Electron Diffraction and Imaging
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Lecture – 15
Kikuchi Diffraction

Welcome you all to this course on electron diffraction and imaging. In the last class we discussed about the property of a lens how it gives raise to diffraction as well as imaging from the same region of the sample right both the information we can obtain about the sample then mention the also about different types of diffraction modes one is a parallel diffraction that is what we normally do in a diffraction beam where a coherent beam of parallel beam we have be use a parallel beam we say that its a plane wave when we use a wave concept to describe it a plane wave is falling onto the sample surface and then we look at the diffraction difference phenomenon which is occurring that is what the conventional diffraction is all about.

Today what we will do it is that I will just mention the little bit about the parallel diffraction and then we will discuss a little bit about the other 2 types of diffraction are there convergent as well as divergent beam diffraction.

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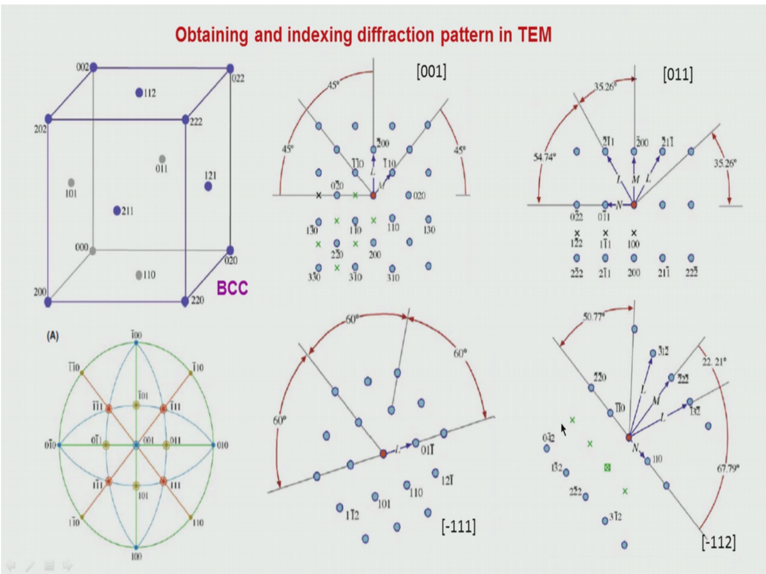

You have studied this concept of reciprocal lattice correct this is a b c c lattice for which a reciprocal lattice is given the property of a cubic lattice is that the plain normal and the direction have got the same indices correct that is only for cubic. So, that is why I have just taken this if you assume that the beam is falling in this direction then what will happen is that for a electron diffraction since the beam energy is very high or the wavelength is very small and the Bragg angle is small less than one degree the almost all the plains which are parallel to the beam direction will give raise to because here these vectors are reciprocal lattice vectors which are perpendicular to the diffraction plane. So, the reciprocal lattice plane this plane if we consider it is the one which will give raise to all the diffraction spots as far as electron diffraction is concerned that is right is it clear.

So, for 001, if we consider then if say this is the origin this reflection will come 0 to 020 will come 220 reflections will come all these reflections will come we can choose any direction and find out the reciprocal lattice plane which is perpendicular to it and that is the one which is going to be the diffraction pattern we get it in a transmission electron microscope, but we till the sample we the same region it may be a single crystal when we tilt it we are looking for the diffractions pattern from different direction, but then when we index it, we should index it in such a way that there is a consistency is there in the indexing and how will the diffraction pattern will appear in the electron microscope also when we do a tilting from one direction to the other that is what I will just describe it now.

The another aspect which I said that to indexed the diffraction pattern I mentioned that we can use stereographic projection how do we use the stereographic, here if you see it this stereographic projection the same direction which we mentioned 001 direction the beam is falling this is for the cubic system stereographic projection what is the information which it gives all the angular relationship between the planes which is being given, but then we have to apply the appropriate structure factor rules extension rules to identify which are the reflections will come that is between 100 and 010 plane or between 200 and 020 plane the angle remains that same right angular relationship does not change at all. So, this reciprocal lattice section is being shown here if you look at this section this is the origin this is the 200 where is reciprocal lattice vector this is the 020 these are all the others which are indexed this is how a diffraction pattern will look like in the electron microscope.

These are all the possession spots will come and here the angular relationship bit is being maintained that is mentioned that between 200 and 110 its 45 degree 020 and this angle is also 45 degree that is what is being done.

You look at this stereographic projection this stereographic projection if you look at it from here to here this is 100 direction correct 100 of comes here and if this is the vector corresponding to that parallel to each then 010 or the 020 should come in this 90 degree away from it that is what essentially happens and the indexing can be done from here to here to here in the same way if you go from this vector you can index all the diffraction spots correctly you understand that is it clear suppose you assume that we are tilting the sample and going to 011. So, on then what will happen then you have to if we try to use this we have to imagine how it is going to be because this is a three dimensional figure is going to be divvy, but if I use this what I can say that 011 is here. So, all spots which are 90 degree away from it will be the spot poles which will be lying on the. So, one 001 one bar 1 0 1 bar one these are all the ones which are going to come now this will not come 1; 1 will come this is how the reflections will come here correct now what is important is that when we take this one also the 100 direction remains the same and that has not changed in the stereographic projection right. So, you see this diffraction spots here 200 comes here then 01 bar 0 comes here that is here and the next spot 2 bar 00 in between spots will come. So, if you look at it if we tilt and reach this particular zone, this is exactly the way the spots will appear in the screen on the screen we will be seeing it and the indexing has to be done this way.

If we use the stereographic projection we will not make any mistake in indexing exactly that same way we will be you see that here from here in the clockwise direction we view you move from here this way you can do the complete indexing you understand that if we tilt that is instead of reaching it frame 1 bar 11 if we try to reach it then what will happen then 110, 90 degree away from it will be 110 101 and 01 bar 1 these are all the spots which are going to be there correct.

Now, you see this diffractions pat pattern how it will appear this is exactly the best spot will appear and the indexing 110 is here 101 will be coming here and 0 one bar one is there this is the way indexing is being done; that means, that when we tilt from the one to the other the same sampled in the microscope and see it we should note down in which direction because we have fixed a coordinate system with respect to a coordinate system we tilt it in a positive or negative direction and when we do that tilt then once we know the crystallography we know which direction the beam is going to come into the sample and depending upon that indexing has to be done in a specific way for which you can see from these example that the stereographic projection helps to index it correctly this is essentially a sections which has been taken free m from the reciprocal lattice that also we can do that, but the way the relatively the way in which it will appear on the screen when we tilt it this is the way the appearance of the different spots will be.

So, we get the spots, but indexing has to be done correctly because these also can be indexed in any other way if we choose an another wrongly correct. So, that is why when we wanted to do defect analysis to find out what all the various types of defects are present and their characteristics indexing of the we may have to go from one zone to another to view the defect in various directions, but when we do that we should index the diffraction pattern also very correctly this we will take it up as an assignment later in a class we will try to do it, but I just wanted to let you know that this is the way it is being done is it clear.

Student: Sir;

Yes

Student: How can we differentiate diffraction pattern where a beam is passing through 001 and;

No because;

Student: 1 and 001 1.

Which one, no that ambiguity always will remain you have to choose one direction has this one and with respect to that once that is fixed that ambiguity is not there.

Student: how that if we have a polycrystalline material?

No, no, it is not a even if it is a polycrystalline material in a TEM, we can make the beam fall on a one single grain and do all the analysis there that is what we are talking about.

Student: Direction.

Lecturer: Which one.

Student: How do we know the beam direction?

How do we know the beam direction is that the beam direction is always we look into the sample from the top if the beam and the crystallographic axis you fix it with respect to x y and this is opposite to it you have to follow a convention which one.

Student: we do not know the;

This is all done after analysis that is you take the pattern after you get the pattern then you have to analyze it and index it this is the way the spots will appear now if we have to index it if we use the stereogram then the indexing will be done properly otherwise we can put this as 111 also and index it if we do not follow any of this logic that is because the tilt which we are giving it is from here to here is 54 degree from here to here is 45 degree and which direction we tilt it all these things are well known this has to be noted down when we do the work is it clear.

This is for 1 bar 12 the same way it is being done.

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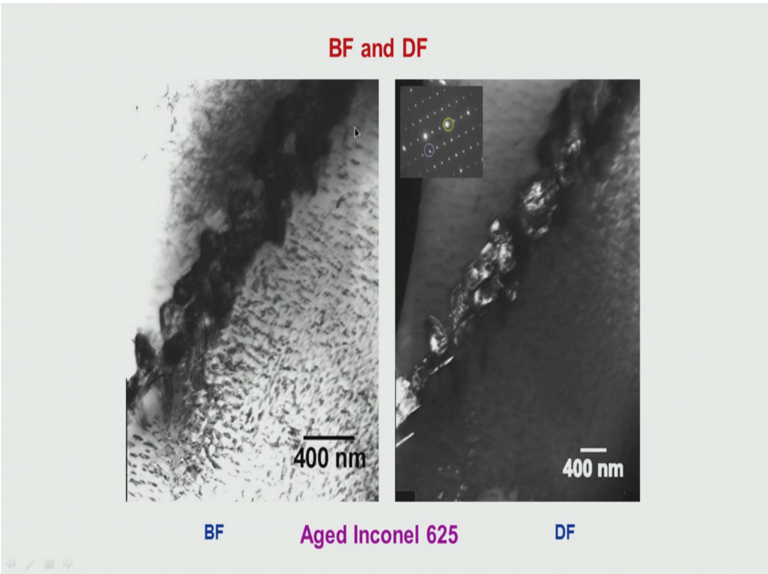

So, one such pattern is being shown which is for an f c c lattice inconel based super alloy here this is the central spot or the un diffracted spot direct beam and these are all the scattered beam if we allow that entered diffractions pattern to form an image then what will happen the diffraction the image due to every diffraction spot as well as the central beam they overlap on each other. So, contrast will not be good because we know that if we look at a beam which is scattered in one particular direction the intensity variation depends upon how much is the scattering which has taken place in other directions if we allow all of them to merge together the contrast will be very poor. So, what we do it we put an aperture around the central beam and then form an image that is what we call it as a bright field image correct the this spot is a diffraction spot.

Student: Below; below that.

Lecturer: this is the spot which I used it this is the super lattice reflection from the precipitate I had put an aperture around this spot that is this diffraction pattern aperture is put. So, because this aperture is in the back focal plane that is where the diffraction pattern if there I can introduce the aperture just below it and choose only this spot then the image which I get it is made up of only where the beam has scattered into this direction. So, that this only regions appear bright this way we can identify that this spot corresponds to m 23 c 6 precipitates now I can tell that this is these are all where there n 23 c 6 precipitates or located at that grain boundary you understand this is how an identification is done.

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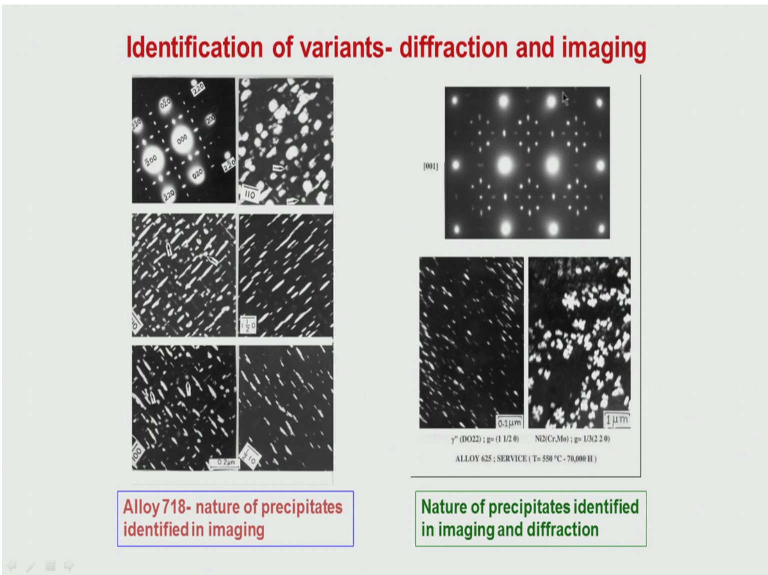

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Similarly, you look at here, here what is being done this is a diffraction pattern which is taken for an another type of a precipitate in the same alloy here various super lattice reflections are there what I mentioned here is what is the super lattice reflection which is been used for imaging it if I put an aperture around this particular one in the back focal plane and use that to form the image I will be getting an image like this if I put an aperture around this one half 0 one of this spots then I get an image like this if I put it around this one 100 type I get an image like this 010 is here if I put it I get an image like this. So, each of this images show the type of precipitates where they are distributed their morphology all this information we can get it from the diffraction pattern; pattern to mains that same, but different spots sometimes a spots could all corresponds to the same variant here there are different variants are there which I had mentioned earlier about orientation variants these are different orientation variants which we can identify is it clear this is an another example where which I am showing it.

Now, here if you look at it this looks like almost perfectly aligned right the beam is passing through 001 because thus intensity of the spots appear almost that same, but suppose we wanted to find out what is the exact orientation how do we find out apart from our visually looking at it and making a while because there is no other way we can do it here right for this purpose we can use what is called as a Kikuchi diffraction what is Kikuchi diffraction it is nothing, but a divergent beam if we use it that will give raise to a diffraction pattern that is called as the Kikuchi diffraction.

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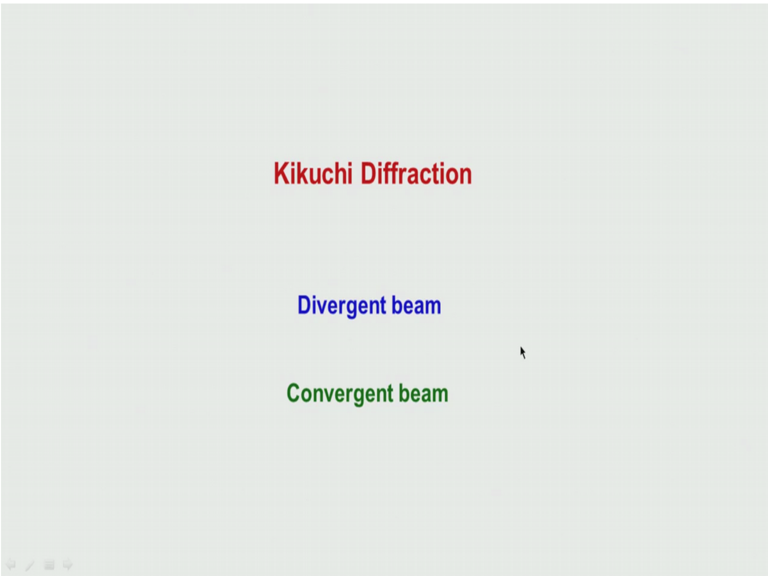

It could be a divergent or it could be a convergent beam it does not matter both of them will give raise to which we will come later.

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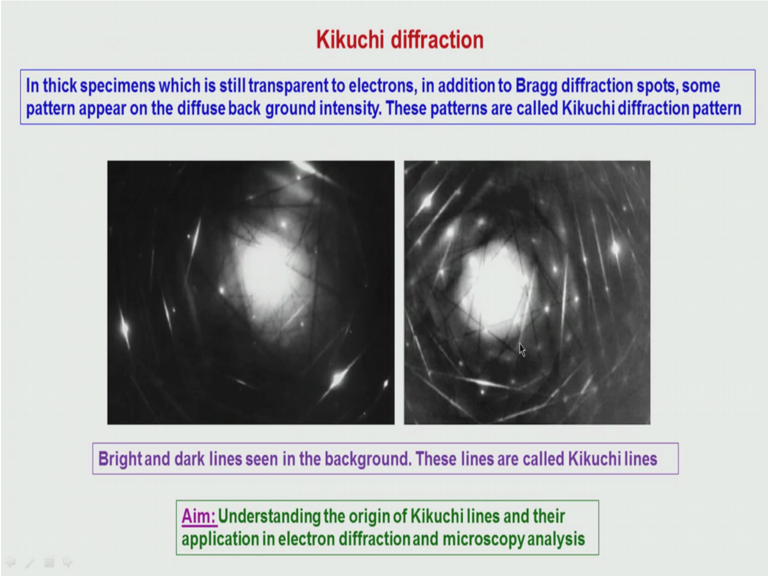

Which specifically with respect to a sample suppose the sample is the thick specimen if we take a diffraction pattern from it apart from the diffraction spots you see that there are lot of bright streaks are seen and similarly dark streaks are also seen correct what are responsible for this streaks that is the whole question how this is being interpreted these streaks and what all information we can get from this the first thing is to understand how this Kikuchi patterns are generated.

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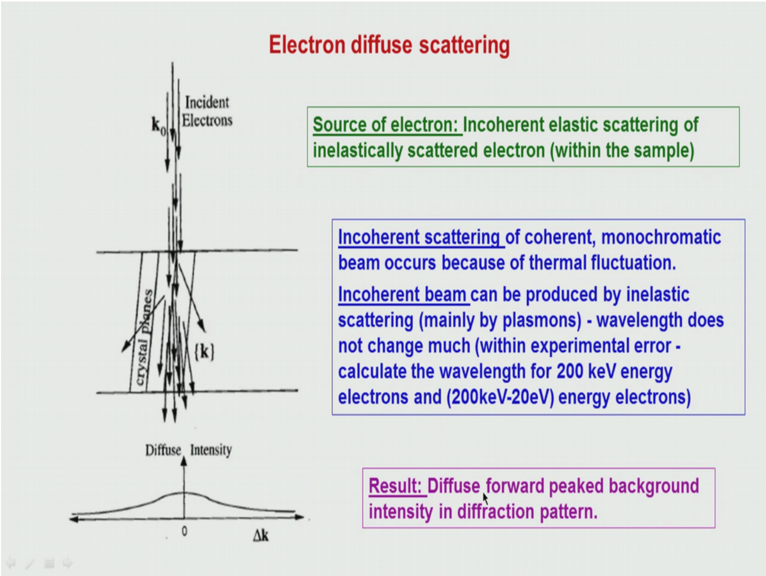

For which if you look at this and incident beam electron which falls on the sample is highly monochromatic very high energy 2 hundred k energy.

We assume that this sample is an amorphous sample when it enters on to it it can undergo an elastics scattering other than that what is the other way in which a scattering could occur any inelastic scattering can take place one by phonon this one another is that due to Plasmon losses some energy could be lost if assume that an electron has lost an energy by Plasmon interaction the generally the energy is ten to twenty k a twenty electron volt energy loss may be there then that point is Plasmon.

Plasmon lattices is a collective oscillation of the electrons takes place when the electron beam passes through the sample it contains electrons are there it gives some energy to this electrons also that way it loses some energy this is called as a Plasmon oscillations in the sample and they are called surplus Plasmon’s and bulk Plasmon’s although, but that energy loss is between 0 to 20 electron volt when such a loss is occurring and int amplitude are the intensity of that wave scattered beam in these direction forward direction is maxima and as we go away from it the angle increases the intensity reduces this will give raise to overall a background intensity which will be there maximum at the center and fading away towards the edge is it clear and this diffuse scattering is what is responsible for the Kikuchi pattern because this sample which we have considered is essentially nothing, but a amorphous sample which we considered. So, we will have only a uniform background intensity which will be there correct.

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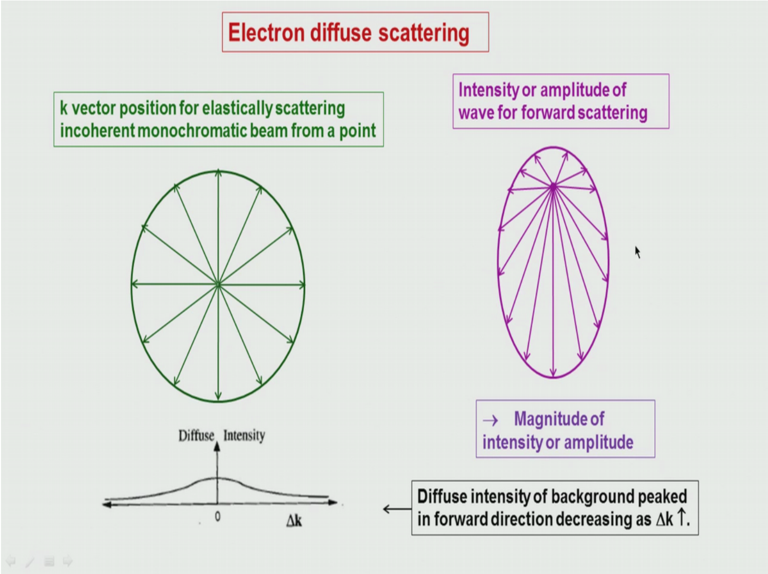

And here what I am showing is the k vector in all the directions it could be there, but if you look at the intensity; intensity of the amplitude this arrow shows the magnitude. So, its maximum in the forward direction and it is decreasing. So, this gives raise to this particular form in which it will be varying that is what we had seen in that diffraction pattern which we had noticed.

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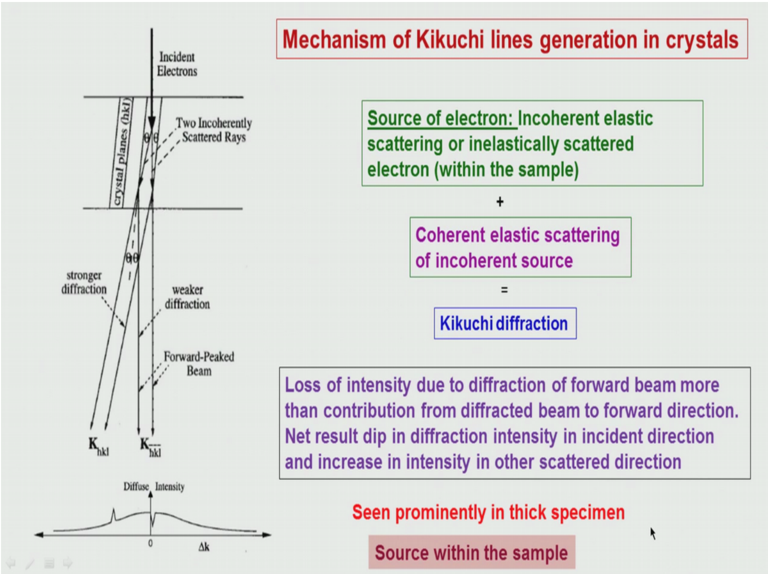

Now, suppose that sample is a crystalline material because it does not matter whenever some atoms are there whether it is a amorphous or a crystalline this process can occur in the sample correct this has happened in the crystalline material also assume that it has occurred here then from this region electron with energy which has lost these are all the incoherently scattered electrons which are coming in all the directions if this plane is there this electron which is coming in these particular direction the electron wave if this satisfies the Bragg angled in all directions it is being scattered, but at this particular direction its satisfies the Bragg condition. So, that is the scattering which is taking place in this direction. So, intensity of the incident beam has come down. So, over the background now there will be a dip which will be coming.

Now, that same beam which will be the beam which is scattered in this direction this also with respect to this plane it satisfies the Bragg condition correct. So, some beam is which is scattered into this particular direction, but as I mentioned the intensity decreases with the angle of scattering because of this intensity decreases. So, it is not able to compensate for the decrease in intensity which is happened. So, it is a net effect which you see similarly the beam which is scattered in this direction it is above the overall background similarly the which is scattered in this direction after having lost something still some intensity is coming in this directions scattered beam this 2 add together this gives a increasing contrast that is why you find that the center of the diffraction pattern you get dark bands dark lines and away from it you see bright lines and the separation between them what does it correspond to the g vector correct and here you should understand that these ones and both of them and since we know this angle this is the direct beam this is the scattered 2 theta we can find out the lattice parameter very accurately from that these spacing can be determined and the source of the radiation is within that sample here correct when the source is within the sample what is the advantage of it if I tilt the sampled like this the source is also within the sample. So, it will tilt by the same amount.

Normally what happens in a parallel diffraction beam if you see this is how the reciprocal lattice spots are there?

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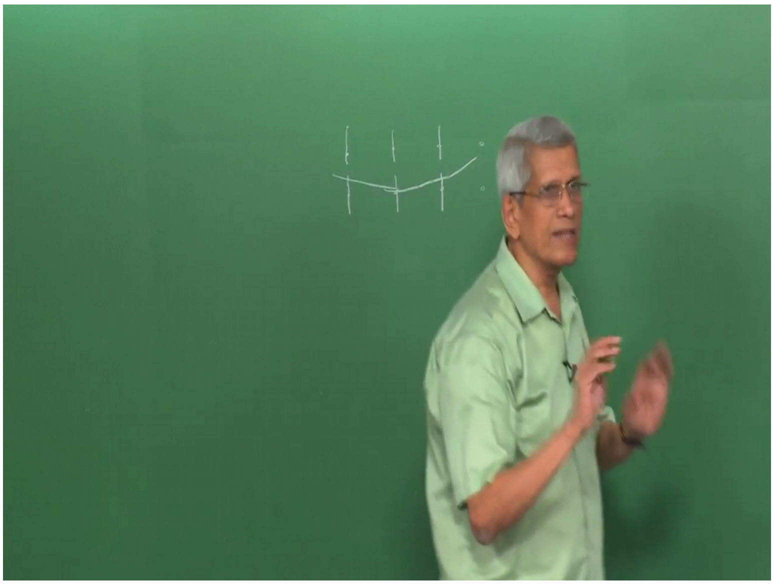

There is a streaking in these direction is there since the sample is the thin and this how the Ewald sphere cuts correct. So, even if the Ewald sphere is touching only this point here it is not touching still we can get the spots corresponding to them even if I tilt the sample by plus minus five degrees still some part of the Ewald sphere can touch and we can still see the diffraction pattern, but if you measure the distances some changes might have happen. So, lights parameter measurement is not accurate, but still the diffraction pattern can be seen, but here the diffraction the Kikuchi pattern is extremely sensitive to the tilt of that sample. So, using this Kikuchi pattern we can identify the beam orientation.

Student: can you repeat why the intensity.

You see here this is amplitude or an intensity in the forward scattered direction it is maxima as the scattering angle theta increases it decreases. So, what will be its effect on this direction? So, in these direction intensity is maximum spot of it is scattered. So, in the overall background there is going to be a reduction in intensities going to happen in the center and this particular one in these direction if you look at it the overall intensity of the beam which is falling is small though here also diffraction takes place what it contributes to it will be always less than what has been lost from here. So, the net effect what we see is a dip will be there similarly the beam which is scattered here in this direction is going to be more.

So, corresponding to overall in this direction this adds to an increase in intensity, but the last which is going to take place here is not a able to compensate for that. So, overall it is essentially an increase here it is a decrease so, but this scattering is an incoherent beam which is generated that is monochromatic that undergoes between this planes and elastics scattering and that gives to a diffraction pattern which we call it as a Kikuchi diffraction is this clear and generally the thicker the sample then what will happen is that the incoherent scattering process probability increases. So, the intensity will be high extremely thin region it will be difficult to see Kikuchi pattern and another is that since source is within that sample we will be able to when we tilt that sample this also tilts along with it the how will it appear the diffraction pattern.

This is something like the beam which is satisfying the Bragg condition the 2 planes are like this a source is here. So, if its satisfies a Bragg angle it is like a cone which is there with a particular angle which is falling on both the sides of that sample surface right and generally when we take a diffraction pattern.

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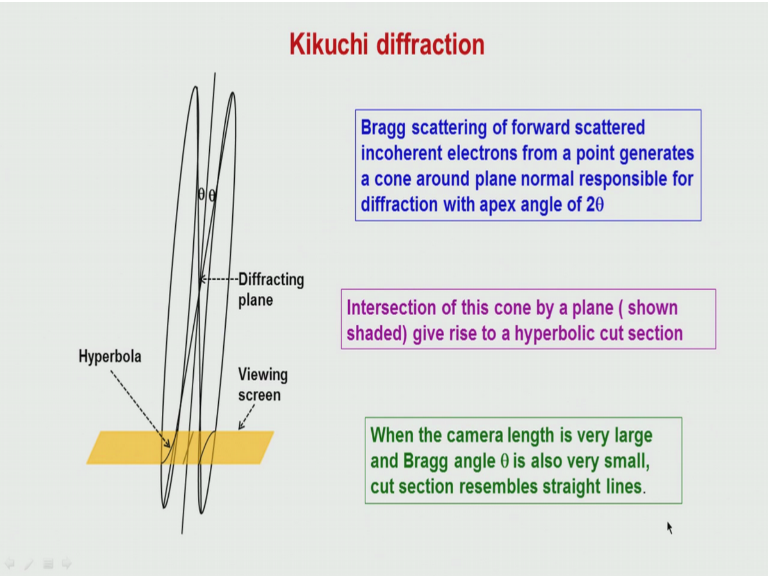

We are keeping the; or its falling on the screen which is below perpendicular to it. So, when a cone is being cut by a sheet of paper it will give a hyperbola that is what it the Kikuchi line should appear, but since the camera constant is very large it appears as a straight line is it clear straight lines this is what it happen what all the applications of this Kikuchi diffraction one accurate crystal orientation determination.

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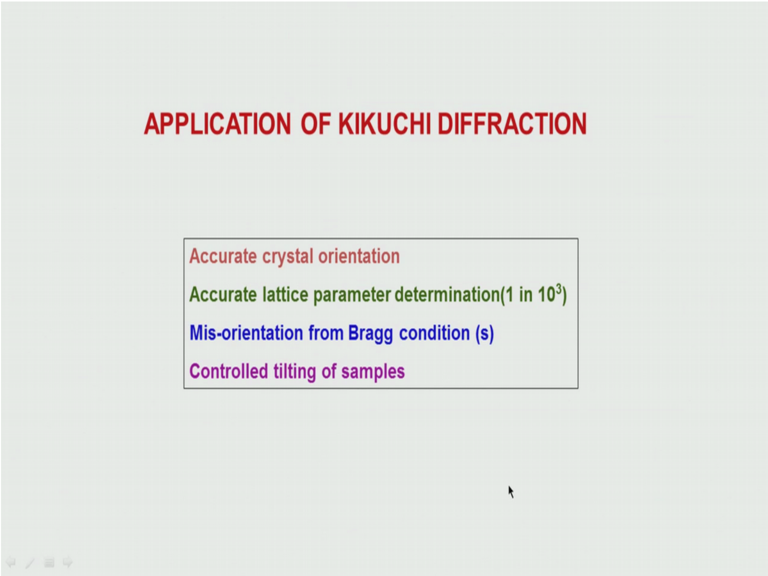

We can do that using it lattice parameter I mentioned can be measured very accurately then misorientation whenever we wonder quite often when we do analysis sometimes we should know from the Bragg condition what is the extent to which the spot is misoriented to calculate that intensitic contrast for that we should know the deviation from the Bragg condition because the deviation from the Bragg condition.

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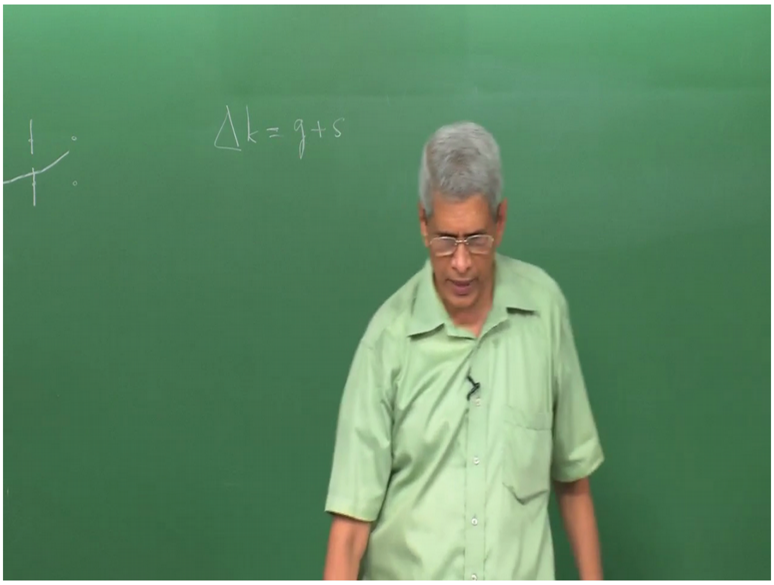

We have already said that when delta k is a general one when we consider reciprocal lattice section thins sam that is small volume of the sample we notice that not only a g, but at values away from g also exact Bragg condition also we get some intensity of the spots correct.

So, this is we wrote it as g plus s s is the slight deviation this will come to it later and this can be used for control tiling of the samples also this what when you do serious microscopy we have to tilt that sample Kikuchi pattern can be used as a gate to go from one zone to the other all this things a few example we will take.

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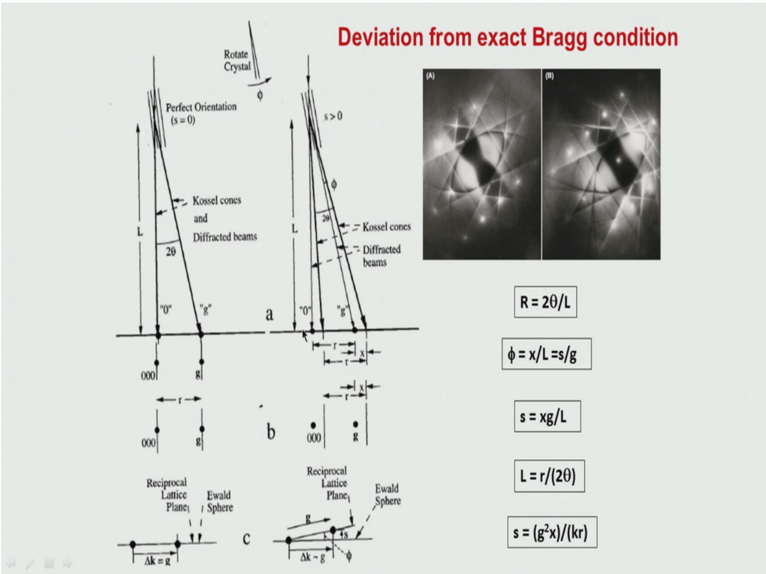

The deviation from an exact Bragg condition suppose here you see that this is satisfying a Bragg condition here it is tilted quite a bit how do you get this information here if you look at it this is the beam which is incident beam diffracted beam this separation between them if we measure it are we can this will be 2 theta will be equal to the tan 2 theta will be equal to R by L correct and since to theta angle is small we will be able to write it in this way and then if we tilt the sample the little bit what will be happened to Kikuchi pattern the spot pattern remains the same you see that here spot pattern remains the same, but the Kikuchi pattern has shifted correct.

So, the Kikuchi pattern shifts a little since we know L this shift we can measure it these also using the same formula we can find out finally, what happens is that this deviation s in reciprocal space we can find out using if we just substitute and do some algebra we will be getting g squared x by k R where k is the one by lambda this way we can find out what is going to be the deviation from the this.

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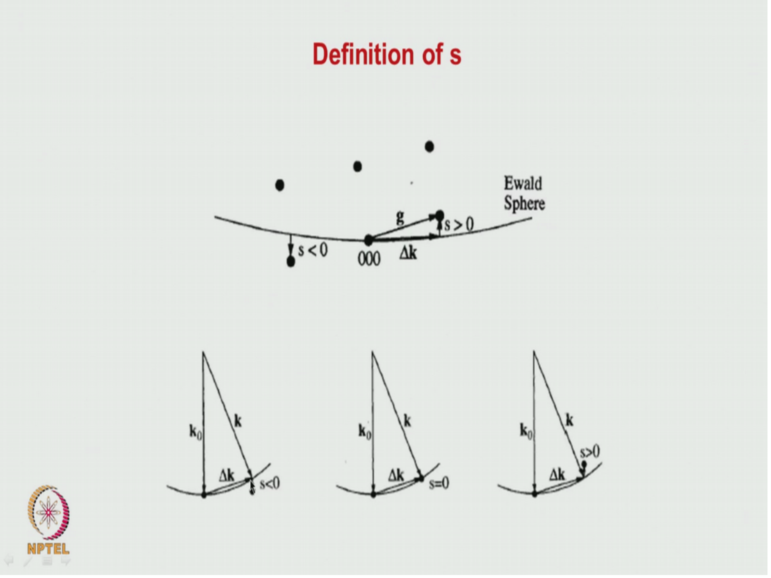

How is this deviation define this is the reciprocal lattice reflections which are there this is the Ewald sphere if the Ewald sphere does not pass through the reciprocal lattice point that can always happen then this is delta k this is g and delta k plus s will be equal to g right here s is positive this is how its defined and how are the coordinates of s defined it is defined with respect to a coordinate system which has chosen that is the in these direction it will be s is at and in the other directions x y and z it will come and these are three cases which we are considering it here the g vector is here down then if Ewald sphere is passing like this then s will be negative right and in this one the Ewald sphere is passing through both the lattice points when Ewald sphere passes through both the lattice points s will be equal to 0 correct and here it is s is greater than 0. So, these are all the sign conventions which are used.

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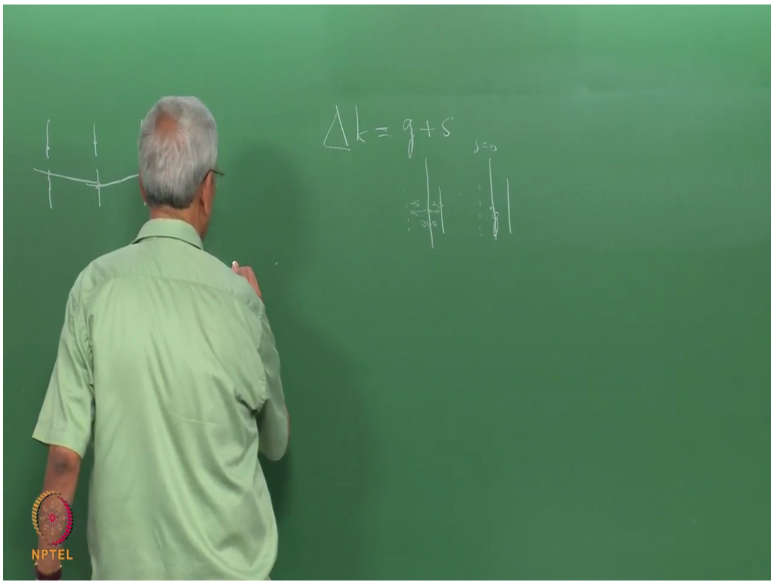

So, essentially what happens is that when we look in the diffraction pattern if this is the center 000 and if this is g if the Kikuchi pattern lies like this away from it then this is positive s suppose Kikuchi pattern is lying like this then this will be negative s this is positive s this is negative s if the Kikuchi pattern lies exactly on it then x equals 0 this is how it will appear in the diffraction pattern this clear.

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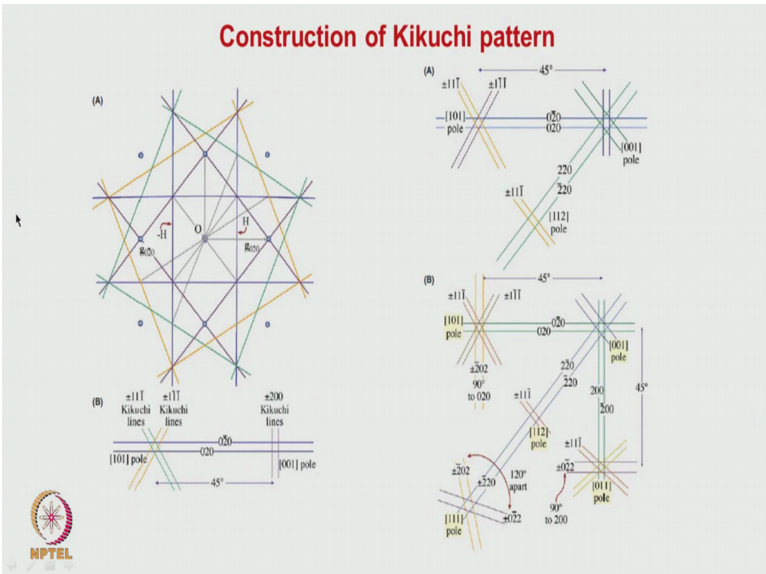

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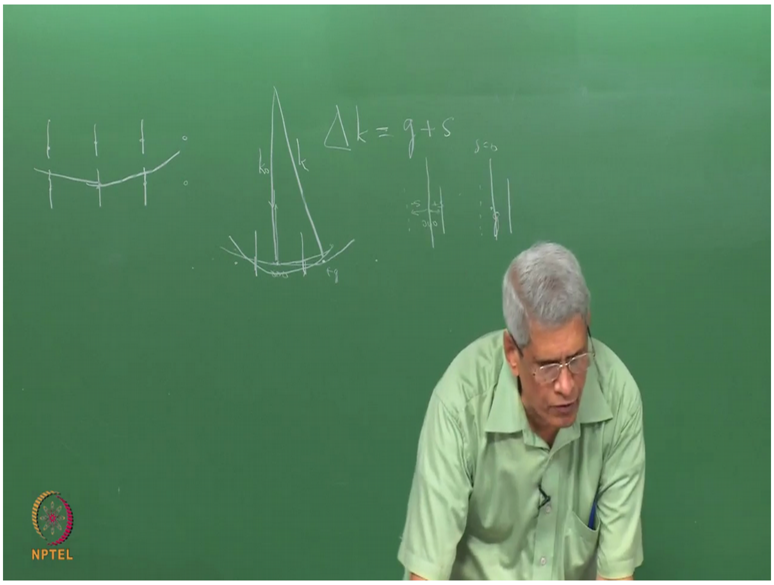

So, what I have shown here the same thing which we can do it you saw that that if we have spots which have symmetric is there if the Kikuchi is pattern passes like this then what is going to happen this is the incident beam direction this is the scattered direction correct k 0 and k it will be is it not, but if you see with respect to this spot this is central spot this is plus g it is not symmetrically disposed what is the normal to this row it will be in this direction correct it is not passing through that if it has to do what we should do we should tilt it in such a way the Kikuchi pattern now if it passes through this then at middle portion of it if it comes the Kikuchi line between the spots that is what is being shown here.

Here if you see it this is 0 to 0 vector is being there this is 2 bar 0 vector this is 0 0 if the Kikuchi pattern one bright line comes here and the dark line comes here then this is perfectly central and this is a symmetric pattern similarly with respect to 0 200 direction the lines will Kikuchi line has to pass like this here the Kikuchi line will pass like; like this various Kikuchi patterns will come this we can observe it and tilt it and accurately get it that when we tilt it the sample they are essentially the spot pattern remains the same only by a small angle of a tilt the Kikuchi pattern is what we are a Kikuchi pattern will be shifting and this is how for 001 the Kikuchi the spots pattern will look like and one 0 one pole this is how it will come.

So, if we go along this Kikuchi pattern we will be reaching this one if I go along this pattern I will be reaching 112 then 111 like that. So, if this pattern is there what I am doing it is I am not looking at what tilt time doing it am [go/going] going along that keeping the Kikuchi pattern when I do it I can go from one zone to another zone accurately that is what essentially can be done. So, this can be used to tilt from one zone to another zone, is it clear?

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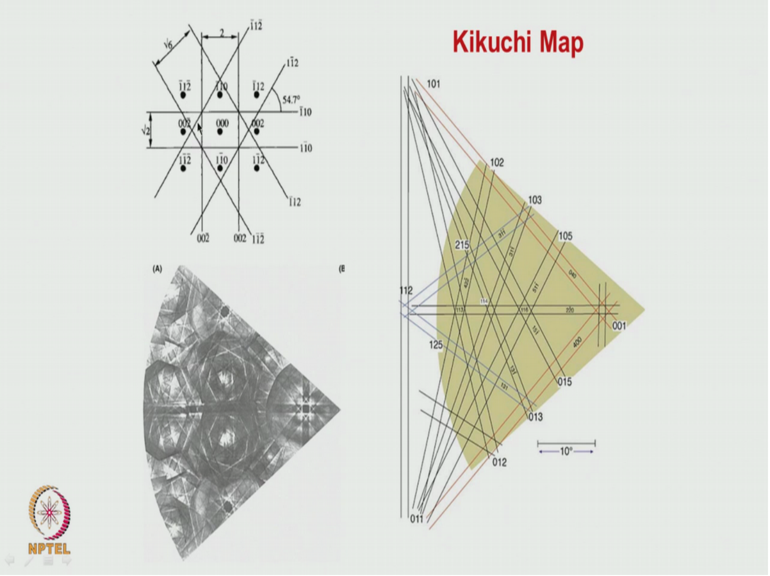

This is essentially for a cubic system that is Kikuchi pattern which has been generated for the various zones with the diffraction spots also there is being superimposed one on top of the other this sort of patterns are also available a standard one which one can keep it along with oneself and one is doing a microscopy and here what is being done is that same spots the same Kikuchi band is being shown how they will be going like this, this is essentially the same figure you see take it remove all those spots it has been simulated, but exactly that same pattern this sort of plots are also available which one can use it when one does microscopy mostly people who look at microscopy of bulk samples they will require this, but not for nano particle. So, here just shown what I had explained till here how if this is the sort of a diffraction pattern which we have how the Kikuchi pattern should appear for it be symmetrical this also I will give it as some exercise which one can try to work it out and find out.

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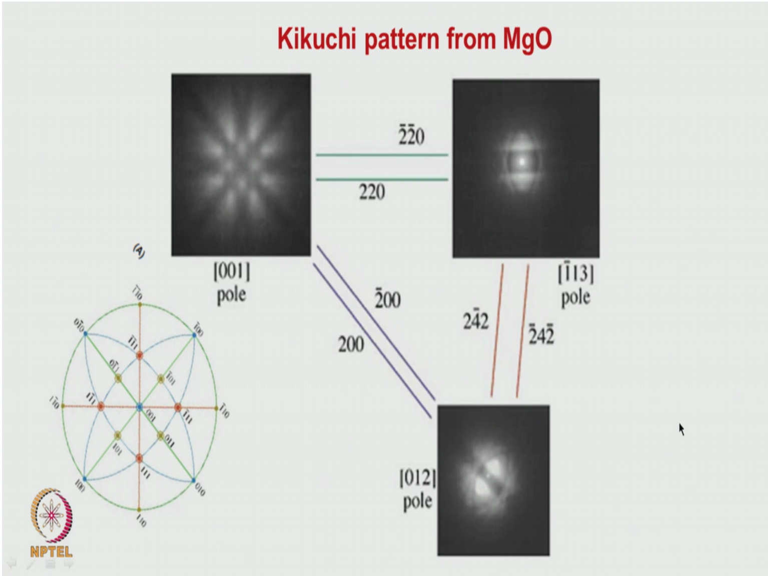

This is from an m g o crystal Kikuchi pattern which has been taken for 001 actual pattern this is 0 1 2 this is one bar one three correspondingly I had just put the stereogram also you can see that from here to in this direction one bar one three will come after some tilt and in this particular direction 011 if you tilt it 0 1 2 will come and if I move along the Kikuchi pattern in these particular direction I will be the going here further if I tilt it and reach I will be reaching one bar one naught pattern here if I go and tilt and go it 011 I will be reaching, but here it has been stopped with 0 1 2 pole which comes somewhere here we can tilt beyond it. So, as we tilt and go along in a particular direction various types of diffraction patterns corresponding to different zones will appear which one.

Student: Kikuchi pattern because that is also we are getting between 2 spots etcetera.

No; that is a construction of a Kikuchi blow in zone construction of a Kikuchi the blow in zone which we considered is essentially how to construct the below in zone with respect to a k vector notation here what we are trying to look at it is there the Kikuchi pattern is nothing, but the diffraction spot which is there if we tilt and then bring in the sample what is the tilt we should be used. So, that we can find out the orientation of the sample accurately that is the beam direction can be determined accurately, but there is a relationship between the Bragg diffraction and the below in zone boundary that just does not change that has nothing to do with this.

Student: sir when this will be similar to that when it.

It appears similar the figure right because one is because there are 2 diffraction patterns which are taking place here one a parallel beam which gives raise to a diffraction pattern which is a spot pattern like this in addition to it part of the beam has lost some energy and this energy loss has taken place as some specific locations where atoms are present on the sample. So, those regions are acting as a source for electron beam and that also gives raise to diffraction in the sample, but since the beam is for this case of Kikuchi diffraction in the beam is within the sample if we tilt the sample the Kikuchi pattern also will tilt along with it the diffractions spot that does not come appear as a diffraction spot it appears as a line that line tilts along with it you understand that. So, that line we have brought it to the center, but both of them are 2 diffraction spots superimposed one on the other you understand that.

Student: When we are treating scattering in the center does not change.

Student: When we are tilting.

Yeah,

Student: The Kikuchi lines also moves.

Yeah,

Student: So, does;

The scattering center does not move that is within the sample in the other case its outside only the sample is being tilted right the beam direction is changing now we want that to use this phenomenon to find out what is the beam direction in which by moving it and keeping if the beam false here the Kikuchi pattern and the other Kikuchi pattern bright and dark lines falls exactly on this then the beam direction is along whatever is the k vector which we are chosen.

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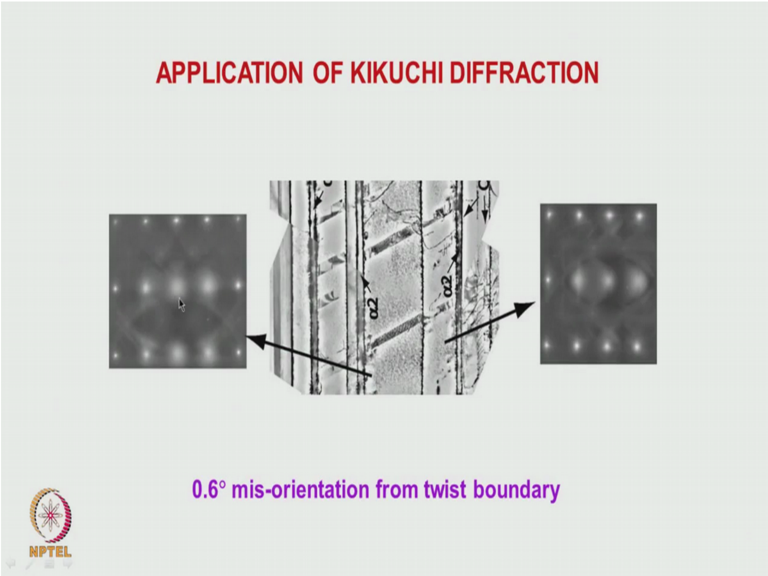

So, if we want it to be symmetric with respect to these 2 then it has shifted such a way that one comes here that other one comes here at the middle that is only the alignment that is because 2 diffraction type of the diffraction patterns we are trying to use both of them there is one gives the large number of spots another gives some lines, but we wanted to use the one which gives the line to find out the beam orientation exactly we wanted to determine that for that purpose its being used is it clear.

So, this is an another case where you can see that the diffraction spots if you look at it they appear it the same, but if you look carefully there is a background there is a pattern which you can see this it is almost symmetric here, here it has shifted coming down; that means, that the Kikuchi pattern has shifted. So, this that is how it has come from this region to this region when I move from here I take one pattern from here I get it like this from this region I take it; that means, that some small deviation has taken place; that means, that if this region satisfies exact Bragg condition when I reach this region is not satisfying the Bragg condition how can it happen only if either there is a small angle boundary is there are small tilt has taken place or a twist has occurred that information how much is the twist from this deviation, we can determine it this has been done in this case it was found that this is a 0.6 degree misorientation twist boundary it is this clear.

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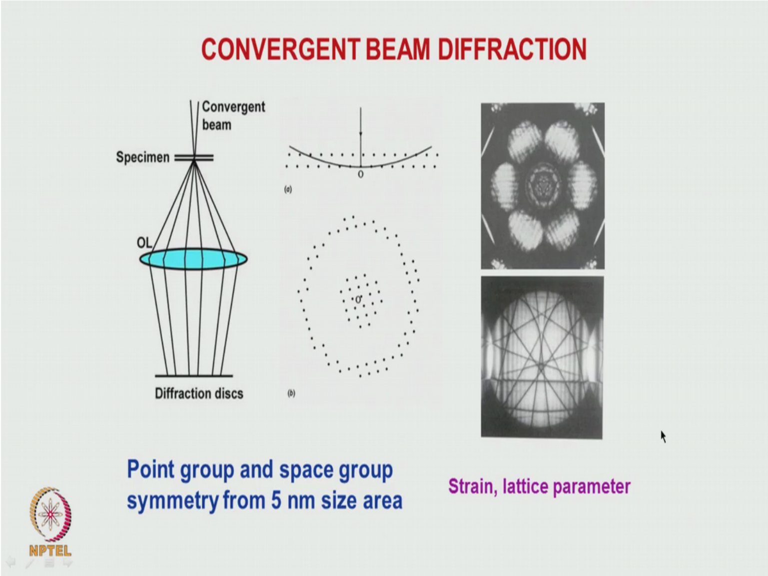

This I just wanted to introduce it, but we will take it up in the next class convergent beam diffraction what is the case which we considered for the Kikuchi diffraction is that due to inelastic scattering correct there is no need that inelastic scattering has to take place for Kikuchi diffraction to take place.

Suppose I make a beam convergent to the sample surface and then that beam will be diverging from here and what will the lens do the lens will just converge them to a some disk on the back focal plane correct, but with respect to some diffract plane one direction of that beam will be satisfying a perfect Bragg condition right and corresponding to that we will be getting some line in this one which will be a dark line and away from it we will be getting bright line. So, if we use either a convergent or a divergent beam we can always get a Kikuchi pattern that is one thing.

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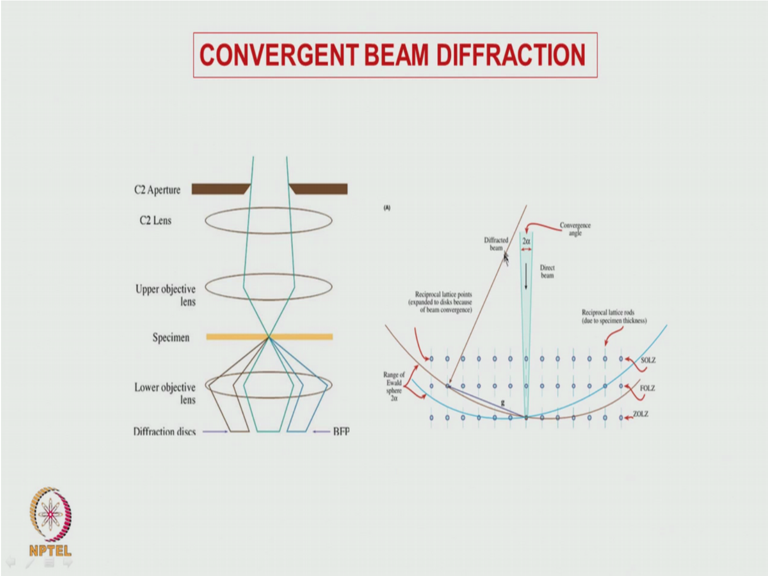

And the other is if I converge a beam this is equivalent to for this particular beam direction this is the Ewald sphere correct for the beam which is coming in this direction this is the Ewald sphere in between the Ewald sphere is like that you remember that by plying with that tilting of the Ewald sphere we can get more diffraction spots into the pattern. So, what will happen is that all the spots which are coming in between will be coming in the diffractions pattern this is what is being done you see this here Ewald sphere is touching here is gives one pattern then the outermost pattern which comes this central spot come from which condition g dot R equals 0 right.

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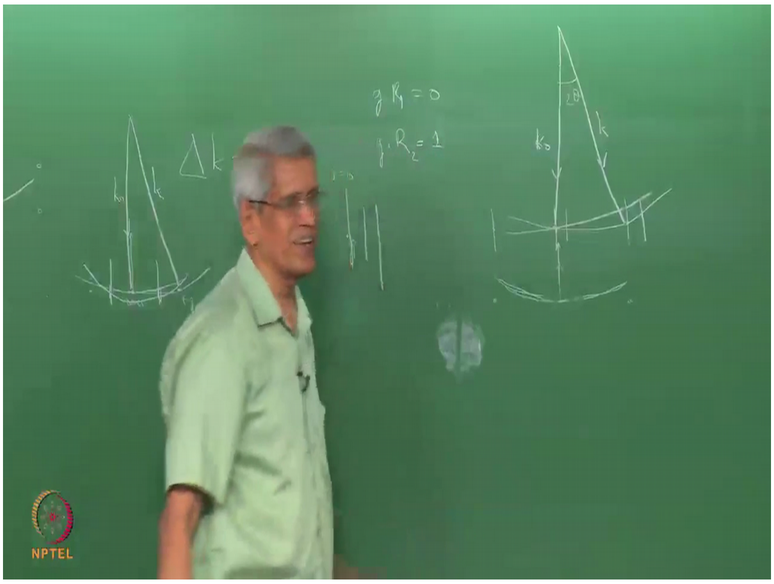

Or delta k dot R equals 0 and the next one comes g dot this is I will put it as R one I will put it as R 2 equal to one right. So, that is nothing, but one plane this is an another Ewald another plane in the reciprocal lattice section. So, simultaneously we are able to image different reciprocal lattice sections and if we index all of them we can reconstruct and get the reciprocal lattice. If we have the reciprocal lattice then from that we can try to construct the real lattice correct that can be done using this then this sort of black lines which are coming in this one if you look at it they exhibit some symmetry even here if you look at it there is a symmetry these exhibits a actually a threefold symmetry you look at the spots this spots exhibit a 6 fold symmetry right like both hexagonal lattice as well as a cubic lattice will exhibit a 6 fold symmetry.

As far as the diffraction spots are concerned that is by looking at a normal parallel beam diffraction spot looking at one diffraction pattern we will not be able to differentiate between whether it is a hexagonal lattice or whether it is a cubic lattice, but if we look at these Kikuchi lines which are coming these extra lines which we can see it from them we can make at the this has got a threefold symmetry that is an indication that the crystal structure is essentially cubic type this sort of informant that we will come to later in the next class.

So, essentially using convergent beam diffraction we can get a lot of information the information which we can get is precise lattice parameter determination the striking sequence along some beam direction we can get it convergent beam what you do it is the beam which is falling on to the sample we using the condenser lens we have we use a parallel beam or you can converge as a beam trope point that is what is being done, but in many modern microscopes there are facilities by which you can press a button it will make the beam convergent with the particular angle that is possible what we can do it manually also when we started when we started doing it on a microscope we used to converge it and get the pattern that is always possible then we have to measure what the convergent angle which we will not know, but modern equipments facilities are there we can put it and say this is a convergent triangle.

There are 2 types of Kikuchi lines are going to be there I will come to all the details of its, but what I mentioned if that even with the coherent beam also if the beam is a convergent beam if it falls onto a sample or a divergent beam we can still get a Kikuchi line in the Kikuchi line is that suppose this is a sample which is all other planes are not diffracting then when this beam this forms a spot it will be of uniform intensity right and if particular plane is satisfying Bragg condition then in the direct beam in that region they will not be any intensity. So, what will happen if that when we get a central spot like this in this you will find that the region which does not satisfy there is a reduction in intensity one line you will be seeing it sharply that is a Kikuchi line that is how this lines are appearing on this these are all taken under a condition sample there are many other effects are there which we will be talking about it in the next class.