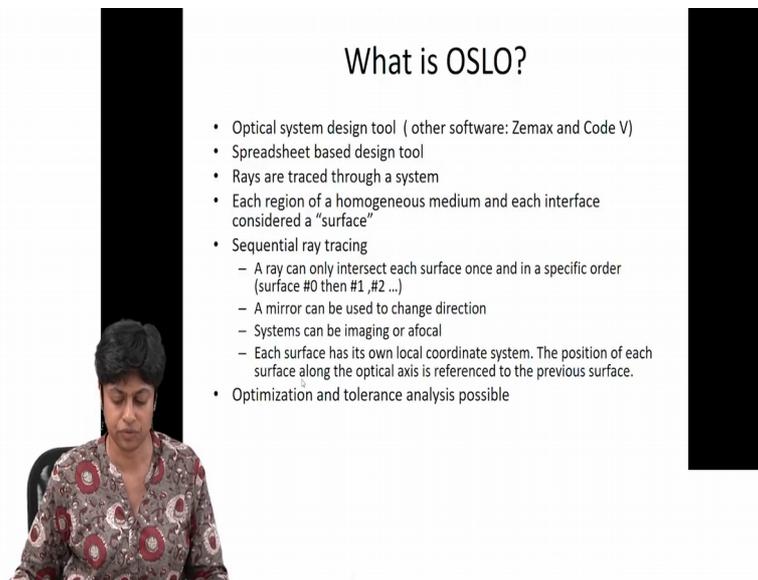**Optical Engineering**
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Lecture – 04
Lab 1 – Introduction to OSLO

So, welcome back, for the afternoon lab session. We are going to be working in this course on a simulation tool called OSLO right which is optic software for layout and optimization and for those of you who are on the online course we will be giving you instructions on where and how to download it. It is a free tool. So, there are different versions of the software and for this course we will be using the first version which is freely accessible to students. So, you need to download the educational version ok.

So, that is what I hope you have installed on your desktops ok. So, let us see how we go from here.

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So, it is an optical system design tool and there are other tools like this most commonly a tools called Zemax and Code V. So, you might so if you work in optics at all if you buy optical components from companies like Thorlabs and Melles Griot they may even have the optical designs of their systems and you can download those designs either in OSLO or in Zemax ok. It is a spreadsheet tool as you will see when we open the software. So, you enter

all the information as part of a spreadsheet. What the software allows you to do is to trace rays through the system.

Now, before the advent of computing and sophisticated computing power optical engineers optical systems have been around for centuries optical engineers have also been around and poor things have been painfully tracing rays manually doing through calculations. We learned how to do some of those calculations, but you are spared from actually having to do the manual calculation of those rays. But, earlier in order to figure out if a system was good or not you had to send a ray through it and see what happened to that ray.

Now, there is an infinite number of rays you can trace through a system. So, they had to pick very carefully which rays. So, you have to be intelligent about the choice of rays because manually tracing through a complicated system with many interfaces. We spent now half an hour going through two interfaces, a complicated system and today's world has many systems with 30 – 40 interfaces in them, 30 – 40 lenses in the right. The fact that we watch sports and you feel you are on the field with the sports player because you see the sweat trickling down it is because of they sophisticated zoom lens cameras which have maybe 30 lenses in them.

You have to trace rays through every single one of those elements. This tool is now doing that for us, but even here you had half the potential, you have the ability to say which other rays even though it can do it much faster than a person calculating it manually it still makes sense to say choose a particular ray and we will in this course see what do we mean by a particular ray, why are some rays better than others or some rays are better than others because they give us some information, but we must be cautious we must not think this ray has told us this is a good image point and therefore, believe it is the best image point for every ray ok.

So, the power of this software is it allows you to pick which ray you want to trace through the system. You can pick a number of rays to trace them through the system and observe their behavior at the image plane that allows you to decide is this a good optical system or not ok. So, you trace rays through the system. Now, how what is the system for this software? The system comprises of surfaces, the air is a surface. It is traveling through a medium of refractive index one.

So, you have to tell it every distance it travels through does this distance, this material I am traveling through does it have a certain refractive index? If so what the interface that the ray will finally arrive at? What is the curvature of that interface and then what is the refractive

index of the medium after that. So, this is how you will go through the software. It is sequential ray tracing; that means, in this software you cannot send a ray through the same surface more than once. In an actual optical system you could have a light ray go this way, reflect off a mirror and then travel back through all the elements again.

You can do that by replicating your optics, but you cannot send the same ray in this software back through the same surfaces, not directly ok. So, it is sequential ray tracing you can use mirrors to change direction, you can choose whether the system you are designing is an imaging a focal system or an afocal system – these terms will become clearer as we go along also you will spend the whole lab course learning about the coordinates of the system and you will understand why there are so many different coordinates we associate with all the surfaces of this system.

It is a very powerful tool because it is not just that you give it some input. You say here is a surface, this is the radius of curvature, this is the refractive index, here is another surface it is not that you just throw a lot of information and trace some rays, you can also do optimization. You can say I want the best focus to be at this location, calculate what is the radius of curvature that will give me that or where should the interface be placed such that I get this image here.

As we go along in the course you will see it is very hard to get a perfect image. We are working with spherical surfaces, rays are not always paraxial. So, you are going to have aberrations in your system. You can design or set up the software such that the program such that you say find the image where this particular aberration is minimum or optimize the curvature such that this particular aberration goes to 0 or becomes minimum. So, you can do a lot of optimization, you can do a lot of tolerance.

Say you have finally, done your optimization and you have come at what you believe is a very good system and you give it now to a manufacturer and say build this for me, make this lens, put it at this place, leave a gap, put another lens here.

Now, when a person is manufacturing they will always be manufacturing errors. The lens may be slightly tilted, it may be laterally out of position, it may be axially out of position. You can enter all these tolerance numbers and find out what is the quality of the image when there are all these errors that could come around when you actually assemble your optics and mechanics ok. So, you can do tolerance also.

We will not in this course cover programming, but there is you can write programs that are very similar to C language. So, you do not just use the spreadsheet, but you can actually write a program that makes it much more powerful, the kind of setups or systems that you can design ok. So, that option is also there.
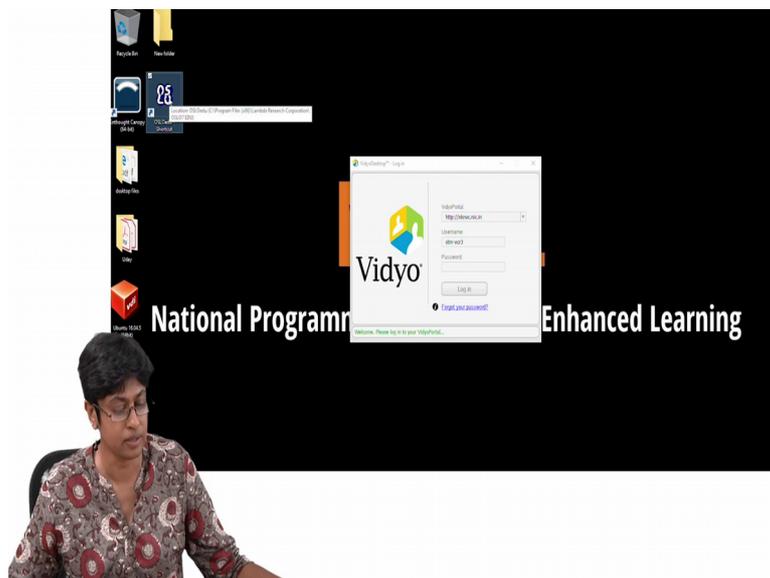
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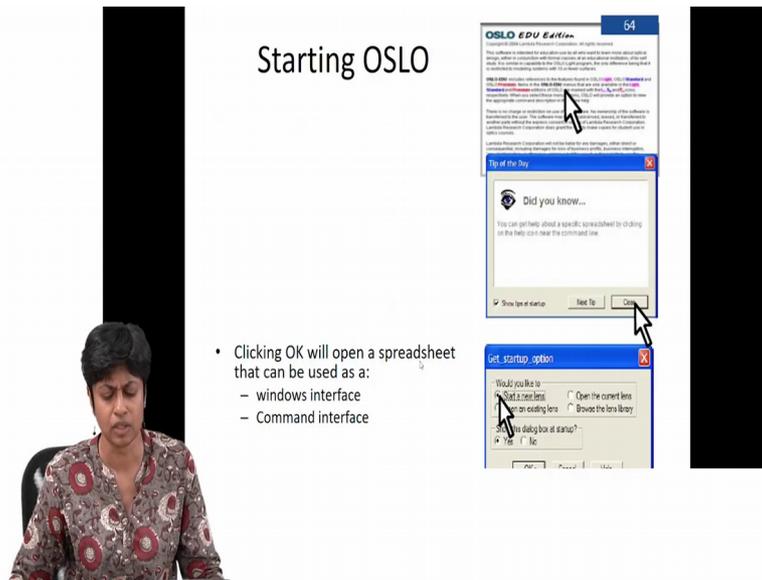
So, when you start OSLO and if you have your systems in front of you, I would say, do that now. So, remember when you are starting OSLO what you are doing is now let me just do this.

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So, this you will have this icon here.

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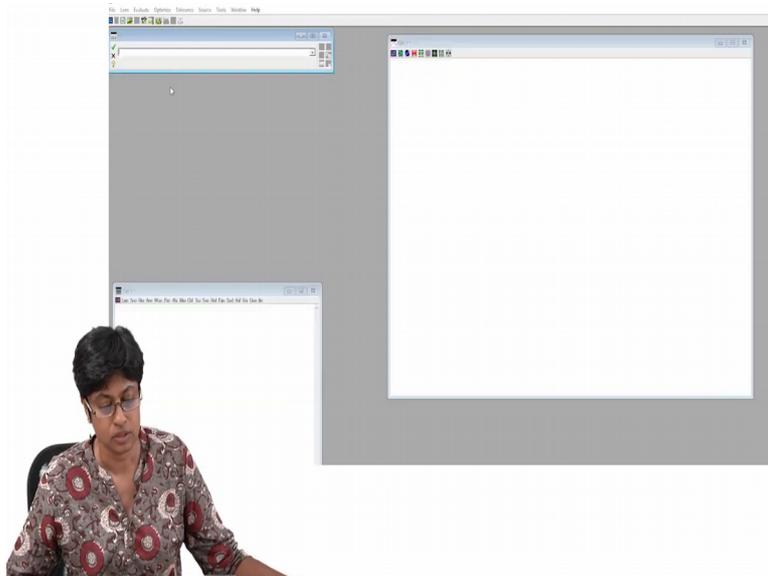
So, this is what you will get when you start OSLO right. So, please open it up if you have not already on your systems. You can see there are three main windows – there is this window here which you are going to see is your spreadsheet window.

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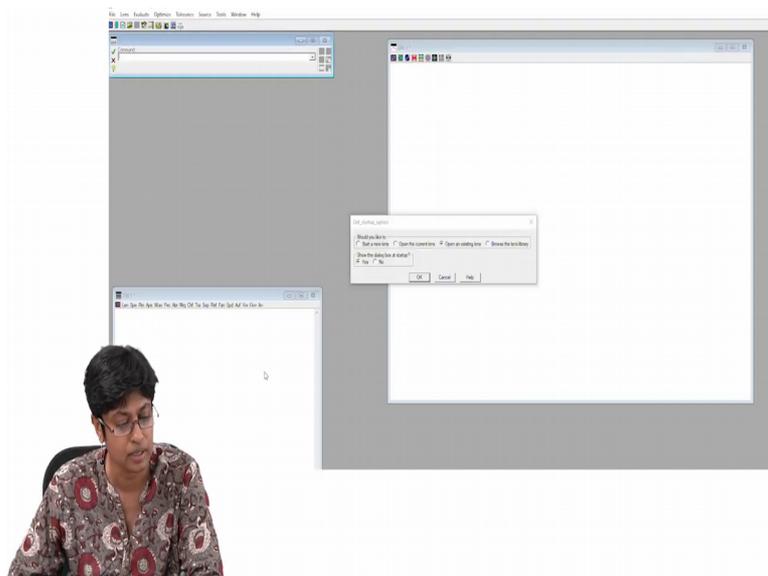
And, there is a text window down here and there is a graphics window down here onto the side here. So, you first get asked if you want to start a new lens or you want to pull out a lens that you have previously been working on or from their library.

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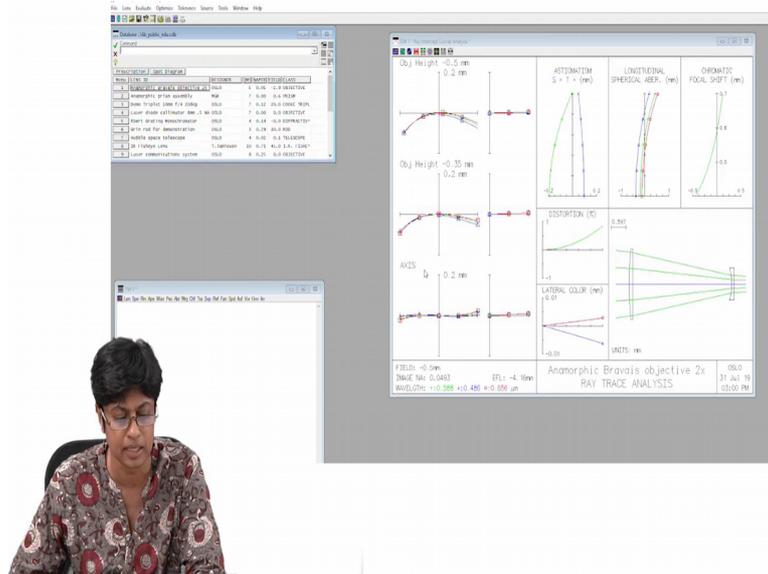
So, if I look at let us say browse the lens library, there is a list of options in the library.

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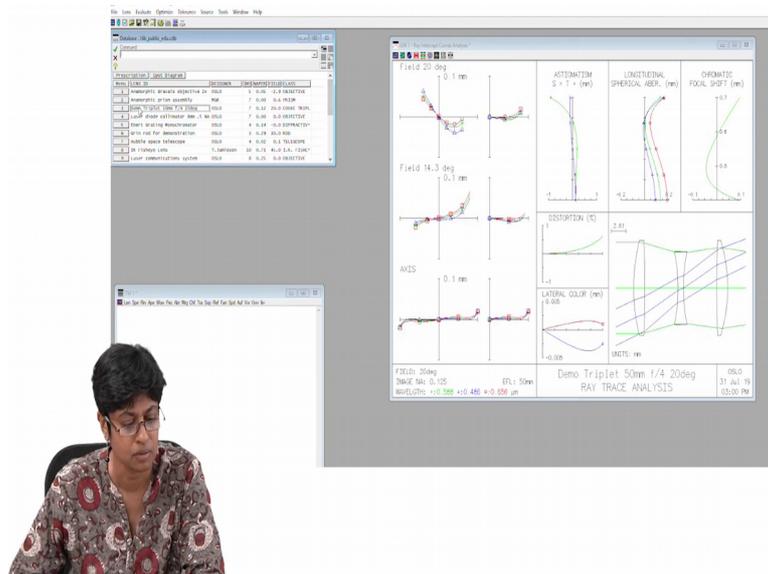
Let us take one particular one this green arrow is always what you use to accept something might that not work, yeah. So, there is my spreadsheet ok. So, this is why we call it a spreadsheet based software. So, you can see this spreadsheet now contains all the design. So, this is I pulled out something from the library. The actual design is shown in this small window over here. I can toggle that on and off with this Draw on and Draw off.

But, it was also shown in this larger graphics window here and you can see this particular system that I have picked it is called a triplet it consists of three lenses and you can see the three lenses over here. Now, it is three lenses, but there is the distance before the first interface that is one surface in OSLO, then you have the first interface, then you have a material off and the material is given here SK 16. So, that is the material or that is the glass that is being used. So, that is the material of this lens.

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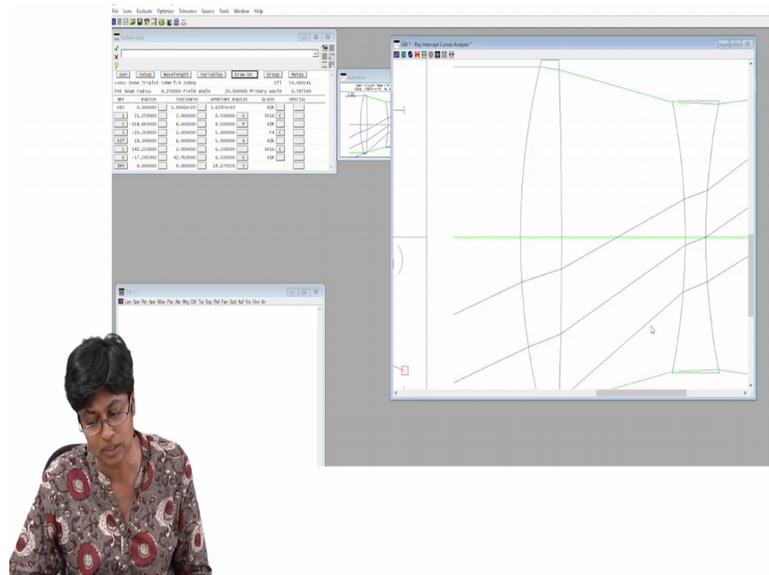
That material continues till the next interface which is here and then you have air again till this interface you have another material it is another glass type F4 and then you have the next interface you have air again and then you go back to the same glass type SK16 and you have two interfaces. So, you can see your spreadsheet actually has the object which is the default starting plane as I said always leftmost and then you have although it is a three-lens system it actually has seven rows counting the row where the image is counting the plain where the image is.

So, it is a three-lens system, but in order to describe the three lenses you need to take into account the distances in between. So, all together every this is counted as one, this is counted as one, this curvature, this medium is counted as one and so on ok. So, let me go back to the presentation. So, you might see something like this when you start and I clicked I did not click on start a new lens, I clicked on browse the lens library.

But, you can click on start a new lens and in this educational version of the software that we are using you will only be allowed to put in 10 surfaces that is the limit, but for everything we do in this course to learn the software that is more than enough. We do have a license for the premium version. So, if somebody needs to use it for something else, you can borrow the license from us and then there is no limit to the number of surfaces you can work with ok.

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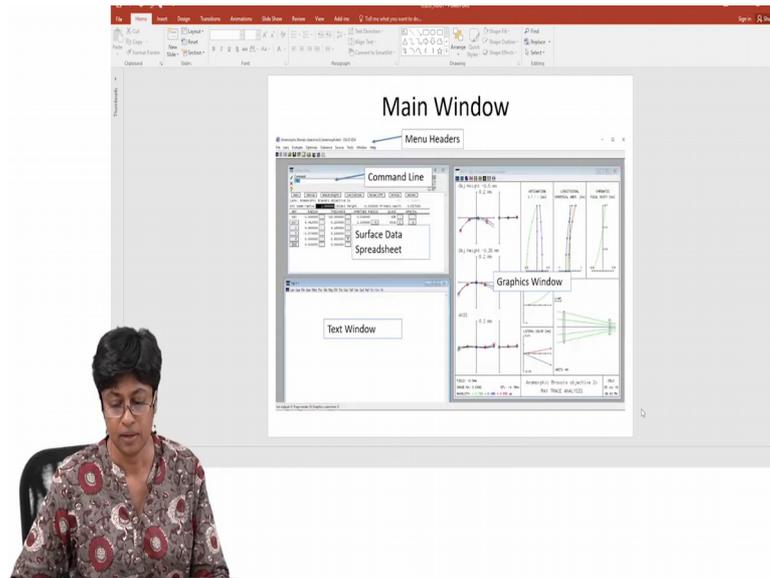
You already have seen this main window that opens up and like I said there are three main windows as part of this the spreadsheet window which contains surface data. You type in any command or information in the command line here so, I hope you are looking at this on your screens at the same time; the graphics window and you will come to understand what these different colorful curves mean, but at the lower right-hand corner this is actually the optical system that you have designed. So, this shows you the lenses or mirrors of your system.

And, this text window you can use the different menu choices here to give you information so, you have different radii of curvature. You can use these buttons here to get back the information or if you run some program or you do an iteration or an optimization all that information can be picked out from this text window ok. It will you it will become clearer as you go along.
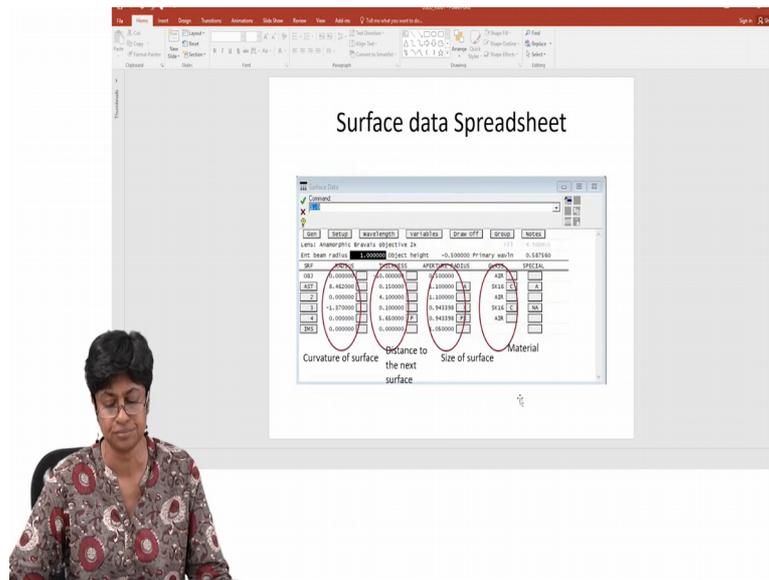
Let us look at that surface window in a little more detail ok. There are rows and columns. Each row is for one surface of the optical setup and each column therefore, gives me all of the information about every surface in that. So, what is the parameters of importance is the radius of curvature. So, we are talking about elements that have power, they bend the wave that is incident on them. So, they have some curvature that the radius of curvature is what is given in the first column.

So, in this particular design it is as you can see the lens name is given there it is an objective lens of 2X magnification there are four surfaces I am not counting the object plane and I am not counting the image plane. So, there are four surfaces and the first column gives you the radius of curvature of all of them. It is a bit unfortunate that for a planar surface a surface with no curvature you enter 0 here actually not mathematically correct, but if you want to have a planar surface you will enter the number 0 ok. So, that is why you see so many 0s in this first column.

The second column is called thickness, but really what it is if you say I have the lens of oh, it does not write on this ok. If you have a lens of a certain curvature and now this lens has a certain thickness say 2 millimeters I will enter in that row. So, let us look at the first row here I will talk about why he does not say the number 1 and it has the letters AST we will talk about that later, but that is the first row. It is radius of curvature is 8.462 and the thickness of

how much distance after that curvature is comprising of this glass material SK16 and it is given here is 0.15 ok. This is the thickness till the next interface.

The next interface is a planar interface. So, it has 0 and it is air after this and how much is air there are 4.1 millimeters of air after this ok. It is air till what? Till the next interface which is a glass of SK16 and the radius of curvature of that glass is minus 1.37 ok. So, I will enter the radius of curvature of a particular surface in the first column, I will enter what how much does that continue that material continue the thickness it is called thickness we would think of it as distance in the next column; do not worry too much about aperture radius. This is to do with the size of the lens; so that I can have a lens of this size or lens of this size or lens of this size it is different from the curvature of the lens.

So, aperture radius is the radius corresponding to the dimension or the size of your optical element; the next column gives you the material that you are using. Let us say I put in a this a radius of curvature 50 and the second surface has a radius of curvature minus 50. Now, I have I do not see anything in this window, I am not sure why these graphics windows not working. Do not worry about it.

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Just look at this window for the time being. I do not see anything here and that is because though I have changed radius of curvature, I have not changed material anywhere. So, this system has no power, there is no refractive index anywhere right. It is I have a radius of curvature and I have air and I have air, nothing is going to happen. For something to happen

there is to be an interface; that means, I have to be a change in material ok. So, I can go to this and I can either go to the catalog, these are the list of actual catalogues of companies that provide glasses right. So, you might have heard of Corning for example, they supply different types of glasses.

So, I can go into any one of these catalogs and pull out a glass type I am going to just enter BK7 which is a very commonly used glass type. It has pulled it out from the catalog which is why this little c comes over here ok. The moment I do this you see something happened in my graphics window because now there is a change in material. But, I have not told OSLO how to look at anything yet. So, it is still not giving me a lot of information.

To make this a little clearer let us give this lens some thickness and actually OSLO is still not looking at the last image plane which is this last row over here. So, I am going to go to this last column and force it to look at that image plane ok.
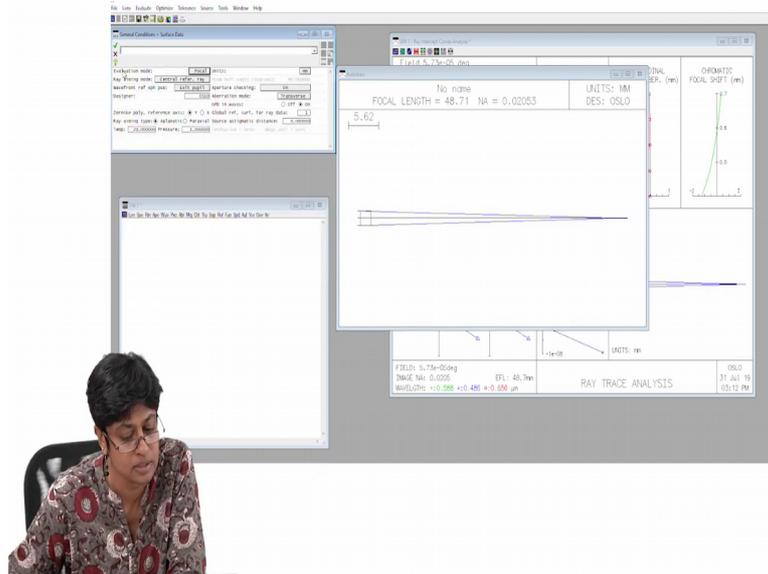
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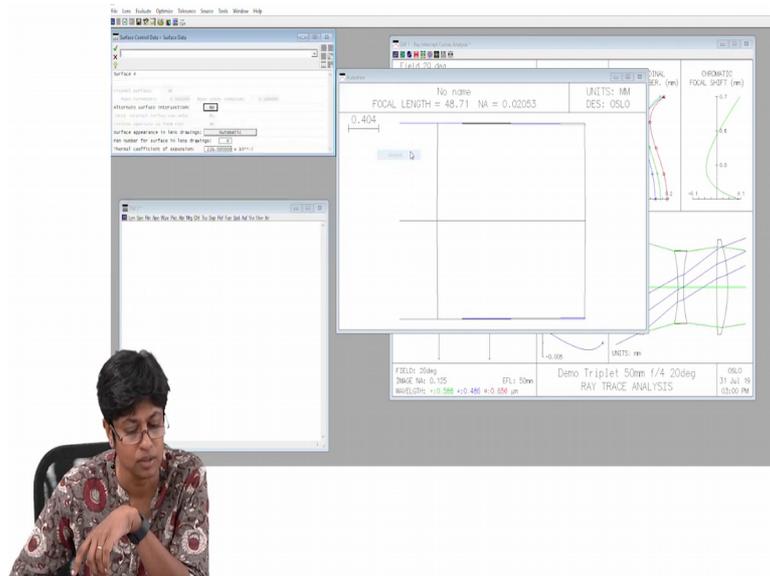
So, it is a SPECIAL column, Surface Control, General and I will say it is not Automatic, I want this plane Drawn and I will accept this. Now, the image plane why has nothing happened after I made that change? The software does not know where you want to look at the image, you might have a beam of light that is coming you have a lens and this beam is getting focused to a point. Now, in our mind the image plane is where that point is, but it is possible you want to look at some plane in between. So, the image plane to the software is where you tell it the image plane is.

So, it does not automatically go to a focus point because it could be you have very bad design and it is not even clear what is the focal point where that occurs plus it depends on what you are doing with the design. You this software is very powerful, it allows you to look at the rays anywhere. So, you need to tell it where to look at the rays ok. So, I am going to carry out an operation now, do not we will talk about this operation in detail later.

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I am forcing it now to enter a distance that is where the focus is happening. I have an extra row here. So, I am just going to delete it. You can see these operations are very standard for any spreadsheet that we use. So, now, in this graphics window I am still not sure why this is not updating yeah ok. Now, it is updated ok. So, maybe we can well let us look at this to start with. You can see that you have made a lens, its incident light is coming from very far away from this distance this.

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So, the distance is if you can see if I press this General button over here it I can set what are the units. So, the units are by default millimeter, but I could change that if I wanted to. So, let us leave it as a millimeter. I am in designing a system that is focal. I am looking at imaging; I want the beam to focus. So, that is I otherwise I could choose a focal, but let it b focal and let us just say this is first class right. The entrance beam radius is just 1 millimeter. We will come to what this field angle is, you can see it is a small angle. Basically, I am tracing an on-axis ray, there is no angle right.

And, you can see that it is focusing what is focusing the first surface has radius of 50 millimeters, the second surface is minus 50, the thickness of this lens is 2 millimeters and the material I have used is something called BK7 ok. I can change this. Let us say I make this minus 100 and now you see that the distance at where the focus is happening has changed. It was 48 millimeters then I have reduced the power of this lens and therefore, the distance has increased. It was focusing closer because I have reduced the power of the lens the focus point is happening further away.

The best way to learn the software is to open it up and play around with it, as you can see it because it is this spreadsheet-based it is quite you should be quite familiar with it ok.
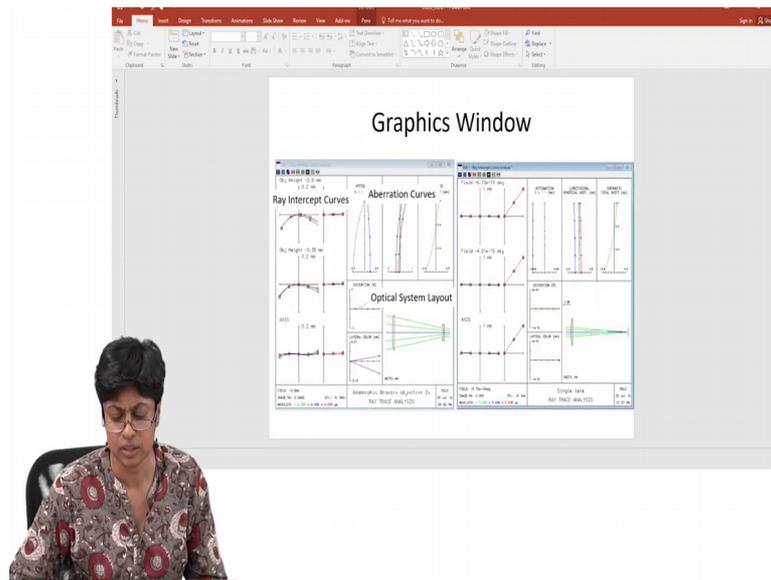
So, let us just run through this. I have two sets of graphics windows taken from two different designs. This design is for a focal design. So, if you look at the optical system here it comprises two lenses, but you can see the light after the second lens is not getting focused, but it is coming out as a parallel beam of rays and in the second system you can see it is getting focused over here. These are the curves all these curves they you will over time begin to understand what they mean they tell you about the aberrations of the system and thereby tell you the quality of your system.

You have different types of aberrations. It could be how bad is the system when I send different wavelengths of light. So, what is the chromatic aberration or how that is the system because it is a spherical surface and not some other surface right? So, all these curves together will tell you about all the different aberration or the effect of all the different aberrations and analyzing these will allow you to decide do can I stop my design now have I reached something satisfactory or no these curves show me there is still a lot of aberration I need to redesign or reoptimize my design.

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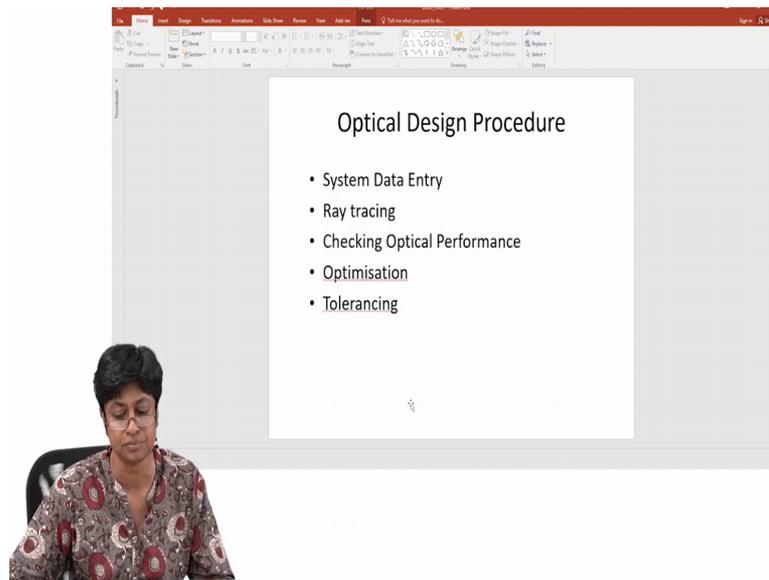
You need to as I said you need to enter data, carry out the ray tracing, check the performance. One way of checking is to look at those graphical windows and the curves there, do your optimization and in this course we would not do tolerancing, but if you were using this for manufacturing purposes you would also do tolerance.

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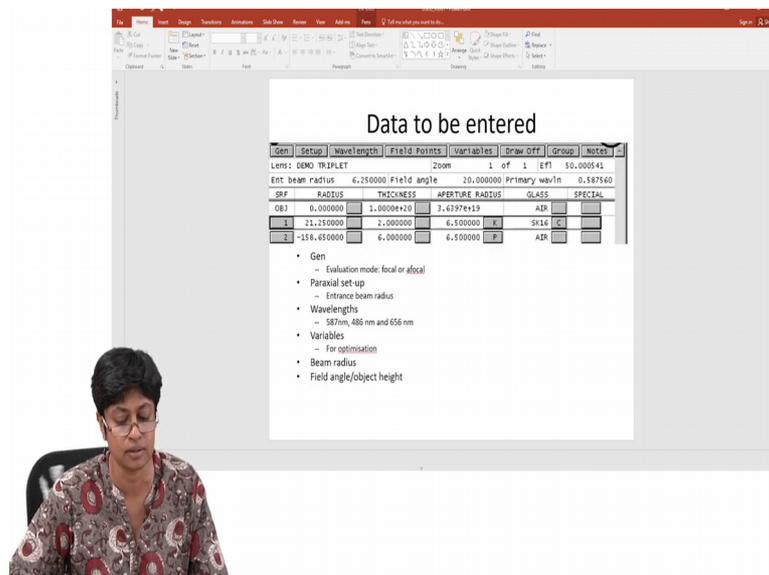
Again, this is your spreadsheet and we have already run through some of these when I showed you in the software, but you will have to go maybe into the general mode and check whether you want to do a focal or an a focal system. If for some reason you wanted to change

units you would have to do that. Units by default are millimeters except for wavelengths; wavelengths are always in nanometers. Again, the system is set by default to these three visible wavelengths with the prime wavelength being this if you are going to work at some other wavelengths you would have to change that. You have to always enter the beam radius and the field angle.

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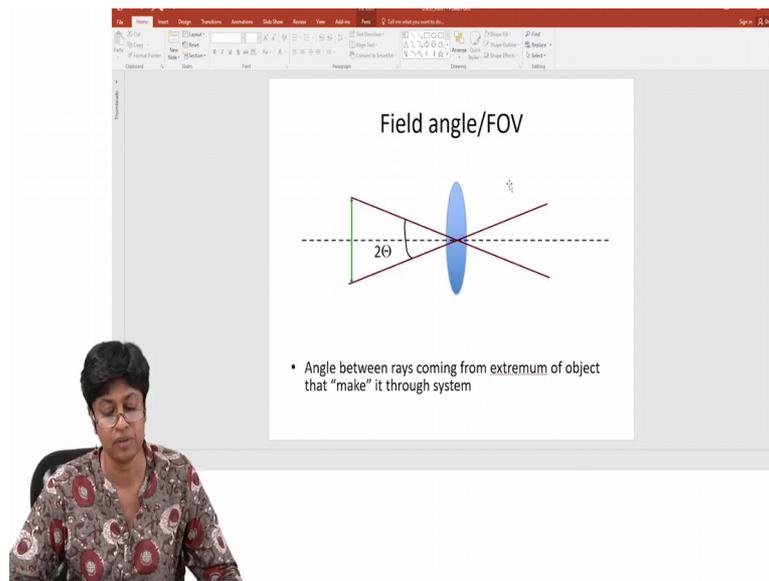
And, by field angle this is what we mean. What are the rays coming from the extremum of the object and that is 2 theta what you enter is half that angle ok. There is a lot more that you need to know, but for the first class this is a good introduction. So, I hope that you have exercise sheets with you.

So, you can now start following the instructions and do the first two exercises. They are very simple based on what we have learned in the last two classes. The first exercise is just to demonstrate Snell's law and the second exercise is to design a simple lens and change the object position and look at what happens to the image and where the image is formed.