Design of Mechatronic Systems
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Lecture 07
CD ROM Part - III

We will continue little bit discussion about our CD ROM drive, there are a lot of fundamentals that we saw last time with respect to it, we will just kind of brush up some of the things again and proceed then for some kind of conclusions that we can draw from this exercise. So, let us go ahead and have a look at some of the.

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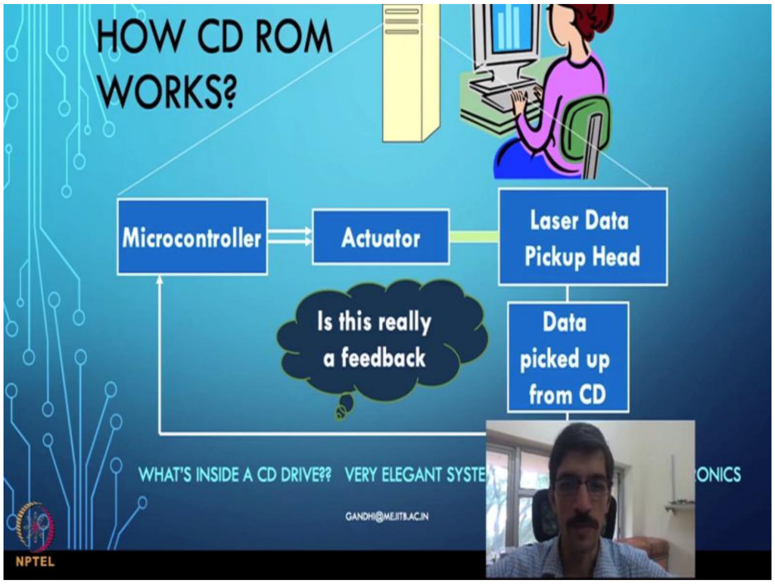

So, now, what we saw I will quickly go through here.

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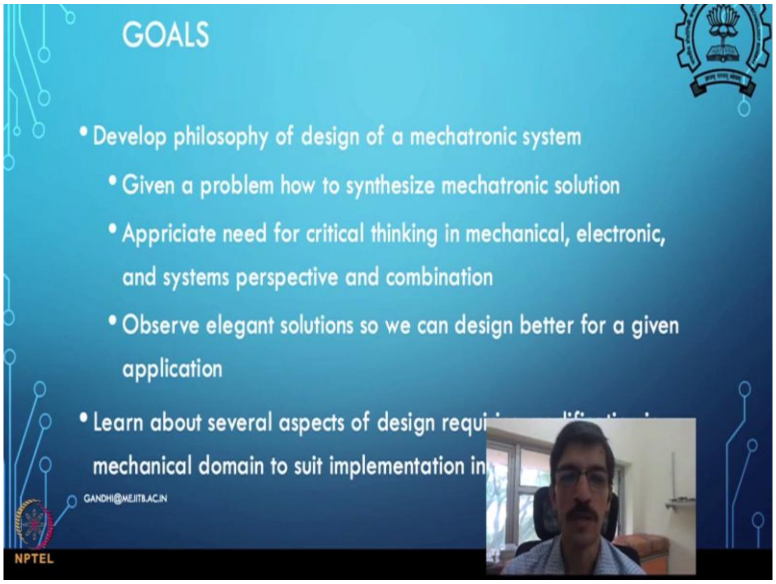

So, the goals that we set was to kind of develop some kind of a philosophy for this design of mechatronic systems and appreciate some of the things that solutions that are already existing in the existing devices.

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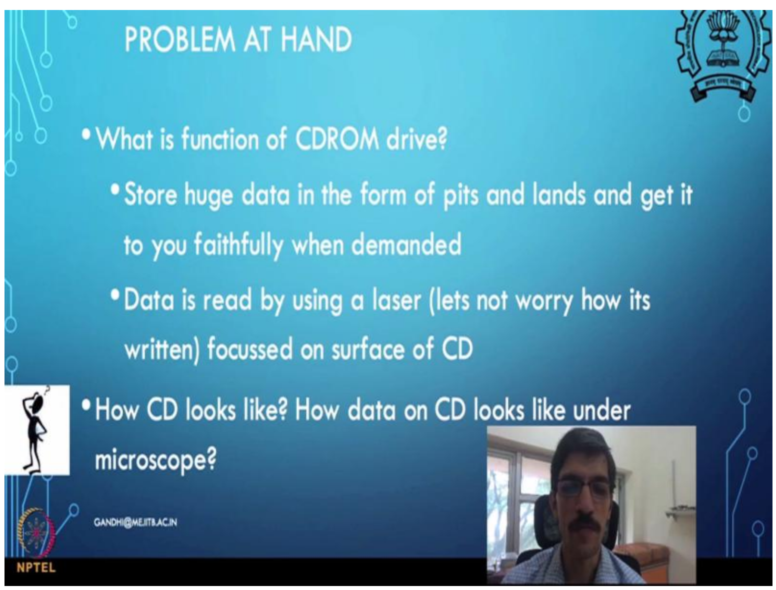

So, let us see what we did we did a lot of things for CD ROM drive.

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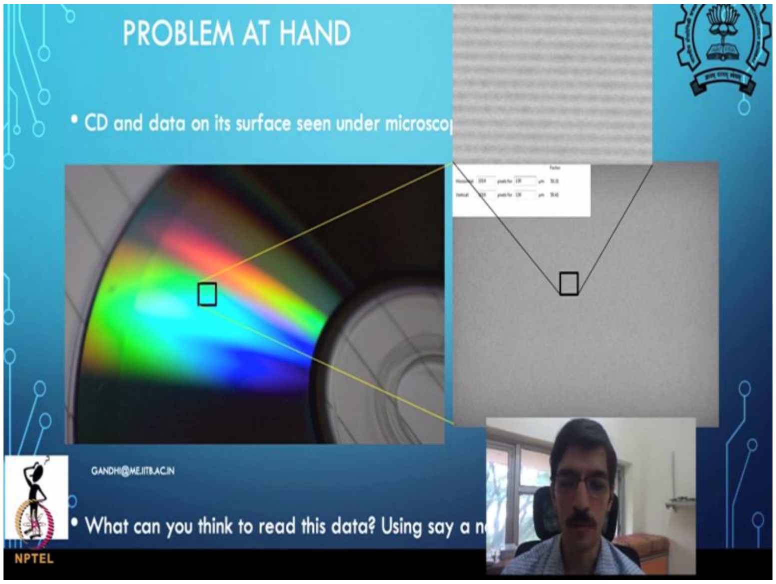

And you can see we started off with this CD surface, and like we thought about like a different kind of ideas that can come up for like looking at this data and like registering it digitally into the computer.

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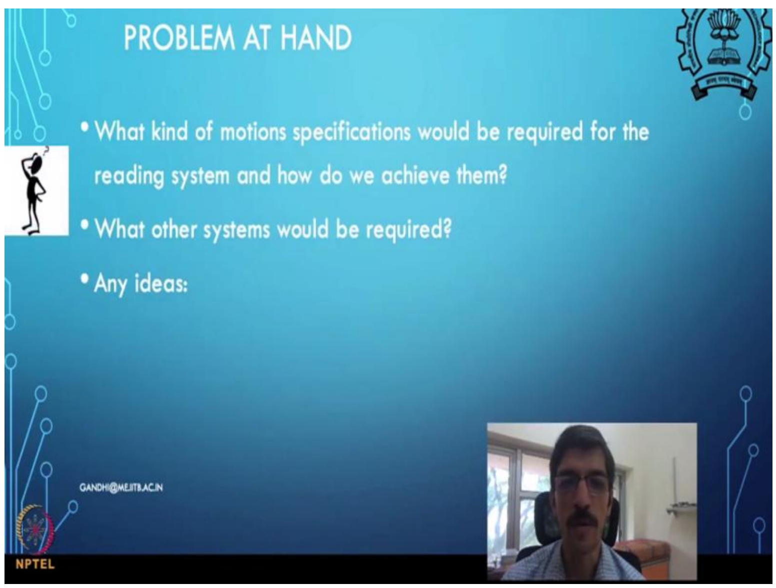

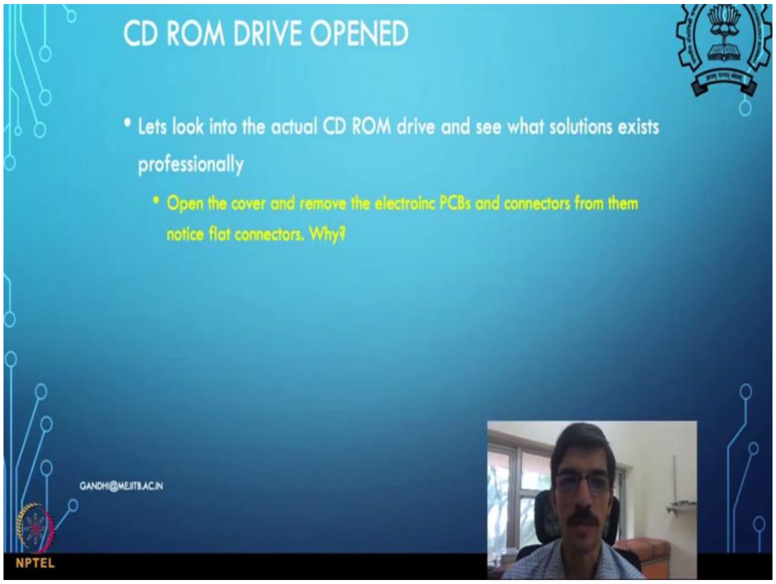
CD ROM DRIVE OPENED
• Lets look into the actual CD ROM drive and see what solutions exists professionally
• Open the cover and remove the electroinc PCBs and connectors from them notice flat connectors. Why?
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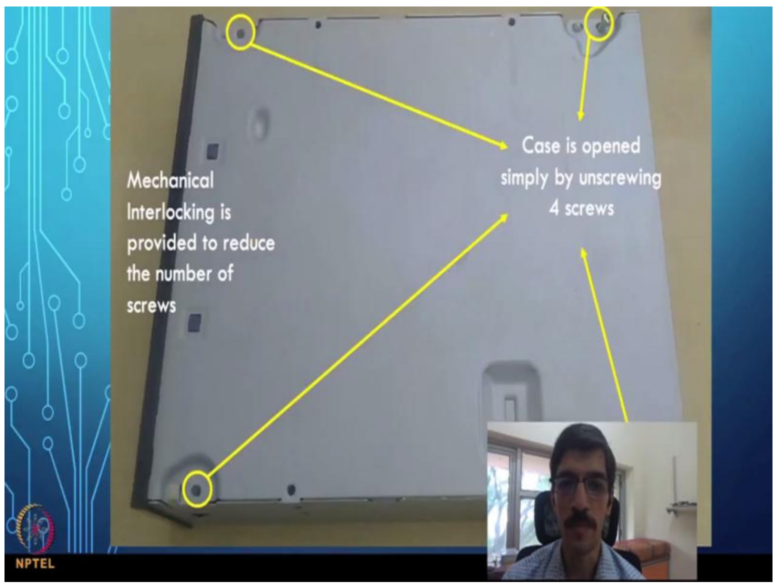
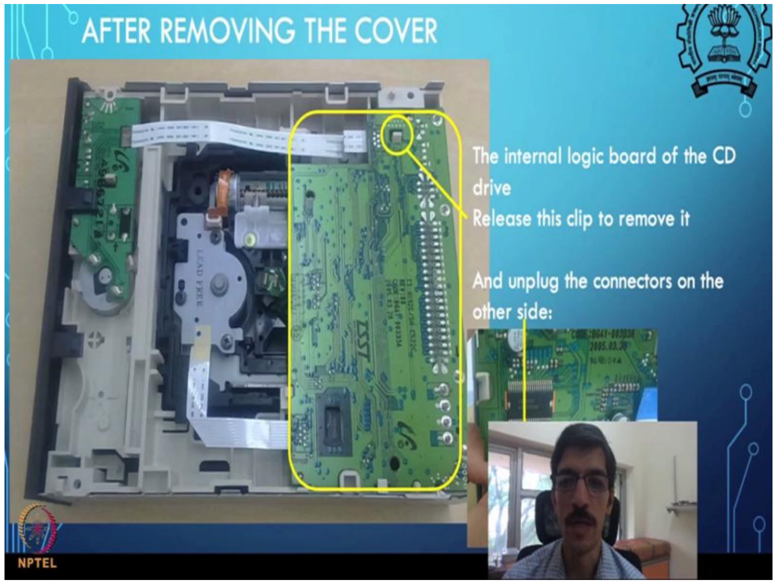
NPTEL


Mechanical Interlocking is provided to reduce the number of screws
Case is opened simply by unscrewing 4 screws
NPTEL


AFTER REMOVING THE COVER
The internal logic board of the CD drive
Release this clip to remove it
And unplug the connectors on the other side:
NPTEL


The tray can be opened and is removed by releasing a clip that otherwise prevents the tray from being fully ejected
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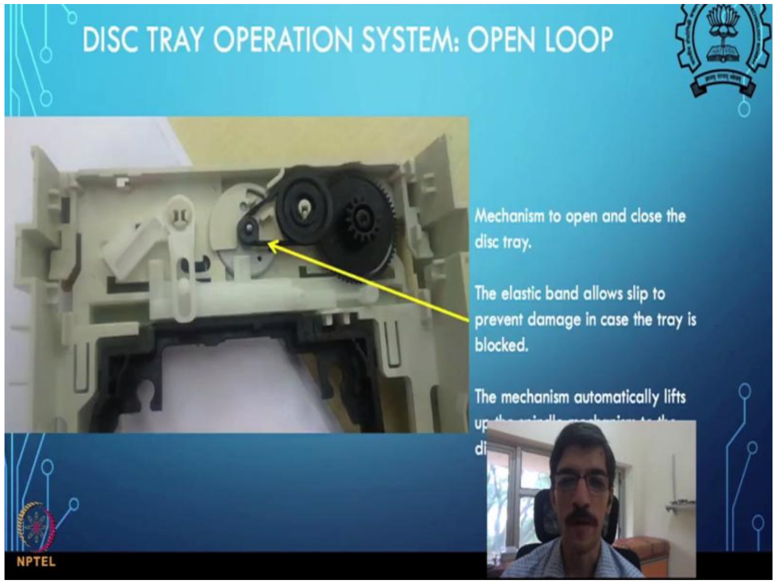
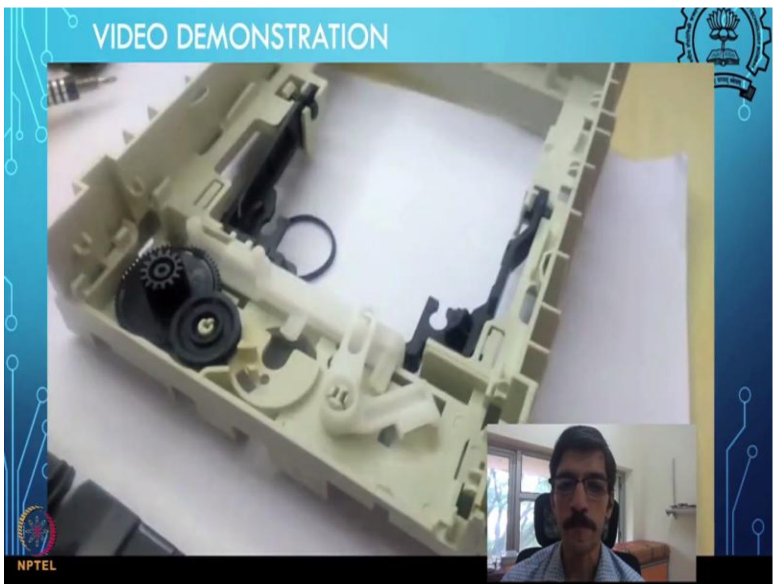

DISC TRAY OPERATION SYSTEM: OPEN LOOP
Mechanism to open and close the disc tray.
The elastic band allows slip to prevent damage in case the tray is blocked.
The mechanism automatically lifts
NPTEL


VIDEO DEMONSTRATION
NPTEL

CD ROM DRIVE OPENED

- Lets look into the actual CD ROM drive and see what solutions exists professionally
  - Open the cover and remove the electroinc PCBs and connectors from them notice flat connectors. Why?
  - Access the place where CD is kept and observe
  - See the optical pick up assembly that runs on the surface of CD and observe

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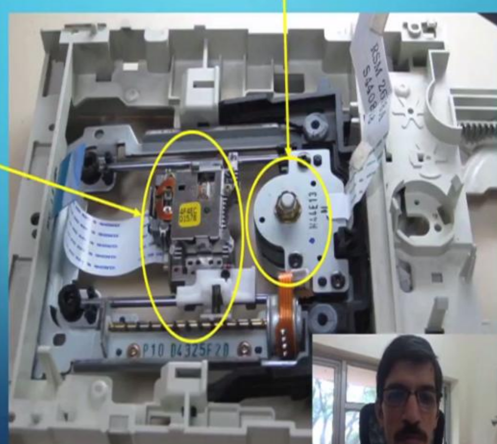
CDROM/WRITER DRIVE OPENED UP



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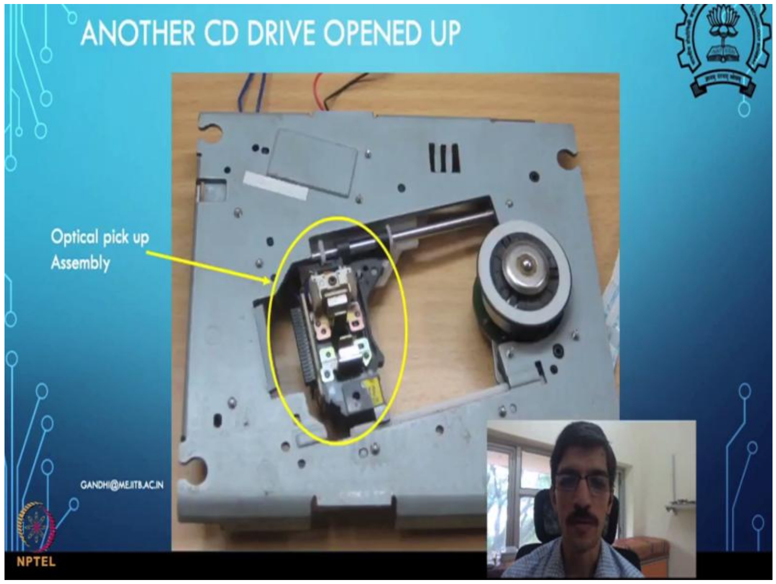
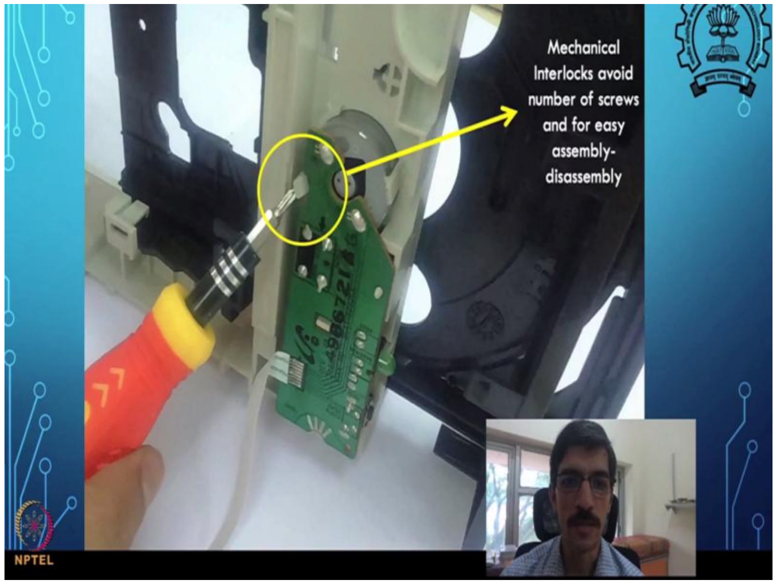
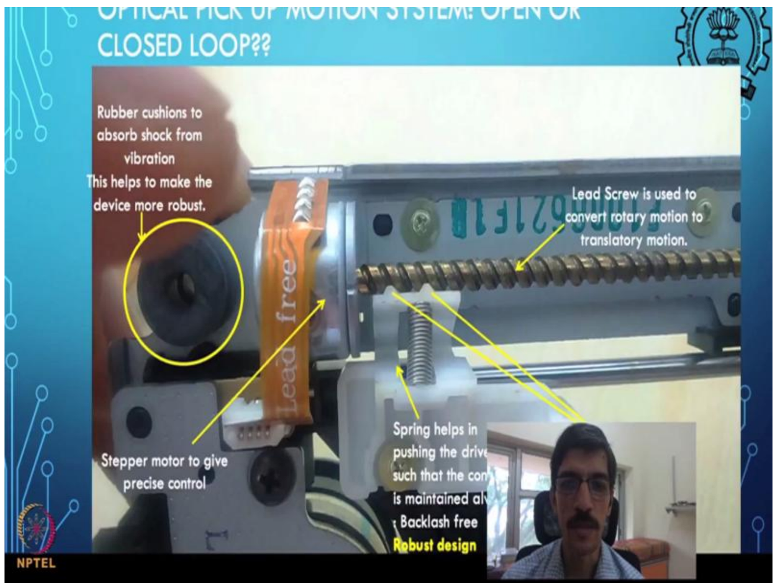


CD ROM DRIVE OPENED

- Observations:
  - what different components you find in the drive? what are they for?
  - What are the components responsible for achieving fine motion of the laser? And rotation of CD
  - Why we need these components for achieving fine positioning?
- Lets start addressing these questions from mechanical /mechatronics system perspective one by one.


Mechanical
Interlocks avoid
number of screws
and for easy
assembly-
disassembly
NPTEL


CLOSED LOOP??
Rubber cushions to
absorb shock from
vibration
This helps to make the
device more robust.
Lead Screw is used to
convert rotary motion to
translatory motion.
Stepper motor to give
precise control
Spring helps in
Backlash free
Robust design
NPTEL

And then like we came across these multiple systems. So, CD ejecting system or the Gross positioning system, Fine positioning systems and things like that. So, so, this summary of these systems is something up here.

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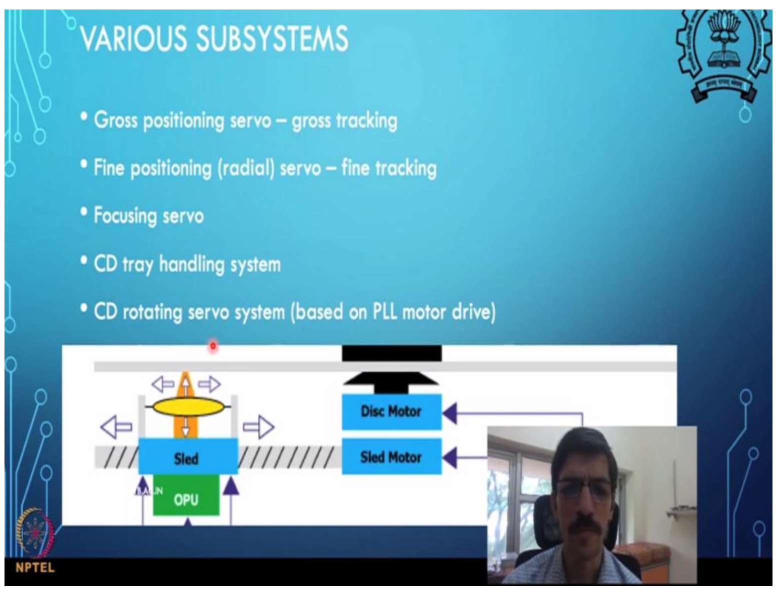

So, these are the main systems that we saw that the Gross positioning system, then Fine positioning systems and then Focusing system and then CD tray handling system and CD rotating servo system. Now, this CD handling and tray handling systems, servo system are something which we are we have not like we have just seen the CD tray handling system but servo system or CD rotating servo is just a motor which is kind of like you get a drive at a speed which is controlled by the position of the device.

So, we will talk about that a little bit. Maybe, but it is not very it is just maintaining the speed to certain extent for the CD disc. And maybe I can tell you right now only that this CD systems are constant linear velocity systems, which means like linear velocity at a point on the surface of the CD which is under the CD head, under this laser, that velocity will be constant. So, as we know that, if I rotate a **CD at constant** angular velocity, then the linear velocity at multiple points on the surface of the CD will change its ωr, you all are you all know that.

So, to maintain this velocity constant here, we want to let linear velocity to be constant at a surface here, I will need to vary the velocity of angular rotation of the CD in some kind of a way. And that can be maintained by using something called Phase Locked Loop kind of drive for the, for **this motor.** So this is a BLDC kind of motor, brushless DC motor, and it is controlled by, speed is controlled by using this phase locked loop kind of a drive and its drive and other systems we will see it later.

It is like a three phase kind of motor, three terminals are typically output for a BLDC motor, and we control these phases to kind of like maintain some speed of drive. So that is a disc or servo system for the CD, which is rotating and we will have a chance to see CD motors some time. Or maybe I can flash you some picture of it. So, if you see this maybe if I go here.

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You can see this is opened up a CD servo motor and its cover you can see up here. So, this is a cover of the, of the motor and this is a motor opened. So, you can see that right this is a motor.

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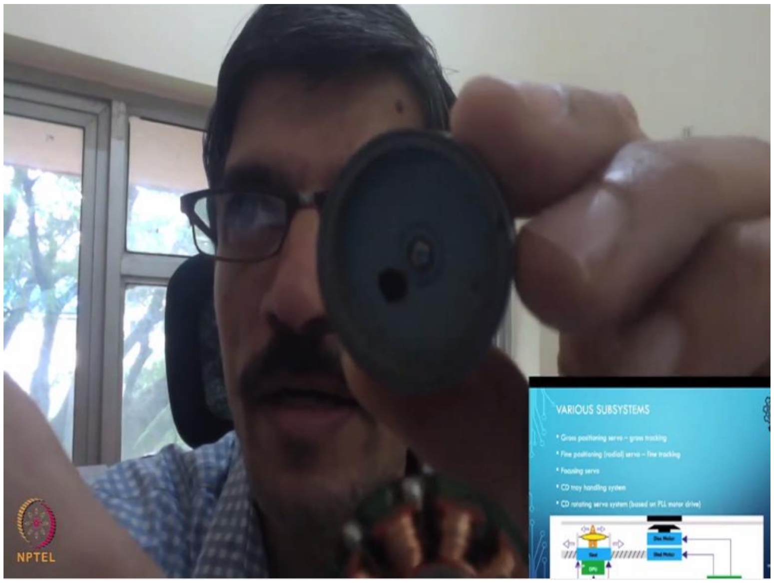

And this is like a cover of a motor. This cover will have a magnet inside and on the top there is some kind of a disc here inside that there are balls if you just move this around you will hear some sound of balls there. Think about why those balls are present up there.

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And if you see this notice this motor on this motor at one point you will find that there are this maybe I can rotate it and show you here at this point there are if you see is see there are this small little sensor that you see up here where my finger is those are Hall Effect sensors to sense the field one this is one Hall Effect sensors, another one is up here. So, those are Hall Effect sensors. So, that is a mechanism for CD drive this drive basically.

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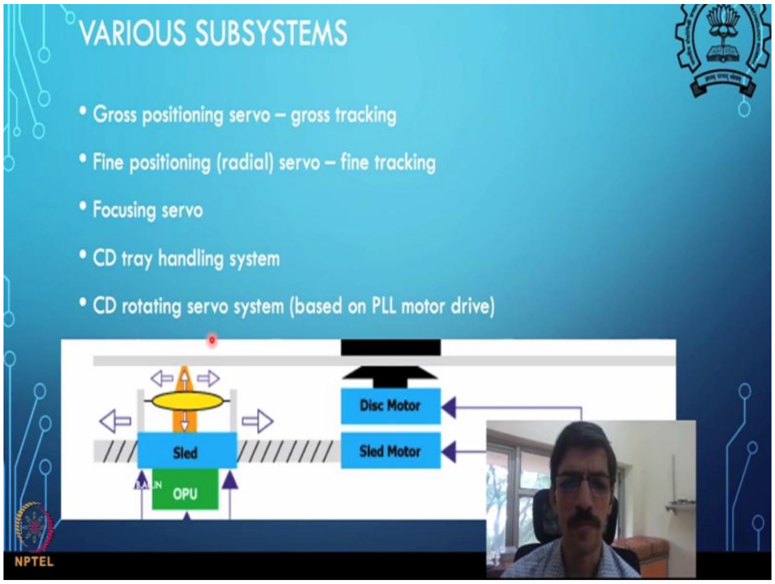

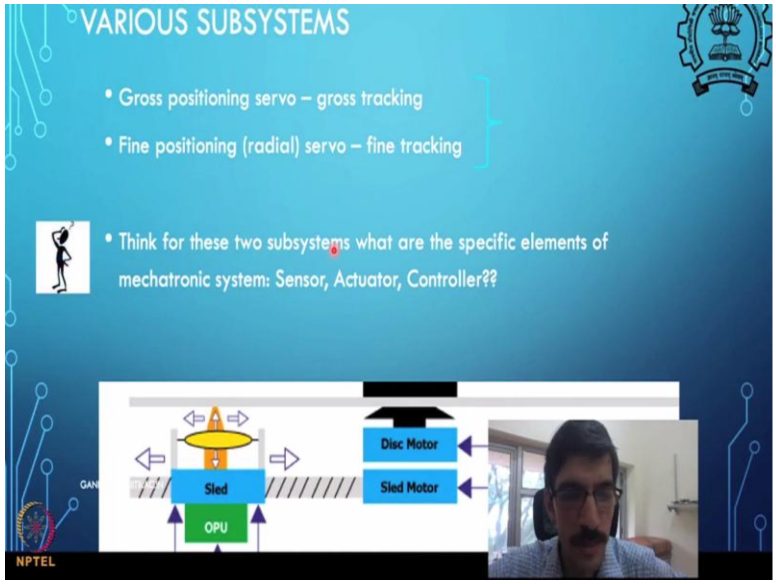
VARIOUS SUBSYSTEMS
Gross positioning servo – gross tracking
Fine positioning (radial) servo – fine tracking
Think for these two subsystems what are the specific elements of mechatronic system: Sensor, Actuator, Controller??
Disc Motor
Sled Motor
Sled
OPU
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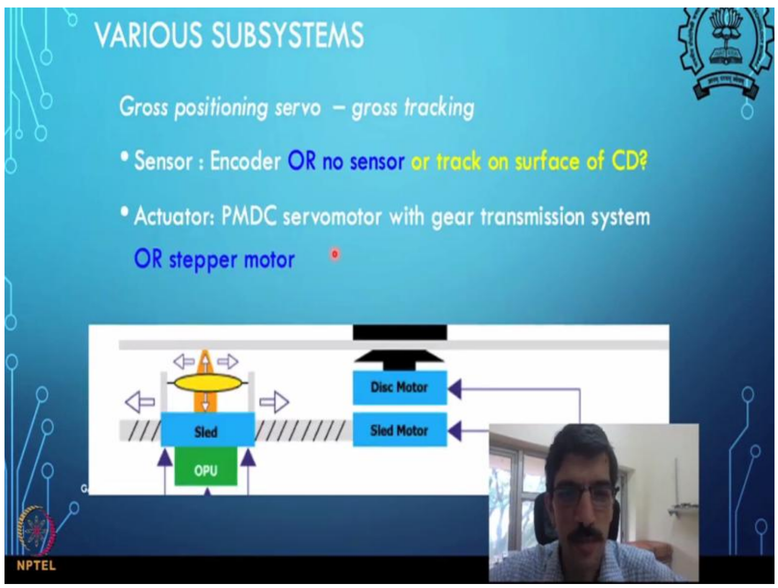
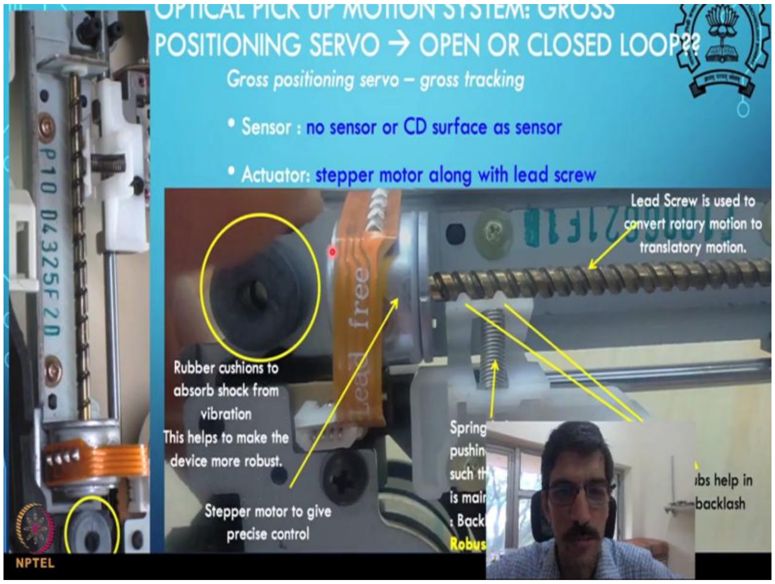

VARIOUS SUBSYSTEMS
Gross positioning servo – gross tracking
Sensor : Encoder OR no sensor or track on surface of CD?
Actuator: PMDC servomotor with gear transmission system OR stepper motor
Disc Motor
Sled Motor
Sled
OPU
NPTEL



Then what we saw we saw then various subsystems and list components and things like that. So, you remember all these different, different things that we saw.

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And then this is a mechanism some kind of a way to kind of prevent a backlash in the system.

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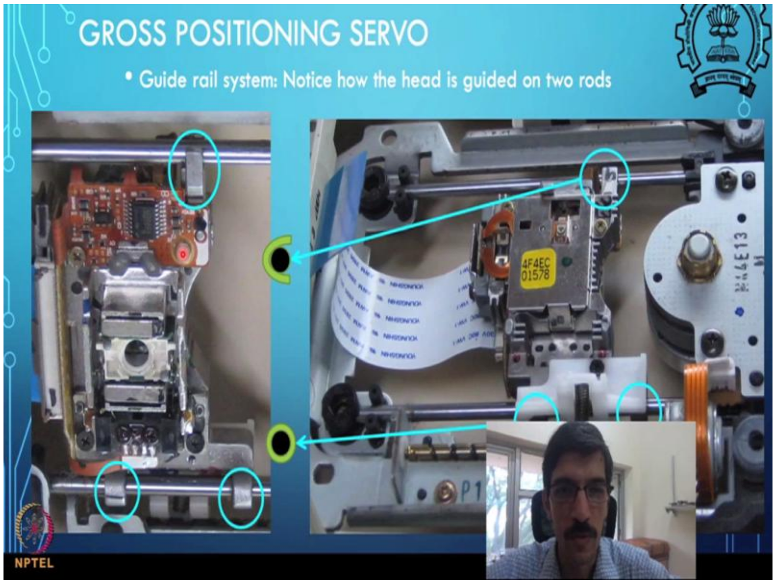

And a stepper motor that is used for driving this and this is another kind of a fundamental we saw that you need these two supports to guide on one side and only one single support can be there on the other side is okay if you start putting both the support, supports on the other side also then if the alignment of these two rods is not exactly parallel, then you will see that the drive will jam in no time actually. So, if you start driving at some position you will find that system gets jam. So, that is what we do not want to have.

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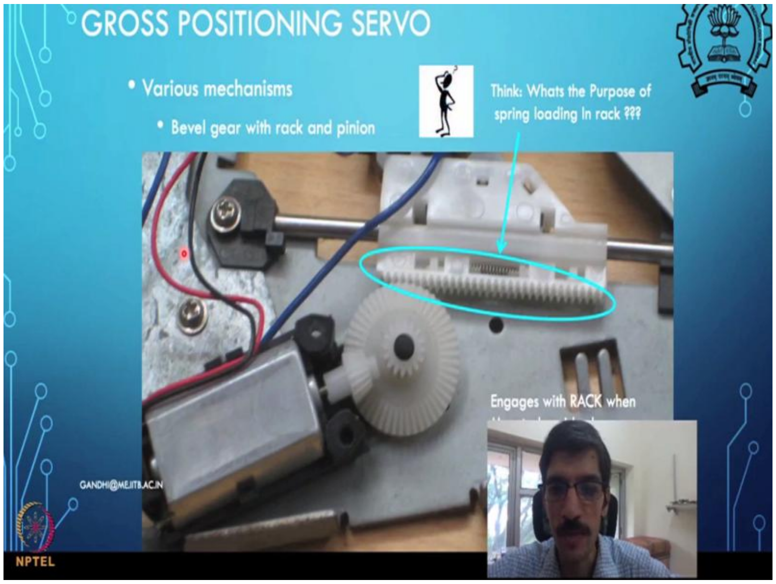

Then this is another way of preventing backlash.

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By using like a spring loaded two racks with you give kind of a pre compression in the spring so that the two racks are getting pushed away from each other and then you engage them into the pinion teeth and then like this mechanism will start working that the one rack is pushing on the pinion tooth on one side and the other rack is pushing on pinion tooth on the other side of that, other side of the gap.

So, that way like you will find this arrangement works for preventing the backlash. So, you move now pinion in either direction, you have a contact that is happening with the rack on one side with the lower rack and on the other side with the upper rack say for example.

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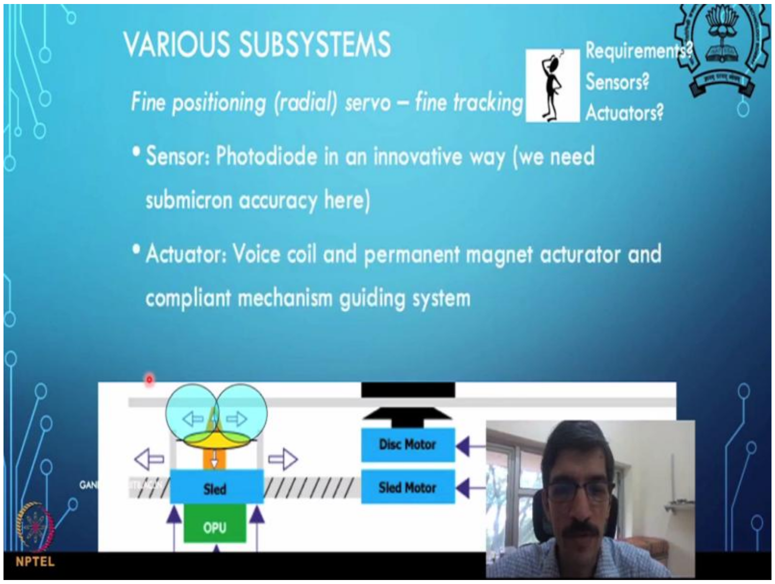

So, now, in Fine positioning, we again saw that, for fine positioning.

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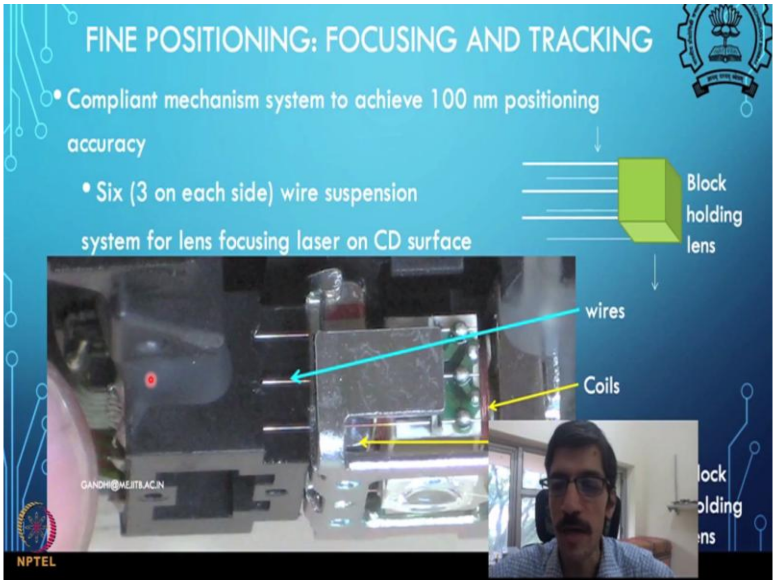


FINE POSITIONING: FOCUSING AND TRACKING: COMPLIANT MECHANISM
• Lens holding block in non deflected position: notice wires!!
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FINE POSITIONING: FOCUSING AND TRACKING: COMPLIANT MECHANISM
• Lens holding block in deflected position: notice wires!!
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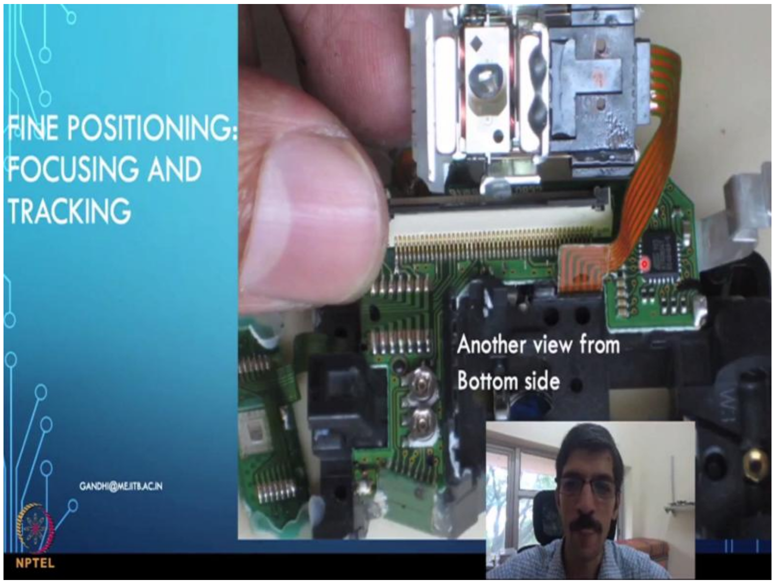

We need to have a compliant kind of a mechanism, which guides the system to go in to finer motion and why this kind of a compliant beams are needed that beams that you see here, why they are needed here. Why do not, we why do not we provided this guide by same way as we have provided with some kind of a rod or some kind of a new support to guide, the main reason for that is a friction.

So, friction is reason which prevents us if you remember the mobile example like if you push something the friction is what prevents you to kind of do fine positioning. Now, when we have this motion coming up, because of the compliance of some linkages or some linkages are bending and getting that motion in place, then actually what happens is, you are preventing the friction to happen.

So, there is no friction in this motion that will happen and see there is no friction then all the nonlinearities in the mathematical or in the physical sense coming because of the friction they are gone. For example, when you reverse the direction of the motion, then friction force changes its direction that is a certain kind of discontinuity in the friction force, which is not desirable that is a non linearity.

So, that is why there are many linear controllers for such a fine application may not work very well. If the friction is present. So friction is handled in this case by changing the design in the mechanical domain such that you do not have the friction coming into the picture. So, this is like one of the kind of characteristics that we are talking about that you change the mechanical domain to so as to have ease of control implementation in the in the electronics kind of a domain or electrical domain.

So, because we saw in the presence of friction it is very difficult to control the system or very fine position the system very accurately and reliably robustly all the time. So, that is a reason. So, so, this system is serving for two purposes one is fine tracking that is there and other is like the fine focusing servo. So, this is a focusing these two servos are happening and we saw in the last class, what are the sensors to kind of have those servos working, so what is the feedback that they will get is where we stopped in the last class.

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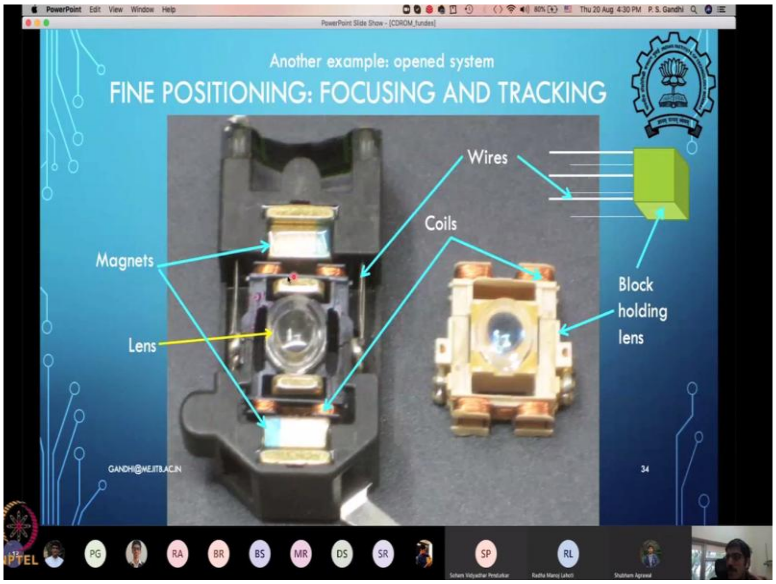

So here, you can see the all these kind of things very clearly, how the coils are placed, then there are magnets and then this is a lens from which the laser beam is coming. And then this is so the magnetic field direction one can see here. So, one can kind of like to do a lot of thinking here and saying, okay, oh, look how these coils are running.

And based on that, like, can I know which direction when the current is past, which direction motion is going to happen? If I want to move it in one way or the other way? How this coil should get energize and all this kind of thinking one can do is sort of big issues. But we will see it, I do not think we need to do that in this part but if needed, one can do all that kind of stuff.

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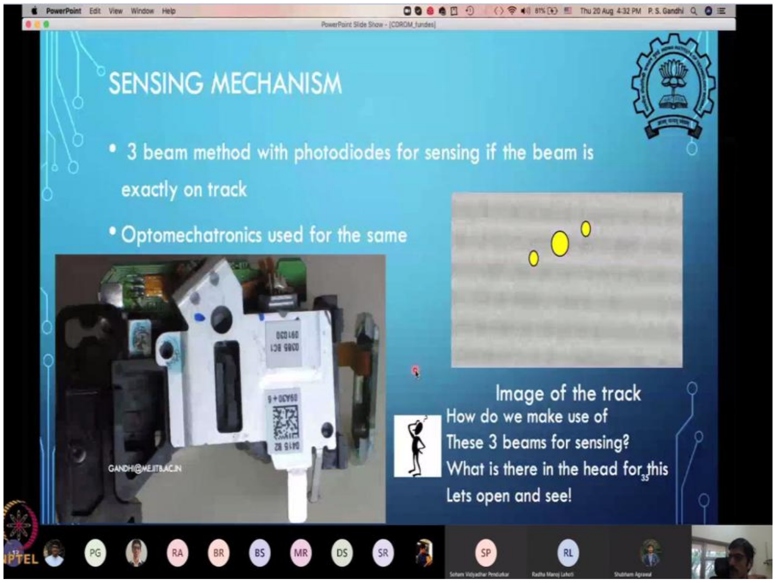

So, here when we came for the Sensing Mechanism, so first, the, again, I am explaining this, for the sake of understanding, we have these three beams that are focused on the surface of the CD, the central beam is for the data, and then these two side beams are for making sure that you are on the track, or you are in the proper data track. So how that happens is what we want to kind of see.

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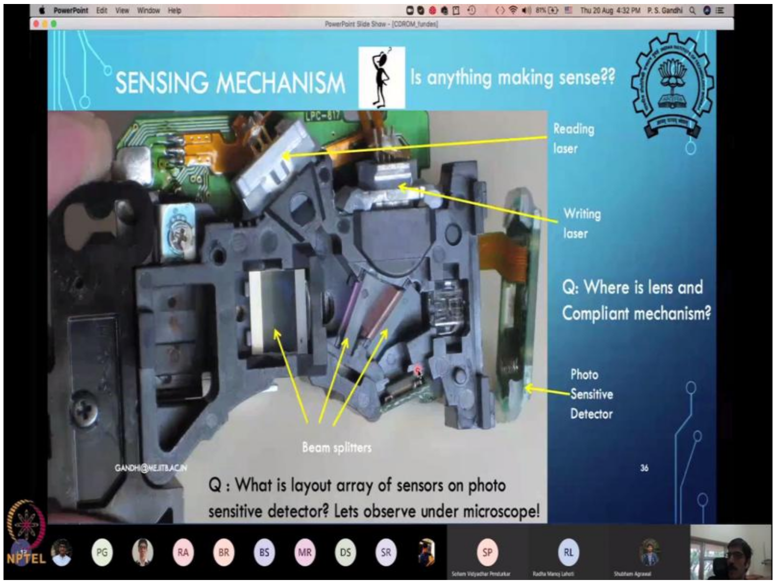

So, this is some kind of a system here, but I will explain it first with respect to the optics Ray diagram.

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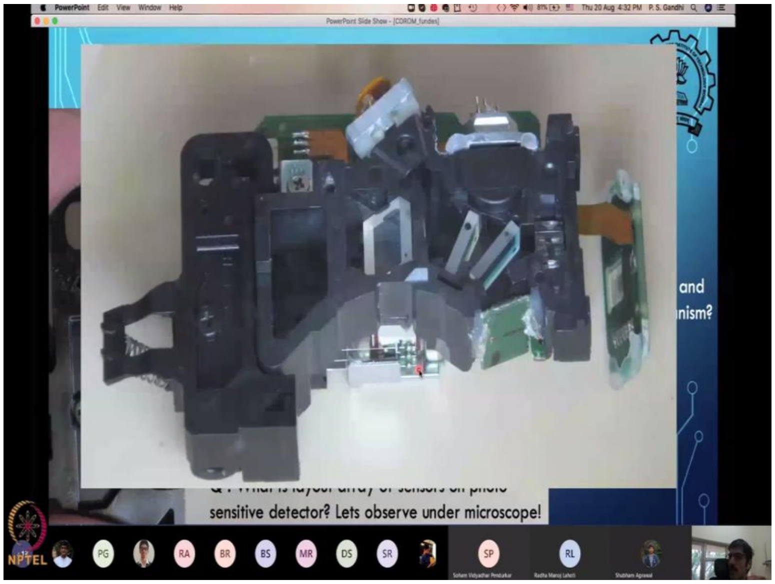

And then, we will come back to these elements how these elements are now, implementing the same Ray diagram, we will talk about that little later after the ray diagram itself. So, let us come to this.

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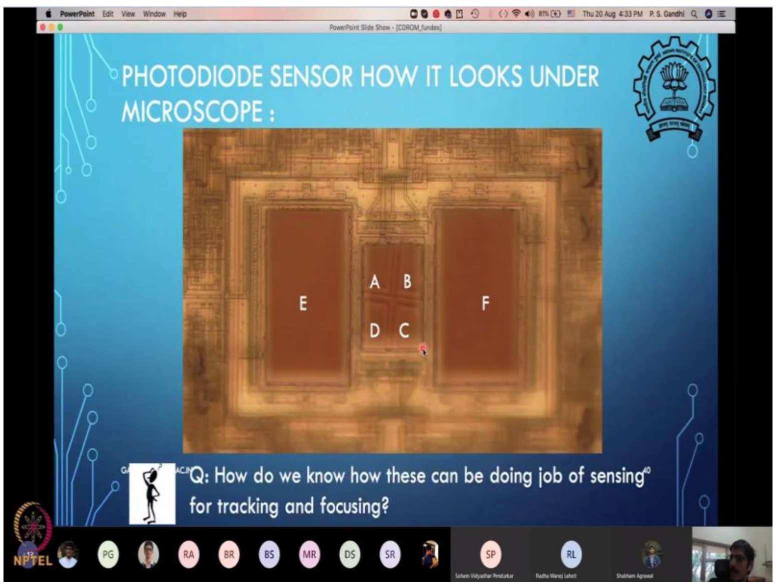

So, this is a photo detector on which these are four. Four elements A B C D here and E and F are on the side. So, let us go to the Ray diagram so you remember that, we have these kind of a facility is there where your three beams are going to fall, their reflections are going to fall on these three places, one is here, the center beam will be here and second side beam will be here.

And E and F are full photodiodes, it is there is a little larger area in E and F then in this A B C D case. So, now, no let us see the ray diagram.

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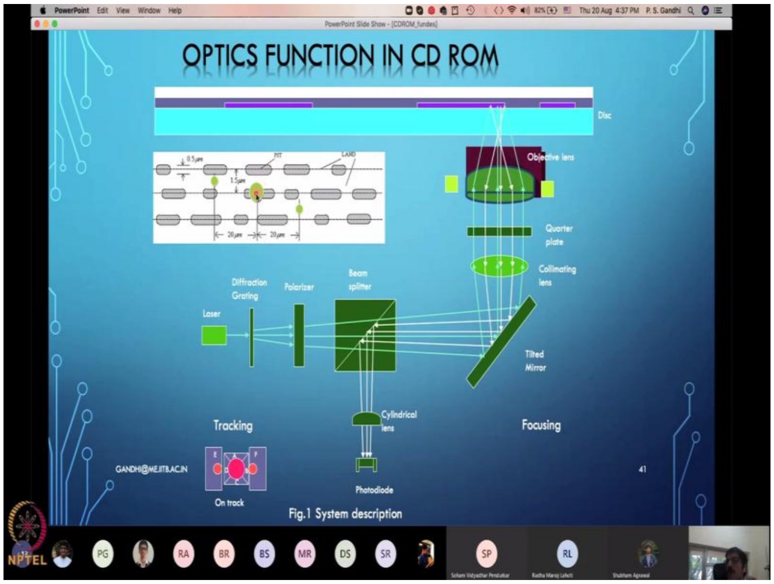

So, the optics what happens actually is the laser gets split into three beams that as we have seen and then it is made to fall on these multiple mirrors or whatever that reflectors to get basically to take it on the surface **of the CD** and when it comes on the surface of CD, that is when it looks the picture that I showed you about liking the actual CD surface image. Then it gets reflected from the surface and then it travels back.

Now, because there is a beam splitter here, the beam splitter will have a function that. So, look even while going this beam would have split and part of the beam would have gone here, but we are not interested in that part, **right now what** we are interested in only what is the transmitted part of the beam. So, also these white rays that are coming back part of them will get reflected and get you into to the laser but we are already interested in those parts of the rays which are going to go to the laser they will not disturb anything up there.

So, only part that is we are interested in is what, what are we getting partially reflected. So, you know this beam splitter thing. Beam splitter is where like when the beams are pass when beam is passed part of the beam will get **transmitted and** part of the beam will get reflected is like a only part transmission happens there. So, and then part of the light so there we can get this beam splitter 50-50 beam splitter or 30-70 beam splitter or that kind of a kind of a specification you get for beam splitter.

So, 70 percent part gets transmitted and only some part will get reflected like that there are specifications. So, we do not get into those details, but like the idea is to kind of like split the beam, so, that one part of the beam gets transmitted and that part gets reflected in the perpendicular direction. So, for this green incident waves, rays here, like a part will get reflected in this direction, because the beam splitter has this mirror in this kind of a tilted fashion but we are not interested in this reflected part that is coming, going there.

We are only interested in this point that in that translated I mean, transmitted part. So, so, also like these white rays some part will get transmitted, which are which we are not interested in, we are only interested in the reflected part. And that is where that part goes into the photodiode. So photo detector when it comes, like so, so it this beam look on the surface like this, and the photo detector they look something like that.

So, this is like a reflected reflections of a beam on the photo detector. So, these two side beams are going to fall on these two E and F areas. And the center spot is going to fall on ABCD areas. So, if I say like, A plus B plus C plus D is going to be my data signal. So all that is falling on that central area A plus B plus C plus D will form the data signal. So if the data is not there you will get this full reflection here.

If data is there or either way whatever if the data is there, then I do not get this reflection. So, A plus B plus C plus D will dim out when the data is not there or when the data is there, whatever you want to say for the lands, whenever it comes here on the instead of pits on the land here then I will see full reflection up here. And I will see so in that sense, I can make out a distinction binary distinction between the 0s and 1s that are there on the surface of the CD. That is how this data is read.

Now, comes to sensing. So, now, we want to sense whether the thing is on the track or not for that, these are the two side beams that are used here. Now, these two side beams get reflected in on E and F parts. Now, imagine if you have some small error in the motion and it goes off the track.

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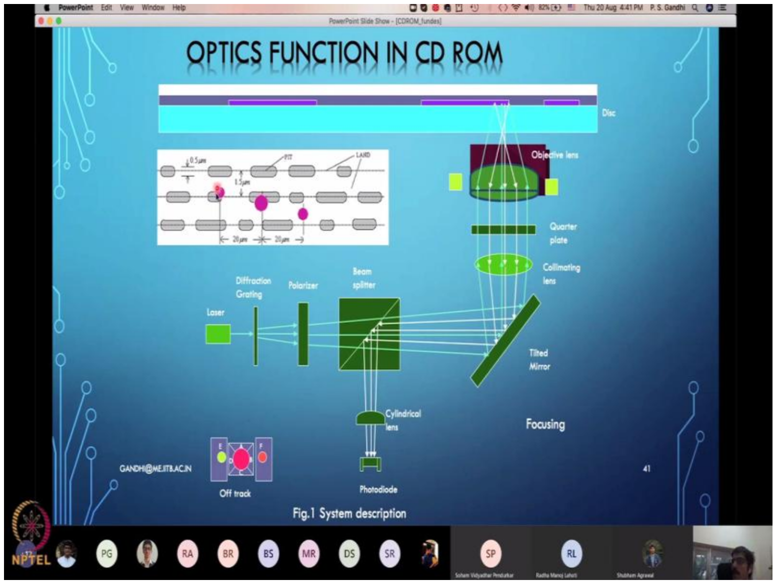

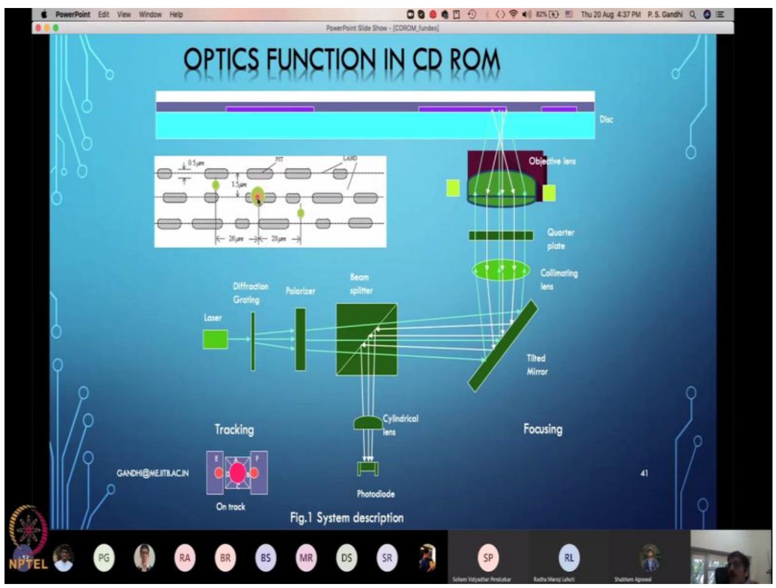

So, now the beams are position is something like this. So, you will find that like the beam which is say on track E is now start interfering with the data, more moment it starts interfering with the data, previously, it was not, then its intensity is going to go down. So whatever you are getting on E is going to go down the intensity. And that is how you say that, it has started moving in this direction.

Same thing will happen to this spot E, spot E, spot F here has not yet started interfering with this other track, it is important to see that, they are a little a little closer to the central track than to other two tracks so it is there so, the right position of this part is not exactly in the middle of these two tracks, otherwise this not happen. So, there this position is a little more closer to the track that is getting sensed. So that is why when small error, small motion happens, this direction it start interfering with the track data and its intensity goes down.

Moment, as intensity goes down, we will have to kind of, this is alert error correction signal, and we will move it in the other direction, same thing will happen. So, see if E and F both would have started going down in intensity because F is now interfering with the other track, then we would our goal is lost. E and F we do not want we want E and F to be having a differential kind of sensing so that we have a tracking error nicely captured.

So, you can see that this F spot has not yet started interfering with this, but E has already started kind of quite good interfering with the data track. So, the same thing will happen in the other direction also, then F will start interfering with the data tracks and this E has not yet started with interfering with these other data track. And then you will see the differential intensity signal will come E minus F is going to kind of give you the tracking error, is that part clear? Any doubts or questions about that?

Student: Sir, what if **right now** in this figure in the three red, pink color beams, what if there is a, what if there was a land I mean the black part right below the F beam?

Professor Prasanna S Gandhi: Black part right below the F beam?

Student: Both of them, are both start to dim out.

Professor Prasanna S Gandhi: See what will happen is first E will start dimming out. E and F both start dimming out at the same time, that is not going to happen because there is a small kind of see this land area here between the two tracks is much larger, but these spots are not in the middle of the land area to begin with. That is the important kind of consideration here to begin with, they are more closer to the data track which is which is why we this is a data that we are interested in a for these data track it will be this spot will be closer.

So, this relative positions of these three spots is what is important. So they are adjusted in such a way that they are closer to the data track, but they have not, they are not touching to the data track in the normal kind of full position like this, this position, but I mean I am may or may not have drawn it really that kind of a nicely here, but this spot is more closer in the normal position to the reading data track than the neighboring tracks.

This spot is also more closer to the reading data track than to the neighboring track, so then the moment the small error starts happening either this direction or the opposite direction, like immediately it will start interfering and it will get a differential signal, but at that time other F is or say if E started interfering F will not interfere yet but immediately once you see the error you are going to correct it so it will not happen ever. Like that.

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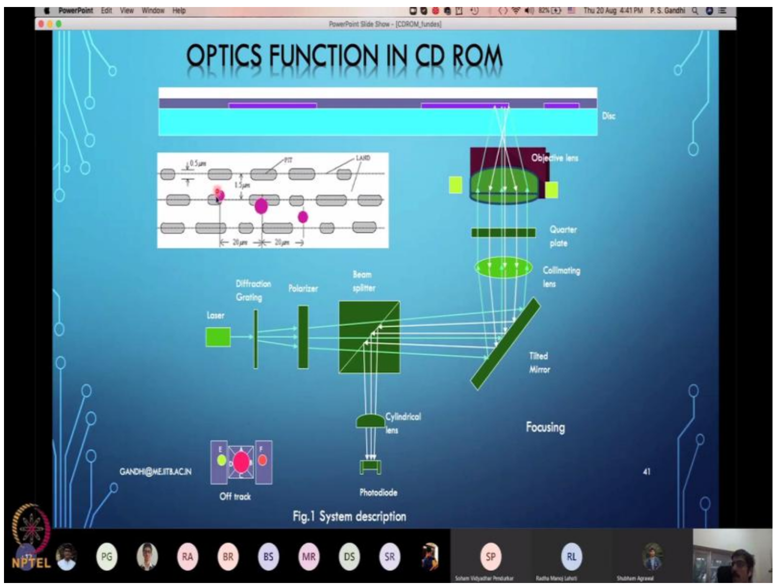

Of course if you can have go pass that correction and go beyond like that, this is independent then like we are actually coming out of the closed I mean the good control loop, which should not happen actually. So you will have some kind of tolerances and design in such a way that this is not happening. Okay?

Student: Sir, Please ignore the question if there is a lot of physics required why they only three spots?

Professor Prasanna S Gandhi: Oh, you are right I mean if you are writing your physics also for, they should be infinite number of spots, that is perfectly fine, but we are not interested in those spots, because those reflections are not going to fall in the any of these spaces here, one, and other thing is the intensity as you if you have seen this physics little bit more detail, like you will find that, when there is kind of a transmission grating happens for a laser beam, the central spot is much stronger than side spots and then, as you kind of go away away away then side spot will diminish in the intensity also.

Student: Yes, yes. Thank You.

Professor Prasanna S Gandhi: So, their intensity also low and they are not falling in the on the photodiode anyway, we are not worried about them.

Student: Yes Sir.

Professor Prasanna S Gandhi: Good. It is good that you know, I am glad that you are thinking in physics and in all these different domains, it is very good. See, that is what I this kind of a thinking is what is important in this course or in general, for any development of a new conceiving a new system, like this kind of critical thinking is essential, actually, with the practical thing and theoretical thing both, I mean, both domains. Nice.

And we will do, we will do this is I think the very, I mean, I would say quite complex system, not all mechatronic systems are like this are more complex than these, but if you are if you can understand and appreciate this particular system, then a lot of different systems will be very, very easy to design for you I mean, so it is not very difficult, you will be able to design them very nicely.

Say for example, you might have seen like the scanner system, for example, is very, very simple as compared to this and we can relate whatever fundamental we have learned from this system very nicely to the scanner system also. So, if you understand this system, well, like or the concepts that we are kind of taking away from the system well, then, like they will help you long way to design many, many different kinds of interesting mechatronic systems and I will give you some examples that we have done in our lab, but there is a lot of other things that can be possible.

By just extension further extension kind thing, of the concept that we have learned or started with this foundation. So, this part clear then we can move on to the focusing part. And focusing part with Physics rather.

Student: Sir.

Professor Prasanna S Gandhi: Yeah.

Student: When the like when the information, like when the rays pass through the beam splitter is not information lost due to.

Professor Prasanna S Gandhi: Yes, you are right.

Student: Then How do you compensate for that?

Professor Prasanna S Gandhi: We use a stronger laser, that is it. So, see when the beam splitter as you, as the name suggests, it will split the beam part of the beam only what we are interested in. So, so, we have to ignore the rest of the part which we are not interested in that much kind of intensity of the beam is lost. But it is okay, I mean, we use a laser which is a little bit higher power and we can go away with that, no problem.

Student: Sir, cannot something better be done for example, like the tilted mirror, so it can be made to during the incident time it can be made to be at that 45 degree angle or whatever and during the reflection, it can be made at some other angles, so that, like, you do not need a beam splitter then you get another reflector.

Professor Prasanna S Gandhi: But then you need to move the mirror then, right?

Student: Like periodically move the mirror.

Professor Prasanna S Gandhi: But periodically, how will, what is the period of that motion can you think about? See when the data is coming and getting reflected, you are not stopping at any point to read the data on the surface is continuously moving CD? How fast you can do this motion, right?

Student: Correct.

Professor Prasanna S Gandhi: And actually by saving this kind of a doing these kind of additional thing what we are saving from the practical perspective, we are saving just laser power. I mean, the people are 1 milli watt to increasing the laser power from 1 milliwatt to 2 milliwatt is not a big deal. It is hardly any cost. If you think of your pointer laser, that has, some few milliwatts 4-5 milliwatts of power. I mean, this is, you need much, much lesser power for the laser, which is there in the CD ROM drive. So, that perspective also, we do not save much actually.

See, I mean, people would do these kind of decisions based on their commercial, value viability. I mean, we do not need to be a restricting to discussions for a commercial kind of a perspective. I mean, we should do all academic kind of a possible explorations to just see, what are the fundamental is there like that. But, that is the kind of thing.

Student: Okay.

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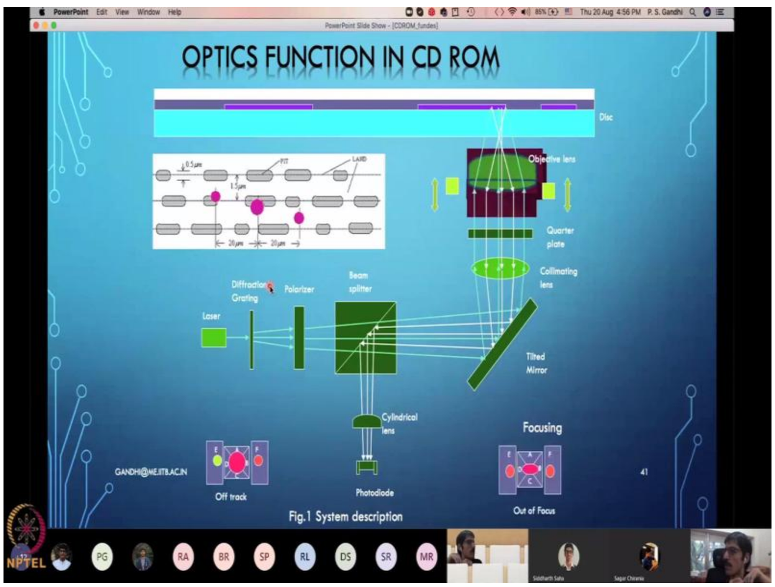

Now, let us kind of look at this focusing part of it. So in focus, you see what happens is, so let us see. so, when things are out of focus, in one direction, then the spot gets stretched in the elliptical kind of fashion. In with like, the minor axis of ellipse shifting, its direction. And then major axis of ellipse are, major axes of ellipses is aligned to end these B and D spots here in this particular case. When the defocusing happens in other direction, so like, it let me go to the slide here itself.

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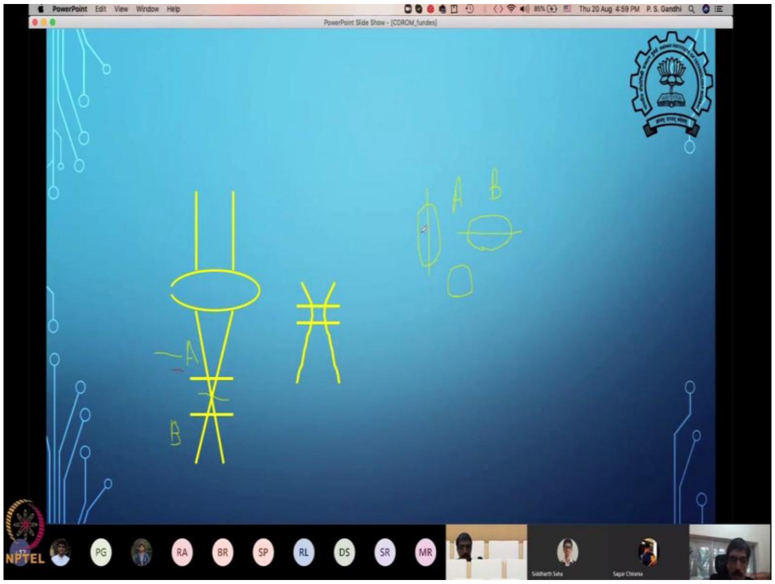

I wanted to get this laser pointer here so that I can show you some stuff. Let us get pen here. So you see that, we are when we are a focus out of focus in this direction. Pen color? So, so we are out of focus in this direction, this side, then, the ellipse happens, like this for example. And when you are out of focus, so this is a position A here. So, this is A, when it is out of focus in this direction, then when it goes out of focus in at the B side on the on the opposite side, it will go like that.

This is B position here. So this is B position here. So, so, when it is at a completely at the focus then only it is going to be a perfect circle in, in one position it will have a major axis ellipse in this direction in other defocusing position it will have major axis of ellipse in this direction is how the rays travel. So, in this kind of a spherical and cylindrical kind of lens, the lens has a combination the spherical and cylindrical parts as I said in the previous class as well and that makes it behave in this kind of fashion.

And the spot goes on one side elliptical in one major axis and on the other side in the perpendicular major axis, like that the spot behaves. And because and in the center only, only in the focus, it is perfectly as a circle up here? And that is how that is the reason the focusing can be detected now this so, if this happens on now your photodiode A B C D parts as shown here.

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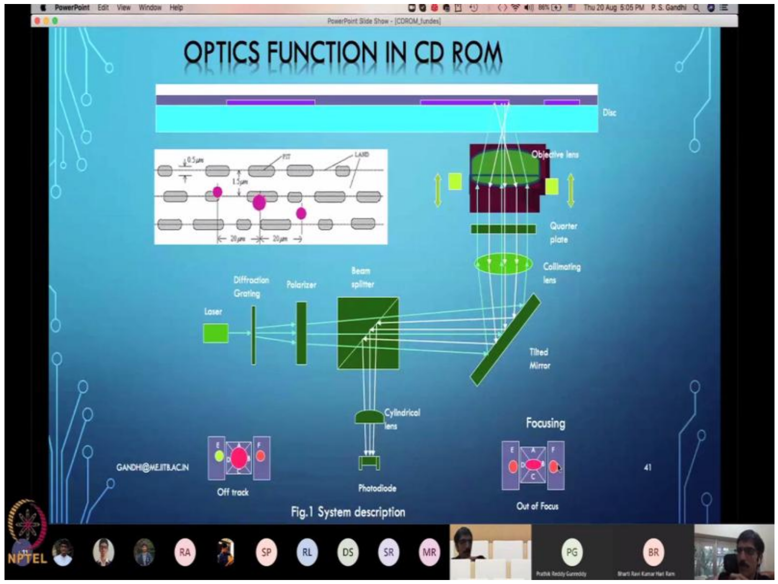

So, focusing on one side it is covering like that, and in the other, other defocus direction it will go A and C direction. So, if I consider this signal (A+C)-(B+D), then it will have a, have a error signal covered up there. And that is how I can detect whether it is in focus or it has gone out of focus. So, is that part clear? Is any question about this part again?

Student: Sir what is the parameter that decides which direction the focus is going?

Professor Prasanna S Gandhi: We do not need to know that, we just need to know that. If it is going in one direction, I have the signal positive (A+C)-(B+D) will be positive if it is going in either direction (A+C)-(B+D) will be negative that is it. I do not really need to know whether it is going positive upward direction or down direction I will just so, so, I mean of course I need to move the lens in appropriate direction if it is not going the appropriate direction typically people just change the sign and make it go in appropriate direction.

So, there are a lot of these small, small other kind of practical things where you know whether the sign is positive or not it has a lot of physical way the system is and like how your sensors are, how their gains are and all these kind of things affect actually so you do not need to worry about so if you say oh A plus this signal is what is coming up and I want to move for the signal positive I need to move it in this direction and then I can give a positive signal to the coils and then the coils will move in appropriate direction.

If that positive signal is taking the coils in the opposite direction, I will just change the sign of the force that is given and I will change them to go in a proper direction. This we often need to do in the practical world when we are kind of even configuring simple motor and the encoder six system like you will need to do that what is the direction of encoder positive that needs to match with the direction of positive force on the motor of PWM positive or whatever direction of the motor positive that needs to get matched they need to be mapped properly in the practical world. So that otherwise the negative feedback will happen and instead of stabilizing the system it will destabilize the system. So, is that part anything on this more?

Student: Sir, I want to ask for example, if the displacement of the disc is too large for the compliance mechanism to cover up, is there indeed in such situation?

Professor Prasanna S Gandhi: Come again. What is large for the disc to cover up?

Student: There must be range of this compliant Mechanism.

Professor Prasanna S Gandhi: So, look this, so normally you will design the system to kind of like satisfy the specification. So, so, for example, you this wiggling or like, the undulations on the CD surface are designed to be maybe within say 100 microns, then this compliant mechanism will be moving only plus minus 100 microns or plus minus 50 microns, that kind of a motion and that will be sufficient.

So, you will design the system to kind of do whatever things typically it is not going to be more than 100, 200 macros I do not expect this motion of the undulations on the surface of the CD to happen that way and beyond that, if it is there, I mean, if somebody has crashed your CD, so much that this crash is going beyond that, then it cannot focus it not will work and then they will say, CD has damaged.

Student: Okay, Thanks.

Professor Prasanna S Gandhi: So, this is about the focusing system and now, you can imagine if this, this spots here on the track the side **spots are going** out of focus, that can also be detected by the exactly same way. So, instead of E and F you will have other kind of four sensors A', B', C', D', and A'', B'', C'' and D'' in the place of E and F.

And then there also we will correct for the focus of their thing, then your complaint mechanism will be always maintained maintaining the tilt also, tilt will be also kind of taken care of. So, if you need that kind of a precision, there are some kind of a CD-ROM drives I have seen, I will see if I can get a picture of these photodiode is interesting picture to look at you can see that E and F blocks also are kind of showing like, the split A, B, C, D kind of split.

So, if this is clear, then that maybe we can stop here and like your take up the scanner in the next lecture. And, maybe I think it may be worthwhile to go over this more such systems, maybe in the future at some point again, we will do something some exercise with respect to some system like that, and that will form up our fundamentals of positioning and making these kind of choices of different mechanisms and things like that, more, more firm.

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Now, I would like you to pause and like to think over your own summary of lessons that you have learned. So, I would like you to jot them down maybe this can be a very useful kind of a learning exercise, say if you like to see something out, observe something and then think about and see what are the kinds of ideas which can be generalized for generally the development of some similar kind of systems.

So, that is what you need to, you need to kind of start having getting that ability so that whenever you open just do not open from I just want to know what is there inside we want to go beyond that and see not only what is there inside, but also what we can learn from it what are the fundamentals, why people have done it the way they have done it inside. So, that is what we want to kind of capture there.

So, you go, go ahead and think about we have done so much of a discussion based on that, what are the kind of things that you can generalize from the thing, do not go beyond this point, unless you have a listed kind of your own observations and conclusions of how do you generalize these things that you have you have seen so far. So, once you are done with that listing, then you proceed. So I am proceeding right now, but you can pause your video and then proceed next.

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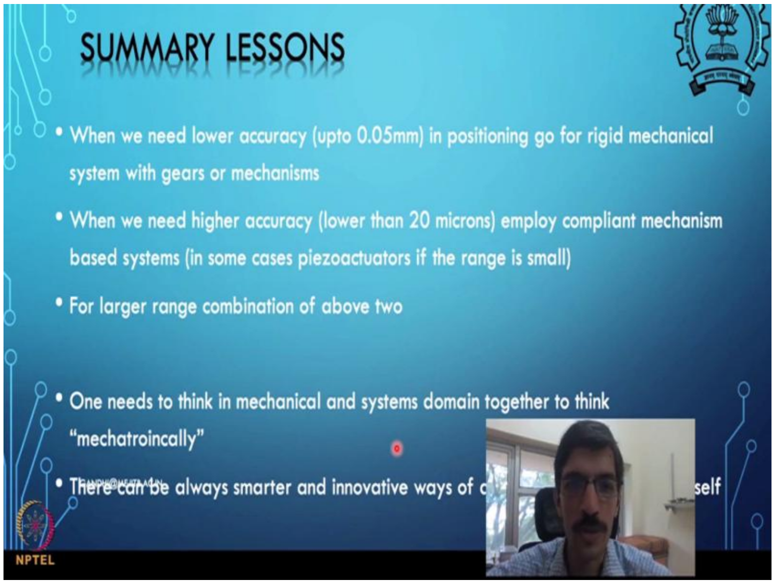

So, these are some of the summary lessons I can list. So, you may have some more kind of things to add to it. So, so, just think, it might be some kind of a trivial or may be important, but trivial, but important things that maybe you might have learned from this that may be important. So, this is not an exhaustive list of everything that we have for everybody the learning would be different from observe, making the observations about some things.

So, one of the important fundamentals here is to kind of see when we want to kind of have accuracy to be very, very fine accuracy positioning, say 50 micron in this case, then the rigid mechanical systems with the gears and other kind of a mechanism can be ok, 50 micron 100 micron positioning that can be very easily obtained by our rigid kind of mechanical systems with gears or other kind of stuff.

Of course, you need to take care of backlash for sure. So, again, backlash is difficult to handle in the controls, so that is why you see in CD ROM drive, you will have a way to kind of take care of the backlash in the mechanical domain itself so that you do not need to worry about that in control of backlash. So, one of the important things is that when we want positioning accuracy moderate not really, really fine then you can go for this rigid mechanical systems that we had here as a rack and pinion or screw type of a drive for gross positioning servo in the CD ROM drive.

Now, when we demand very high accuracy, which is much lesser than 20 micron or a nanometer kind of range, then we need to employ like different system only rigid for a systems may not work in this particular case, we can imply the compliant mechanism system that will kind of do a job for a very, very good kind of accuracy with a good range, but there are many there are many other kind of such systems that may be available, one of them is a say, piezo kind of drives piezoactuators they can get up go do very, very fine kind of positioning, but their range will be typically limited.

So, compliant motion systems or compliant motion platforms can be actuated by piezos also nobody prevents you to do that. So, forever for example, like whatever is driven in the stage that block and that was compliant mechanism that was driven by the magnetic drive that can be also possible by using piezo drive, but piezo drive the disadvantage is that it will not give the range that is needed for the control to happen.

So, for example, piezos will typically have a range of maybe about 100 of 100 microns, but in here if you see in focusing servo you may need to go beyond maybe 100-200 microns overall kind of a motion. So, so, typically it is not used and also piezos are costly, that is another reason piezo might not have been used in CD ROM drive. And for larger range of motion, you can combine this fine positioning and gross positioning together as we have seen that is done in the CD ROM drive.

Then this is another very important thing, some of the examples we already saw, we need to think in mechanical and electronics system, electronic systems domain together. So, this is like a mechatronics kind of a thinking that that will happen here. And then maybe always some smarter or innovative ways to design so do not constrain yourself that whatever you are thinking is only the possibility kind of thing there might be some still you can be open to maybe other possibilities.

Then you will start kind of thinking a little more and like get to more finer thing or maybe when you experience some things are not really working so, well then also you will have an opportunity to correct and like go ahead.

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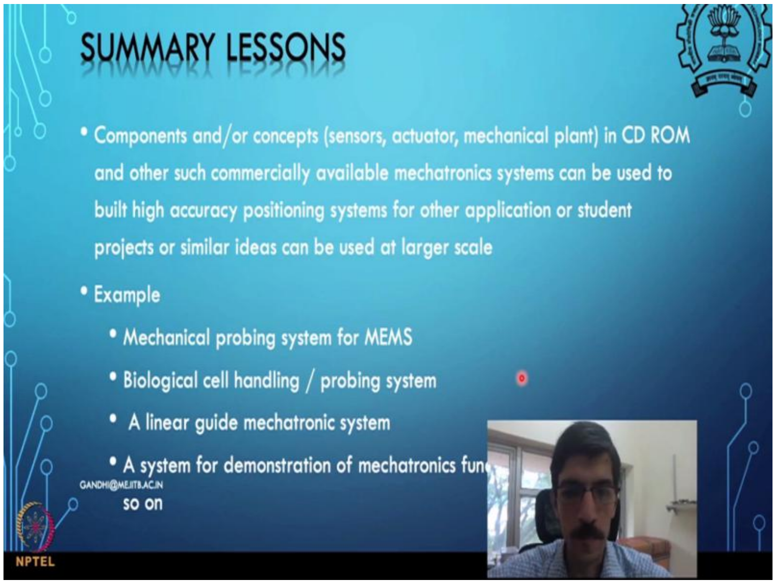

Then this components is now see this other kind of a thing is that this components that you saw in the CD ROM drive that actuators or sensors or some plants these kinds of components can be useful for developing some other systems, or you can use the same fundamentals, but may not be this competent because you are the power and size that is needed, but the same concepts can be employed in other domains. So, I will show you some of the examples of use utility of compliant mechanisms for example in doing 3D printing.

So, that we have done in the in our labs. So, that kind of application one can kind of think about from inspired from CD ROM kind of system. Then, you can have some examples of such a kind are like the mechanical probing system for MEMS, these are the thing that we have developed, so, that you have a compliant mechanism, which is probing things mechanically typically, there are electronic probes in the to check the IC’s, you have a pads you make electrical contacts and probe some of the devices on the silicon chip to kind of see the response of their devices and things like that.

But now, you can have a mechanical probing in a sense, if you have a say micro cantilever then you can have a tip of that micro cantilever actuated by a probe, probe is nothing but simple needle kind of thing, which is now controlled by a force in the sense if you give small touch to this cantilever very tiny micro cantilever like the probe, which will be mounted on some kind of other compliant mechanism system like a CD ROM drive, compliant mechanism system and then what will happen is even if you do a small displacement of the probe by giving displacement to the base of the cantilever in the CD ROM drive system.

Base of the compliant mechanism in the CD ROM drive system kind of a thing. Then the cantilever will get control force. So, the cantilever that you are kind of measuring is getting controlled force. So, that kind of base is called mechanical kind of a probing system. So, this may or may not have been so clear right now, but think about this, if you want to kind of probe some mechanical device such that the force that I am applying is very controlled force, but I do not want to use any kind of a mechatronics in that thing, I just have a mechanical kind of a way of changing these ports, how can I, how can I do that? so, so, that is a kind of idea there.

Then you will have like, a lot of fine positioning system for biological cell handling or biological cell stress, stressing systems setting like that do can be very delicate systems can be developed based on such a mechanism directly or like I am using the concepts from the, from the mechanism.

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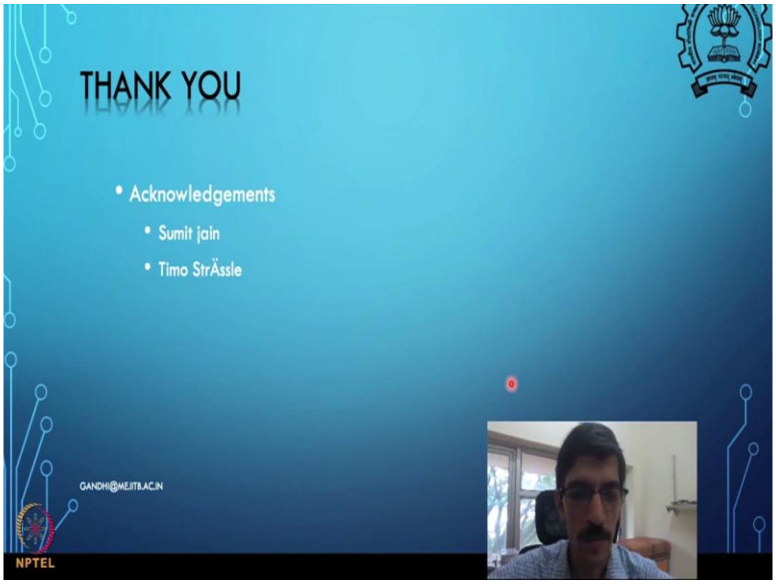

Then, now will switch and look at the next topic which is based, which is on under mechatronic system, which is a Scanner.