Optical Engineering

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Lecture – 27
Lab 6 – OSLO

Good afternoon. So, we are here for the last session of Labs concerning the software OSLO.

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And we are going to do something a little different today. This today's lab is not so much about the optics of a system, but rather how do you model tilts or when you move or displace an object away from the optical axis. So, it's more a lab on how to use certain tools within OSLO.

Now, up till now all the exercises that you have done had every element placed along the optical axis right and the only coordinate you worried about was, what is the distance of the next element from this element. So, what you might not have realized that you were doing is you were in fact, using some kind of local coordinate system because if you had an element here you gave the thickness to the next surface. So, let's say you said something like 10 mm and that meant the next surface appeared 10 mm away. If you had another surface and you said 10 that 10 was measured from this surface not from this surface right.

So, in effect you are measuring a distance always from the current surface to the next surface. Now this works for many optical systems since many optical systems will have one single linear optical axis. But if you have a system which has a mirror in it and the mirror tilts the light of course, the entire optical axis of the system is going to change that is one thing and secondly, even if I had a system where all my elements are supposed to lie on the same linear optical axis, it may be that while manufacturing this system a lens does not go into the exact position that it should have gone into and its displaced from its position or its rotated.

Now, I want to study this rotation or displacement without affecting subsequent elements. So, let say I had a system as I have drawn here which has three elements in it, it may be that element 1 and 3 are correctly positioned it may be that they are correctly positioned. But element 2 is in the wrong place or has the wrong tilt. Now I want to be able to place element 1 and element 3 correctly and move element 2 either move it. So, I could move it in the x direction, move it in the y direction move it out of the correct place in the z direction, but not move element 3. In your current techniques if you play said let say element 2 had a Δz error.

So, it should have been 10 mm from element 1, but instead it was 12 mm. So, there is a 2 mm error. Element 3 is still 10 mm away from the original location of element 2, but if I just write 10 now I have changed my system because now the entire length is 22 mm not 20. So, in this case you might say I know it's 2. I will have just the next distance, but sometimes you want to study the effect of varying. So, you may do a study where you say let me vary the position of element 2 and I want element 3 to stay in the same place during this study. I do not want element three linked to the coordinate system of element 2.

So, in order to study such cases and they are very important, once you have a perfect optical design or what looks like a perfect optical design, what people will do is run something called a Monte Carlo simulation. So, they will put in all the maximum values of error for the tilts and positions of each element and the Monte Carlo simulation will assign a random value that lies within the range for each element and see if the overall result is acceptable. It may be that element 2 moves and element 3 moves in such a way they compensate for an error, but some other element moves in such a way that it aggravates there.

So, you need to see in all possible cases do I still get an acceptable result. So, its we could do all that we did up till today just assuming that the next element is place this much distance from the first element and we did not look at tilt at all ok. So, in today's class or today's lab exercises are all for you to understand tilt and how to achieve tilt ok. So, it could be that you have a mirror or even if you do not have a mirror how do you tilt one element and not affect the others.

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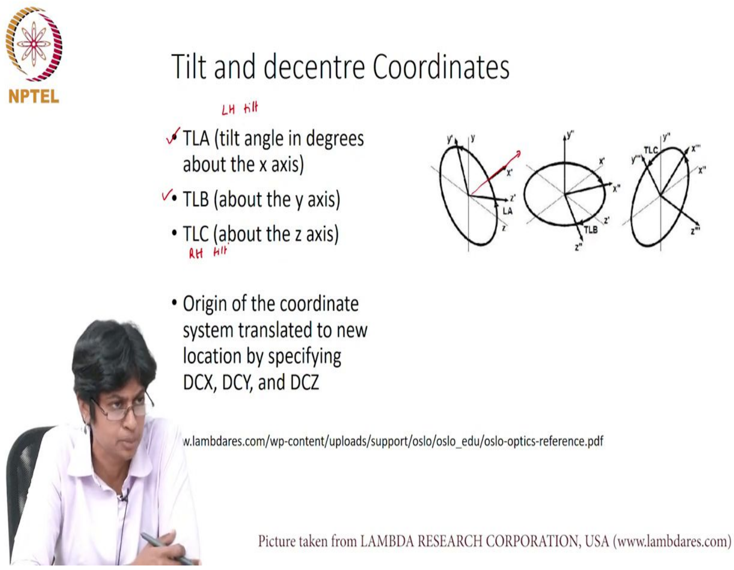

So, to do this first we need to understand the coordinates that they use, there are 6 coordinates, 3 for tilt and 3 for the origin of your coordinate system. So, the tilt angles are given as TLA, TLB, TLC and as shown in this figure TLA is when the optical element rotates about the x axis. So, the x axis is here right and so, the element is rotating in the plane orthogonal to that that is TLA. TLB is similar to the y axis however, and TLC is about the z axis that is typically our optical system ok. Both this and this are left handed tilts whereas, TLC is a right handed.

So, I can tilt any element and if I am doing so, I am doing so, by these using these any combination of these three angles or I could displace the entire origin of my that surface and then their displacements are DCX, DCY, DCZ this each one of course, a displacement along that respective axis.

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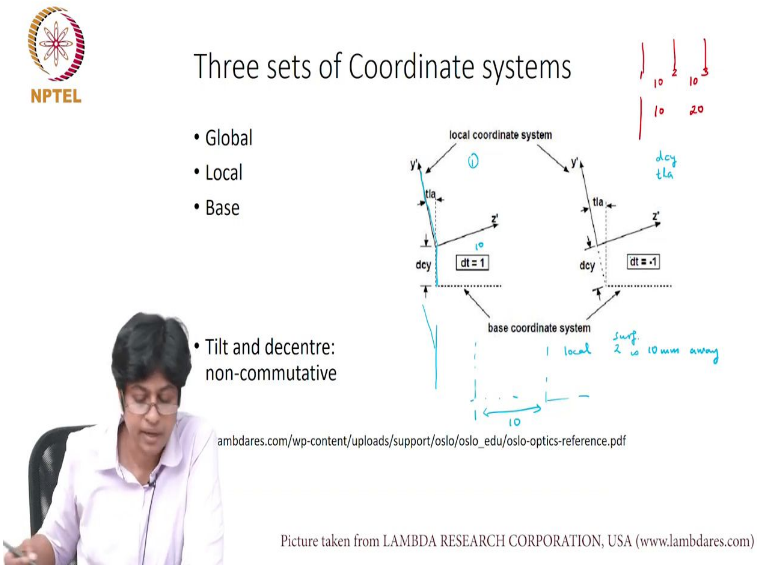

Now there are three sets of coordinate systems that you need to get acquainted with to be able to do what I said our goal was.

So, the first its not the first, but one of them is call the global system we have not been using the global system. The global system as the name suggests, will assign or you will assign one surface as your global reference surface. Any tilt or any decentre or any distance will be measured from that global surface. So, this is not you have been using local coordinates, you were always saying from this position a distance of so, much from this position a distance of so, much right.

The global coordinate system is always with respect to a reference surface. So, in the example I gave just now if I said we had three surfaces, in the local we said this is a distance of 10 surface 2 is a distance of 10 millimeters from surface 1, surface 3 is a another distance of 10 in global we would say this is 10 and this is 20 because if I gave the global reference as 1. I could say the global reference is 2 I can mix any system with my global reference then I might have some negative numbers to a conflict ok.

So, I decide which is the global reference, but any measurement then is made from that reference point ok. So, that the global coordinate system is easy to understand is actually not the easiest system to use because it's easier to make measurements along the optical axis, its easier to make measurements with respect to the previous surface ok. So, that is why the default coordinate system that you have been using though you might have been not aware of it is the local coordinate system.

Now, if you look at these two figures over here, the dashed line shows you the y and z axis of some elements of the some element that you cannot see the x axis the that variation that sticking out of the board, but this is showing you the coordinate system that is used the dashed lines show you the coordinate system of the local setting. You could displace and tilt that surface and the displaced tilted version is shown here.

So, let me use another color. So, this is a displaced tilt. So, whatever surface was here has been displaced along the y axis and tilted and now it is showing like this ok. I can now say the next surface will be 10 mms away from this surface, if I use the local coordinate system this is the local let see this is surface 1, if I am using local coordinate system and I say surface 2 is 10 millimeters away it's going to be 10 millimeters like this ok. I could on the other hand say I will not use the local coordinate I will use the base coordinate and then surface 2 is going to be 10 millimeters away like this is that clear?

So, I have the global that is fairly easy, some surface gets designated as the reference every measurement is made from there or I have the local. So, I have a surface and its untitled undecentred coordinate system is the measures is the coordinate system I make my measurement from for the next surface or I can say I have a surface and its tilted and decentered and its tilted decentred coordinate system acts as a coordinate system from which I define the location of the next location and orientation of the next surface. These are the three coordinate systems you need to be familiar with.

And as we go along you will understand why it's important to have local and base. I can achieve everything using both local and base or the global coordinate system ok. Now one thing that may not initially be apparent, but on some thought should be clear tilt and decenter are non commutative operations. So, if you tilt first and then decentre or you do the operations in reverse. So, you descend first and then tilt so you do not end up with the same system and that is an example that is actually given over here.

So, if you look at these two figures both have the same tilt d c y and both have the same sorry both have the same decentre d c y and the same tilt TLA ok. But in this figure the descent was carried out first and then the tilt was carried out and in this second figure the reverse was done and you can see the end result is not the same right. So, you need to tell OSLO which order you want to do an operation. So, if you will see there is a certain screen you can enter the coordinates. So, for that surface what you want to do with that surface, it may be that you want to both tilt and decenter that surface then you need to tell OSLO the order in which those operations need to be carried out.

So, if you were writing programming you would say you would use the command $dt1$ you would use the command $dt1$; that means, decentre first tilt next and if $dt1$ is equal to - 1 it means tilt first decentre next.

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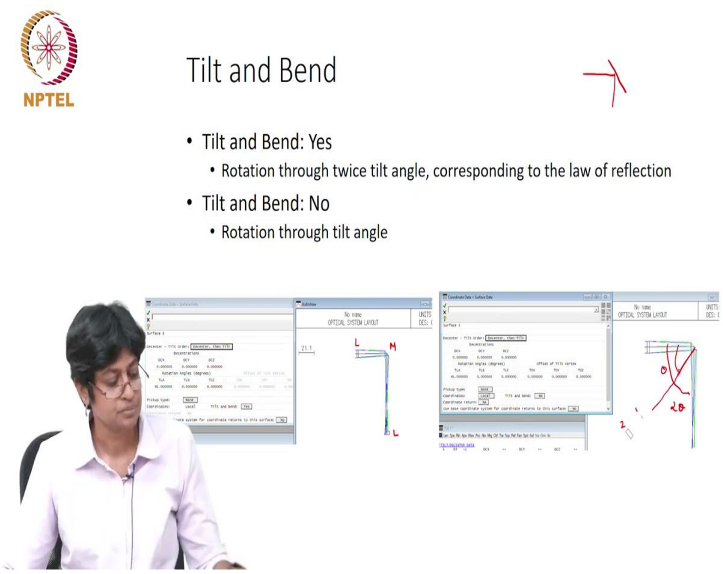

Now, you also need to tell OSLO to say you have a surface and you tilt that surface. Now you need to tell OSLO and I will give you an example of the difference here. So, here I have a system and it may not be very clear, but there is one lens here and there is a second lens here and there is a mirror here.

So, in this case the tilt and bend option has been given as yes. So, this is the coordinate window you are going to see that soon and you can see over here, you have chosen tilt and bend yes ok. In the same system if I had chosen tilt and bend no because there is a mirror here the light has to obey the law of reflection, but I do not necessarily need to put my components in that direction right. So, the components have followed just where the angle took them the natural theta saying this is a local coordinate system.

So, you can see it says it's local. So, I say theta and these are placed at an angle theta right. So, this element this angle is theta this angle is 2θ right. So, these elements are placed along the optical axis given by the local coordinate system following the tilt theta whereas, the rays of light are following the law of reflection and therefore, they bend 2θ from the mirror.

So, again depending on what I want to study I might say actually carry out a tilt and bend or do not carry out a tilt and bend. Again you will see why I would think I would always want to tilt and bend, but again we will see where there may be cases you do not want to tilt and bend ok.

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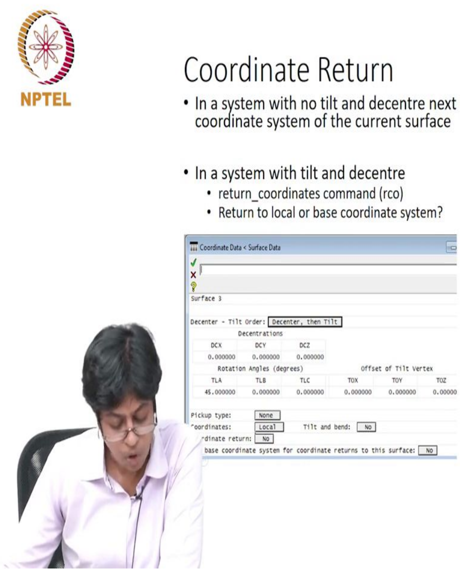

Now if I have different surfaces and I at one surface enter some coordinates which causes a tilt and a decentre or any one of those operations. I now need to decide if the next surface follows the local coordinate system of this surface or not. And I must have some way of telling OSLO please follow this new tilted decentered coordinate system or please follow some other coordinate system that may be the untitled undecentered.

So, the operation that carries that out is called the coordinate return. So, again you have this window over here is the coordinate window this window you will open from the special column ok. And you can see your coordinates are local in this case tilt and bend is no, but there is a there is a option here coordinate return and in this case its chosen as no.

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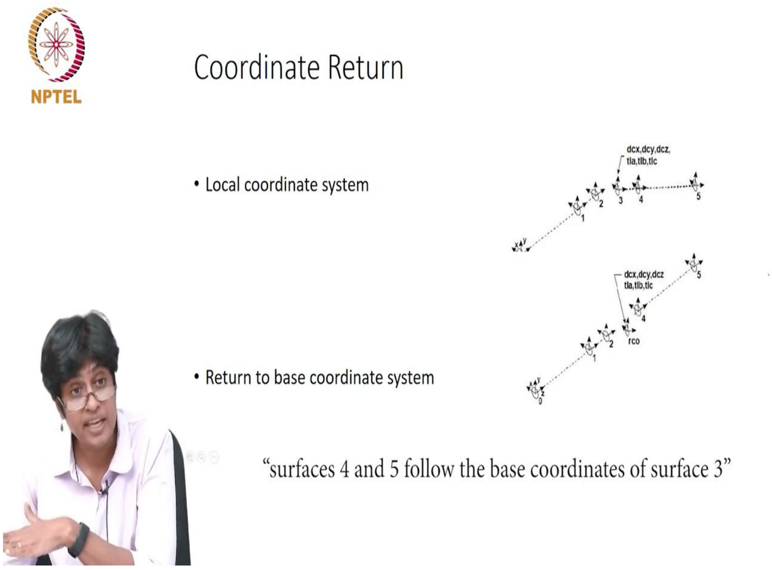

Now, let us look at what; that means. We use the local coordinate system and we have a series of elements ok. So, they are showing you this is the starting one and then there are five different elements. Element 3 has been displaced and tilted and because you are using the local coordinates element 4 now follows the new z axis of element 3. So, all the subsequent elements in this case elements 4 and 5 or surfaces 4 and 5 lie along the newly defined coordinate system, which has been defined by the new position of surface 3.

No coordinate return was carried out here ok. If you carry out a coordinate return and you go to the untitled undisplaced coordinate system of element 3 or surface3. So, elements or rather surfaces 4 and 5 continue along this original path. So, you should be able to see the difference over here in the upper figure no return to coordinate has been done. So, the surfaces 4 and 5 follow the original coordinate system of surface 3 in the lower figure and return to coordinates that an RCO command has been carried out and therefore, surfaces 4 and 5 are along the original optical axis.

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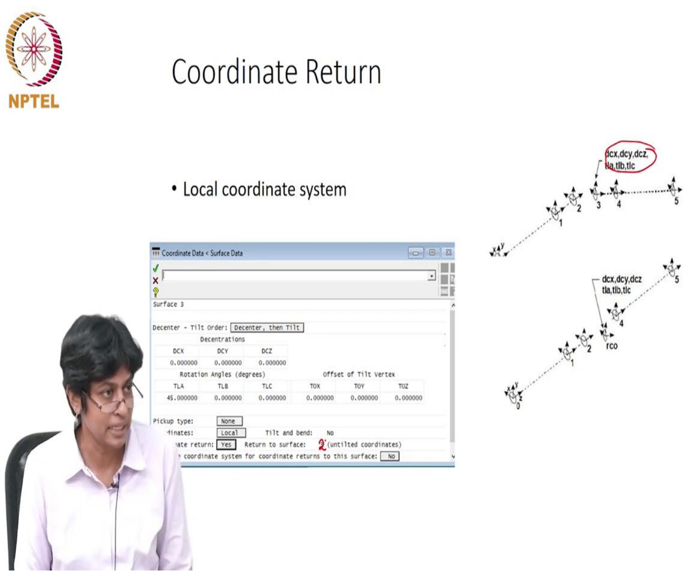

And if you were to look at the coordinate system coordinate data you can see your coordinates are local and there is a coordinate return and even here you have the option of saying return to coordinates do not use the current local coordinates, return to coordinates and I can say which surface coordinates I return to. Now I cannot see surface 3 that had all of these displacements in tilt. So, when we say return to coordinates you can return either to the original coordinates of surface 3 that is what is shown here return to. So, this is what will come up as your default option, but you could also choose surface 2 or surface 1 you can choose any earlier surface to return to. Clearly cannot choose a later surface to return to.

And say use had put return to surface 2 over here. Now what coordinate system of surface 2 should you return to? Should you return to surface twos local coordinate system or its base coordinate system because it may have been tilted or moved. So, the lower line says use the base coordinate system when any one is returned to this surface, use the base or local coordinate system of this surface as the returned coordinate system ok. So, I know its a lot to take in, I am running through it now you are going to have all this information in the file that you have and so, you can work through it slowly.

So, the key points to take away are that you have three coordinate systems: global, local and base you have been working with locally, so far. We are going to in today's class do exercises that help you get to know the global system better as well as the local and base systems better.

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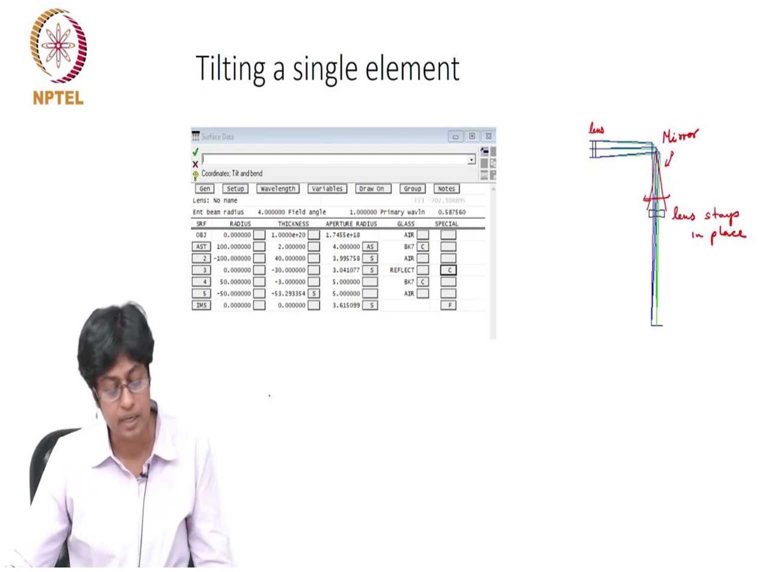

So, let's say we wanted to tilt a single element. So, in this figure over here. So, this is actually an exercise you are going to work through in today’s class, if you look at this figure here its similar to what I had shown earlier you have two surfaces. So, this is one lens and you have another lens and you have a mirror.

Now, let say I wanted to tilt this mirror such that this beam scans the beam moves, but lens 2 stays in place. Where would you need this? Say you are using a beam of light to scan something. The optics is all stationary after the mirror, but you are moving the mirror and maybe you have a lens to focus a spot and that focus spot has to move around in a straight line right. So, I need lens two to stay in place if lens 2 is linked to the coordinate system of the mirror every time the mirror moves lens 2 is going to move. So, I cannot link it to its local coordinate system, I have to set up the system such that I can tilt the mirror without moving the lens.

So, if you look at this setup I have just put two lenses. These are the images from this spreadsheet over here and now we want to set it up so that we can move the mirror without moving the second lens ok.

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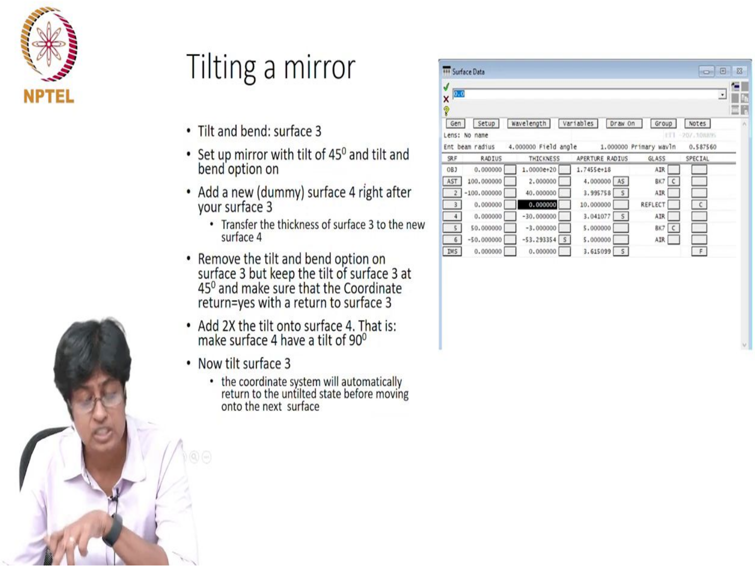

So, here is a sequence of there are many different ways of doing it. And I have given you two different methods in the write up that you have. This is one method using local coordinates the other method is using global coordinates; personally I find this easier, but you are free to use any system that you want. And I thought running through it together would make it a little easier.

So, we want to tilt the mirror and the mirror happens to be the third surface of our system. So, what are the different things that we need to do? We need to set up the mirror with the tilt of 45 degrees and the tilt and bend option on.

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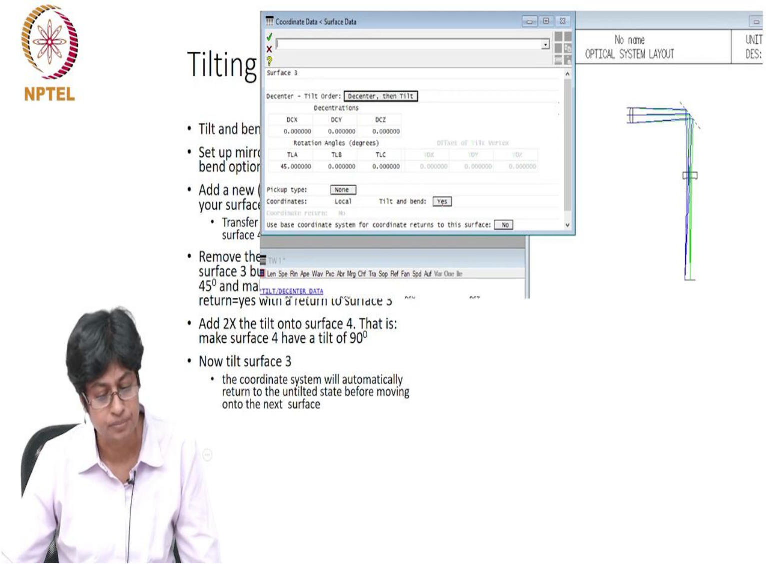

So, if I go to the coordinate window I am going to set up 45^{θ} and the tilt and bend option is on. Then, I am going to cheat. I want to tilt, but I do not change the optical system.

So, I actually add what is called a dummy surface. It's called a dummy surface because optically that surface plays no role in the system you are putting it in the system to work around the coordinate system ok. So, you are putting in a surface, so that you can play around with the coordinates in an actual system you would not have an extra surface in there ok. So, its only there to help you play around with the coordinates. So, you add a dummy surface ok. So, you if you look at the previous or I do not have that screenshot.

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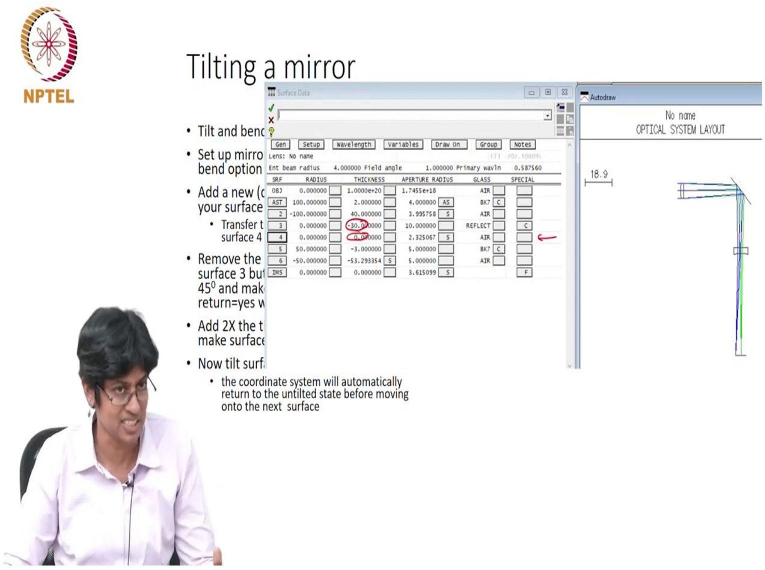

You have now this extra row that does not change your optical system. If you look at your optical system it is exactly the same because I have inserted a row there is no power there is no thickness. So, this does not change anything in your system.

I, however, need to transfer this thickness onto this; because I want this surface is just going to add that extra thickness and then I am going to change something in the coordinates of surface 3 ok. So, I need to transfer the thickness of surface 3 to the new surface 4 and that is what this screenshot shows you now all I have done is transfer the thickness. My diagram still does not change because I have not changed anything in the optics and surface 4 lies exactly on surface 3 at the moment.

So, if I were to look at the optical system at this point you would not be able to tell any difference I have not done anything with the coordinates yet. Now I will set this up by tilting surface 3 by 45^{θ} and we put a tilt and bend on it to ensure that both the optics as well as the light follow the same path.

Now, let us go back to surface 3, remove the tilt and bend option, and put a coordinate return on ok.

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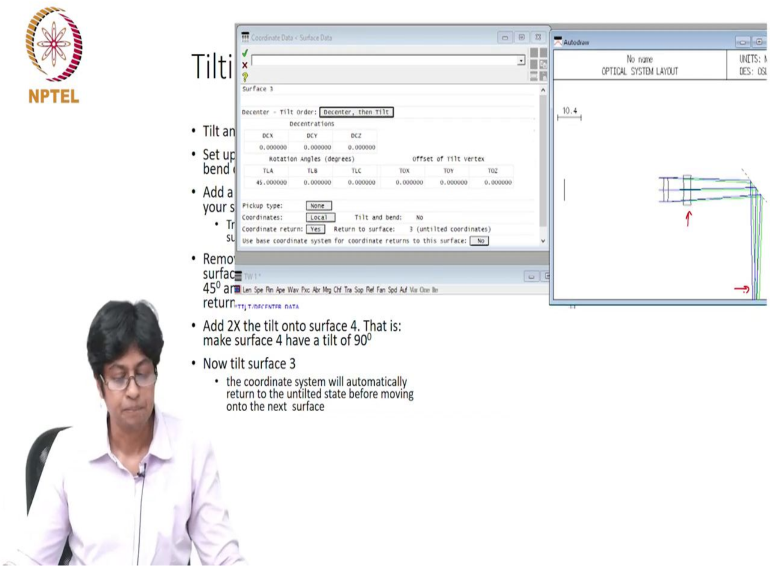

The moment you would remove the tilt and bend option you are going to see your optics goes haywire ok. So, do not be alarmed when you are working with coordinates if during the process of setting up the coordinates, an element seems to go and sit in completely the wrong place ok. This element should have been somewhere here, but I have removed the tilt and bend and its gone to some crazy location.

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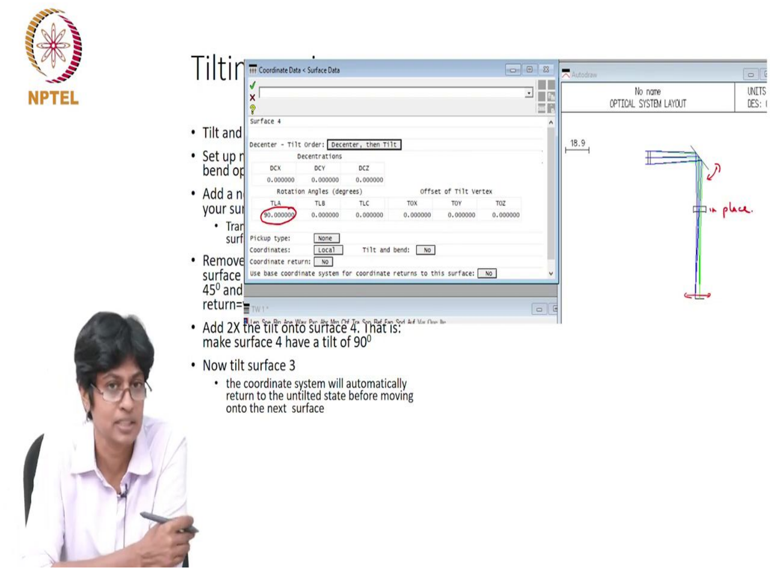

I now add and double the tilt angle. So, I had 45 originally. I had 90 over here to surface 4 and that brings it back now to the right location.

Now, what is the whole purpose of doing this? The whole purpose is to create two surfaces one surface is doing the optics and one surface is allowing me to manipulate the coordinates and manipulate the coordinates in such a way that we should be able to tilt this mirror and move the beam here translate the beam here and this stays in place while this lens stays in place.

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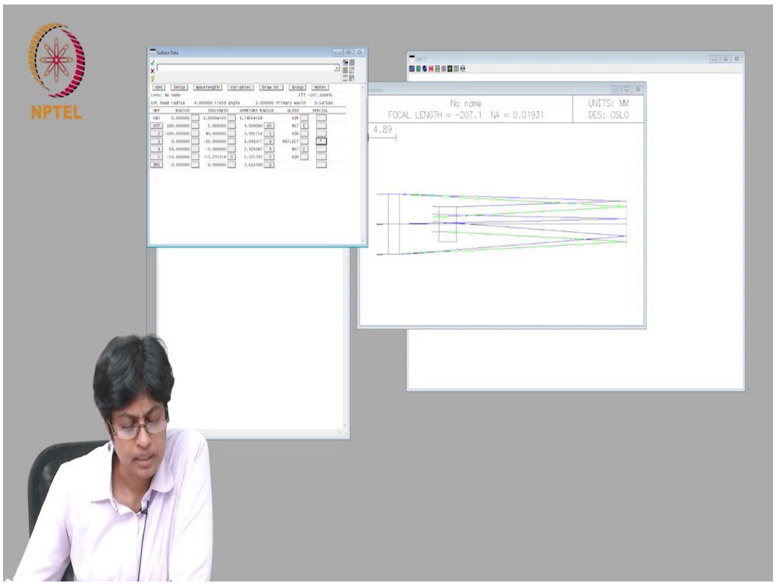

So, let us just try to do this ok. So, I have entered all the numbers of the example what I have not done is do the.

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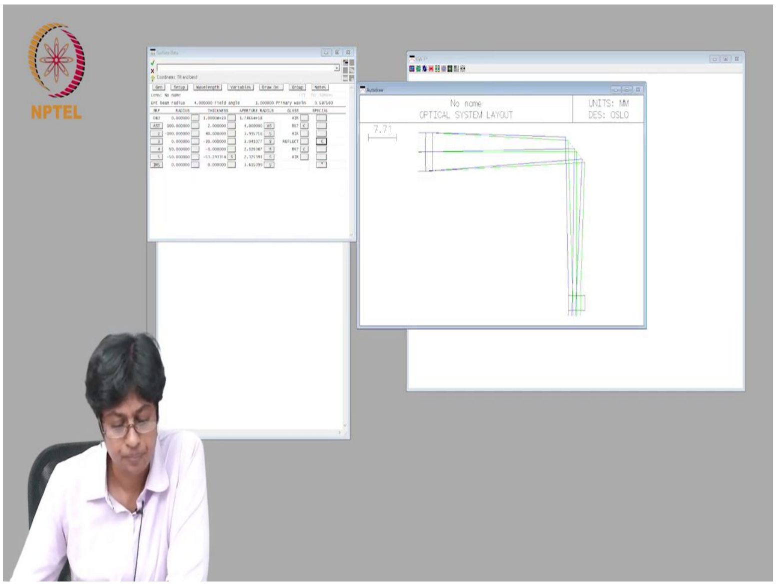

So, the coordinates are you go to the special column surface 3 coordinates and I am going to enter a tilt of 45^{0} . And I want to tilt and bend on and I say yes and I also want to see this last surface.

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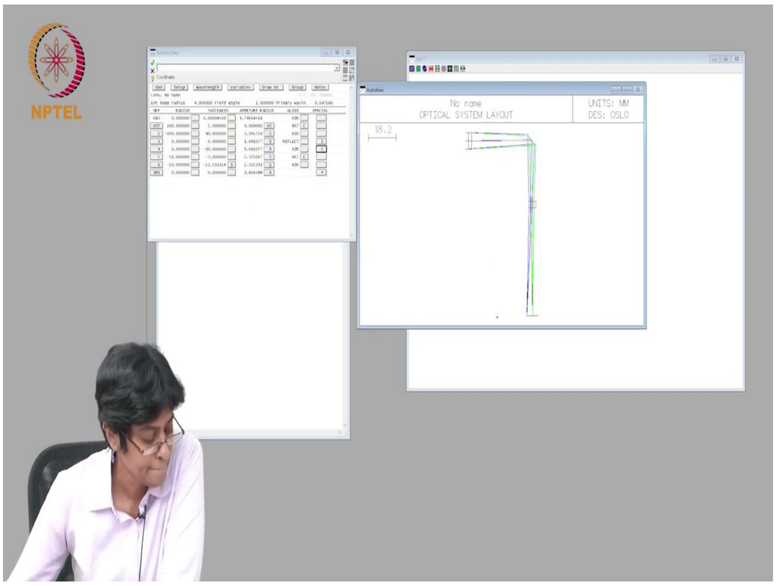

And now I want to add a dummy surface. So, I am going to insert a dummy surface and I will do what I just said. So, we will make this 0 and we like this minus 30 your optical system should not change at all right. When we are using a mirror you in the glass type you go here and choose reflect and you need to tell OSLO I am interested in tracing the rays after the mirror because I can have a partially reflecting mirror and the light could go through. So, OSLO is not going to assume you want to look at the reflected light.

So, in order to tell the software you are interested in the reflected light all thicknesses after the mirror need to be negative ok. So, that is why I put minus 30 over here ok.

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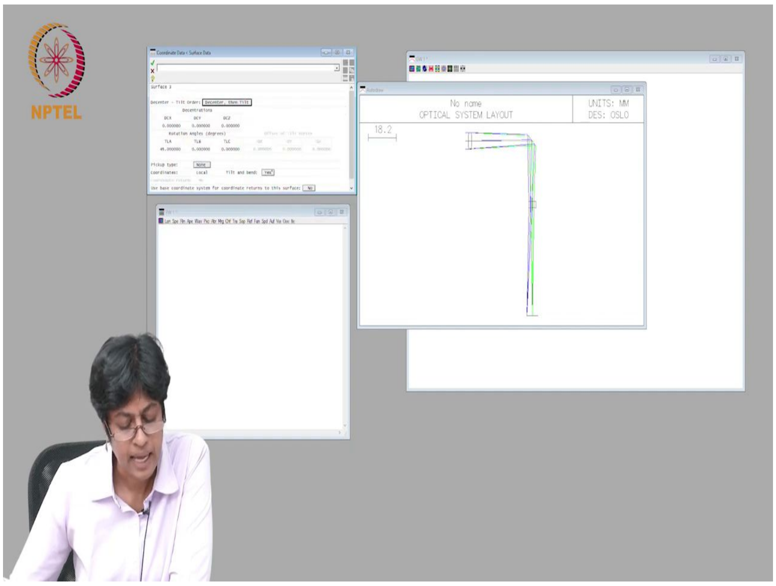

I have added a dummy surface. I have transferred the thickness and now I will go back to surface 3 coordinates and I will remove the tilt and bend ok. I still have a 45^{θ} angle over here and now one other difference I am going to say is that, change the coordinate return make it yes and I am going to say return to that surface 3 itself, but the untilted coordinates ok. Now since I have done that I am in the process of setting up my system this has the wrong location.

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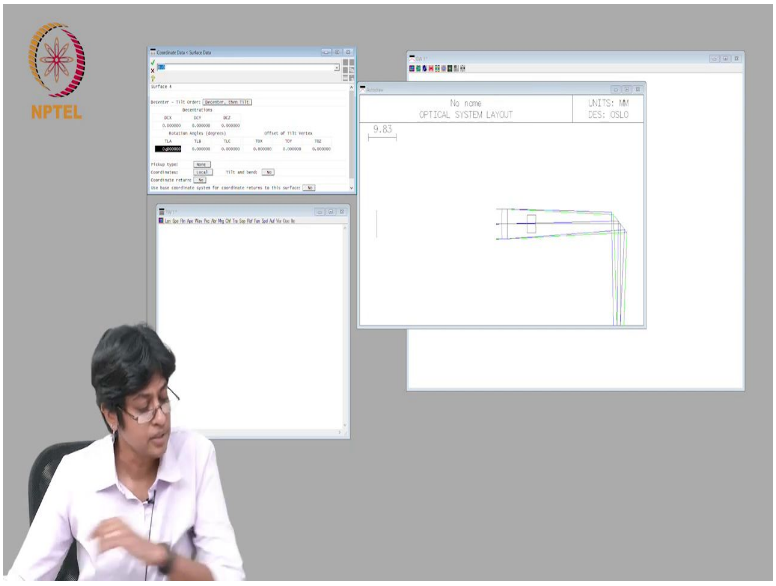

So, I am going to go now to the coordinates of surface 4 and give it a 90 degree tilt ok. Why because this is a 90^{θ} tilt with respect to the untitled coordinate system of surface 3 ok. So, if I would have had my elements like this, now I have an actual9 degree tilt ok. Surface 4 should be clear to you now surface 4 is linked to the untitled undisplaced coordinates of surface 3 right.

So, if I change surface 3, surface 4 continues to remain linked to the untitled undisplaced therefore, I can do anything to surface 3 now and it should not affect surface ok. This is where your famous last words and now I will tilt surface three and everything will go all over the place. So, let us see if it works.

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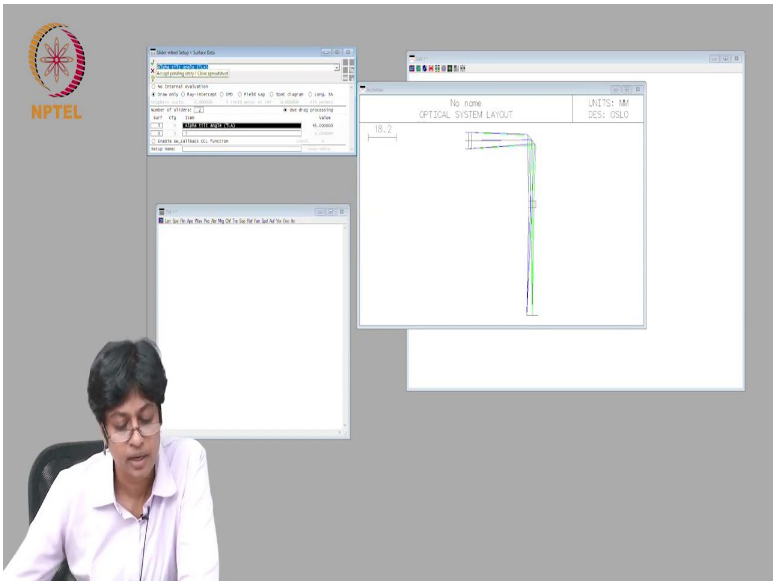

So, how do I want to do this tilting? I want to tilt the surface three best ways to put a slider wheel design, let us put surface 3. What is the parameter of interest is the tilt of surface 3 right.

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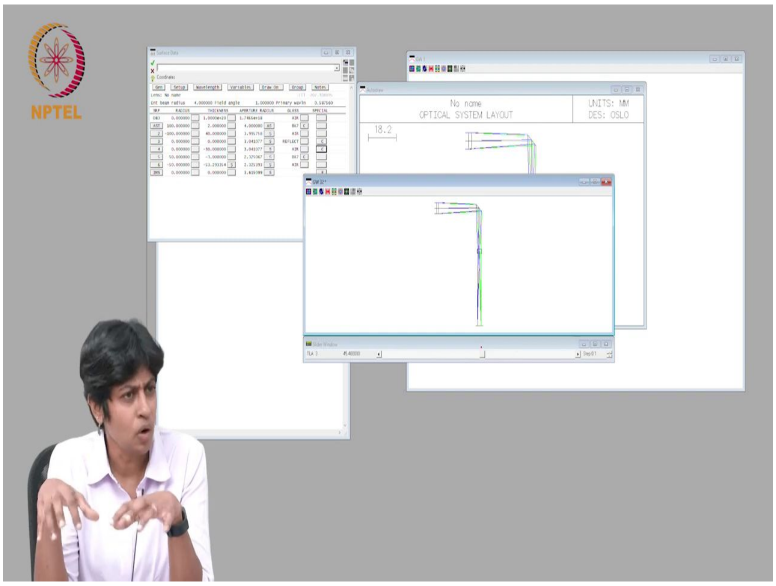

So, I now have a slider wheel and thank goodness. If I move surface 3 now you can see surface 4 is not changing right ok. This is more or less the exercise that you have to do in one of the exercises you have to work out for today’s class, but you can see the idea is how do I control tilt and how do not only control tilt, but control it independently of the other surfaces ok.

In this example all we have done is tilt, but of course, I could set it up so that I am doing the same thing for displacement. And if even if I move displace something surface 4 is not going to change its setup with respect to the untitled undisplaced coordinate system of surface 3 ok.

So, I hope with that brief introduction you have a better understanding of the coordinate systems available in OSLO right. And this is just a very brief introduction to a lot of different things you can do. And as I said in the document given to you for today's class, there are two methods by which to achieve this tilting without displacing or tilting the subsequent elements that is not to say those are the only two methods, you may come up with some other method it they; I mean there are depending on how you play around with all the different options available ok.

So, I would suggest there are again about two documents for you to go through today. So, please go through them and work through the different exercises. His question is why cannot I do the same thing without surface 4 and just say the surface after surface 3 returns to the untitled version of surface 3. If you did not have a mirror, you could do that easily because you have a mirror you also want to say do I tilt and bend or not there is an extra variable that comes into play there. You are right, you do not need the dummy surface if you were not having us. That surface that was being displaced or tilted was a mirror. If it was not a mirror then you would not need that.

You can try you there may be some combination that allows you to do that, but my intuition is that because you also are saying the light goes for 2θ I am giving θ, but the light goes 2 theta this extra variable is it makes it easier with the dummy surface to take all these different things into account.

But you do not need a dummy surface if you know in the example in the powerpoint. I had a sequence of elements and one element was moved out and the rest were back. There is no need of a dummy surface there then I will say just go back to the coordinate system of the undisplaced surface. The dummy where the surface is only because I am. I have a mirror here.