Experimental Physics - II
Prof. Amal Kumar Das
Department of Physics
Indian Institute of Technology, Kharagpur

Lecture – 43
Single Slit Diffraction

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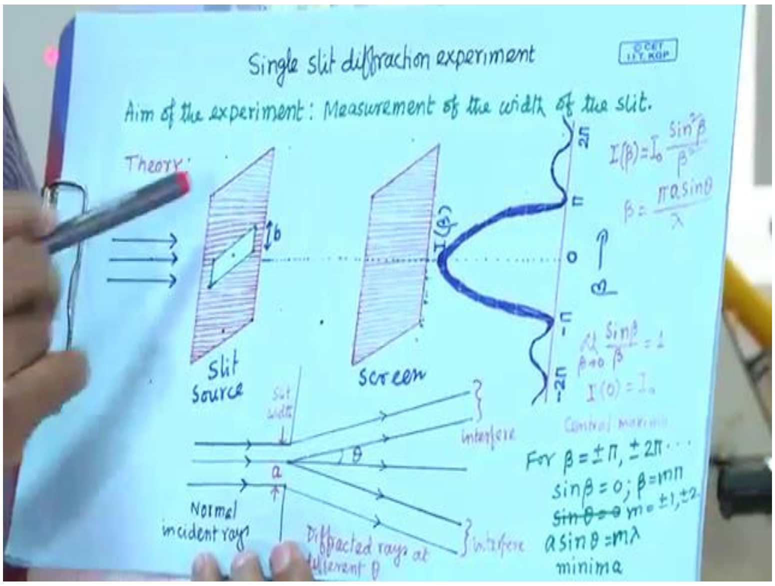

today I will demonstrate a Single Slit Diffraction experiment. aim of this experiment is measurement of the width of the slit. we have a slit single slit, its width is b. So now, parallel rays are falling normally on the slit this red part is opaque and this rectangular part is open. light will pass through this slit and after passing through the slit, if slit width is its width is in the order of the wavelength of this light; then we will see the diffraction pattern on the screen.

the diffraction pattern we will see on the screen is like this. these the intensity, intensity variation on the screen we will see like this, like this these one is called the central maxima, this is called central maxima and this other one is mini secondary maxima and between this maxima these are the minima, it is the dark point this dark point. minima maxima we will see here two kinds of maxima. This one is central maxima; it's we get generally at direct position if you these dotted line follows.

at direct position you see the central maxima and both side of central maxima we get the secondary maxima and between secondary maxima and central maxima we get the minima intensity variation as a function of beta, intensity variation as a function of beta equal to I 0 sin squared beta by beta square. What is beta? Beta is equal to pi a sin theta by lambda. how this formula has come that I have discussed in previous class during the discussion of the diffraction in general.

beta depends on the wavelength. in our case when will we do experiment wavelength is fixed. We will take a laser light of wavelength of I think red light we will take. 632.8 Angstrom, not Angstrom this nanometre 632.8 most probably, we will check it. this lambda is fixed for our experiment. Now, a sin theta; what is a? Sorry here I have written b, but they are written; it is I will change it a.

this slit width slit width is a. it will depend on a and it will depend on theta. What is theta? Theta is diffracted angle. this light from the slit it will be diffracted in different direction and say here I have shown this a set up parallel rays from middle panel design in between others will be there. this sets are parallel rays they will interfere for this angle theta. angle theta will vary we will get different sets of parallel rays, they will interfere and that.

that is why we tell diffraction is nothing, but the interference among secondary wavelength. when this wave fronts falls on the slit then on the slit each point will act as a secondary source from each point again, we will get the we get the secondary wavelets. that is what that is the Huygens principle. So now, the secondary wavelets this; this secondary wavelets will interfere, and we will get this diffraction pattern.

this interference will happen at different angles ok, at different angle we will get this get set off parallel rays and they will interfere for that angle. And, we will get the depending on the interference condition you know intensity will be maxima or minima. you know already we have done experiment on interference. we will get the intensity variation due to interference. this is theta.

obviously, that theta will vary on the screen, this theta will vary beta is varying means for different theta we will get for a particular slit width. If we keep the slit width constant for a particular slit width, we will get this variation because, of variation of theta, because of variation of theta. That means, that because of variation of beta because beta is related with this theta following this. So now, here intensity when intensity will be maximum, when intensity will be minimum; from here you can find out.

So now, if beta equal to 0 sin beta by beta whole square for beta equal to 0 then if we take a limit beta tends to 0, then it is 1. this intensity will be I 0 maximum intensity will get when beta equal to 0 and for any other value of beta. this intensity will less than I 0 and when theta will increase; obviously, you can see this theta is increasing, beta will increase beta will increase. if you know beta sin beta by beta whole square.

you can find out this factor and you can get the intensity. this I 0 equal to I beta equal to 0 equal to I 0 that we get for beta equal to 0. this is the central maxima we tell this is the central maxima for beta equal to 0 and then beta is varying; this intensity drastically falling. then for beta equal to plus minus pi plus minus 2 pi; that means, it is a beta equal to m pi. What will happen? Beta sin beta sin pi sin 2 pi sin 3 pi etcetera. 0 but beta is not equal to 0. we are asking this intensity this factor will be 0.

I beta will be 0 or beta equal to m pi; this is called minima. this is called minima diffraction minima and that minima will get form equal to plus minus 1 plus minus 2. this plus minus this start this term is coming because, this side both sides symmetrically will get the order and from here you are getting if beta equal to m pi; beta equal to m pi. a sin theta from this relation a sin theta equal to m lambda, you will get this condition a sin theta equal to m lambda.

this is the condition for diffraction minima. What are those diffraction minima? These, these minus pi minus 2 pi plus pi plus 2 pi etcetera, that will be the diffraction minima and diffraction maxima also one can find out, but we will not go to that. this maxima generally secondary this maxima, here at theta equal to 0 we get the central maxima. But secondary maxima we supposed to get at 3 pi by 2 3 by 2 pi; that means, 1.5 pi and then 2.5 pi.

But, it is not exactly it is not exactly 1.5 pi, it is a slightly less than that it is the one point I think 435 and this other one is 2.47 pi it is not 2.5 2.47 pi why it is not exactly 1.5 or 2.5 that can be from graphical method one can find out. we are not going to in that direction. here for this experiment our working formula is a sin theta equal to m lambda. that is for minima diffraction minima.

what we will do to measure the width of the slit; if we can find out; if we can find out this theta value. If we can find out this theta value for different minima for different minima then we will be able to we will be lambda is known to us, m also will be known to us. Because, this is the; this is the first order minima, then second order minima, third order minima.

m will be 1 2 3 then we can find out a if we can measure theta for different order. we will get a for different order and then we take average of that will be the slit width of single slit, width of the single slit.

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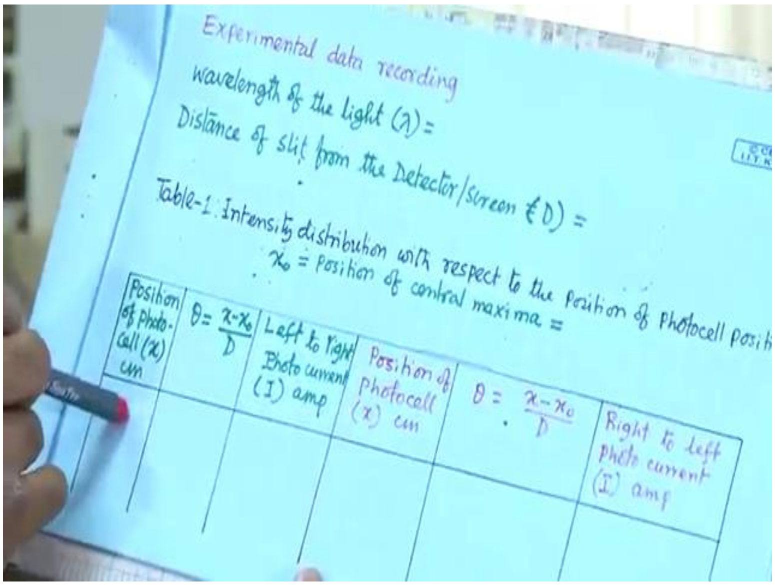

for doing experiment we will use these tables. we will note down the wavelength of the light we will use for the experiment, then we will note down the distance of the slit from the screen or from the detector that is capital D. that we will note down what is the distance between slit and the detector or screen. that we need for calculation that will note down.

Now, now what we will do? Using the photo detector photocell, we will measure, we will measure the intensity at different place different place means you have to move across the vertical direction; across the vertical direction this intensity is varying. that photo cell will move say we will take extremely left ok, then we will move from left to and for each position we will note down the intensity in terms of current photo current or photo voltage this if it is say 0 or x 0 and other that distance if it is x; from the centre where theta equal to 0 this distance will be x minus x 0 x minus x 0 and this if it is x from the centre x minus x 0 ok; sin theta sin theta for small theta sin theta equal to tan theta, tan theta equal to you can write this divide by this distance. x minus x 0 divided by D capital D that as I told that distance between the slit and the screen, distance between the slit and the screen if it is D capital D; this distance from the centre. that is x minus x 0 divide by this distance screen and slit that distance capital D that will be sin theta

we will measure intensity for different value of x for different value of x, initially we will note down this x 0. then x versus the intensity or photo current, in terms of photo current or photo voltage we have to note down. Then we will draw the graph; we will draw the graph as a function of a theta we can find out; we can find out the minima at which angle we are getting minima

we will note down that we will note down that angle and then from this relation a sin theta equal to m lambda for different order theta from the graph we will know and then we will find out the a. that we have to note down, for that this is the; this is the table. intensity distribution with respect to the position of photocell position either with respect to the position of the photocell position

at x 0 equal to position of central maxima ok, we will note down and then position of photocells we will note down in centimetre or millimetre whatever and then theta will be x minus x 0 divide by D as I explained for that theta when will move from left to. how these photo current I is varying, or photo voltage are varying; that we will note down as a function of; as a function of theta or as a function of position x or photocell.

we will note down and we will find out the we will find out the intensity at different angle. Similarly, we will note down from left to when we are going; we will note down again from to left when will move from to left; we will again note down the x position corresponding theta and then corresponding intensity. we will get two sets of data ok, just this is a repetition of the measurement when we are moving from left to, then one set data. And when we are moving to left say another set of data. theta versus the intensity that data we will get.

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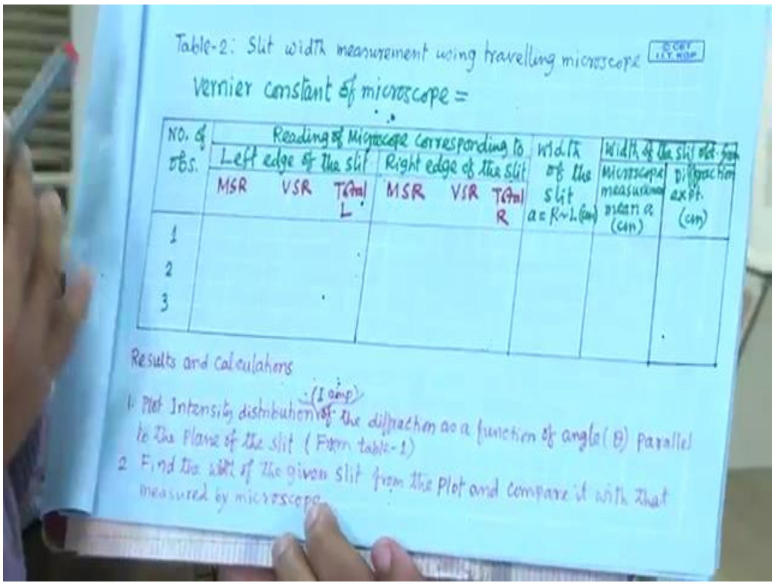

And, then the we will measure slit width using the travelling microscope for comparison whatever the experimental we have measured from diffraction experiment. we will verify using the travelling microscope. we will note down the Vernier constant of the microscope and then we will take reading of microscope corresponding to left edge of the slit, main scale reading, Vernier scale reading total.

if it is L similarly for the edge of the slit, we will take note down the reading and then width of the slit is a equal to R minus L, that we will get from microscope and from our experiment from our diffraction experiment from graph we will get the value.

that width of the slit from the microscope measurement, this mean value of a we will get and from experimental diffraction experiment we will get; this we can compare. we will take data and then we will plot intensity distribution of the diffraction as a function of angle theta; this photo cell should be parallel to the plain of the slit of course. from table 1 we will get this data and then we will find out the width of the given slit from the plot as well as we will measure using the microscope travelling microscope; for comparison

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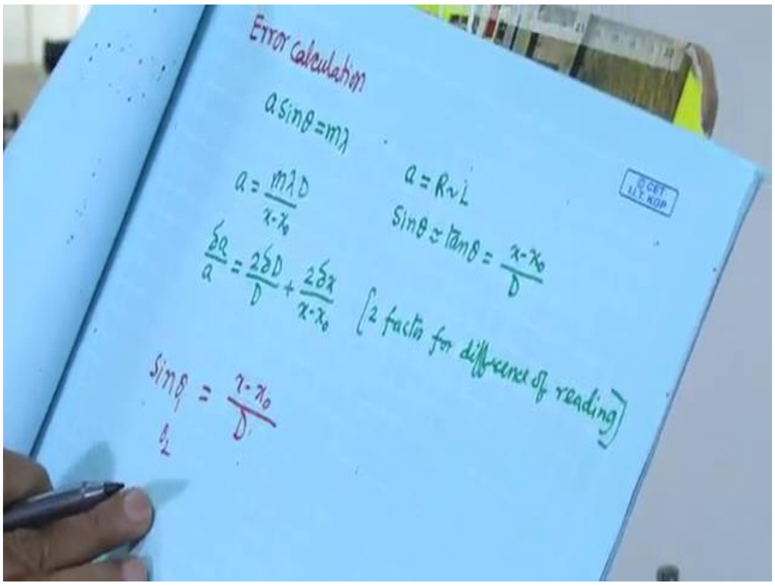

And the error calculation for this is very simple; a sin theta equal to m lambda, a is difference of two reading R minus L and sin theta is x minus x 0 by D as I told. here also this D is the distance between the slit and the screen or photocell.

this D also difference of two reading. here if you take del a by a; then m is order count so no error, lambda is given. error will come from D and x minus x 0. this 2 del D by D plus 2 del x by x minus x 0, this factor 2 we have written because of the difference of the reading both D and this x is the difference of two reading. that is why this factor 2 is come has come

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now I will demonstrate the experiment in our lab. this a slit I think from here you can see that slit I can I can rotate and change the slit width, I think I am increasing slit width you see slit width is increasing, this is a very large slit width. I am now decreasing the slit width

I am now decreasing the slit width, just rotating the screw now it is 0, I can change the slit width and keep say this is the slit width keep at a particular value. this is the a. this type of slit you are using in our the same slit we are using here. this is the slit ok, this is the slit same slit. I have kept at a particular width. I will not disturb that width ok, now this is the laser

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its wavelength is as I told 632.8 nano meter. this laser beam is falling on the slit.

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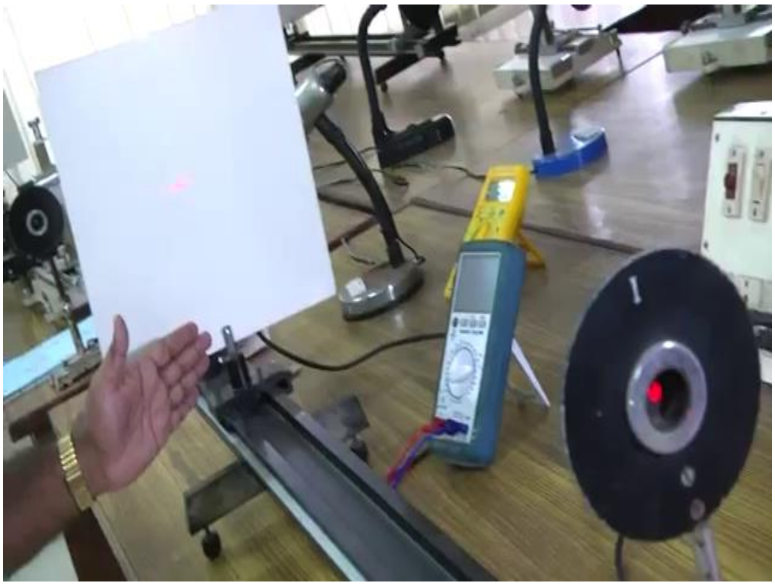

laser beam is falling on the slit, now here this is a screen, here this is a screen. we are seeing the diffraction pattern. we are seeing the diffraction pattern. this is the central one highest intensity diagram you have seen, in the diagram you have seen the central one will be highest intensity, central one will be highest intensity. And, then this side one, the secondary one that intensity will decrease and between this maxima there are minima

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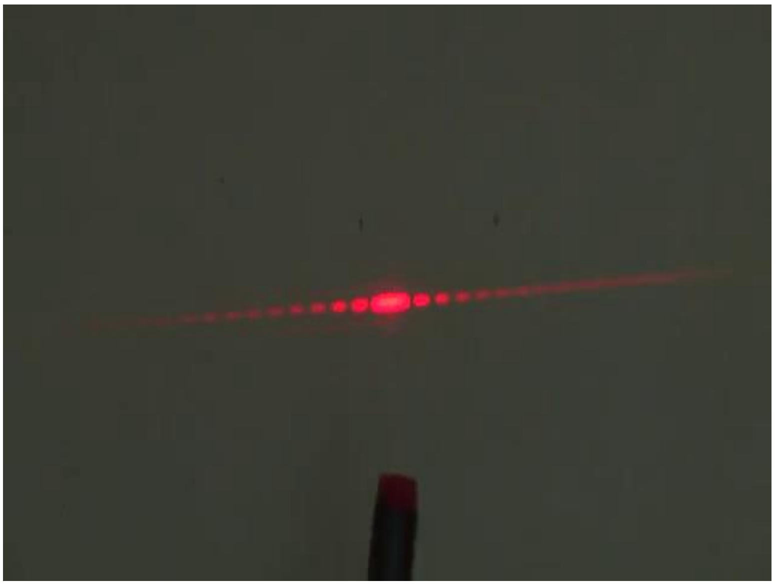

you are getting the central maxima and then this first order, secondary maxima, second order, third order, fourth order, fifth, six, seven, eight and able to see many order. this is because of laser light we are able to see many order; with other light we cannot see because this laser light have higher intensity. this other side also first order, second order, secondary maxima, third order, fourth order, fifth order; now between these secondary maxima you can see the gap ok, there is no light.

that is the diffraction minima and the condition for that minima a sin theta equal to m lambda. we will measure the; we will measure the intensity as a fab we will use photocell. if photocell if we vary what the we will note down different position of the photocell and corresponding photo current or photo voltage we will note down. that photo current will be proportional to the intensity of this light. that is the property of this photocell

then we will get this x versus the photo current and central one, if I take that reading as a x 0; it can be 0 also if we adjust the position of the photocell, but that you do not need. this you can take as a x 0, now with respect to the central maxima just we will vary the position of the photocell and we will note the. we will start from say left and then left to, we will move and take the reading for different position of photocell; we will note down the current photo current. this will be one set of data and second set of data you can take when you are moving from to left this is the task, then we will plot the intensity photo current versus this x minus x 0 or this angle theta, theta equal to x minus x 0 divided by D. D will remain constant, only we will vary the x here just I would like to show you the because, in this formula what you are getting? As I showed you as I showed you this as I showed you that a sin theta equal to m lambda. a sin theta equal to m lambda and then sin theta equal to sin theta equal to x minus x 0 divided by D.

from here you can see that for a particular order; for a particular order if it is for m equal to say 1 this angle is say theta 1 m equal to 2 this angle is theta 2. for a this for a particular distance of the screen whatever theta 1 you will get, if you increase; if you increase D what will happen? If you increase D then this value will decrease, if we increase this value will decrease ok, but theta in because of the position of the screen you cannot change theta.

the that theta is defined by this slit width ok, that theta is defined by the slit width and diffracted angle. what I am trying to say if D increase this value x also increase for the same order; that means, order this first order will move this other side. when D will increase then what you will see? You will see that x also this order will move other side. I am increasing see I am increasing you can see the separation is I think let me decrease because not much distance that side. now distance I am decreasing; these order will be you see closer, it will be closer

x will decrease because, D is decrease x will decrease to keep this theta 1 same because, that is coming from the slit this fringe that spacing it will depend on the screen distance from the slit, screen distance from the slit. Also, that theta will depend on a. if a is if a is increase or decrease ok; order that position of the order will change or if a increased for a same order, theta will decrease. If a increase to for same order first it has to be lambda.

So that means, theta will increase for first order minima ok; that means, it will a increase, it will decrease. it will come towards the first order that will come towards the central one, central maxima. If theta is decrease then sorry a is decrease theta will increase for same order; that means, this first order will move away from the central one. that I can demonstrate, I can show you I am changing the slit width. now I am increasing the slit width you know sorry; I think no I decrease the slit width.

it is 0 now ok, no I think we have to show that one ok; I am increasing you see this first order minima. it is coming closer to the central maxima. all order is moving towards the central maxima, you see the central maxima that is the effect of the width of the slit. Now, I am decreasing you see the central maxima are moving not central maxima that minima are moving away from the distance are increasing. theta is increasing x by d that is the angle see.

we will keep at a particular we will keep at a particular angle that means, we you now we have kept not a particular angle, particular a slit width. then we will not disturb that one, also as I showed this if you change the these distance also it is the varying this also we have to keep at a particular distance slit width for a particular slit width a and for a particular distance D, that distance between the slit and the screen For this we will do the experiment.

What experiment we will do? We will measure the intensity of the diffraction pattern as a function of theta, means as a function of a position of the photocells from there you can find out theta. So now, I will remove the screen

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Now, I will remove the screen. this is the photocell So now, that diffraction pattern is falling on the photocell. photocell will give photo current or photo voltage

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this we are measuring using the multi meter, you can see this we are we will measure using the multi meter. I think we if we can switch off just I have it is a it should be 0. we should switch off the light, I think these light have very high intensity you cannot choose. this light if others room light is falling on the photocell, it is giving current So now, we see these the photocell and it is on the stage of a micro metre here is a screw gauge it’s a circular scales are there as well as linear scales are there.

if I change just rotate the circular scale, this a position of the photocell will change and that I can note down. here there are in circular scale there are 100 division. if I rotate once 1 millimetre means I think you can see. here is a millimetre scale and here is a circular scale it has 100 division 0 to 100 division. if I rotate one complete rotation then it will be here it will move by 1 millimetre. it’s a list count is 0.001 centimetre or 0.01 millimetre.

you have to take reading from here. So now, I will show you; I will show you the reading. let me take is extremely I think you take extremely left or anyway I am just sitting at the centre. when I will get the maximum current maximum voltage current or voltage whatever. this is the central position it is a reading is giving 193, what happens I think. because from outside if light falls on this, I just stopped it; it has some still it is I think if I can switch off this one. its I have change scale.

if I just it is a going minus negative sign. it is so 1 180 this in millivolt, this 192 it is giving 192. if I change just this intensity we will change, you see now from central maxima it is going towards the first minima ok; its reading is getting changed, reading is getting changed. for each position you know this we have to note down, I am not noting down just showing the variation of the intensity. I am about to get to the yes about to get to the minima, but it is fluctuating, it is heavily fluctuating. I do not know this camera light is falling on it.

this way you have to move and note down the photo current. And, that photo current corresponds to photo current corresponds to the intensity of light.

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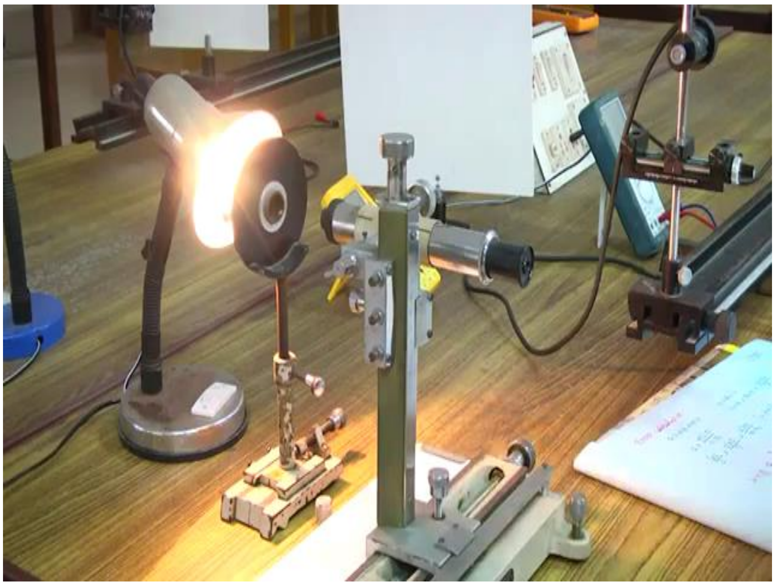

now what we will do? we will use this travelling microscope; we will use this travelling microscope and put this one I think yes. we have to adjust height either here or here. I think let us put light here, then we will see yes, I got, but I have to yes, I got night nice. this processor I have to anyway I got the slit. actually, I had to take out that one and put here; this is the another slit. just set here and then you focused and put you see use this, this scale horizontal scale.

And, crosswire you should say that edge or left edge, take the reading Vernier constant you have to find out its I can see the 50 division and corresponding anyway you know how to find out, many times I have discussed. you take the reading for left edge and then move again to put the crosswire at the other edge, take the reading. difference of this reading will be the slit width from microscope whatever value you got and plotting the graph of intensity means photo current versus the angle, angle you will get x minus x 0 divided by D

If we put plot graph from graph you will see the intensity variation. find out the minima, first order minima, second order minima and what is the angle for that. for first order, second order, third order you find out this angle, put in this formula, a sin theta equal to m lambda. sin theta is known from the graph, theta is known mean sin theta is known, m also known order. lambda also given 632.8 nanometre. you can calculate a, a for first order, a for second order, a for third order minima and from both side you can get.

you will get few readings and or for a and you can take average of that, that will be the slit width I think I tried to show you the pattern of the single slit diffraction. And, how to measure them that I tried to describe and only reading I cannot take because, it is a it takes a long time. that is your job to take it but following the procedure as I explained. I will stop here.

Thank you for your attention.