Experimental Physics - III
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Lecture - 41
Zeeman Effect (contd.)

You are welcome to modern physics lab of Department of Physics IIT Kharagpur. Today I will demonstrate Zeeman Effect in our laboratory.

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This is the experimental setup for Zeeman Effect. As I mentioned giving theoretical discussion of Zeeman Effect, we will choose mercury source in our laboratory.

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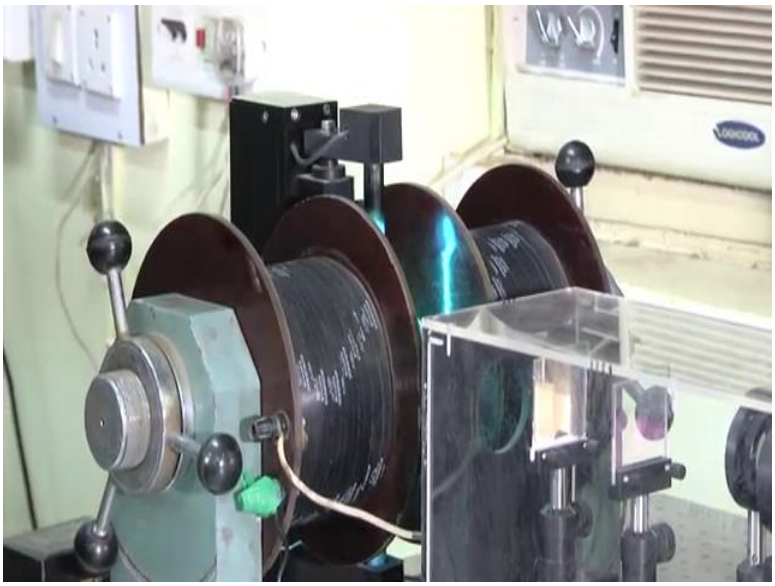

This is the mercury source, this is the mercury source, why I have chosen mercury source that I have explain.

From mercury source different color of lights means light of different wavelengths are coming. as I told that we will choose green color that wavelength is 546 nanometer.

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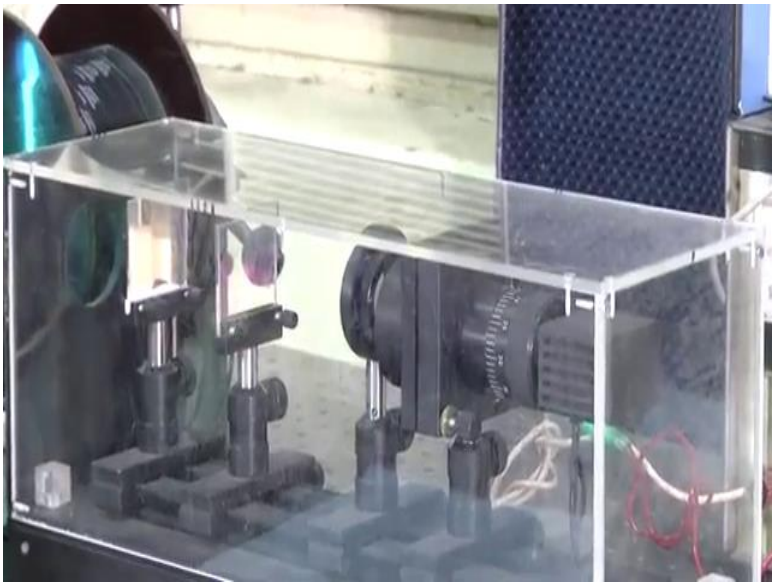

For that, we have used this interference filter. This interference filter it will just allow to pass this green light of having wavelength 546. In addition, with some bandwidth with some bandwidth of course, and other light will not pass through it.

then this light green light it is a it will fall on this glass plate, this glass plate probably it is used for making it of its called broad source. Because in case of Michelson interferometer in case of Fabry Perot interferometer, the path difference not path difference, I think this yes the path it will travel through this interferometer that path is constant at everywhere.

That is why we need variation of angle incident angle ok. In case of Newton's ring there whatever these air film we used, that is waste film. There this variation of thickness is there. In case of this interferometer is a word is thickness. Whatever mechanism we are using, there this air film thickness is constant in case of Newton's ring, their waste film we use their thickness varies.

Where thickness varies there, we use the incident light of constant incident angle ok. Why do we use this constant thickness, there we use this, the variation of the angles. That is why here this glass plate it will make this broad source. light will fall on the interferometer with a different angle with all source of angle incident angles.

Now, here this one is it is a polarizer, here we have used one polarizer. Why I have used polarizer that I will tell you, I will tell you. Now, this light is falling on this part, this part is inter Fabry Perot interferometer. There etalon is there; etalon is as I mentioned that 2 mirrors separated by constant distance d ok. That is inside here, but I can show you.

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This kind of things is here. This is the etalon one this is the one plate one mirror you can tell, it is a 90 percent it can reflect and 10 percent it can transmit. This is one mirror.

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In addition, other side you can see this is another mirror. One mirror is fixed another mirror you can adjust with this screw systems are there, here 3 screw systems are there. You can change the adjust the distance of this of these 2 mirrors. Or you can also tilt it you can adjust these 2 mirror. This type of things we have used here. this in front of that one there is a lens as this type of setup ok.

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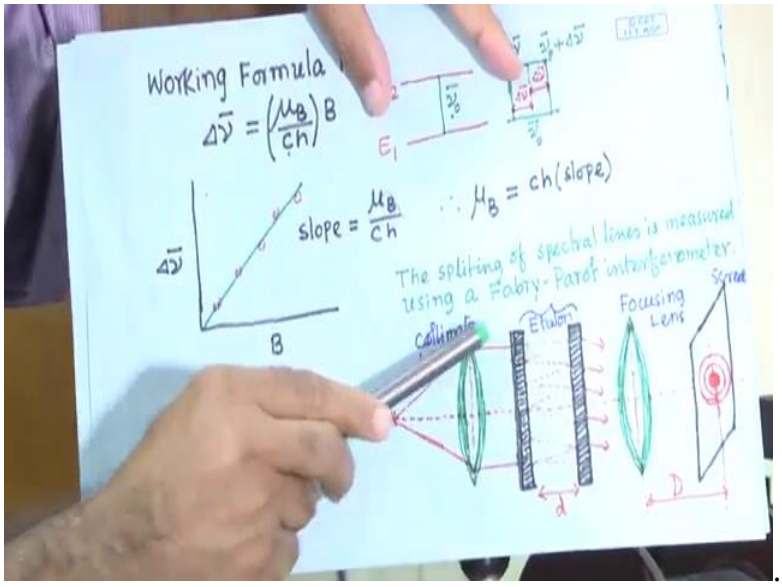

This is the etalon as I showed you as I showed you here ok. now, in front of this there is a lens here collimator lens. It is here and the other side also another lens is there another lens is there inside you cannot see. This together is it is the interferometer ok.

Then one can use the telescope or eyepiece as a skin for seeing the fringe, but in our case, we have used CCD camera. We have used CCD camera and that image whatever this we have catching on the CCD camera and that will displayed on the computer monitor ok.

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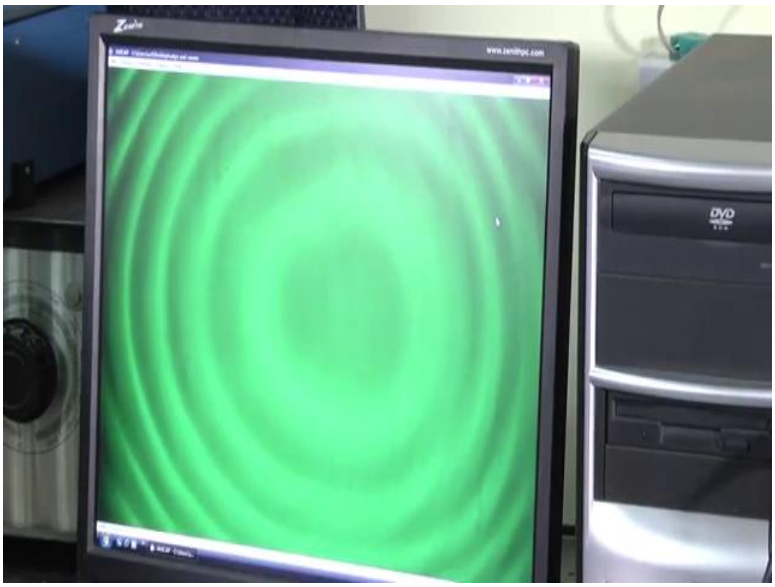

Now we have need an arrangement for applying magnetic field. this is the electromagnet this is the electromagnet ok, it has 2 pole piece. This source we have put between the pole piece ok. this is the power supply.

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This is the power supply for the electromagnet. There are 2 coils. in that coils we pass current; here you can see current and voltage it is a one can see. We give we pass current through these coils and then, it will produce a magnetic field. magnetic field will vary with current.

Initially we have to calibrate this magnet. for calibration, we will use Gauss meter we will use Gauss meter ok. This is the probe, it is called Hall probe.

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If you put between the pole piece, if you put between the pole piece and vary the current and vary the current, current of the magnet ok. then I think that is not working, I do not know, we will let me check it why I am not getting reading.

let me check it yes, you can see this magnetic field it changing, when I am changing current is the magnetic field is changing ok. I will change current and this see magnetic field. Now what we have to do? Let me make it 0. What we have to do? We have to calibrate this magnet first, this magnetic field versus magnetic field versus coil current ok.

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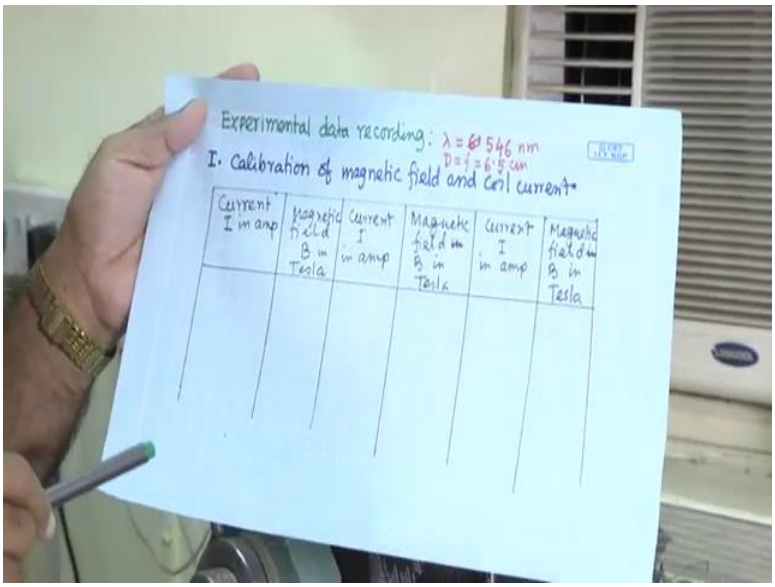

Calibration of magnetic field and coil current it amperes or milli amperes and then corresponding magnetic field using the Gauss meter, ok.

Current corresponding magnetic field I have to note down right; I have to note down. Then, what we do? We plot graph we plot graph magnetic field versus the current. From that graph, one can find out the how much magnetic field you are applying during your experiment.

We will apply current, we will note down the current and corresponding magnetic field from this graph we will find out ok. that is the way we will measure magnetic field or we will apply magnetic field on the source in the source ok.

Next, what we have to do? We have to measure the we have to measure the splitting of spectral lines, splitting of spectral line as a function of magnetic field ok. initially first what we have to do, before applying magnetic field, before applying magnetic field we have to measure we have to measure the separation between 2 mirrors of etalons this small d, that we have to measure.

For that how to measure that one, how to measure that one? This is you see this if I put light nothing is coming ok. This whatever image is found on the or fringe is found on the CCD camera, that we are seeing here in magnified way. For this camera what is the pixel that is supplied by the company that one has to know.

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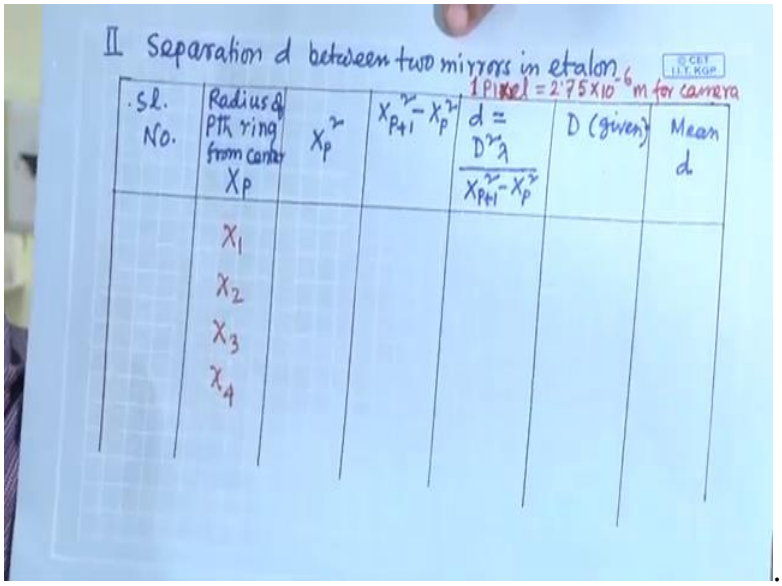

In our case, 1 pixel is equal to 2.75 into 10 to the power minus 6 meters for this camera; that means 1 pixel equal to 2.75 micrometer ok. That if you know here whatever length will measure that is in terms of pixel, from that pixel one can find out the length in micrometer or meter ok. For measuring the d separation d between the 2 mirrors in the etalon, what we have to do? We have to measure the radius of the ring of the P th ring from center ok.

As I discussed during theory, that central that the central order is the maximum number of order in center that is the maximum ok. If it is n, then when you are going outward. this next one will be n minus 1 then n minus 2 n minus 3 n minus 4 n minus 5 ok. Outward this is the you will get 1 then 2, 3, 4 when you will reach here at the center.

That is an order number is maximum. However, this formula we have written in such a way, that we have taken care that center 1, if we consider this is the if we count the is the 1, 2, 3, 4, 5. That is the we are telling here whatever I am telling radius of P th ring from center ok. That means, P th ring I am counting from if it is P is 3, third ring I will take this is 1, 2, 3 this is the third ring ok.

This P th ring here it is not n th or n minus 1 or minus 2 minus 3. I have here adjusted the formula in such a way that will count the this ring this one has a from center this is 0 this is a 1, 2, 3, 4, 5. radius of P th ring from center if it is the radius is X P so; that means, for first ring say X 1, X 2, X 3, X 4 ok.

That we will note down then corresponding X P square means X 1 square X 2 square X 3 square X 4 square you can calculate. this is X P plus 1 square minus X P square. Here X 2 square minus X 1 squares, you will get reading here and then X 3 square minus X 2 square X 4 square minus X 3 square.

If you take 5 ring reading of the 5 ring, radius of the 5 ring, then the here you will get 4 reading ok. For each one for each one you will calculate using this formula as I if showed you earlier. d equal to D square lambda by this ok. D is the D is the distance of the screen ok. This is the focal length of the lens.

That is given that is given that is I think that I will show you. And lambda we have chosen 6 5, 5 6 4, 546; 546 nanometer. These given lambda is we have selected that also given and then we are measuring this and you can find out small d. mean small d you can find out ok.

For this measuring how you will do measurement. here software is given actually you can we can save it just this file.

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I think you have to capture. I have already I have saved it. That then you can analyze that. you have to whatever we have saved that you have to upload open Amal say open file open ok.

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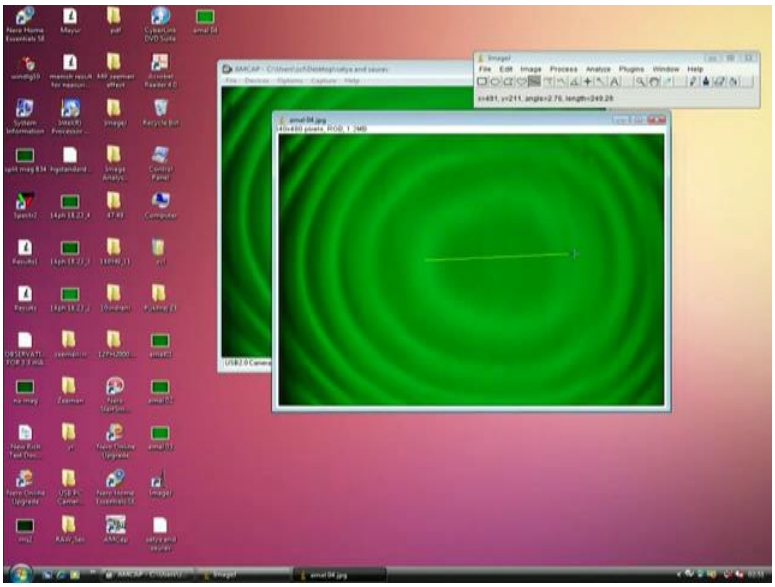

Now this is the captured one ok. here you have option that I will choose say line, now I have to measure the radius ok. For first ring actually what we will do we will measure the diameter and then we will take half of it. we will take diameter ok. What is the value

that here in you will see in terms of a pixel. here it is showing this value X value is 488 y value is 201.

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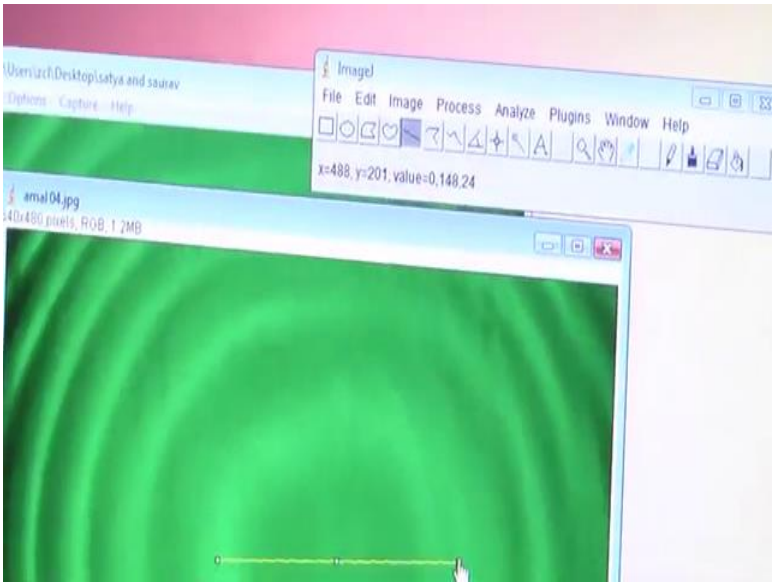

But I do not know let me check once more.

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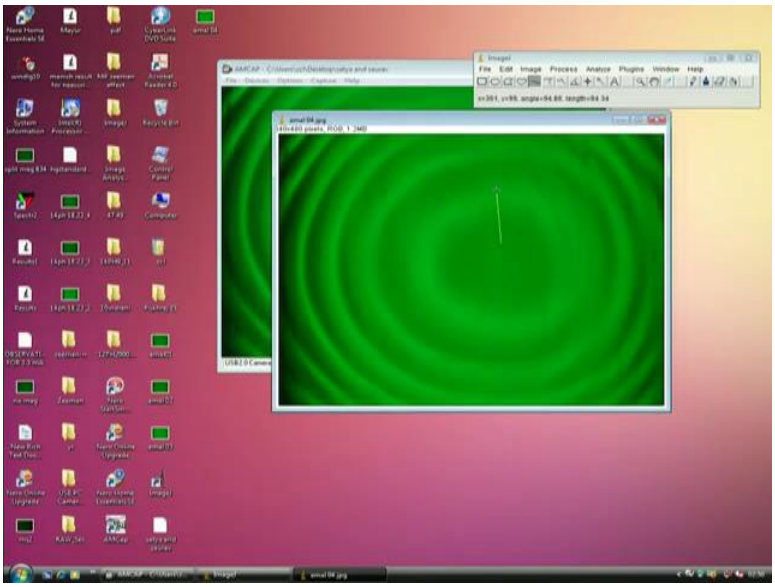

It is giving length 94.34 pixel. giving length 94 point.

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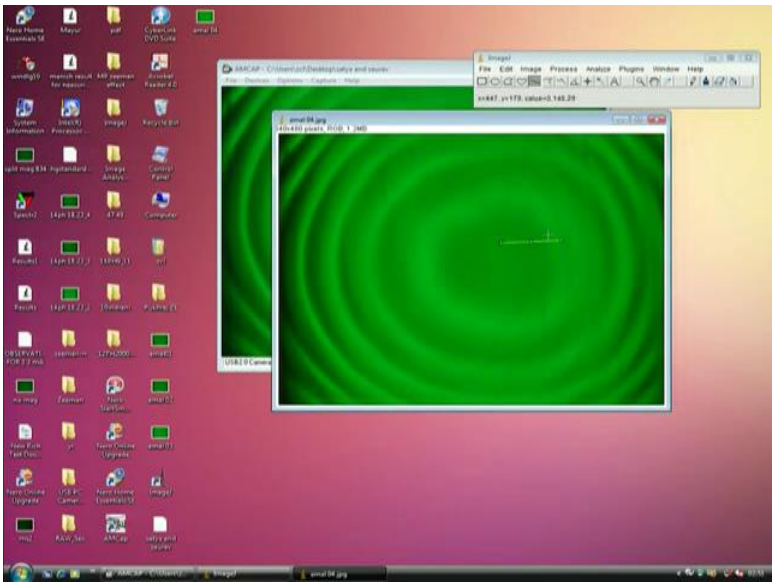

It is a giving different length. Radius you can measure, but I think it is better to measure this diameter also it may not be the accurate one. A length it is a 250 kind of things. this say we can measure this length.

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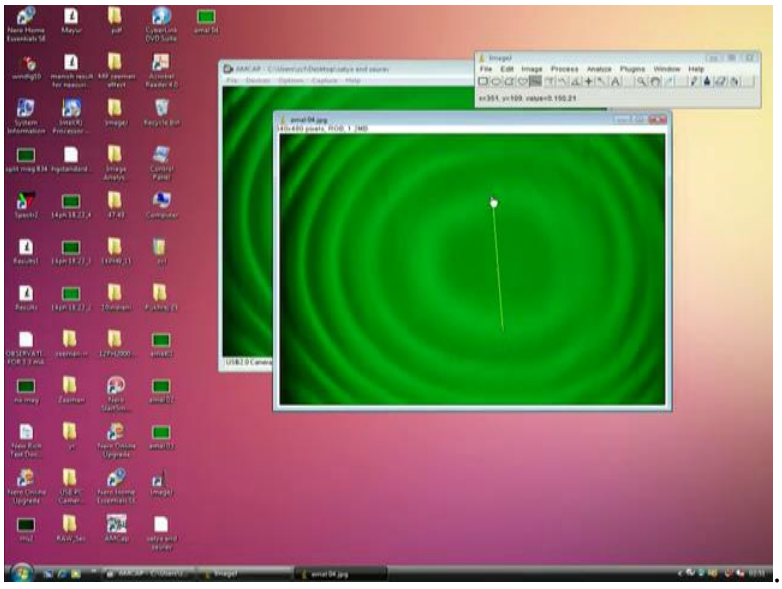

This would be the diameter ok. Diameter of this of this ring first ring in pixel, you will get from this software or you can take print out and then all alone can use scale and pencil to find out the diameter. that you have to for first ring for second ring third ring.

What is the radius that you have to note down that you have to note down here ok; for first ring second ring third ring fourth ring?

And this one pixel is this that conversion is there. then from here you will find out this d value.

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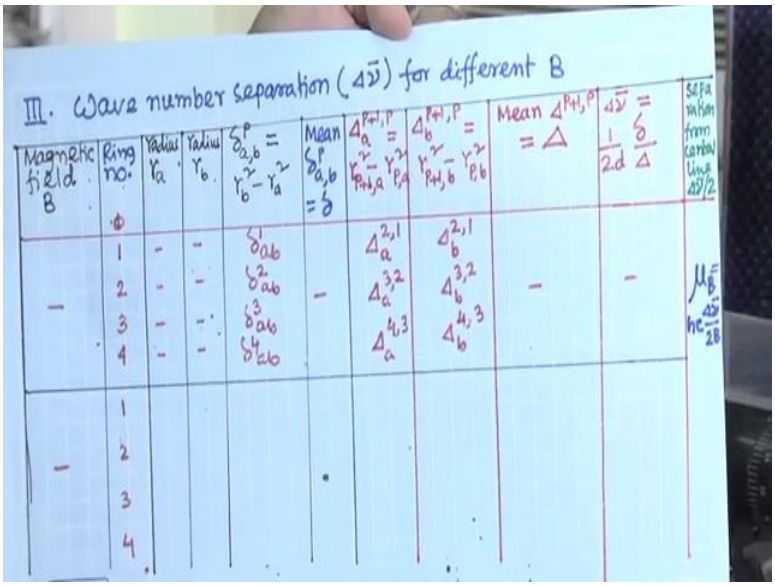

Now, second third table is wave number separation del nu for different magnetic field ok. for that what I have to do? For that we will apply magnetic field, particular magnetic field, then we have to we have to measures we have to measures measure radius here also radius of ring 1, ring 2, ring 3, ring 4.

Ring 1 ring means it is for a particular wavelength. here what you will get, when we apply magnetic field we are expecting that it will be splitted. You will get 3 rings what rings will be 3 rings. However, in our experiment, you will see 2 rings why? For that, we have used this polarizer; actually, this in 1 line is splitted into 3 lines. Out of this 3, whatever nu 0 nu 0 plus del nu 0 minus del nu. These 3 lines out of this 3, 1 where del ml equal to 0 that is pi polarized light.

And where del ml equal to plus minus 1 that is sigma polarized light ok. pi polarization and sigma polarization you know this electric component of this light they are perpendicular they are perpendicular. If we use the polarizer, optic axis we have said in such a way that either pi polarized light or the sigma polarized light will pass through it.

Here we have we have we have set optic axis we have kept in such way that sigma polarized light will pass through it ok. Just to avoid clumsy of the of the of the fringe if it is 3. It will be difficult to see them. If it is 2 then it will easier ok. for that this polarizer we have used.

This original one will be will not show there only whatever we will see we will see the two splitted one delta nu this side and delta nu the other side from the. 1 is higher than delta nu, higher than original 1 and 1 is less than the delta nu less than the original 1 ok. Then the experimental setup is such that here we will see the 1 ring will splitted into 2 ok.

Now that splitted into 2 that 2 that we are we are telling a and b. these two wavelength lambda a and lambda b for that this 2 ring will gets one ring will be splitted into 2 at present. This radius of this two ring one is r a and another is r b. we will measure for first ring r a and r b, for second ring r a and r b third ring r a and r b ok. If you if you just take this reading rest of the things just your calculation ok.

What is that calculation? Then here we will take r b square minus r a square ok. This is delta P a b delta P ab that what is delta P ab that I have explained you. We will get for first ring P a is P th ring. First ring, second ring, third ring, fourth ring here for first ring r b square minus r a square. This is delta 1 ab. these value here whatever we will get this these are independent of this a b and P ok. that I have mentioned earlier.

We will find out the average delta small delta ok. Then here we are going to calculate rp plus one a square minus r P a square. Here the first ring and second ring for wavelength lambda an ok, taking the difference here wavelength for lambda b we are taking the difference radius square of the successive rings first.

Second for b or for a we are taking the difference that we are telling the capital lambda capital lambda and these are independent of P. there is a from this data. you have to you have to basically. You have already data here radius you have already ok.

Now only you have to consider this P and P plus 1 means first, second, third. , here difference you are taking for the between ab, but for first ring ok. Here you are taking difference for a for first and second ring here taking difference of b, but first and second ring ok. You have this data and this data is sufficient for calculation all these things.

These will be average of this will give you capital del. del nu bar will be 1 by 2 d small delta by capital delta ok.

This you will find out. Now, here this different you are measuring the 2 delta nu whatever in theory I told delta nu, that delta nu is from the origin original spectral line that ring for original wavelength and the now ring for the splitted one. What is that difference in wave number that is delta nu?

But here whatever we are measuring we are measuring between this from original between these 2 splitted one. It will be 2 delta nu. That is why we have to fit with this your theory. delta nu bar by 2 you have to take now delta nu bar by 2 you have to use mu b equal to hc delta nu bar by 2 B for calculation of Bohr magneton ok.

this for one particular magnetic field, then you take for second magnetic field third magnetic field fourth magnetic field fifth magnetic field at this 5 data you should take ok. Now, just I will show how to then you should plot data graph and then from graph, you will get slope and that slope will be used for calculating this mu b.

Now just I will show how to how it is changing with magnetic field. That the same way you have to calculate this the diameter from diameter you can calculate the radius, but I will not calculate again. This is our original I think yes-live one ok. now, magnetic field is 0; this is the fringe pattern.

Now, I will apply magnetic field and see the change ok. I am applying magnetic field I am applying magnetic field you see splitting started.

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I think switch off light, then I think it is a can be seen better or I think I should ok. You can see the splitting you can see the splitting let me put again 0 ok, 0 magnetic field. Now am I applying magnetic field it is splitted, it is splitted, its splitted merge again ok. You have to apply different field.

Say I have applied this field ok. Now, I have to measure, I have to capture this picture and I have to measure the radius of this; I think this is difficult to see. I will take this one is a say third ring first second third ring. this is one and this is second one. For a and for b for lambda a and for lambda b and then one this for lambda a and lambda b. it is independent of number of number of fringe; I mean this independent of p. that is why there is no problem.

For this field what is the diameters of r a and r b that we have to we have to find out then I will increase field more. Now, for this field again you measure the diameter or radius for r a this for lambda a and lambda b. then I will go third field ok. this way at least to vary you take data for high field and then you calculate as I mentioned here.

Just if you take this set of data take this set of data, then rest of the things you can calculate. And you can plot graph and from graph, we can find out the mu b ok. This is a very nice experiment where you can see the effect of magnetic field on spectral lines and in theory whatever we have seen that exactly we could demonstrate here ok. I think I will stop here.

Thank you.