow move the light across this disc. So, it is actually the beam that is just moving laterally like this. But because the disc is spinning, you are accessing every radial point of the disc. And light reflects and what I, I do not know if I have that here do not have it. It reflects calibrating your pin no, hence you know somehow here the return path will go up like this ok. So, the onward path does this. You could think of it as a beam splitter again and the return path would go here and there is it you know gets converted to an electrical signal and then you have a whole bunch of electronics and you may process that takes place. That now converts this light into either data or audio or video.

So, how does this light reflecting off the disc carry the information? Somehow, we need it to carry information. Now in a regular communication system, the very early way of coding information into light is you want to send a word, you will convert every word into code. And that code is finally it is a binary code, so you convert it into 1's and 0's right. So, that you just need two bits of information and with those two bits of information, you can encode anything.

If I try to put that idea into light and in fact, early communication in light the simplest way of modulating light, so that it carried information was to think of when I am talking, I am talking about say sending something through a fiber for example. You could think of switching on and switching off the light. So, you have your bits of 1 and 0 and there is nothing but the laser going off.

But we have a lot of information that we want to convey. So, that is a very bulky way. If you want to convert a large volume of data into just 1's and 0's, you are creating a very large volume of 1's and 0's.

So, it is not a very efficient way of storing information. Plus, finally you want to be able to make; for example when you say light reflects off this; this disc is wobbling, how do you decide what is 1 and 0? If there is a clear system, there is no noise you might say yes, it is obvious. What about in a system where there is noise? I am putting some threshold and saying above this is 1 below this is 0. So, you want to have slightly more sophisticated ways of imposing that information on light.

So, how is it done in the CD? And you cannot think of it in terms of the light alone because the light here is falling on the discs. So, the way you write that information into the disc is as important as how you read it ok. So, there is no one unit of this which is more important than the other.

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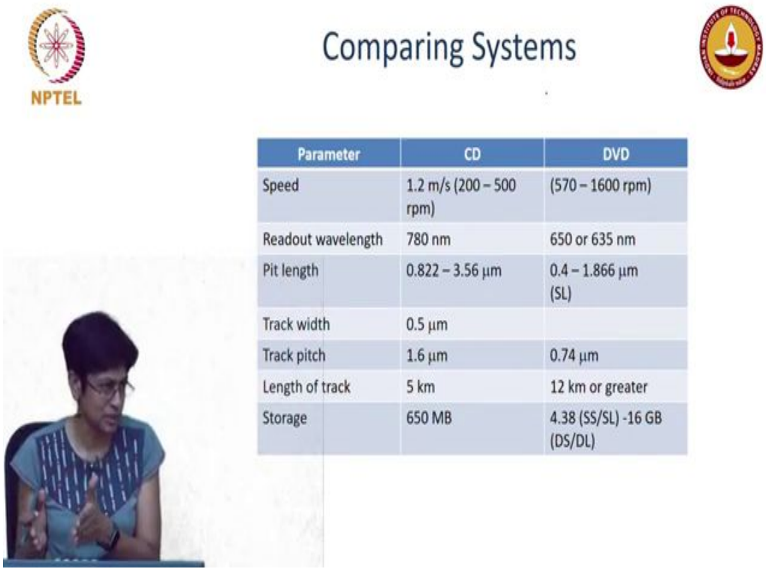

This I think I showed you earlier also. I will say a CD or a DVD system I am using interchangeably. But of course, the technology is slightly more refined for the DVD, because you are one thing if you have a higher wavelength and now you should know very clearly the higher wavelength does what for the spot size.

Student: (Refer Time: 05:03).

You are getting better spot size right. So, you want to be able to reduce the spot size right and thereby put more information on it ok. So, did I say higher wavelength? Lower wavelength, lower wavelength will give you better spot size. So, you can store more information onto your disc ok.

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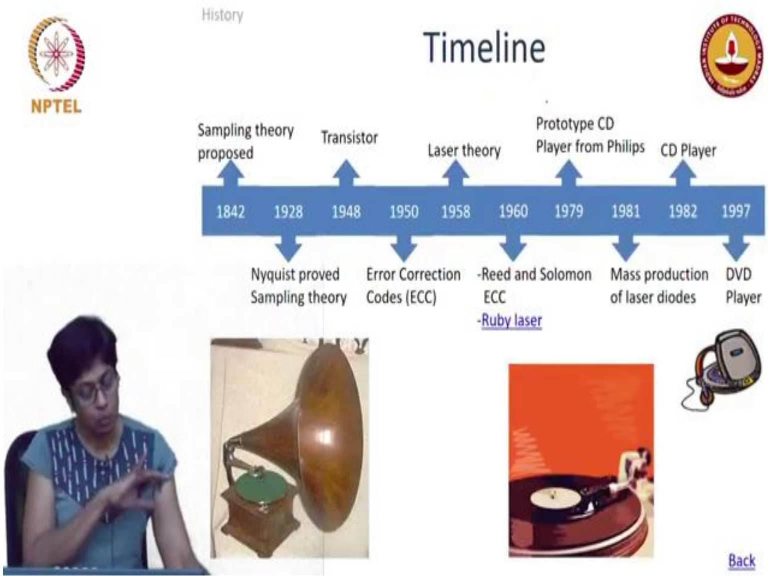

So, I will not go into the details of this, but the CD is a very good system to study. If you want to look at how optics can play a part in something that is very interdisciplinary in nature. So, all of the points listed out here are required to have the development of the CD or DVD. You would not have been able to get that compact system the CD is a compact disc. If you have not had all these developments and you can see these developments are in a variety of fields. They are not all in optics right.

There is encoding, there is electronics; I have not even put in all the stuff related to the motors here which is in mechanics. But all of these were required and you can see the very early discoveries in 1842 and all the way till 1997 before you had a compact disc player ok. So, it really is from a variety of fields that knowledge has been pulled in to create the system. And that is true of many systems: the CD, I am talking about, is now just representative.

But this is true of many systems and that is why learning optics is very useful because you may be designing or working with systems like this. And the more you understand every part of your system, will make you do a better job of the part you are working on ok.

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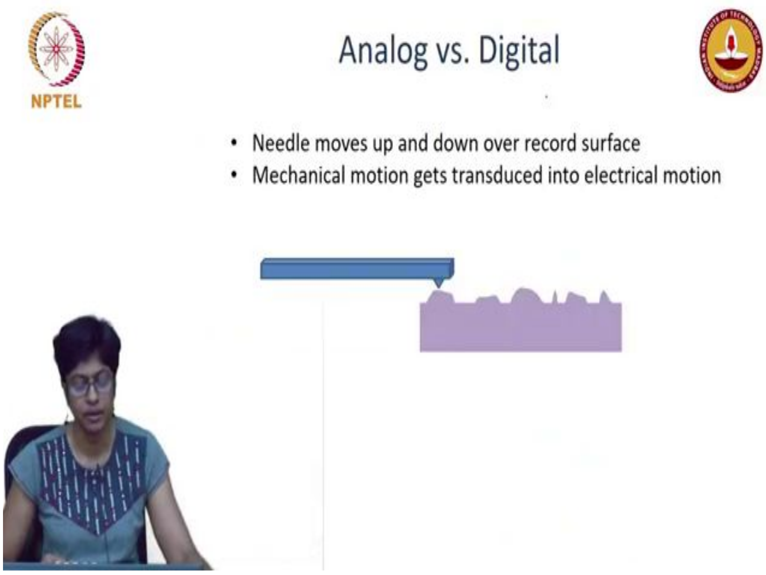

Of course, you are storing information. So, the big difference when the CD came out was till then music, for example, was not stored in digital format; but was stored in an analog format. And what happened was you had a stylus that moved across right. I have shown you some bumps over here. What is happening is as the stylus is moving across; you can see this needle is changing its height depending on the bump on the disc.

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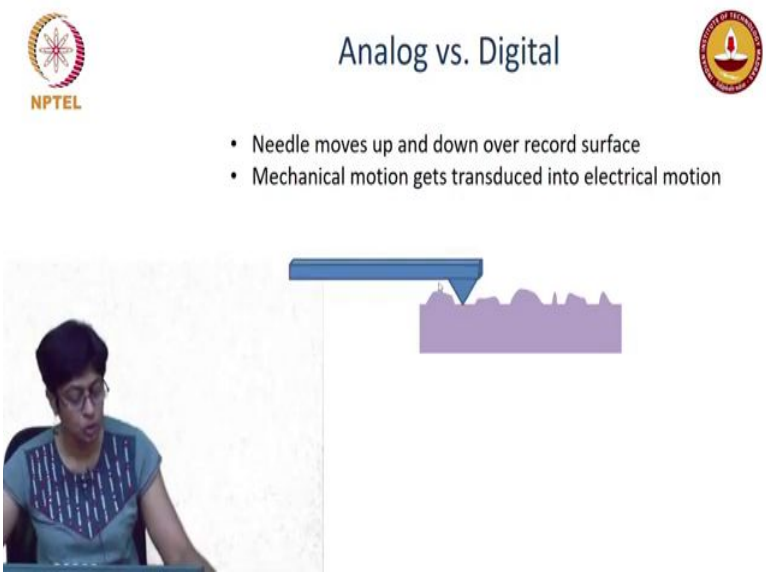

So, if there is no bump, it will fall to a lower height. If there is a bump, it will go. And that mechanical movement was getting transformed into an audio thing. But everything every bump on that, every piece of dirt on this, everything the stylus is responding to it that is one thing. And the second thing is it is also a contact method.

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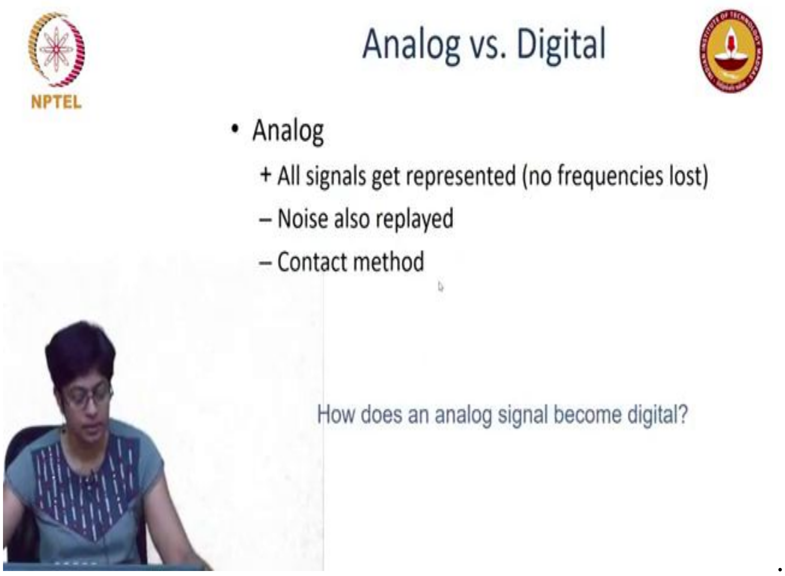

So, that needle, so if you had an l p record and you are playing music, that needle was literally scratching out your favourite song right. And if it was your favourite song, you scratched it out many times and eventually you would literally scratch it out right. The disc was damaged right. So, the CD made many major changes, one is this information was not going to be stored analog anymore which meant you could filter out frequencies, noise frequencies for example. Plus, it is not a contact method, in the sense there is no mechanical contact.

Of course, light is falling on it, but there is no mechanical mode. So, in principle that disc is not going to ever get damaged ok. It is quite sensitive to humidity, it is sealed and in a place which is not extremely humid a disc can really last forever, but you know places like this we may still see damaged discs because of humidity. But in general, it has a longer lifetime then the l p ok.

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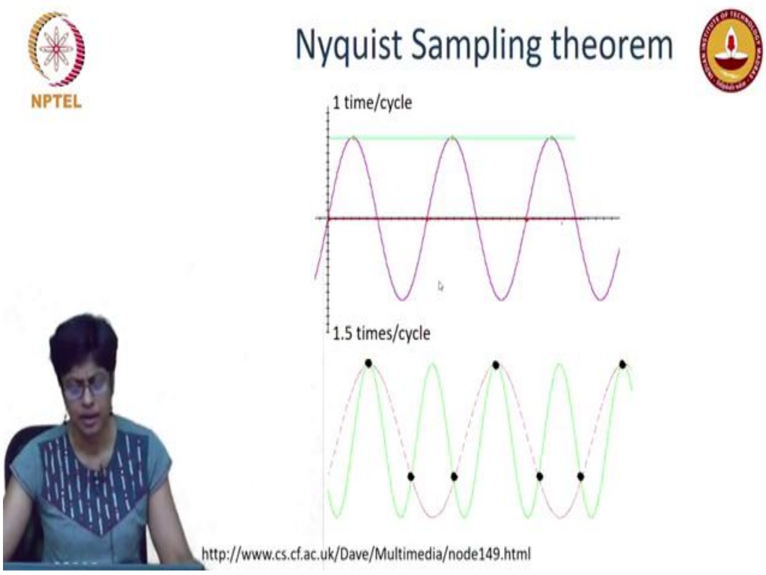

Let me not go through this; I think you should all know this part. So, basically you are converting the data into digital data. And somehow the digital data has to be stored on the disc. Now an l p would initially they would release small ones and maybe it had one song on it. And then they would have bigger ones which would if you have a few songs; maybe you flipped it over you would have some more songs and maybe you could get 8 songs or 10 songs on it ok, that was it.

But now because we have changed the way we are formatting the data and because I had a desire to have more information, there needs to be a way to put more information that is one thing or to see is there some way to reduce the information. So, I am shooting a movie, I am taking a scene and there is a lot of video files. It is a very large file. Is everything in that video file actually required for me ok?

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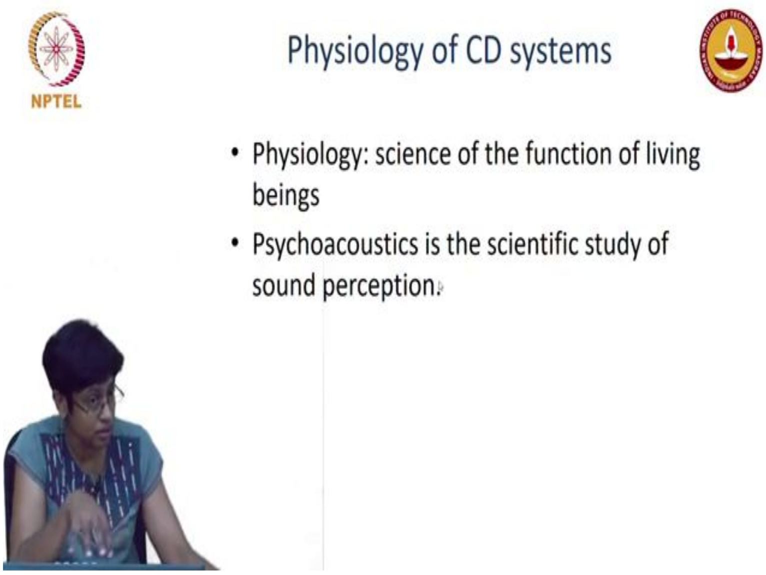

So, the CD player is really interesting, because it did not just look at the optics and the electronics and the mechanics of it. They also looked at physiology. What is physiology?

Student: Working (Refer Time: 10:36).

It is how the human body works. Why do you need to look at physiology? I have already given you a clue with my previous sentence. We said we want to somehow get rid of information. Ok let us see physiology is a science of study of living beings and psychoacoustics is a scientific study of sound perception. They needed people with this background to help them.

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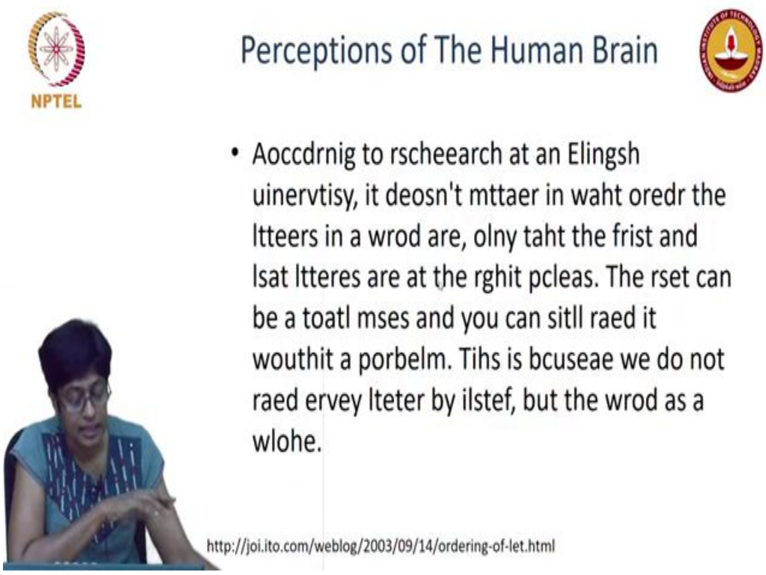

And let us see why. Can you read this? Ok. This is what something that my students give me often looks like, because they are too lazy to run spell check. And if your project reports come like this, I will not be smiling right.

So, I am not by putting this up here, I am not accepting this. But the point is, though it is atrociously spelled, we can read it. I mean if I asked one of you to stand up and read it aloud, you will do it like this; you will not struggle right. Because our brain is able to correct for those mistakes ok. So, it is not that in a CD; we are saving the data that is scrambled, but the fact is we can exploit the way our brain works and say even if there is some problem with the data, even if we do something to the data that would help us.

And I will explain what I mean by that. The point is the brain will adjust for that and give us correct information or what looks like correct information ok.

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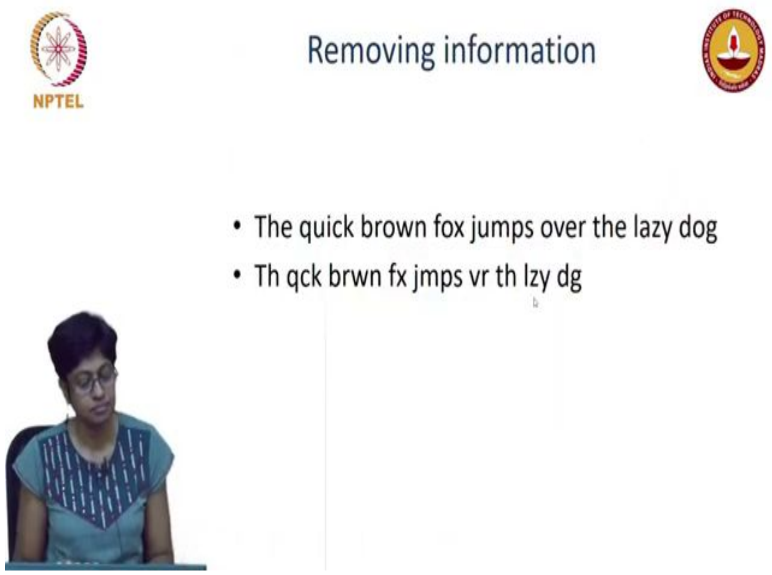

Another important thing is, again, if I ask you to read the bottom sentence, if I am not given you the top sentence, you would still read it correctly right. So, we have removed information, we have removed crucial information. And yet you could in principle say I have not lost anything because I could reconstruct the upper sentence perfectly right.

So, it is ideas like this that came from physiology and psychoacoustics it said, when we record music or when we record a video or for a movie; there is a huge quantum of data you convert it into digital data and it is a large quantity of data. Now if I say I need all that data and I have to put it on the disc, it is really very hard because you would need 10 discs for one movie right. And I you guys may be too young to remember, but when CDs first came out with movies. So, you had audio CDs first for some years, then you had CDs with movies and one movie was on 2 CDs.

So, you have to take out one and put in the second one because they could not fit it into one right. Now you may have 2 movies on one DVD. In fact, the really bad where they pirated, they will give you 10 movies on a DVD with some extra interviews thrown in for free right. But earlier it was only so they got better and better doing this coding.

So, they are taking advantage of the fact that you can remove some information and we still correct it. Now, in the two examples I gave here, you can see something is wrong and you are able to correct it. What needs to be done when you are with the way data is put on the CD, you must it must be given in such a way that we do not see there is something wrong.

But you have removed information and what is left is enough for us just to see it as if all the information is there ok. And so, this is yes we did analog to digital, but you could reduce the amount of information by saying well if the eye, the eye is sensitive to some colour at some intensity.

If you have a certain intensity for some time on the screen and you immediately thereafter have a lower intensity or a different colour. You could remove those because your eye is not sensitive for some time after that. If you hear a certain frequency for a certain time for some moments after that you will not hear other frequencies. So, you can filter out those frequencies and we have not lost anything.

So, the trick in coding there was not to remove a lot of information and we see its wrong, but our brain says I still know that is a man or that is a woman or that is a dog right. You removed information, but you live enough that we see it as a whole. And they are in that process a lot of understanding of how the human body, especially the senses of the human body, our ears and our eyes. How they work was needed to say what can be removed ok.

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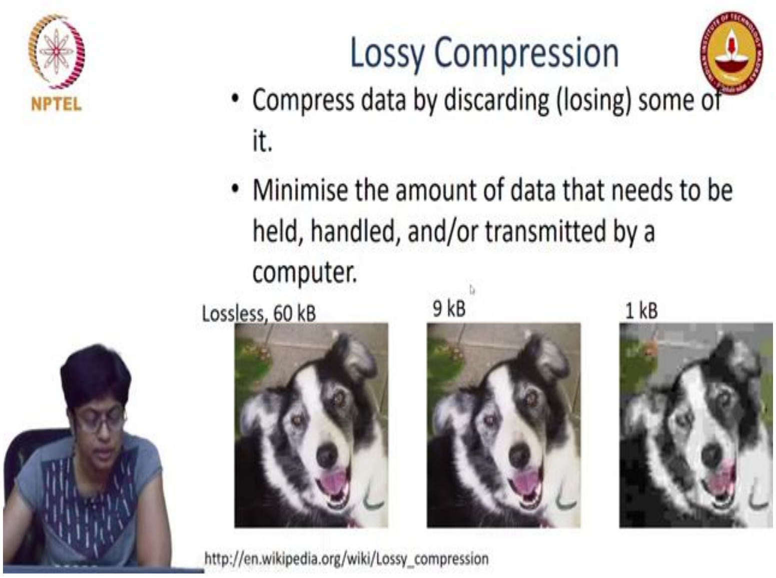

So, this example shows you that when you are talking about discarding data. The original image is a 60 kilobyte image. You see the picture very clearly. But as you go down, when you go down to 9 kilobyte you may not notice much difference, but you are an order of magnitude less in data right.

So, you are actually throwing away some data, but it is still the resolution of our eye and maybe of the display system. I am using it adequately to just show it as almost a good image. But if we go down even further, almost another order of magnitude, then you start to see there is a problem with it right. So, ideas like this were used to reduce the amount of data which needed to be put on the disc in their phase ok.

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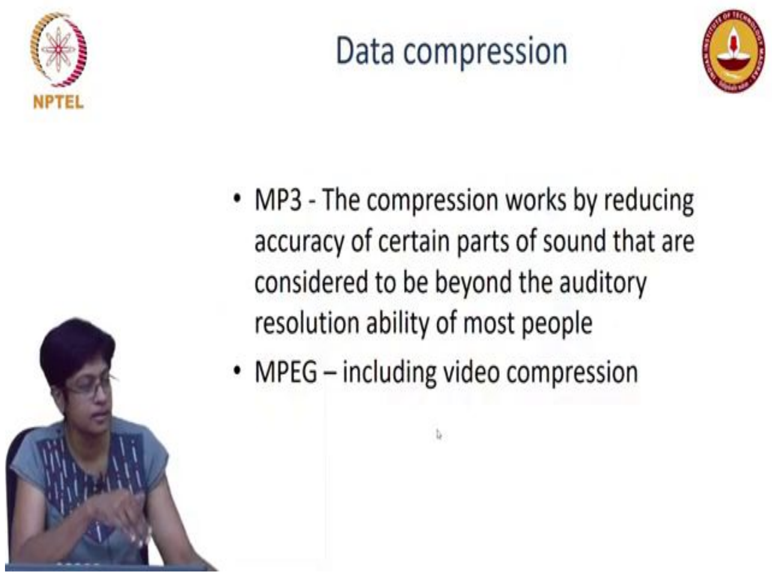

And these are the data compression techniques we call MP3 and MPEG and so on. And of course, you have many versions now, because they keep improving on these techniques ok.

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So, this is the part which really relates to this course which is how is data stored? So, I have always been saying light falls on the CD, reflects off the CD and somehow in that reflected light is information right. So, it turns out it is not a simple reflection, it is not that there is a part of the CD which is dark, and a part which is bright. And we are saying there is no reflection, there is reflection. I have a 0 and a 1, that is not what you are doing.

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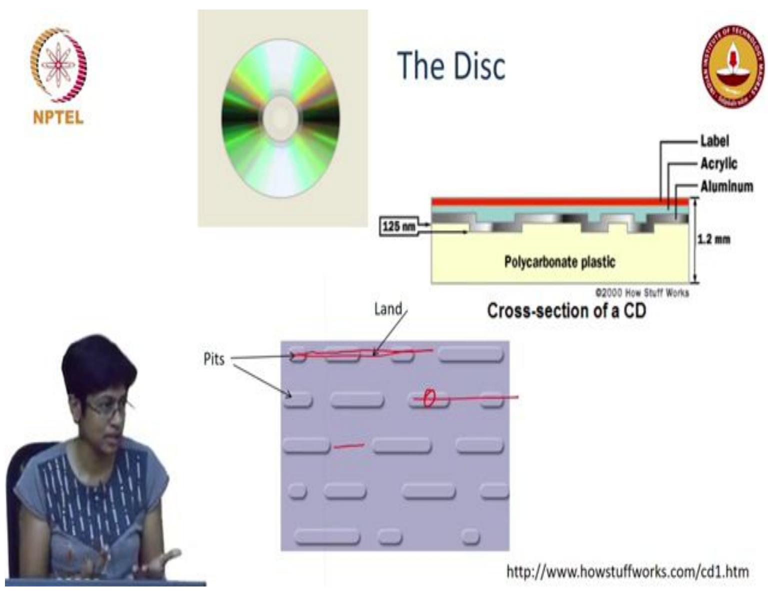

You are using interference ok. So, if you were to magnify, what the surface of a CD would look like? This is what you would see right and there is where you have these they are called pits they look like bumps, they are called pits because from the other side they have pits right. And the region between them is land and if you look at the side view this is how a typical CD would look ok.

So, this is the protective label and then you have this structure and this is where the information is stored and you can see that you have 125 nanometre heights over here. Now if I tell you that we're using interference, I still need to have my 0's and my 1's. How are we getting the 0's and the 1's now with interference?

Student: Constructive.

Constructive destructive interference. So, this height I have put a number here, this height clearly is for the system depending on the wavelength of the light that you are using. Because light will hit the top of this surface and some of it hits the side. And it is a reflection from both, but if you have got the height right, they will cancel out. And in this place, there is nothing there, there is no interference here and you have a bright signal. And that is how your 0's and 1's are stored ok.

Everything is encoded in this, because remember the disc is spinning, but you need to read one track at a time. So, you need the laser to travel across this track and then only go into the next track, it is a spiral actually. So, it will just continuously follow the spiral. But because the disc is spinning maybe your player is sitting on a table and something bumps into the table.

It should not be that the laser suddenly shifts over here right. We are talking about hundreds of nanometers at the most micron of spacing right, it is a small distance. So, it cannot be that you are reading this and then you shift into this track. So, you use the track itself with feedback to say am I on the track. And what if you had a region where you had a lot of empty space? There is no information coming back, it is it's just high reflection, high reflection, high reflection.

So, the way they code the data is that they always make sure there is a pit, maybe the data does not need the pit. But it is like they have a header there they said if I have so many bits of data some bits are reserved just to say, yes we are on the track ok. So, there are many different types of coding that were developed especially for the CD, they may get used in other systems as well. But everything is done based on light reflecting off that track.

So, you are keeping the light on the track, using that reflection you are getting the data of the track using that reflection, you are ensuring that you do not switch from one track to the other using that reflection ok.

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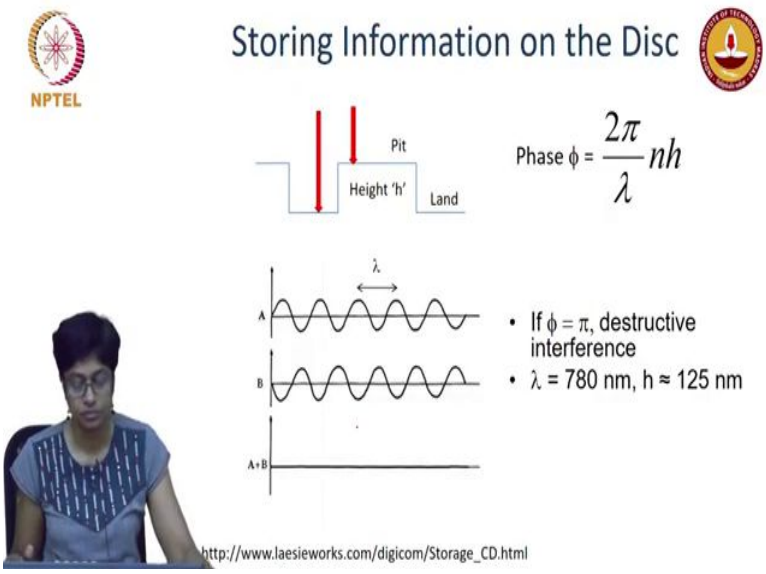

So, if you so, this is what I was saying, you have light reflecting from the top over here, light reflecting from here and what you will see is, if you have got this height right. A plus B is going to give you perfectly destructive interference. Here for the CD, they started with 780 nanometre wavelength little bit in the IR and therefore, the height was around 125 nanometres for cancellation.

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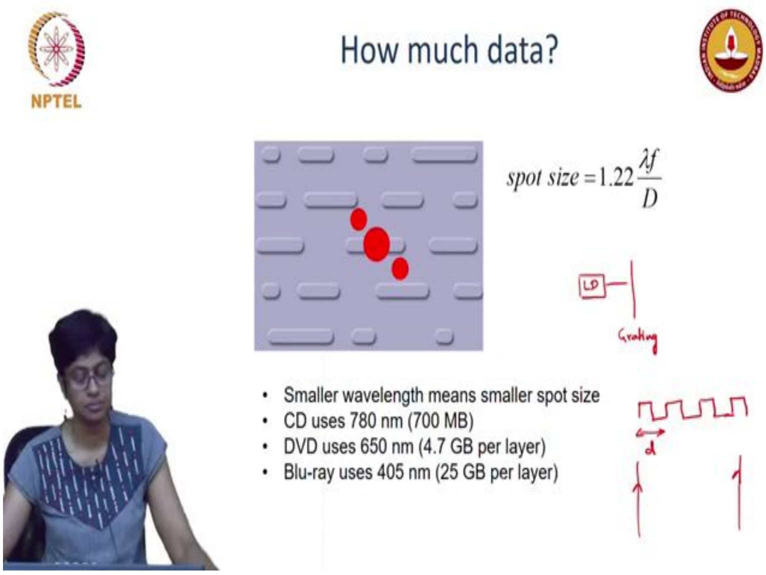

So, this is what it looks like. Now that is the spot on one bit of data ok. And you can see the spot has to be larger, because you need that interference to happen. So, you need light to fall on the land region and light to fall on the pit region and that has to interfere with each other. So, the spot has to be slightly larger, but there are two other spots ok.

Why do you have two other spots over there? As I said those spots should only lie on this land region which is between tracks. So, you are monitoring the reflection of all three spots. If you start seeing information in this spot or this spot you know that the central beam is moving off the track. So, you are using feedback, this spot and this one should give you a uniform constant intensity all the time.

And if it starts getting modulated, then you know that you are moving off track. So, that is used as feedback to keep the central spot all right. How are these three spots generated? We do not have three laser diodes in there. We have one laser diode and a diffraction grating. Now we could not do diffraction in detail, but you will be doing experiments today in the lab. And the grating is nothing but a device which has a periodic variation in phase ok.

So, it continues and this distance is repeated. So, in this diagram I have drawn it with the height variation that means if a beam of light is incident on this; periodically parts of the beam go through a slightly longer path length then the other paths. In other words, this device is generating a large number of beams with slight phase differences between them.

And because you know an interference when I have two beams interfering, some places we will have constructive interference and some destructive. The grating is now no longer two beams of light, its many beams of light, the place where constructive interference happens is going to be very limited ok. A good way to think about it is;iIf I have pain if I have two beams of light, I get constructive interference over a larger area.

I get destructive in some places, but I get constructive both of these happen over larger ok. That is like having two people in the room and maybe you can get them to agree on some things right. Now put 10 people in the room and say let us see how many things we agree on. Agreement is going to come down drastically and put 100 people in the room and especially if they are from IIT. The number of people are going to not agree.

So, the points you agree or not are going to be less and that is kind of what is happening in interference. Constructive interference happens when a certain condition is met. And it gets harder to meet that condition the more beans you put in. So, the places where that happens in less places, so a grating will give you very sharp lines. And you would say this is where constructive interference happens and it doesn't happen anywhere else ok.

So, the grating creates out of that one incident beam, several spots. And in fact, it has a 0th order and too higher orders and that is what we are looking at over here ok. And you can see as the smaller wavelength will give you a smaller spot size. So, the development in technology was the CD started with 780 nanometers and the original discs could 700 MB of data. But the DVD shifted to a slightly lower wavelength and they could do 4.7 gigabytes of data per layer and some DVDs actually had two layers of information ok.

And the Blu-ray discs were so called, because they shifted to blue light right and that was 25 gigabytes. So, you could either put more information or the quality became better. Because you could you did not have to use that much compression on the data ok.

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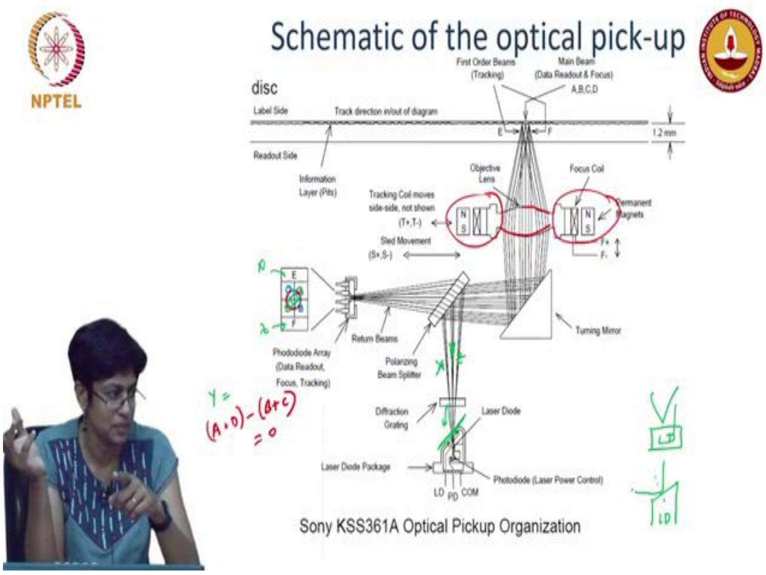

So, this is the schematic of a pickup head from a Sony system. And this is the laser diode over here ok, this is the diffraction grating. So, this is just one beam of light, but when it hits the grating it gets split. So, these three lines here just to show the spread of the light coming out of the laser diode. But when it hits this, it forms three distinct beams because of the grating.

This is a beam splitter in this case they have used a polarizing beam splitter. So, that the light coming out is polarized in one way and it initially will get reflected. So, this beam splitter reflects one polarization that goes to this mirror that turns it around and sends it through this lens that focuses it onto the disc ok.

The interference reflected light comes back and through the process of interference actually or reflection here, there is a polarization change. So, in this system they have not put anything to specifically change polarization. In some systems, they may actually add an element that will rotate the polarization. Here there must be something on the way you can have a polarization change in reflection.

So, they may be exploiting that. So, that the returning light is of a different polarization and therefore, will pass through the beam splitter and not get reflected ok. And then it goes to this photodiode, but it is not one photodiode anymore. It is a set of ray containing 6 actual individual units ok it is altogether, but you could read them separately. Do you remember at least why we needed this 4 this A B C D? We talked about it when we talked about aberrations.

When we talked about how you could use an aberration in a good way? It is so heartening to see how you have all absorbed optical engineering. And I am throwing back what I taught you at me. What aberration did we use in a positive way? What are the aberrations you remember? 5 mono chromatic aberrations. What are they? You do not remember the 5 mono chromatic aberrations? (Refer Time: 28:42).

Student: Spherical, astigmatism.

Spherical, astigmatism.

Student: Coma.

Coma

Student: Distortion.

Distortion.

Student: (Refer Time: 28:50).

Curvature.

Student: Curvature.

Ok right. You remember that we used one of these in some way.

Student: (Refer Time: 28:57)

We said that if you have astigmatism in your system, the spot will no longer focus on a circular spot, but an elliptical spot. So, we use it as feedback, I have drawn this is a nice static system over here. But this disc is spinning and you saw that the variation in height of the pit was 125 nanometres. That means, I must get that right. The focal length cannot shift too much.

So, if it is spinning the beam, what if there is a little jitter or movement in that, how do I make sure that I am getting that focal position correct? So, I am getting back the light reflected correctly by interfering correctly. Well if you look at this the lens is here right. This is the lens, but it is got these control coils over here. So, they used so that the lens can be moved up and down or sideways.

Up and down is to ensure you are always on focus, sideways is to ensure you are always on the right track right. Now, if I have a circular spot here, I may be doing A plus B minus B plus C. If I have a circular spot aligned correctly this signal will be 0. If on the other hand we have an elliptical spot, then this is going to be negative. And if we have an elliptical spot like this it is going to be positive. So, I can tell exactly how the lens should be moved, such that I keep the spot focused on the layer of the data layer of the disc.

In addition, the two this so I have A B C over let us call them something an x y z. y is this signal y is coming back to the centre of your detector, x is falling here and z is falling here. They must be of constant uniform intensity because they should fall only on the region of land, between the spiral of data. If they start getting modulated it means a whole beam has drifted.

So, you are monitoring all these signals and using it as feedback which is going back to this lens, which has it as a lens with magnetic coils right. And that allows you to move the lens accordingly. So, of course, there is a lot of electronics that is happening here right. And the electronics aim is to make this optical signal useful to ensure that you are getting correct data.

Now, you notice this laser diode sorry this yeah, the laser diode over here. Why is the outer facet tilted like this? You know when I usually draw a source, I will say here is a laser diode and here is a light coming out. But this one is drawn like this, why is that?

Student: Brewster angle.

Pardon.

Student: Brewster angle.

Ok so it could be that they will, if it is not Brewster angle. Because Brewster angle means you want reflected light to have a certain polarization right. I do not want any reflected light here. But you are getting the idea why would I want it to be like this? You want light going back into your source. So, although you have used a polarizing beam split turn, ideally no light should come back. There is always a chance that maybe at this point it hits the grating. And there is some reflection.

And when light comes back onto this surface it will go right through. Whereas, when it comes back to this surface, Snell's law tells us a lot of it is going to go off at this angle and not enter. Some light may transmit, but there is less light going in compared to what is coming out ok. So, these are simple things, but now that you are familiar with optics, you should be able to look at a system like this and understand why you have even, why the window of a device may be tilted or not flat ok.

You may have a thin film coating on it also to prevent assuming there are so many things that could be if he does find the pickup, you will see that the lens of the pickup has a coloured tinge. Because it has an anti-reflection coating at the wavelength of use it will have a colour of a different wavelength right ok.

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I will not go this is what the lens. So, the lens is here and this is the coil. So, you know you send a current and it will magnetize and so, you send a current based on the feedback does the lens have to move laterally left or right does it have to move up does it have to move down right.

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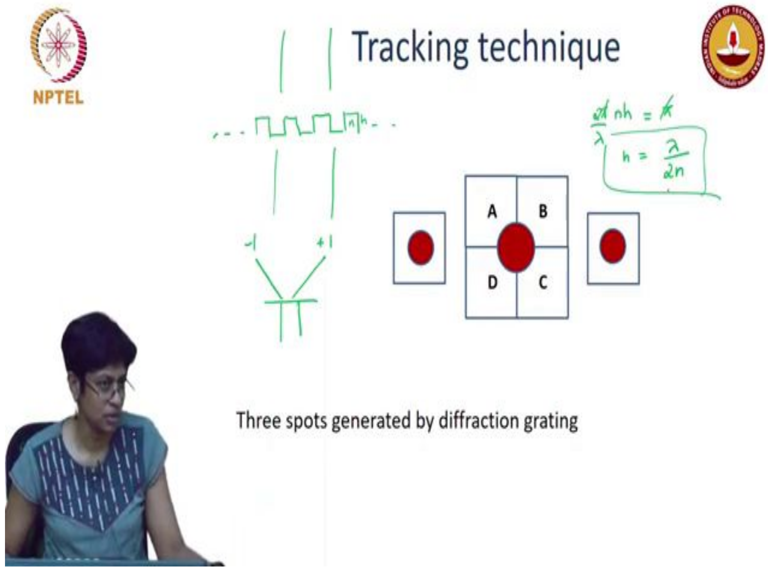

So, that is our tracking technique. These are the three spots generated by the grating. I can design a grating. So, I do not have three spots. So, a grating as I had said it is a structure like this, with the periodic variation in phase right. It could be larger. Light is incident and travels through. But each of these sections now some parts have gone through this height h and the rest has gone through air and this height h has a refractive index n.

So, I can choose such that I have 0 light in the first in the same direction as the incident. So, n h is the path length. That means, a phase seen by those parts of the beam is this and I want this to be destructive. I do not want light to carry through ok. That means, if I pick the height to be lambda by 2 n is that right? Yeah lambda by 2 n,then I will yeah you can keep it there. Then you can destroy the 0th order. But the light has to go somewhere. So, what will happen in the grating is if you illuminate such a grating, you will get light in a first order and light, so you will have a minus 1 order and a plus 1 order. You will not have a 0th order. How do you achieve that by choosing the height correctly. In the case of the CD player, you want a large 0th order, because that is the beam that falls and reflects off and carries the information.

So, you would not have a grating with this satisfying this condition, it will not satisfy this condition. So, that you have light in the 0th order, but there is some light going into the higher orders as well and that is what you use for the tracking ok.

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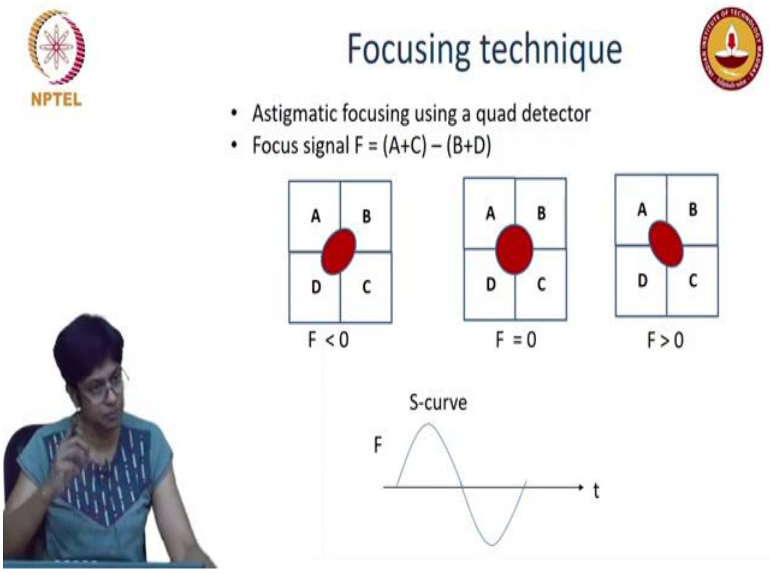

So, as the beam if you are going out of focus as you go out of focus the signal from this curve will look like this. And so, you can tell not only how much you are out of focus, but in which direction you are out of focus and thereby send the correct signal to the lens and correct for it ok, Yeah.

So, I will stop with that for this application. We have time, yeah we have time to look briefly at the other application. You can just pass that pick up head around. So, you should be able to see the lens and it will easily shake because its held by its coil right. Yes?

Student: If we have u v light source.

If you have?

Student: If we have U V light source (Refer Time: 37:53)

U V light source yeah.

Student: I mean (Refer Time: 37:56) if we can store much more (Refer Time: 37:58).

You can, but once you go into u v you cannot use all the same glasses and so on. You need different glasses for that. So, up to blue is you can use these glasses then costs will start going up if you change to UV. You cannot use the same glasses, all glass absorbs UV. That I do not know this, do you have photochromatic glasses?

Student: (Refer Time: 38:20)

Have you heard of photochromic glasses? no.

Student: (Refer Time: 38:31)

Yeah. So, you photochromatic glasses are you can get your when you get your glasses made, you can it is much more expensive. But you can ask for photochromatic glasses; that means, when you go into strong sunlight the glass will darken. Well its strong sunlight, but it is actually strong UV. So, you could go if you go up into the mountains and its really cloudy, the dark glasses will change and they will darken.

Because there is some extra chemical put into the glass which changes, it is nature. So, when it absorbs UV, it becomes not non transmissive ok. But all glass absorbs u v. So, you cannot use them. Then you have to use special glasses and become quite expensive. But in fact, when in the semiconductor industry they use light to write patterns and you know we put more and more chips on to a device right, on to a wafer.

They use u v there because that is a very expensive system, it's one system and they do it. But for these commercial systems you want to mass produce then you want to use you want to bring down the cost as much as possible. UV is used in lithographic systems because smaller wavelength means you can write very small features.

Student: When (Refer Time: 40:04) laser (Refer Time: 40:06) once the laser lens is focused and that is it damaging the (Refer Time: 40:11).

So, his question is does the laser damage. We talked about we have switched from the scratching l p model to this; you are not sending that much power to damage them. The power is very low. It is its not as far as I know it is probably even eye safe. But it is definitely it is not high power. You get CDs you can write on right. So, in here I am telling you how you read, but you can also write on CDs right?.

So, there the disc has a material which is sensitive to light and then you the writer will have higher power because it has to cause a chemical change a permanent chemical, when you even have rewritable CDs, but it has to cause a change there the power would be higher. But the typical CD writer the power is low and does not damage.

Student: This is not CD writer mam?

This is a CD reader; we are only reading the data. I cannot use the same thing to write. Because I will need a different wavelength and you get special discs to write on.

Student: (Refer Time: 41:31) this is directly.

You are reading now? You are the information is already on the disc and its reflecting off and so, in the writer you are not in the disc I showed you, you had these patterns right.

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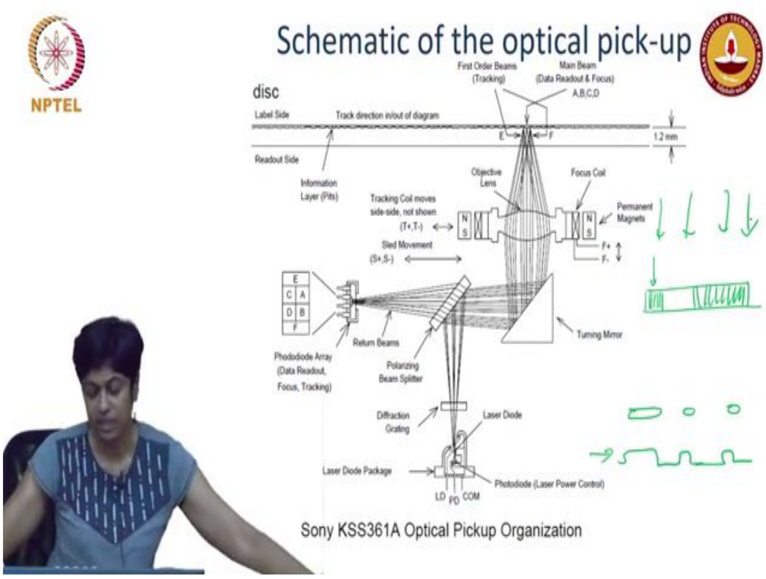

And if you look at them it meant it was something like this right. So, there are height variations in a disc you are reading, but the writing disk is slightly different there you are crossing phase changes you are not removing material. There in the writable disc you would have a disc like this and then say you expose it here. That there is some change that happens and the refractive index changes here. And then you do not expose it in the next region and then you expose it here and a refractive index changes over here.

So, now, I have a varying phase change. That is the same thing I have here, this is nothing but a varying phase change. And if you have a rewritable disc you would flush this with some light which unread the change everywhere and then again I could write on it. So, you may actually have different heads for reading for writing, because you need different wavelengths.

Student: So, mam we see need not both two different set of idea as well as (Refer Time: 43:00)

Yes, you may get it as a combined unit, but it's two different sources of light. They may have combined it in some way that there is a mirror that moves one into place and the other. But it is two different sources of light yeah, and with two different powers also because, you need more power for writing than for reading ok.

We really do not have much time, but I want to just introduce the other topic to you because a lot of these applications were finally, relating to interference.

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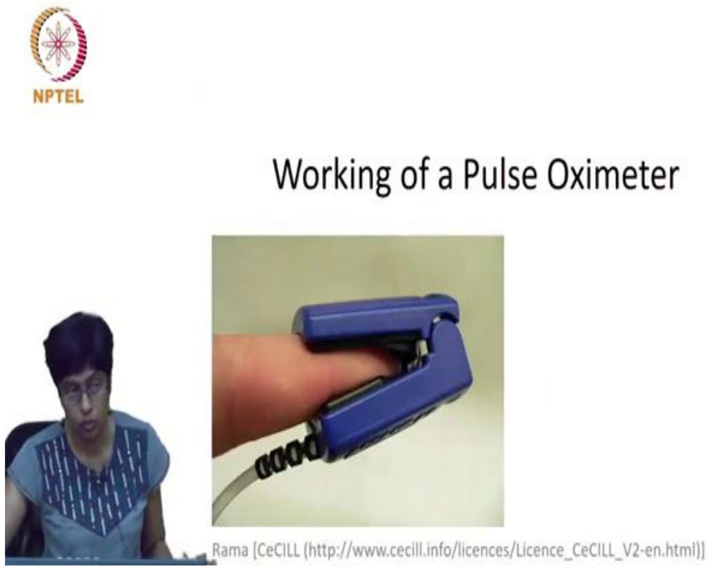

Although the CD player used your knowledge of aberrations and polarization and so, it really, I like that system for this class because it kind of covers everything that you have done. But I just wanted to talk about this. We have a few minutes and I will. So, I am sure you have all seen this right. I hope none of you have had to use it, but you might have seen either somebody in a movie in a hospital or if you visited someone in hospital.

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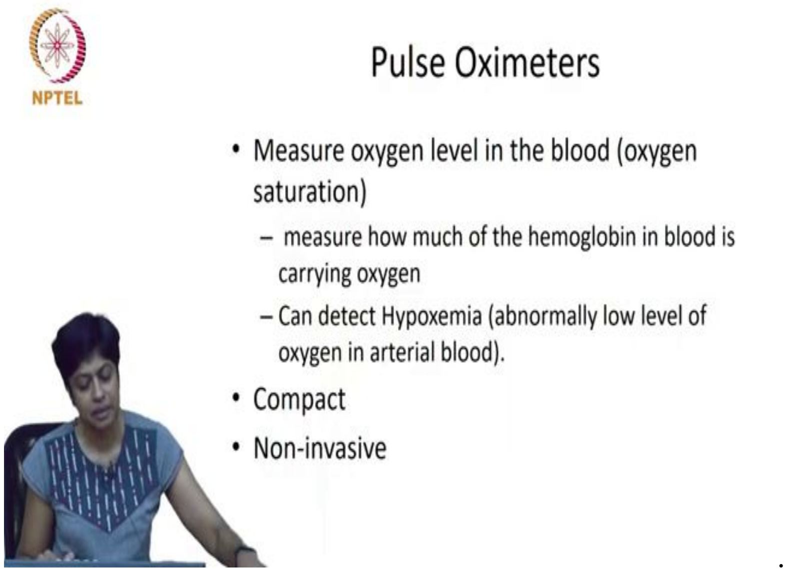

It is called a pulse oximeter. It is measuring the oxygen level in your blood, it is known also as oxygen saturation and basically haemoglobin is what carries oxygen in your blood, and it is measuring therefore, how much haemoglobin has oxygen in it. You can have haemoglobin with oxygen and without oxygen ok.

This is a very important measurement that generally tells you know the status of a patient. So, it does not matter what your illness is, you need to know that the patient's respiration is happening properly, and there is enough oxygen and. So, this is something you want to monitor continuously and if you are monitoring continuously it means that when you the device is on the patient it must be as non-invasive and troublesome to the patient as possible, and it can clearly must be as small as possible ok.

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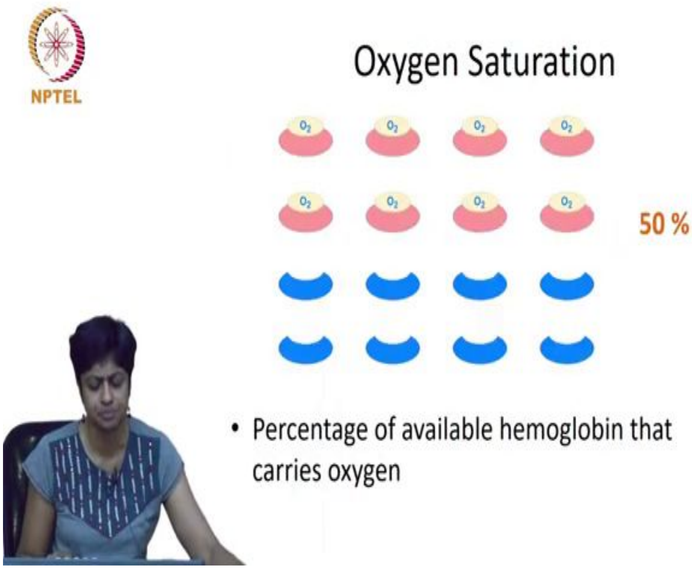

So, what it means to measure is how much haemoglobin has oxygen compared to how much does not, and it is like the percentage which we call the oxygen saturation which is of interest.

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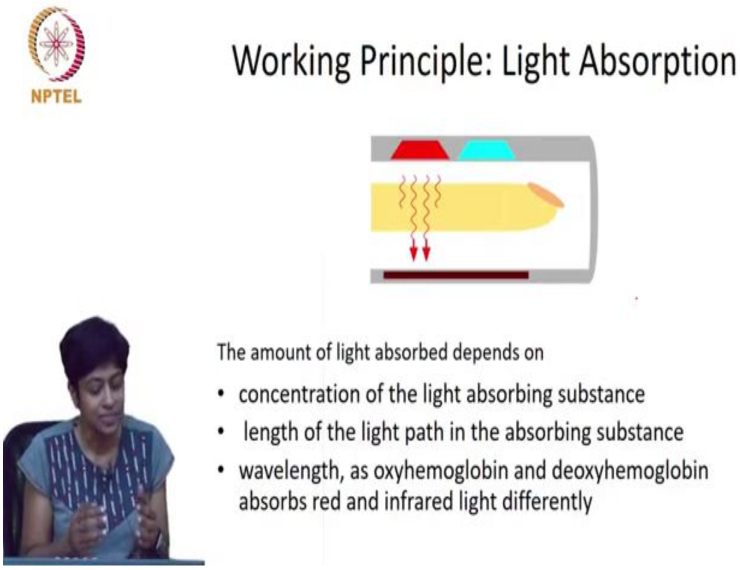

So, it is not interference in its just using light absorption. So, the outer case of this device that you clip on to the finger, is shown here and there are two sources of light and you can see that light will travel through the finger and reach the detector on the other side. Now somehow you are going to use absorption to tell you how much oxygen is there in the or how much oxygenated haemoglobin there is. The absorption depends on various things you can be I mean you should imagine straight off. That if I am just measuring the light that is coming to the detector if you take the people sitting in this room we all have different skin colour right.

So, some people will have a lot more absorption just because of the colour of the skin. Some people have very slim fingers, some people are very fat fingers. So, it could be how much length it has to go through that may have nothing to do with; we may both have the same percentage of oxygen. But somebody may have fatter fingers, but somebody may have fatter fingers than someone else.

So, you cannot be saying they have less oxygen because it so happened their finger was fatter. So, you may have to take this into account, but basically you are using absorption ok. So, we know that concentration of the light absorbing substance, the length of the path and how we use it is that it also depends on the wavelength.

So, that is a trick we are going to use that oxygenated blood and deoxygenated blood absorb differently at different wavelengths and we can use that to adjust or correct for the fact that all of us have different thicknesses of finger and different colours of skin and so on.

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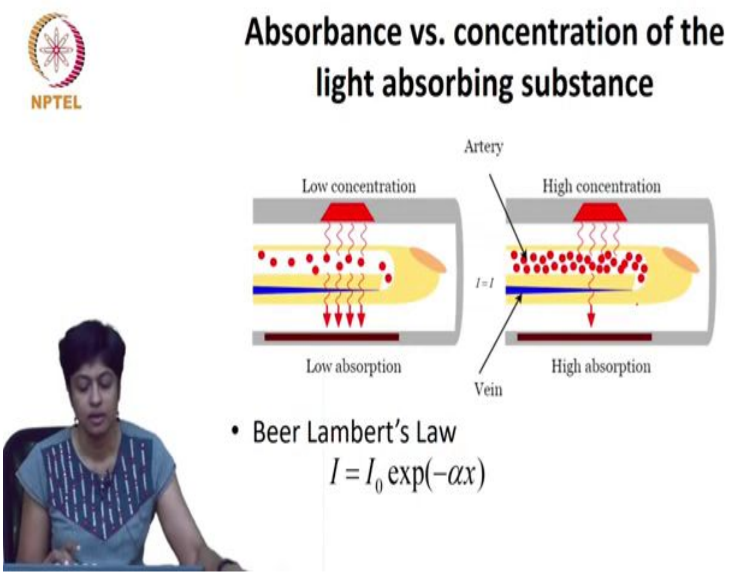

So, the basic idea here is what is called Beer Lambert's Law. You might have encountered this elsewhere. And you are just saying that this is the absorption coefficient and that depends on how much oxygen what is your oxygen saturation and x is the length of the path travelled. So, this is the basic that we are using. Ok.

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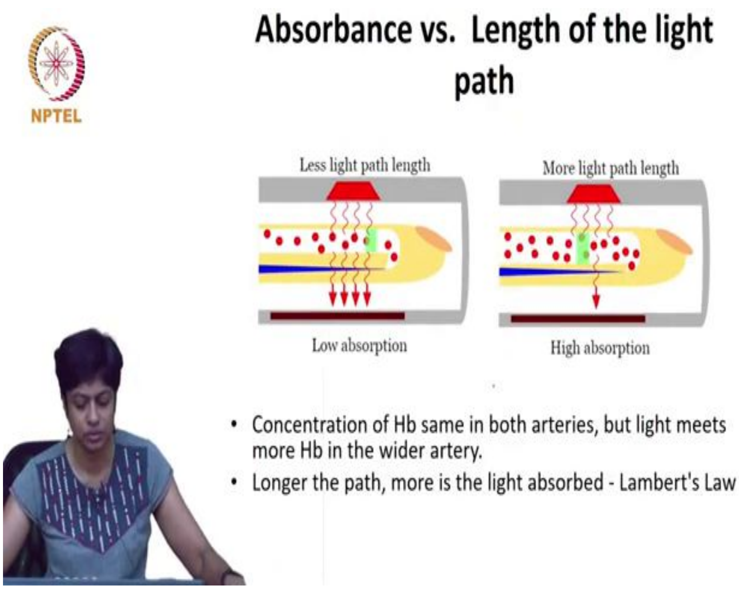

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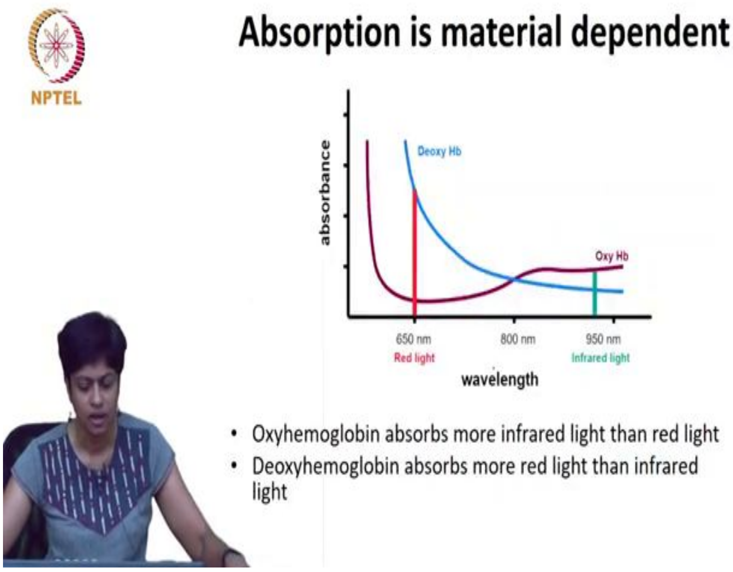

So, what we are saying is that if you look at the deoxygenated blood, its absorption is much higher in the red, than it is in the infrared and if you look at the oxygenated, it is got a higher absorption in the infrared than in the red. And you use this ratio of the absorption at these two wavelengths and you can calibrate your system therefore to say, is there more deoxygenated or less in other words you can actually get the saturation ok.

I will not go into the details, but I wanted to introduce the system to you. Just to say that optical systems come in all kinds ok. They can be as complicated as the CD, DVD player where optics plays a small role and you are using some geometric optics, you are using some interference. It can be as simple as sending a wavelength through something and measuring the output; you have to take into account all the factors that would change.

And in fact, you there are databases because these numbers would vary for Indians compared to Europeans compared to Eskimos right. So, you need another database for the general group of people that you would be using the system with right.

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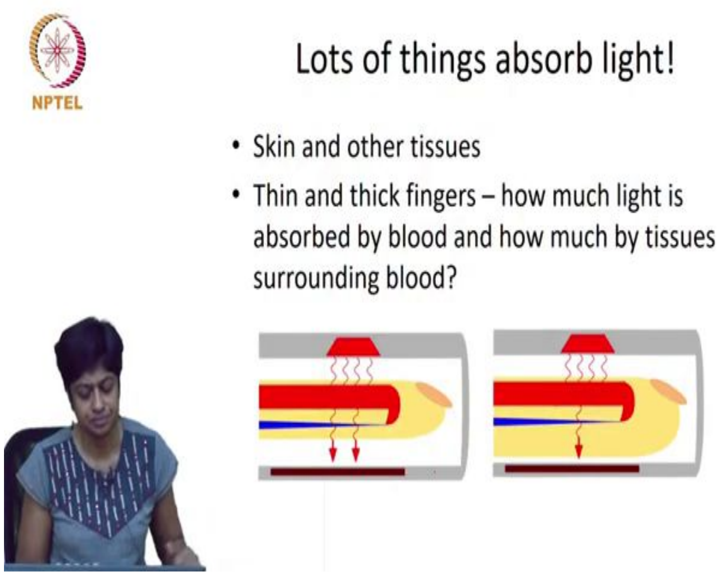

Let me not go through all of this ok.

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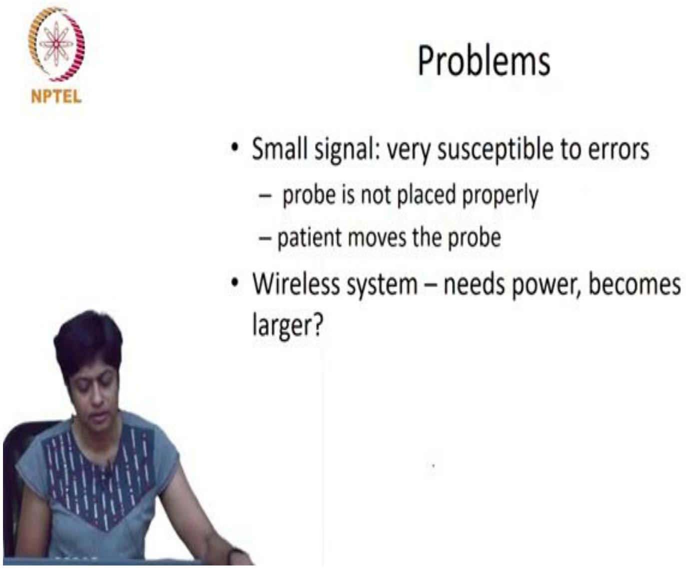

So, what I wanted to end with is that, if you think about it, there are a lot of issues here. It is a very simple system that is very simple. But there can also be a lot of problems and again optics is one part of it, but you also need to worry about the signal processing of it, it is a very small signal that you are measuring.

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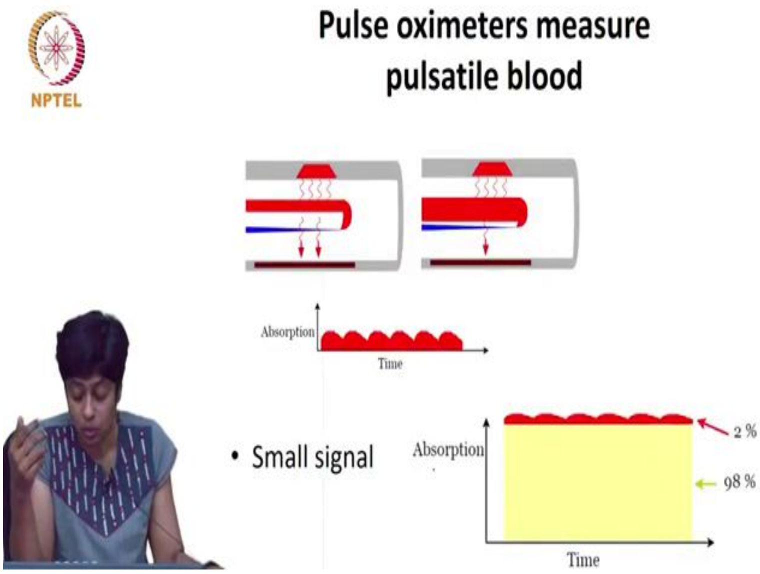

So, in addition what they do is, they look at that and the signal will vary depending on whether you are in the pulse yet. Is it pulsing blood towards that part of the body or away from that part of the body? So, you will actually see these variations here which is why it is called a pulse oximeter, because you can also extract pulse information.

But that signal is a very small signal over a very large background. So, you need a lot of fancy signal processing to pick out this pulse information correctly right. So, there are a lot of and when you move a patient moves around its moving around and the signal should not change because a person moved it has to stay constant. So, there are a lot of issues that you can think have to be approached.

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Why I wanted to bring it to this class is right now, every pulse oximeter in India is imported as are most medical technology right now. So, that is a place where you know you people should or could step in because every hospital you know almost every patient now has a pulse oximeter. So, maybe you can really earn some money over there ok. So, I will end with that you have a lab in the afternoon and next week's presentation but you need to submit reports. Today I think it was the last day. So, please do that ok. Any questions? No?

Student: There are two detectors now.

Yes there are two detectors for I am sorry, I rushed through that I mean; you it could, here it is just shown as one detector it could be that you are looking these are little bit really probably be two detectors because the one is in the red and one is in the infra-red right.

So, you are looking at the absorption of both and you have to do a lot of calibration. I did not want to spend time on that, but you have to do a lot of calibration. Because you have to stick to what is the absorption of the red light, what is the absorption of the infra-red. And because you are making these two measurements, they are both seeing the same thickness of finger and they are both affected by the extra lightness of your skin or the darkness of your skin.

So, those factors are sort of getting cancelled out by looking at both of those rights. And you take the ratio of that. But they, but they do the calibration involves patients who are given less and less oxygen right under controlled conditions right.

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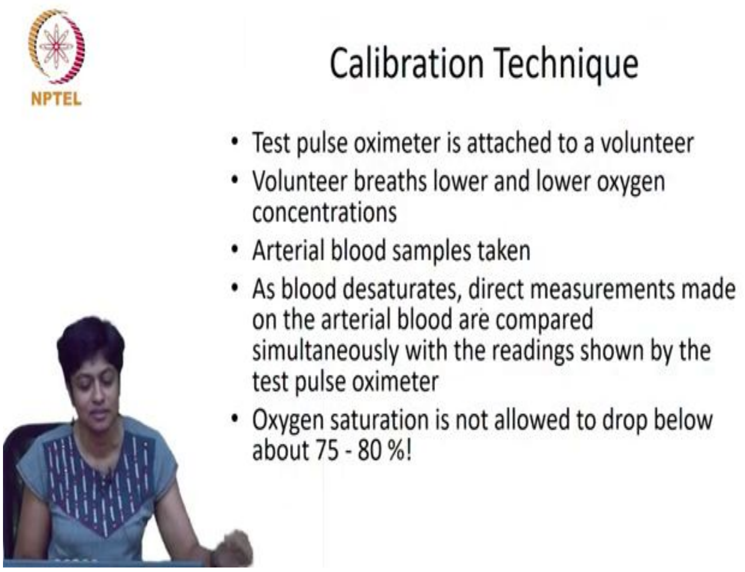

So, you actually will physically, they will take blood samples and measure to calibrate the system initially the first time. They will actually reduce oxygen levels and then take blood samples and measure and say the actual measurement says so much. So, they will do the calibration and ensure the machine is showing that much. I am sure that no people were killed in the process of calibration, I hope.