Optical Engineering
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Lecture - 19
OSLO

Good afternoon. So, we are here for the 4th lab, and we continue with OSLO. And as you have seen, the labs have been structured such that, whatever you are learning in class you get to test out and practice in the lab. So, this one is no different.

Today, you will be working out with aberrations. So, the sheet that has been given to you has several exercises, the first one is to familiarize you with spherical aberration, then there is an exercise on coma, there is a third exercise on astigmatism which you do not need to do in today's class since we have not yet gone over the theory. So, you will need to do the first two exercises, with the and then do the final exercise which is plotting coma and spherical aberration against the shape of the lens to get a graph like we saw in the earlier class, ok.

So, I just want to now, now that you have a little more knowledge of aberrations. I want to go and look at those curves that we have been seeing and just get a better idea of them.

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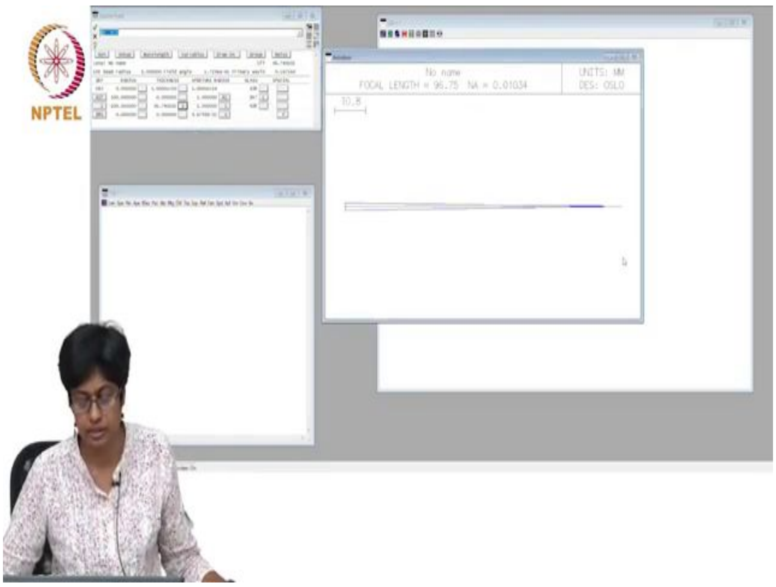

So, I am going to use a simple lens. So, and I am not, for this exercise I am not bothered about what the focal length is.

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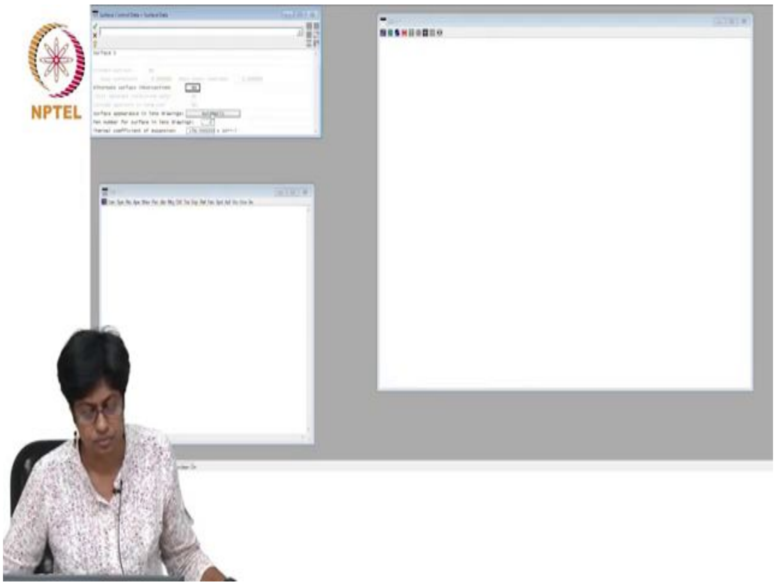

And we will take the axial ray height to be 0. So, right now this is a graphical window output and you can look at various parameters of various outputs if you will. So, of course, there is one where you just look at what are the optics in your system. In this case I just have one lens, so you do not see very much.

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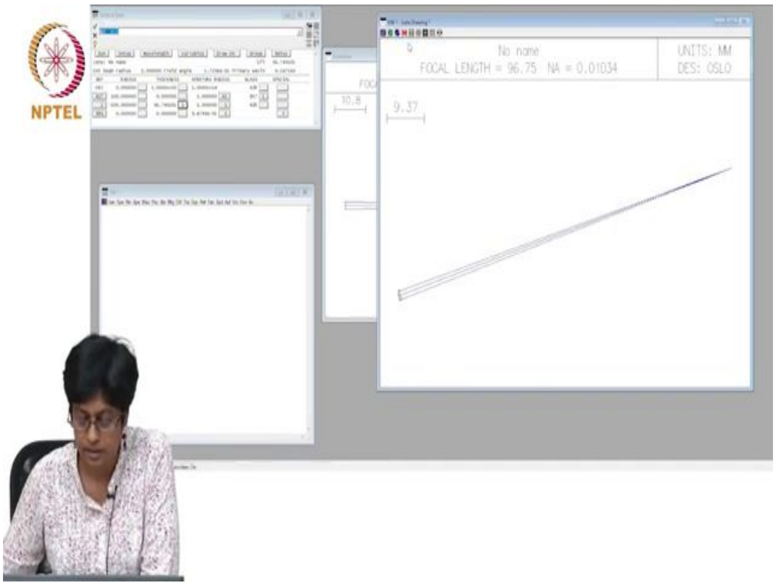

You could look at it in 3D. Again with the single lens it does not tell you very much.

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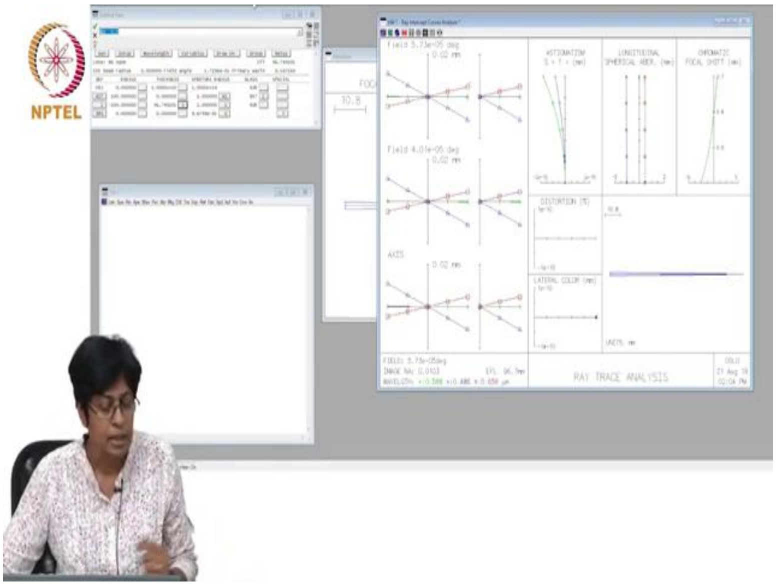

What we have been looking at is these aberration curves and now they should start to make a little more sense to you. What is on the left panel here are the ray intercept curves and as I said they do not tell you anything about the axes. The overall heading of this window right now says ray intercept curves, but please note these are actually the longitudinal aberrations over here. These are not ray interceptor curves, ok. So, the ray intercept curves are actually everything on the left panel. There are 6 curves here. What do you think these 6 curves mean? I mean you have headings. So, you can read the headings and tell me. And actually is there any difference in these 6 curves?

Student: (Refer Time: 03:33).

So, if I take one curve you can see 3 different colored lines and those 3 colored lines ripple are representative of the 3 wavelengths of your system. So, these are the 3 default wavelengths in the visible region, and I have been color coded according to the color blue, red, green. So, in each graph you see those 3 colors. So, those are for the 3 wavelengths. And you can already see this chromatic aberration because the fact you see it as 3 different lines means each wavelength is doing something different. So, that is chromatic aberration straight off, right.

But apart from that you have 6 curves over here, right. Now, if you look at the panel as it is now these rows, so these two are identical to the two below and are identical to the ones below that is because currently our field angle is 0 and each row here is actually plotted for a different value of angle. So, the lowest one is the on axis curve, and right now these are identical the upper two identical because everything is on axis.

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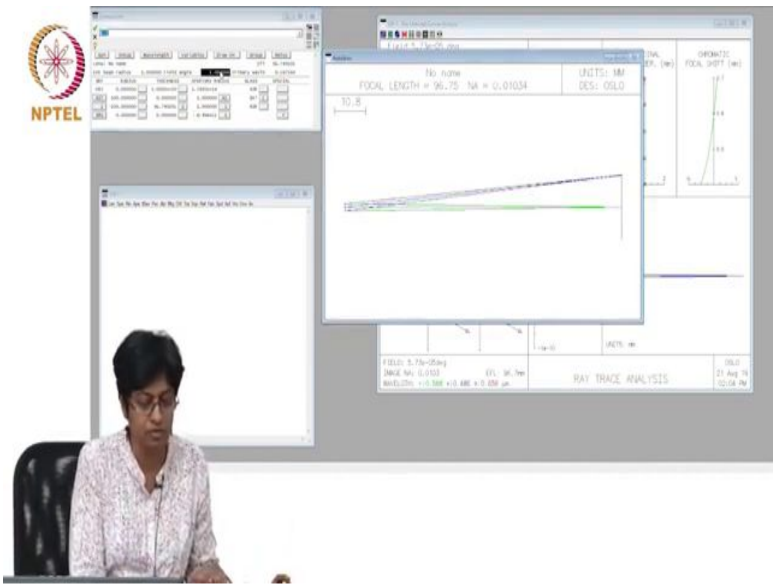

If I go and change the field angle, so this val number that OSLO is using is indicative of 0, if I go and give it a value let us say I give it 5 degrees you can now clearly see that the where the chief ray is going.

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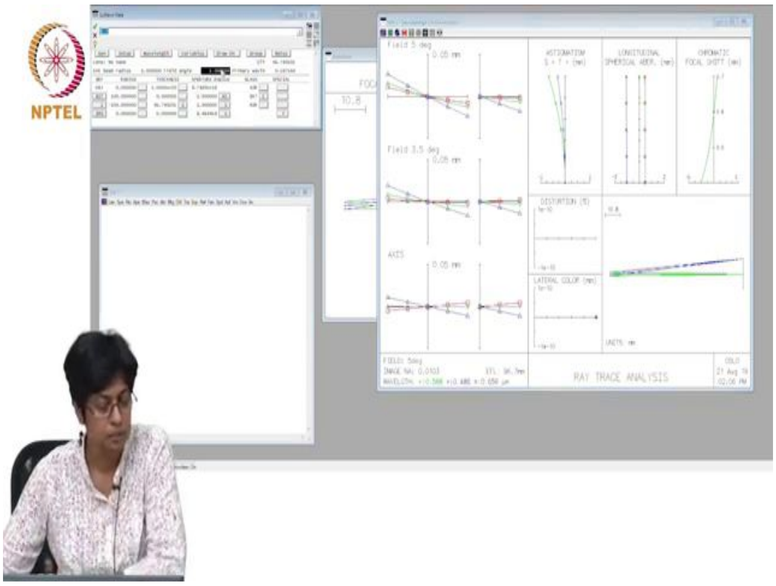

Now, if you come here and re plot these you should see a difference, ok. So, the magnitude here is slightly increasing as you go to the higher curves, and why is that? This is plotted for the rays that are coming on axis. The next one is plotted for the rays that are coming at 0.7 of the maximum field angle, which is 3.5 degrees in this case because we have chosen a field angle of 5 degrees and this is plotted at the maximum of the field angle, right. And I can go and make it more dramatic.

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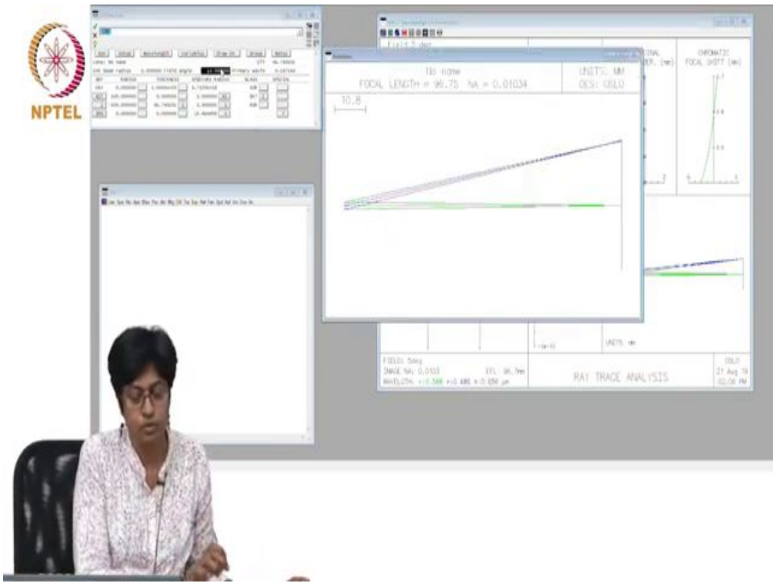

If you change the field angle even more, you can see that at 10 degrees you have much more aberration here than you have over here.

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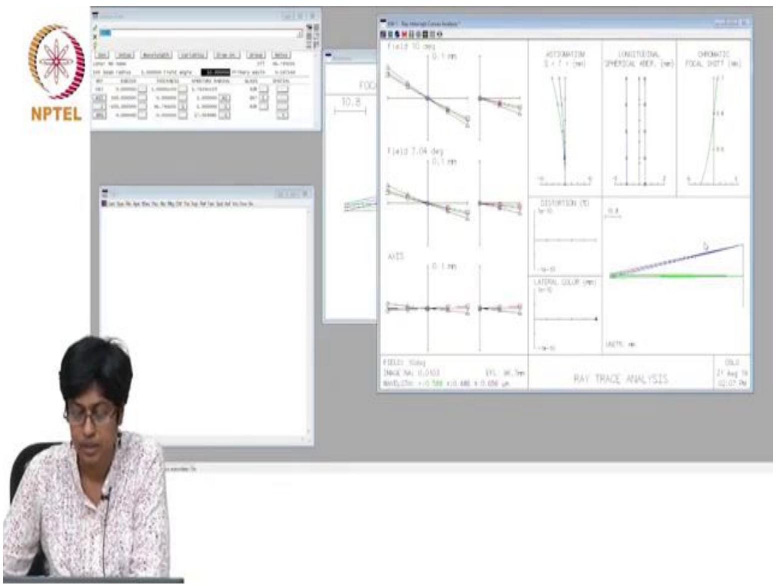

Now, I pointed this out earlier, but just to remind you, every time I re-plotted the graphs get plotted with a different scale and the scale is chosen to what best suits the values that have been generated. But saying you wanted to do a comparison and you plotted something and you got a certain scale, and then you wanted to change something and compare the graphs clearly you would want the scale to be the same.

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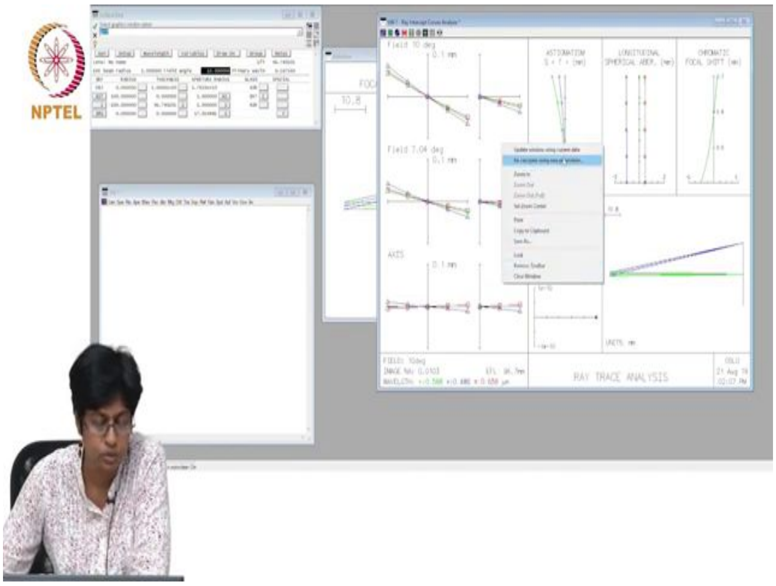

So, you can always right click and say re-calculate using new parameters and you can put in the scale here, right.

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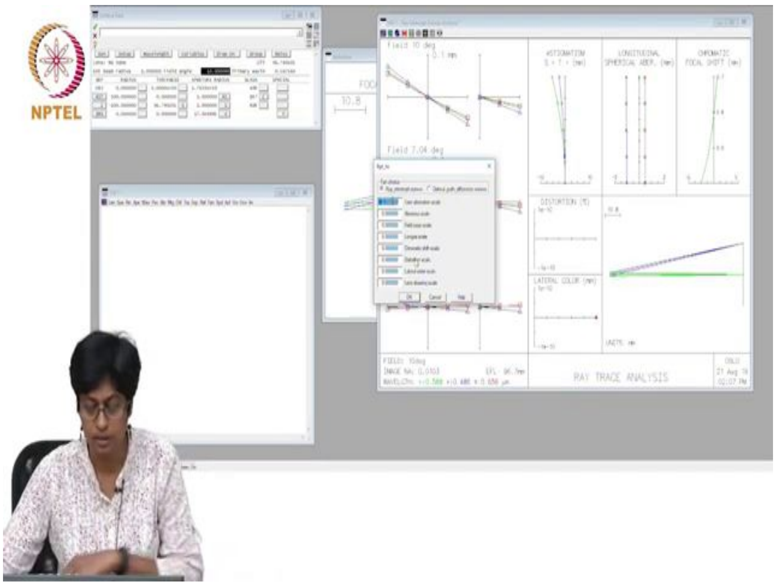

So, you could put in 0.05 let us say.

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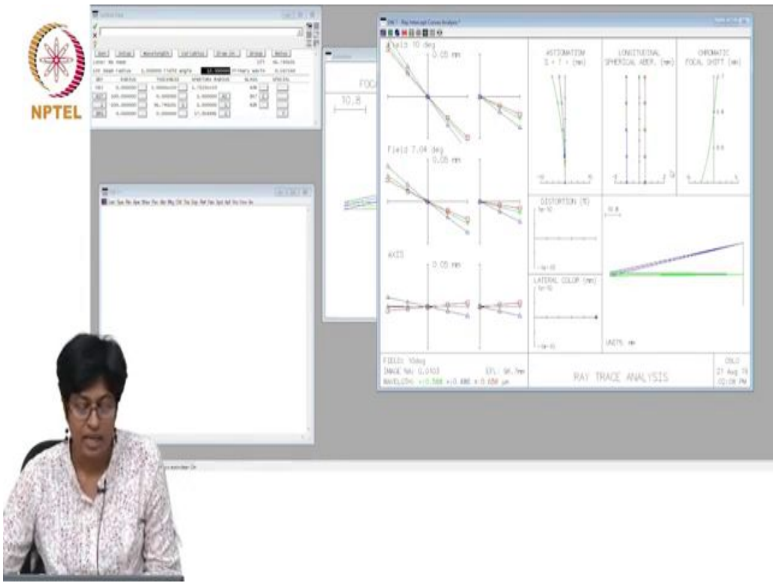

And this and then it plots it with that scale, and so you force it to have a certain scale and that you need to do that if you are generating a number of graphs and then you want to compare, ok.

So, these are your ray intercept curves, each color for each wavelength, each row is 4 ray coming in at a different angle, but I still have 6 of these. Why do I have 6 of these? What is this column and what is this column? No idea. So, the first column is actually the rays; you must think that we are plotting rays, we are plotting rays coming at different angles, but do we just say ray now you should not just say ray you should be asking which ray are we plotting.

And this column is the meridional rays and this column is the sagittal rays, ok. And I want you to go and wonder why and then tell me why for the meridional rays I plot the entire x axis, but for the sagittal I only plot half, ok. I am only plotting half the axis and I stop it. So, you need to tell me why that is, ok. I leave that to you to ponder over, ok.

So, this whole column or this panel here was the ray intercept curves. The upper 3 graphs are now giving you the longitudinal errors; this is. So, this y axis is ray height, these two are ray height and the x axis in the case of the curve labeled astigmatism and the one label longitudinal spherical aberration they are giving you the actual error. So, if you look at longitudinal spherical aberration, you can see that one of the wavelengths has very less aberration, right, but the other ones have more aberration. But if I look at this graph the green for a ray of any height the error is 0. So, this system has been optimized for that wavelength.

Now, if I go to the blue wavelength all the rays have the same focal point, right, but that focal point is not the same as the focal point of the green light, right and similarly for the red. So, the spherical aberration of this system is quite small, it exists but it is quite small, right. And in a stigmatism again we will talk about this in more detail when we actually do astigmatism. Here the chromatic focal shift, the y axis is actually color wavelength and the x axis is giving you the average, ok. So, I hope these graphs now make a little more sense to you. We will not worry about the other two distortions and lateral color we will come to later, yeah.

So, what I wanted to show you was this was what, this graphical window is the one window you might have looked at over the last few weeks, but in today’s exercise you are going to also look at this spot diagram window.

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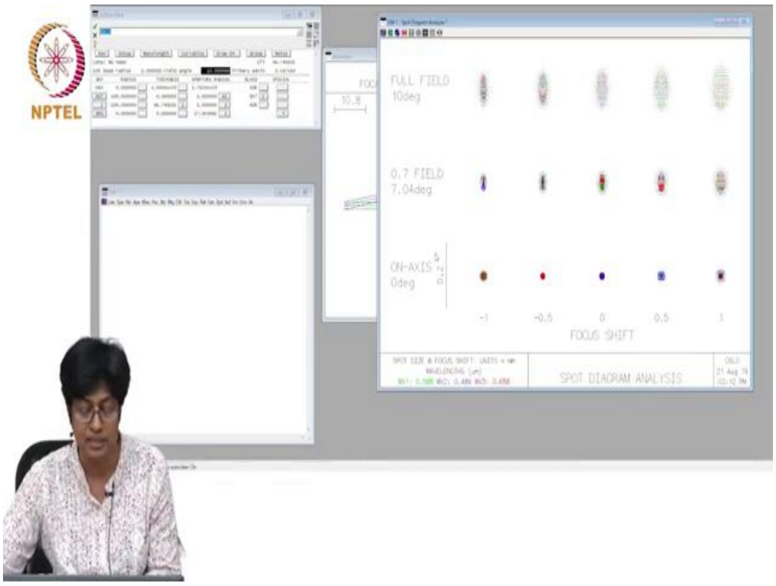

Now, this window tells you this is the image plane whatever you have decided is the image plane and this gives you a cross-section of all the rays that are crossing that plane. So, each individual diagram is one image. So, they have cascaded or put these together as a ray. So, if I look at this image over here, this is the image of the on axis rays at the paraxial image point, ok. These are the rays intercepting the paraxial plane, where it is still the paraxial plane, but it is now for the rays coming in at 0.7 of the field and these are for the rays coming in at the full field, ok.

Student: (Refer Time: 11:17).

So, we have given in this particular example, I right now set the field angle at 10 degrees. So, I can trace the on axis rays, I can trace rays with any angle between 0 and 10 degrees. So, in OSLO by default they will pick trace 3 sets of rays for you one 0 degrees, one at 0.7 of the field, and one at the full field, ok. So, the upper row are all the rays resting for the full field coming in at 10 degrees, the middle row are the ones at 0.7 of the field, and the first row on the lowest row are the on axis rays, ok. So, that is each row. But the middle column is the one that has been taken at the paraxial image plane.

But I could move my image plane a little before the paraxial and that is what this column is, its 0.5 millimeters before the paraxial, this is 1 millimeter before the paraxial, and similarly this column is 0.5 millimeters after the paraxial plane, this is 1 millimeter after the paraxial plane. So, it is like, if you are looking at the on axis rays at the paraxial plane you would see this as your spot. And you can see from all these spots here this is the smallest spot, so this is the best, clearly is the best focus.

Now, see if you are building a system and by mistake maybe there is an error in the manufacturing process and the sensor or the image screen instead of being put at that perfect plane gets put 0.5 millimeters in front. This is how the spot would look, right. And you can actually see here, although I said this is the perfect spot you can actually see this looks a little better. There is some spherical aberration in this system. So, actually moving away, where the circle of list comes fusion is where you will have the best focus.

If you move 1 millimeter, where you start to see the image decrease further. This is how it looks if everything is on an axis. But if you look at the full field you can see how widely spread the spots are. And the scale here is this, this is the scale, this is 0.2 millimeters.

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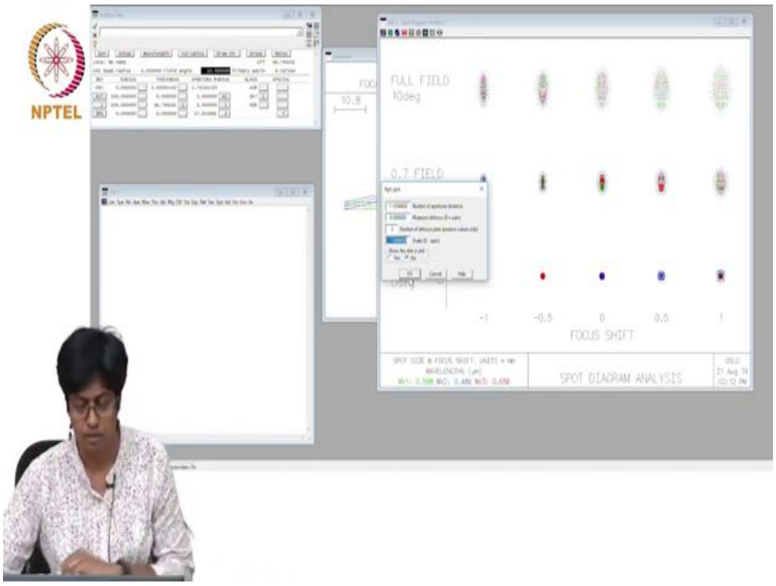

I mean I could re-plot this with let us say I made it 1 millimeter, right.

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So, I will come to that.

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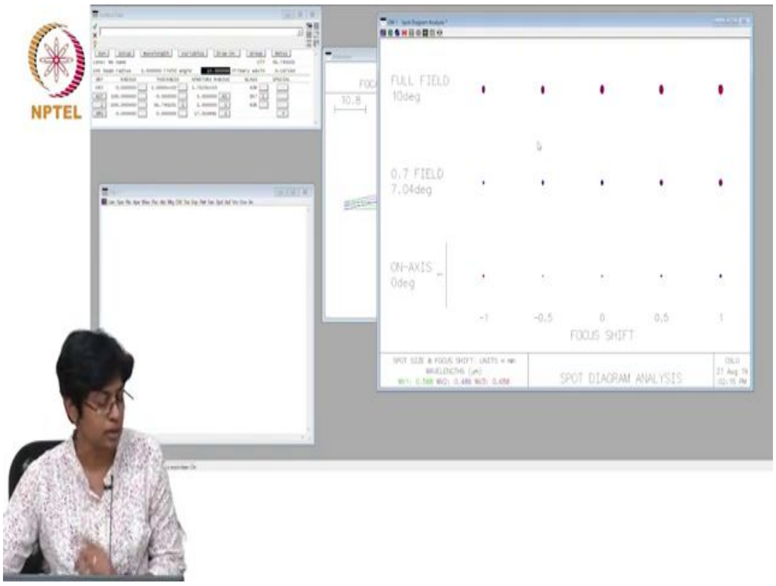

If I make the scale 1 millimeter, you can say it looks so much better because now I have looked at it with a much larger scale. So, it has been magnified in that case. So, that you see it emphasizes the difference between the different points. So, I want, you will in today's exercise use the spot diagram; because it very quickly tells you how good your system is or not.

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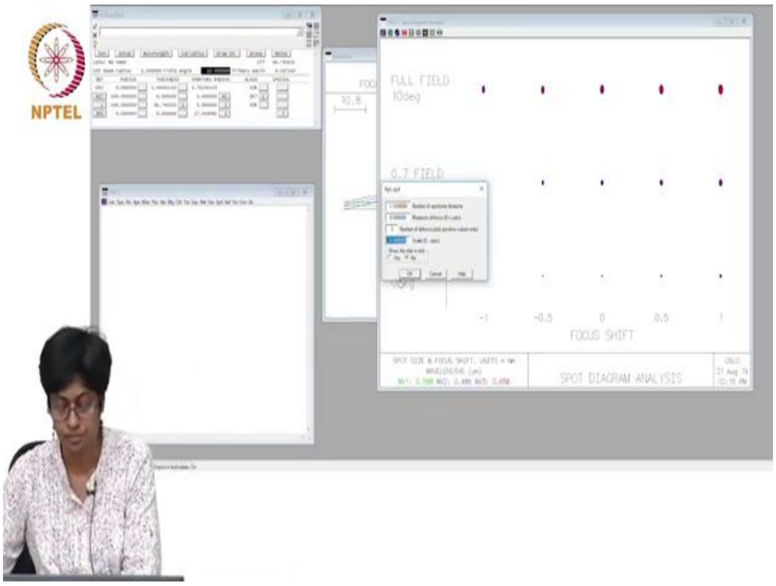

And let us just re-calculate this with a smaller scale, so that you can see the difference, ok.

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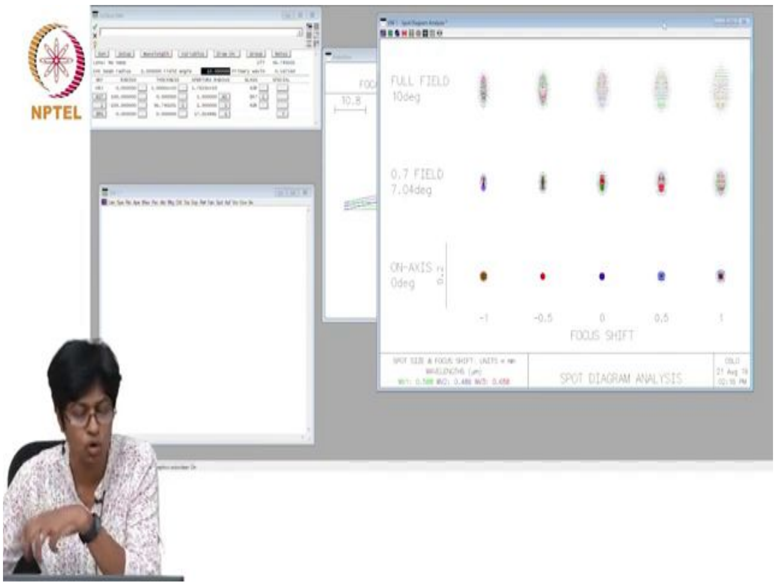

And you can see what is happening here is there more or less symmetrical behavior. It is not completely symmetrical behavior, but it's more or less symmetrical behavior. And you should start looking at these now and you know compare the spot diagram you get in the case of spherical aberration with the one you get for coma and later on with the other aberrations; because looking at these you will start understanding what kind of aberration you have just by the shape and form of these spot diagrams or the aberration curves, ok.

Any questions? In that case, you can start the exercise. And we are choosing we cannot consider say 17 degrees to be only as a system with only paraxial rays. We are including these higher angles because the idea of the exercise is to bring in coma and coma is an axis aberration. So, if I have only one access point you are not really going to see a coma. So, the systems that we are looking at from today onwards do have larger angles than what you have looked at before, and that is specifically to bring in these off axis, large off axis rays, ok. So, you can start the exercise.