Engineering Metrology
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Lecture - 33
Optical Measurements and Nanometrology (part 2 of 3)

Welcome to the next chapter of discussion which is profile projector.

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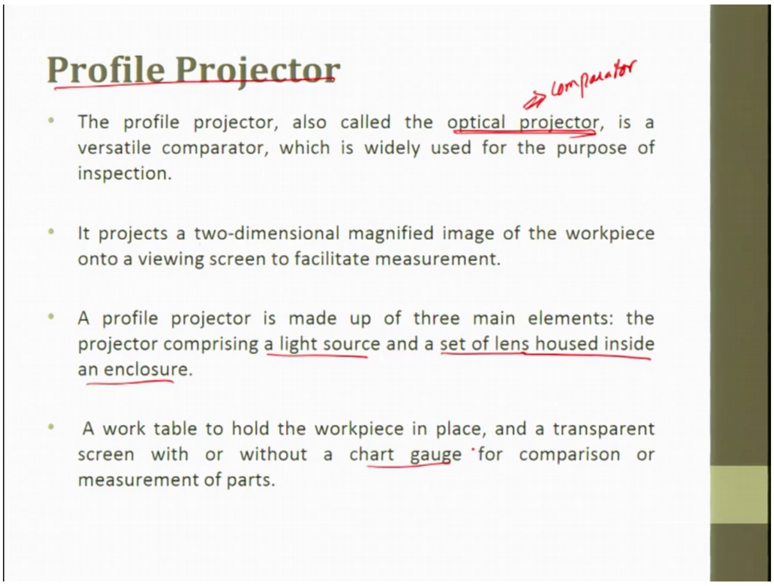

Profile projector is also called as optical projector; is a versatile comparator which is widely used for the purpose of inspection. Profile projector is used more of comparator. Measurements are not the predominant here, but still if you want to do using this optical projector if you want to do profile projector you want to do a comparison it is possible and measurement is also possible. It projects a 2 dimensional magnified image of the workpiece onto a viewing screen to facilitate measurement. A profile projector is made up of 3 main elements. The projector comprising a light source, and a set of lenses housed inside an enclosure, work table to hold the workpiece is placed and their transparent screen with or without the chart gauge for comparison or measurement of the part is done.

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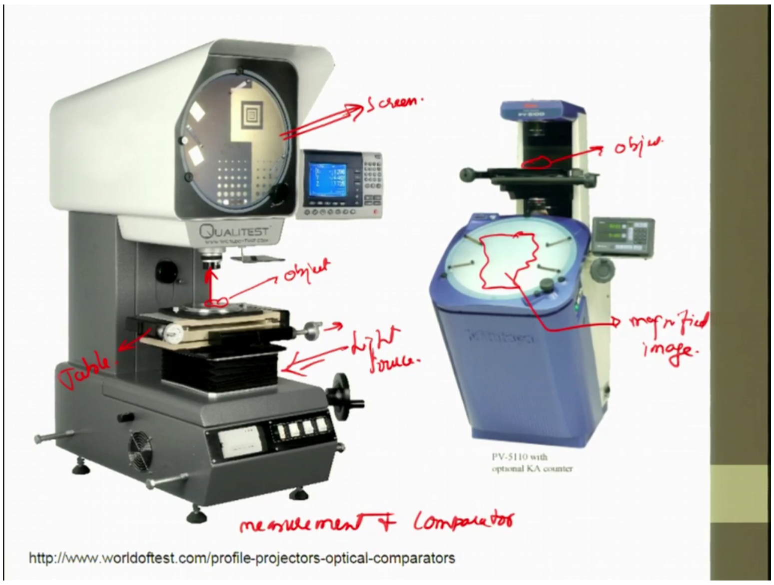

This is a typical profile projector. You can see here, this is the, you can have a light source; this is the table this is a table. So, you can have the light source here. So, the object goes here. So, then it tries to magnify and this is the screen. You can use this for both. You can use this for measurement as well as comparison. Comparator, measurement device or a comparator device. So, you can see here, it you can place the object here, the objects are here the object will be placed here; here you will place the object. So, it goes hits and then you can see the magnified image here, this is the magnified image. Very powerful tool and it is even now it finds lot of application in the tool room applications.

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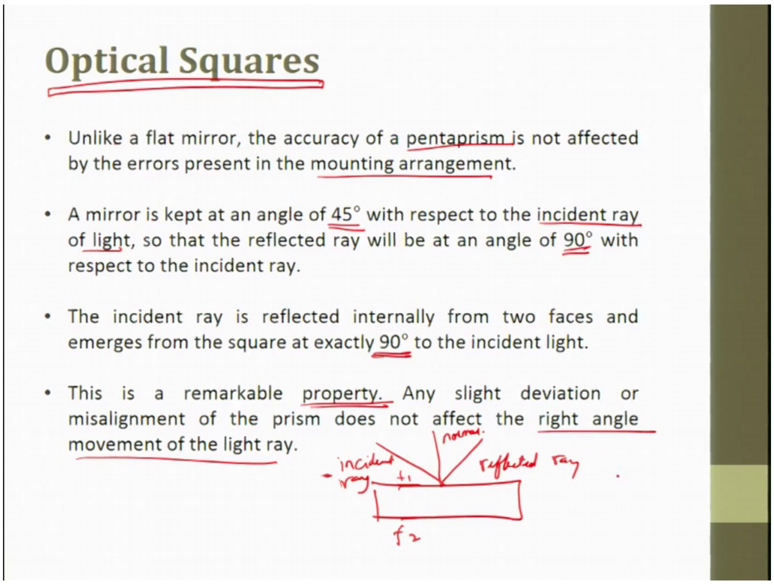

Next is optical square.

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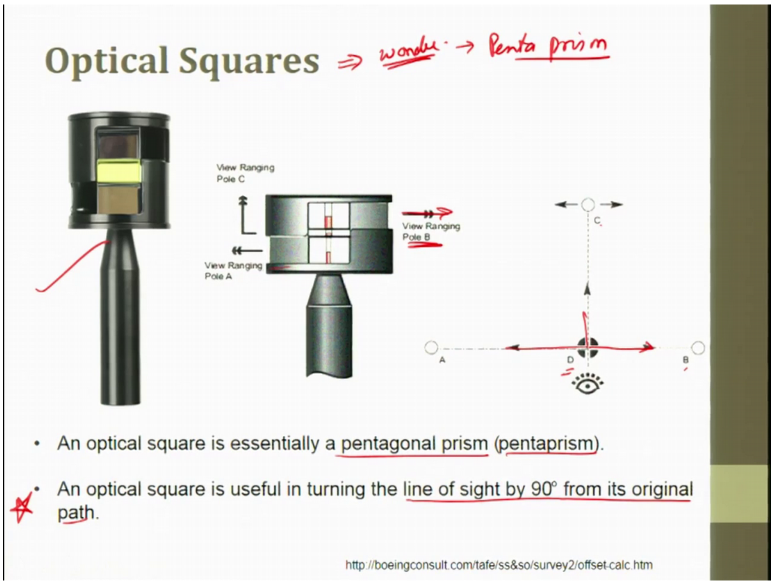

This is called the optical square, these is called the optical square, let us see the optical square. Unlike a flat mirror, the accuracy of a pentaprism is not affected by the error present in the mounting arrangement. The mounting if there is an error that also gets, that also gets magnified when you do the measurement. So, unlike flat mirror the accuracy of pentaprism is not affected by the error percent in the mounting arrangement. A mirror is kept at an angle of 45 degrees with respect to the incident ray of light.

So, if you take this is incident, this is reflective incident ray, reflected ray. And this will be the normal. So, a mirror is kept at an angle of 45 degrees with respect to the incident ray of light so, that the reflected ray will be at an angle of 90 degrees with respect to the incident ray. The incident ray is reflected internally from 2 faces, this is assume that this is face 1 face 2 f 1, f 2, 2 faces and emerges from the square at exactly 90 degrees of the incident light. This is a remarkable property any slight deviation or misalignment of the prism does not affect the right angle movement of the light ray. This is very, very important device optical square which is used to check the perpendicularity of any object.

So, you can see here, an optical square is essentially a pentagonal prism pentaprism. So, you can see this is a range of pole A, this is the range viewing range of pole C, this is the viewing range this is the viewing range for pole B. So, this is how it looks. So, here is your eye so, here is a prism. So, it goes at 90 degrees A B C and D. An optical square is used for is useful in turning the line of sight by 90 degree from the original path, turning the line of sights by 90 degrees to the original path. This is very important parameter and this is a wonderful device, this is a wonder. So, because this pentaprism takes care of many of the machine alignments which is there in the box or in the device itself.

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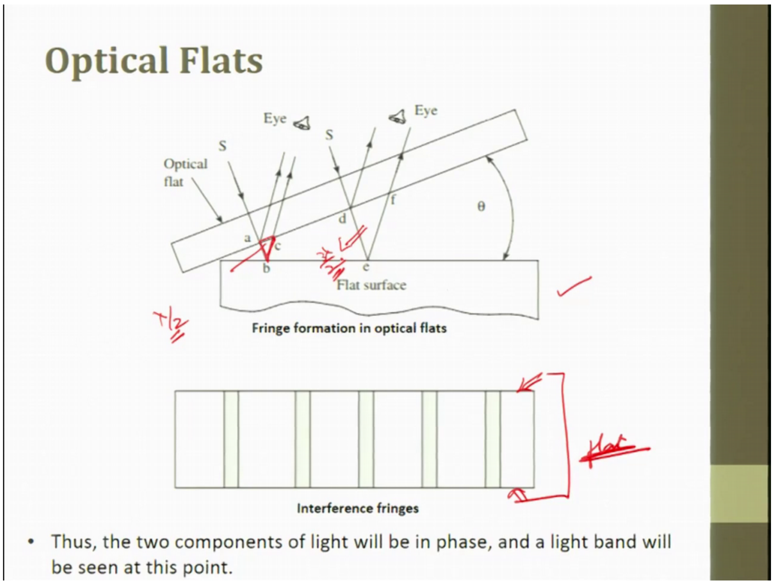

So, next one is optical flat. This is the optical flat, optical flat means you have an optical optical glass, assume it as a plate. The top surface and the bottom surface is completely made flat. And this is predominantly used for generating fringe patterns.

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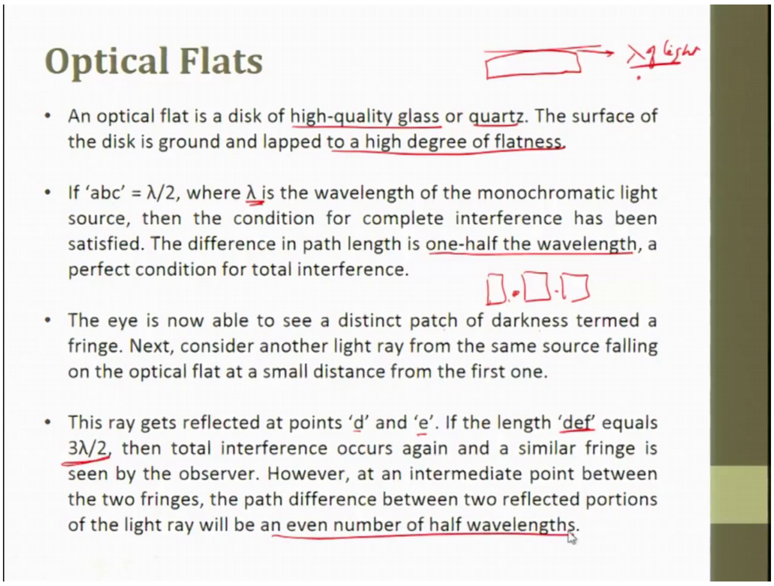

Let us see that, an optical flat is a disc of a high quality glass or quartz. The surface of the disk is ground and lapped to a high degree of flatness. This is basically to measure very small deviations in the object, very small deviations in the object you will be able to measure. And you report this as in terms of wavelength of light, the deviations. Or you try to talk in terms of degrees it is possible, very very small deviations can be measured.

And this is the only device which the only device which gives you such a high resolution measurement. If a b c is equal to lambda by 2; if a b c is equal to lambda by 2, the lambda is the wavelength of a monochromatic light source, then the condition for complete interference has been satisfied. The difference in path length is one half of the wavelength; a perfect condition for total interference. The eye is able so, you can see the eye is able, able to see a distinct patch of darkness termed a fringe so, bright fringe, dark fringe, bright fringe, dark fringe, bright fringe, dark fringe. The eye is now able to see a distinct patch of darkness; these are dark darkness termed as fringes.

Next consider an another light ray from the same source falls on the optical flat at a mall distance from the first one. The this ray gets reflected at points d and e if the length def equals to 3 lambda by 2, then total in interference occurs again, and the same fringe is seen on by the observer; however, at an intermediate point between the 2 fringes, the path difference between the 2 reflected portion of the light will be an even number of half wavelength. So, what we are trying to say is, we are trying to say this is an optical flat, this is a flat surface you want to measure the flatness of the surface, we use an optical flat, both the surfaces are flat at the light from the source falls on it. So, this reflex at a, this reflects reaches the workpiece, reaches the flat bottom side and goes.

So, if we say this, a is lambda by 2, and this is 3 lambda by 2, then we have total interference happening. So, it is placed at a small angle theta. So, it gets reflected from a b and c so that is lambda by 2, and d e and f it is 3 lambda by 2. So, it forms it forms total interference occurs right. So, thus the 2 components of light will be in face, and the light band will be seen at a point. You see light bands at points.

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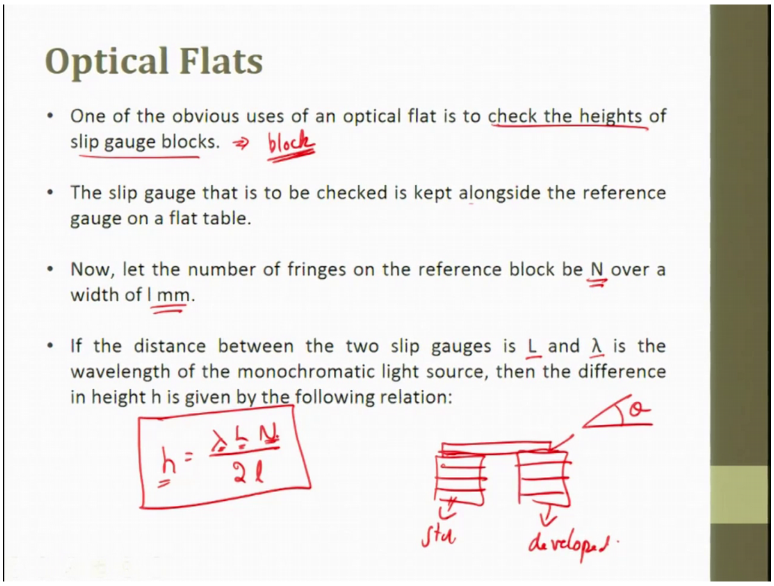

One of the obvious use of optical flat is to check the height of a slip gauge Block. We studied the slip gauge for end measurement. So, we could we made blocks on slip gauge, and these blocks for measuring height we used.

The slip gauge that is to be the checked is kept alongside the reference gauge of on the table flat. So, you can keep it here, this is a standard, and this is your whatever it is developed. You can put an optical flat and try to check. This optical flat of course, will be at an angle. So, there will be an angle small angle theta. The slip gauge that is to be checked is kept along alongside, the reference gauge in a flat table. Now let the fringes of the reference block be n over the width of 1 millimeter. If the distance between the 2 slip gauges is L, and lambda is the wavelength of the monochromatic source of light, then the difference in height can be developed with the following relationship h equal to lambda L N by 2 l.

This is the relationship which gives you the height difference, monochromatic light source L is the 2 slip gauge the distance between the 2 slip gauges, N is the number of fringe pattern and you get to get the relationship.

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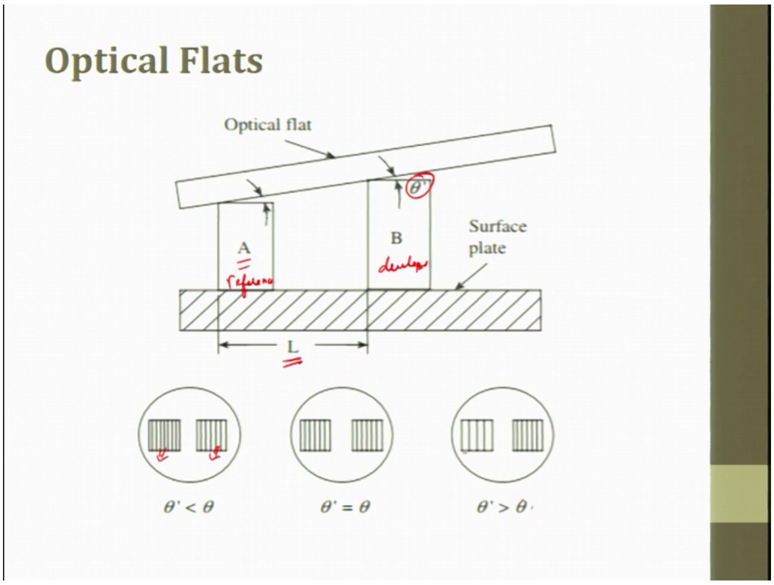

So, these are the 2 slip gauges. So, you can see a can be a reference. This can be maybe what you have developed. So, this both has to be kept on a flat one, this is the distance called L, and this is the small degree and the flat which is placed at a small degree theta. So, when if both theta dash and theta are same you will see the same fringe patterns.

When if it is theta dash is greater than theta, then you see the gap is different between these 2. And when this is less so, you can see the fringe pattern, number of patterns are more number of patterns are less. Just by counting the fringe patterns we can try to see what is the height difference between these two.

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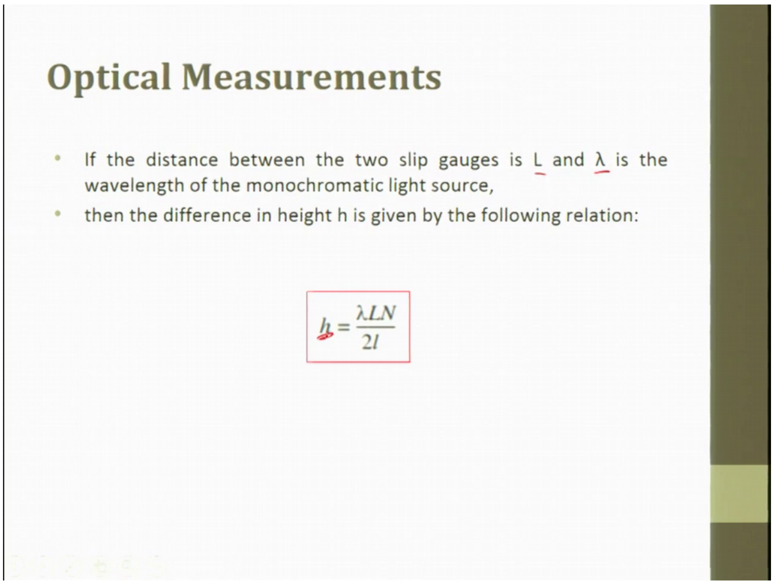

So, if the distance between the 2 slip gauges L and lambda and L is the wavelength of the monochromatic source, then the height difference h is given in the following relationship.

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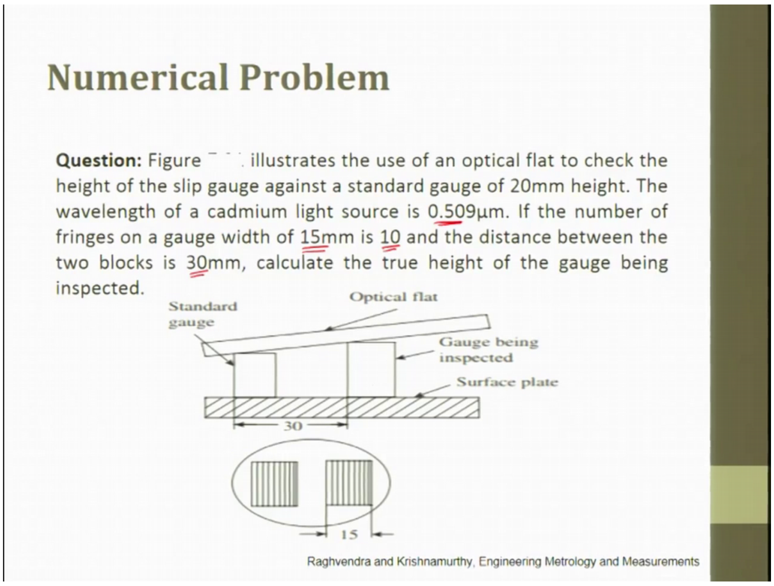

So, let us try to solve a simple question. So, here you can see a figure; which illustrates the use of an optical flat to check the height of a slip gauge Against a standard. This is the developed one, this is a standard of 20 millimeter. So, this is given 20 millimeter, the wavelength of the cadmium light source lambda is given.

If the number of fringes on the gauge width is 15 of width of 15 millimeter is 10, the distance between the 2 blocks is 30, calculate the true height of the gauge Being inspected. So, what they say they say 15 fringe patterns, you get in the 10 millimeter right. So, how do you solve it?

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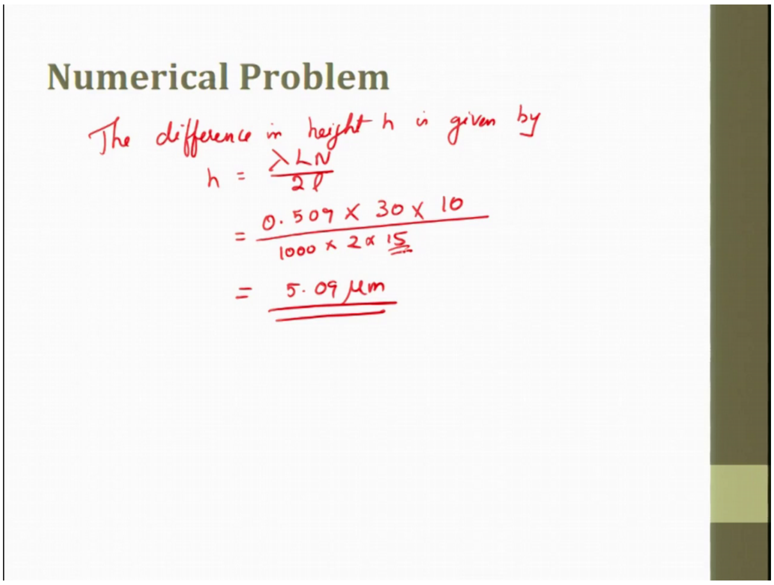

So, the difference in height h is given by the formula; is given by h equal to lambda L N by 2 l. So, this is lambda is 0.509 and what is L? L is 30, what is L? L is the distance between the 2 blocks is 30 into n which is said to be in 10 millimeter it is this much.

And then it is 2 times 15, what is 15? If the number of the fringes on the square gauge width of 15 millimeter is 10, the gauge with is 15. So, you multiply and finally, what you get is 5.09 micrometer is the height difference watch out. So, it is all in microns the height whatever you get reported here is an micron. So, optical flat is exhaustively used for such measurements. So, this is 15 millimeter. So, you are multiplying with 15 right.

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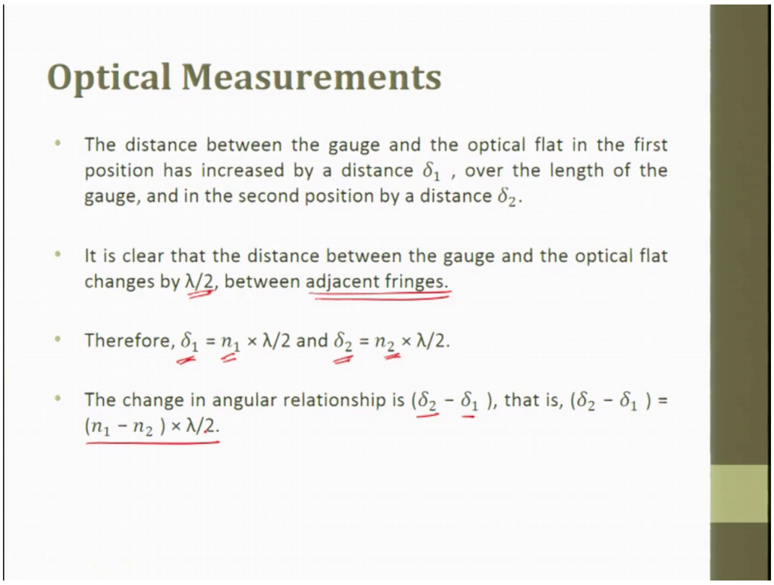

So, the other optical measurements are the distance between the gauge, and the optical flat in the first portion has increased by a distance lambda 1 dou delta 1 over the length of the gauge, and in the second position by a distance of lambda 2

It is clear that the distance between the gauge and the optical flat changes by lambda 2 between the adjacent fringes. So, therefore, lambda delta 1 is called as n 1 lambda by 2, and delta 2 is called as n 2 lambda by 2. So, the change in angular relationship is delta 2 minus delta 1; which is nothing but n 2 minus n 1 into lambda by 2.

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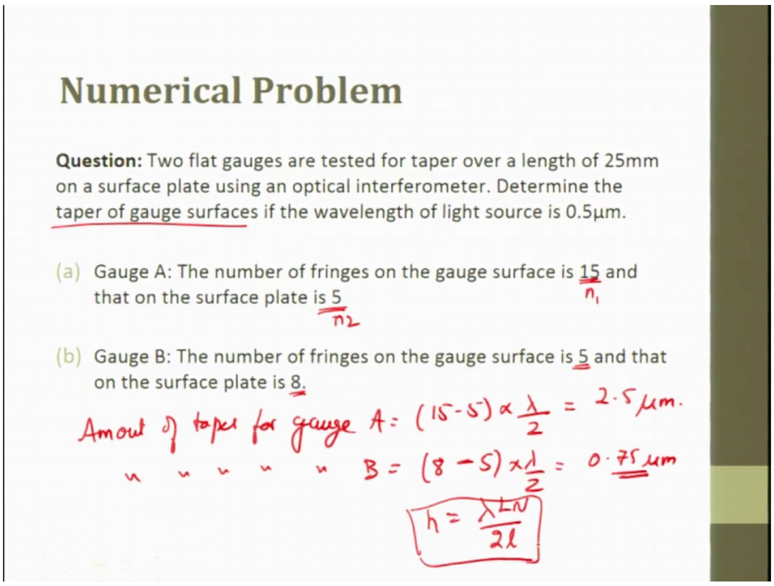

So, let us try to solve another problem and see the 2 optical flats are tested for taper over a length of 25 millimeter on a flat plate using an optical interferometer. Determine the taper of the gauge surface if the wavelength of the light sources 0.5. Gauge A the number of fringes on the gauge surface is 15, and that on the surface plate is 5. Gauge B the number of fringes on the gauge surface is 5 and that on the surface plate is 8.

So, how do you do? So, the amount of taper for gauge A equal to I set 15 minus 5 n 1 minus n 2 into lambda by 2 so, which is nothing but 2.5 micrometer. Amount of taper for gauge B equal to 8 minus 5 into lambda by 2; which is 0.75 mu microns. So, the taper of the gauge surface is to be determined. So, we have found out the taper of the gauge surface. So, what we have done is with the we have found out that taper, we have found out the height. So, height is found out by a formula lambda L N by 2 l. With this 2, this is height and this is taper we can try to use optical flat for measuring the height difference.

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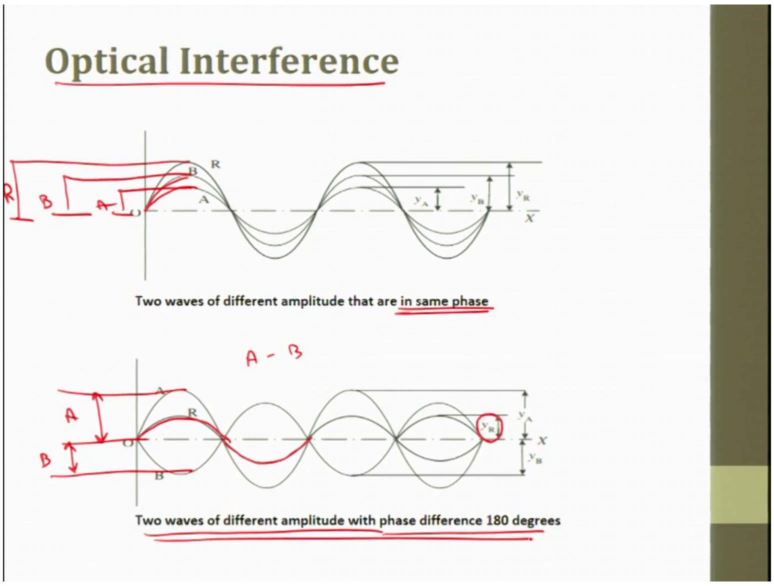

So, next is optical interference, optical interference is we take 2 wavelengths of different amplitude, but of the same phase. So, what are they A is 1, B is the other right, they are of varying amplitude. This is A, and this is B. Since the phase is the same you always try to get a resultant R; which is added of A and B you get R. Here please understand that the light are in phase. If the light R of the same amplitude, but out of phase then you will get a resultant which is subtracting both. So, here you see amplitude A is larger than amplitude B. So, A minus B gives you a resultant R. So, this is y R this is y A y B and this is y R. So, here 2 wavelengths of different amplitudes with phase difference of 180 degrees, you can see there is a subtraction happening between the wavelength. So, this is the concept for creating interference patterns.

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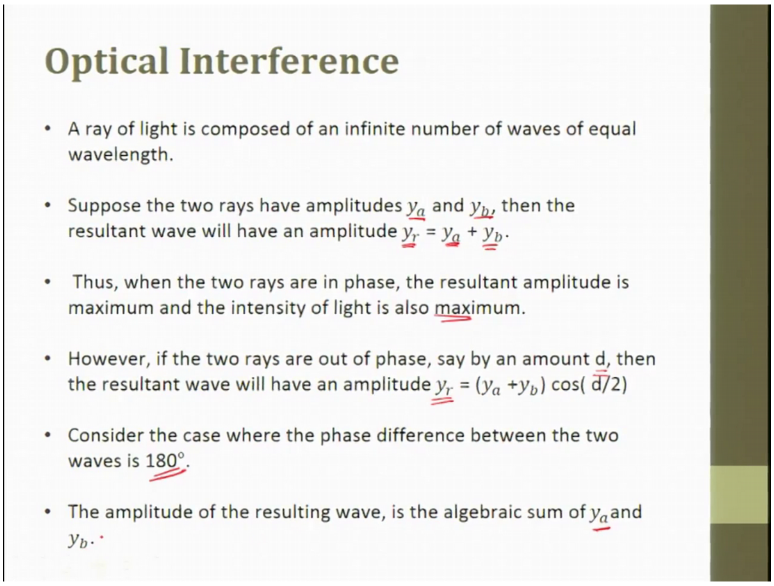

A ray of light is composed of an infinite number of waves of equal wavelength. Suppose a 2 rays have amplitude y A and y B, then the resultant wavelength y R is going to be y A plus y B. Thus, the 2 rays are in phase. So, it is maximum intensity will be there; however, if 2 rays are out of phase, then the amount d amount d then the resultant wavelength is going to be y r y a plus y b into cos d by 2, is out of phase. Considering the case where the phase difference between the 2 is 180 degrees, then the amplitude of the resultant wave is the algebraic sum of y a and y b.

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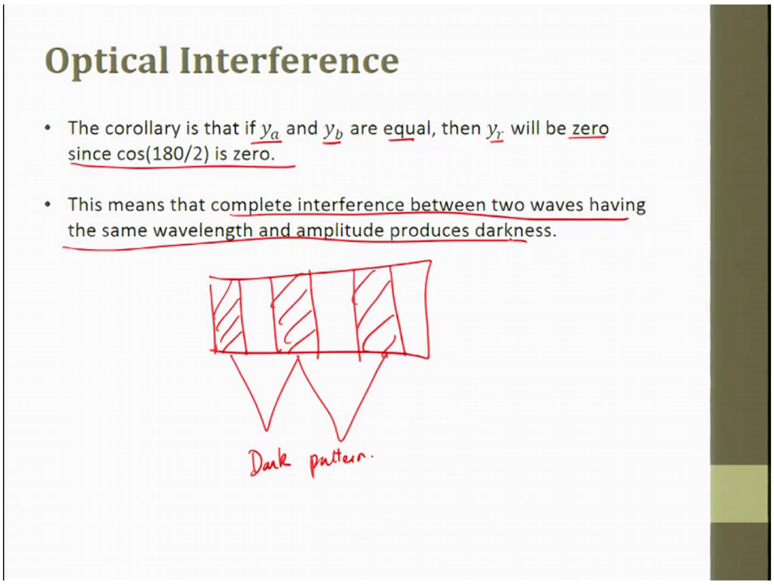

Corollary is that if y a and y b are equal, then y r will be 0, since cos 180 by 2 is 0. This means that complete interference between the 2 waves having the same wavelength and the amplitude produces darkness. So, when we talk about fringe patterns, we say dark fringe white fringe. Then we see a dark, bright, dark, bright. So, these are dark fringe patterns; where they are out of phase. So, complete interference between the 2 wavelengths having the same wavelength and amplitude produces your darkness.

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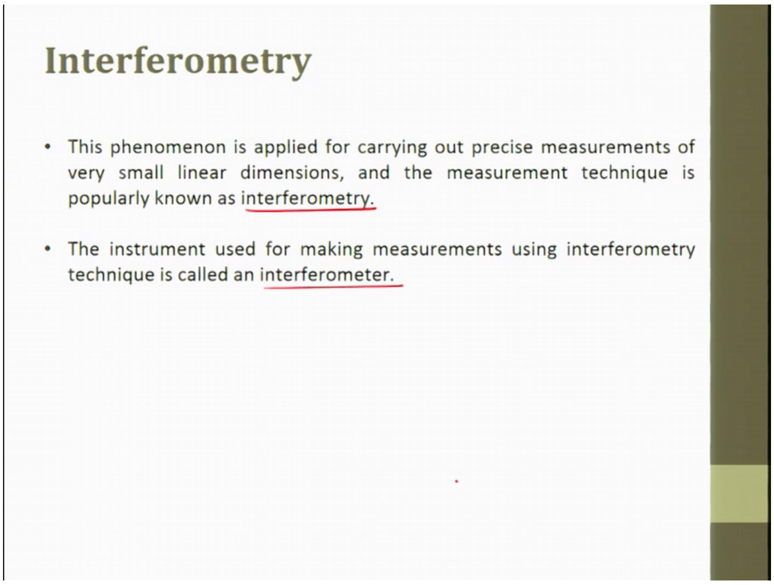

This phenomena is applied to carry out precise measurement of very small linear dimensions and the measurement techniques is popularly known as interferometry. The instrument which is used for measurement is called as interfero meter.

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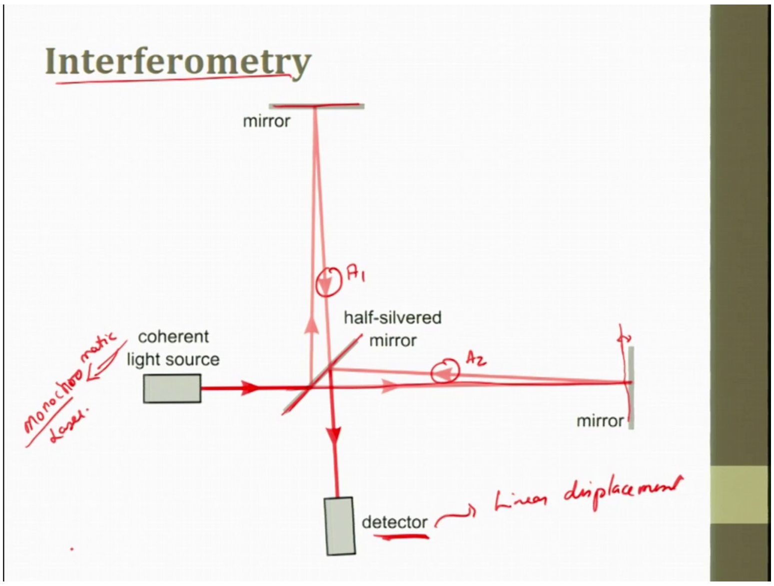

So, this is a typical interferometry. So, here is a coherent light source, this can be a monochromatic light source, or it can even be a laser. Coherent light source; so, this light source hits at a beam splitter. So, then what happened this is half silvered mirror so, the light gets cut here, the light gets cut here and then it tries to travel towards the mirror. And then it so, if the light gets cut here. So, one half goes in this direction, assuming that there is a small change a mirror; there is a small change in angle. Then the light gets reflected back here, right in the same way when the beam splitter is happening at 90 degrees the light ray goes and hits a mirror which is exactly flat and then it comes back.

So, that is a phase difference between this reflection maybe A 1 and A 2. And that is intern this 2 difference is pushed into the detector. So, in this detector the fringe patterns are counted, and you report it in linear displacement. This is a typical interferometry principal, how does it work?

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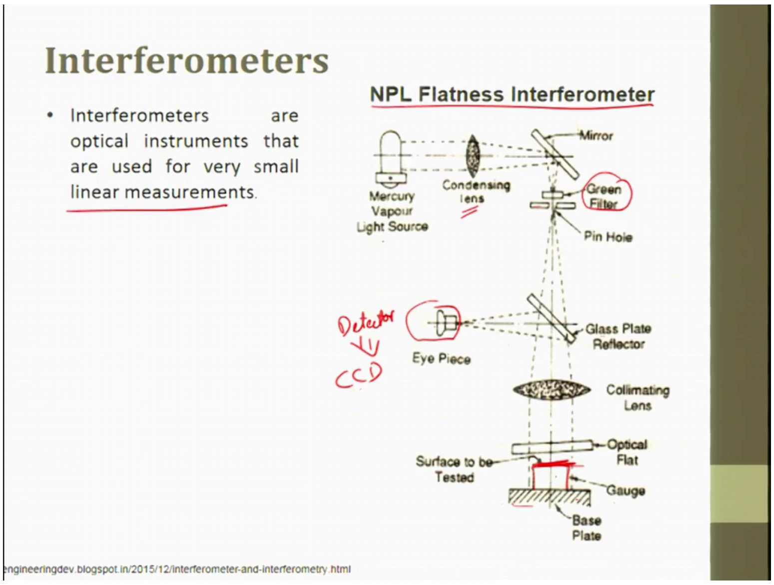

Interferometer are optical instruments that are used for very small linear measurements. So, you have this is an NPL flat interferometer mercury vapour is there or you can put a laser there, a condenser lens is there. So, you have a mirror, then you put green filter, then you have pinholes through which the light passes through, then you have a glass plate reflector, you have an eye piece here.

So, the object is viewed here. That was earlier detector or nowadays you can make it as CCD Charge Coupled Device, camera or detector whatever it is. So, the light hits here then you have a collimated lens, this hits at an optical flat and here is the gauge right. This gauge is resting on a table. So, surface to be tested is this one, and as against this there is an optical flat which is placed. So, the flatness of this surface can be measured by using this interferometry technique.

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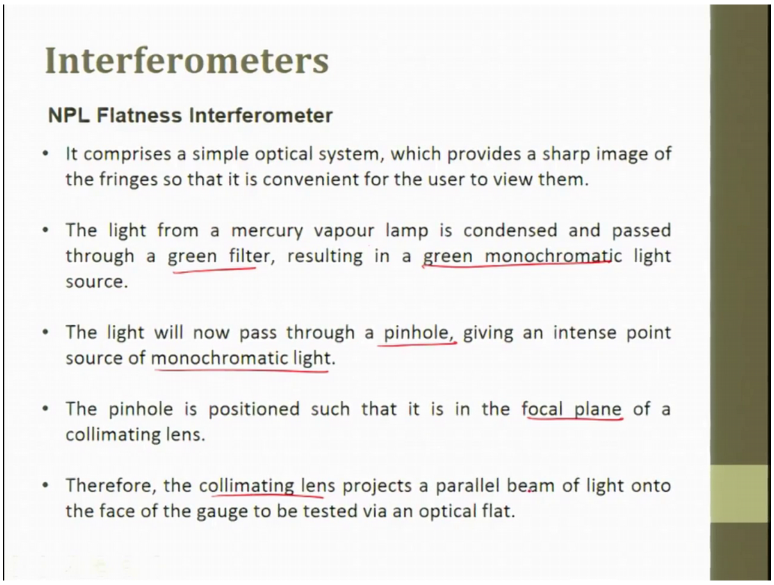

It comprises a simple optical system which provides a sharp image of the fringes so that it is convenient for the user to view them. The light from the mercury lamp is condensed and passed through a green filter resulting in the green monochromatic light source; the light will now pass through a pinhole giving an intensity point source for monochromatic light.

The pinhole is position in such a way in the focal plane of the collimated lens. Therefore, the collimated lens projects a parallel beam of light onto the phase of the gauge to be tested.

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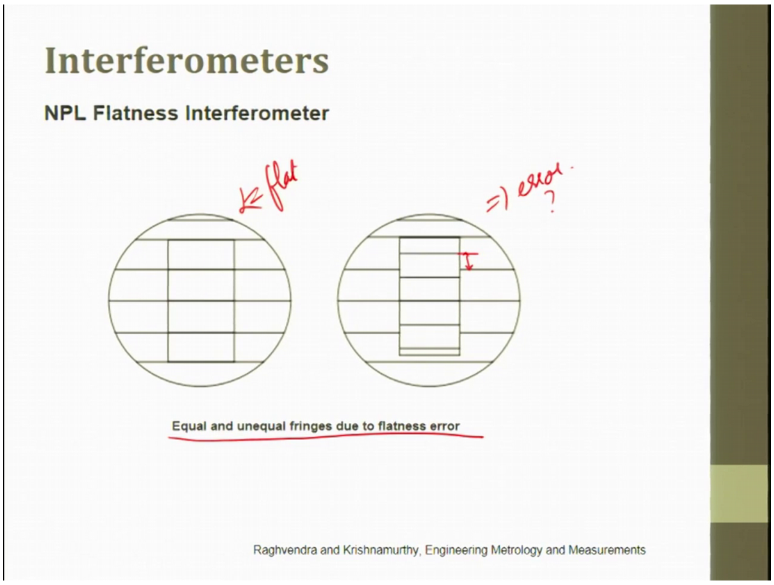

So, if the surface is flat, you can see the fringe patterns continuously are the same. If there is a difference in flatness, then you can see there is a shift in the fringe patterns which is done. So, equal and unequal fringe patterns due to flatness error, this is a flat surface, this is a error surface. So now, you can see that distance whatever it is and then you can the number of fringes distance what you measure, you can try to find out what is the error.

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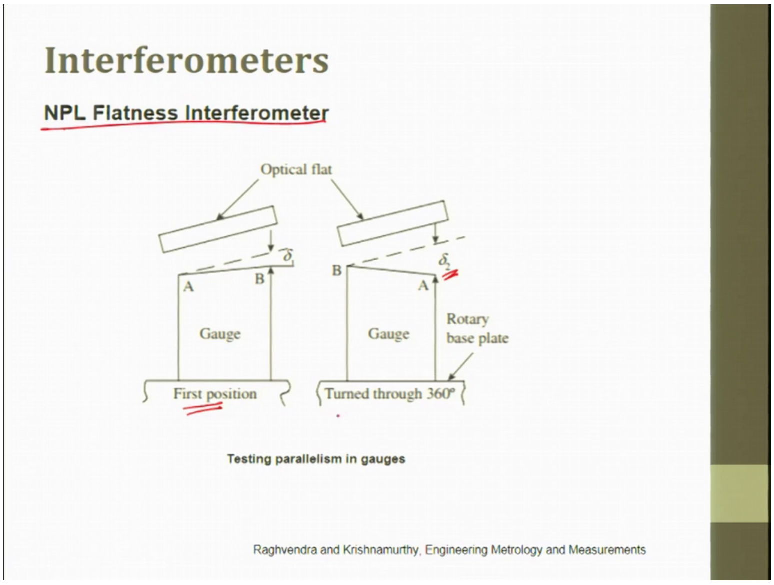

So, the NPL flatness interferometer works like this; the gauge is there. So, you have 2 surfaces, the formula is the same. So, it is placed at an angle. So, you try to take the first position, then you turn it around the gauge and then rotate the table, then place the gauge B A and try to measure the delta 2, using the same optical flat. If you see both the fringe patterns are the same, then these two are flat surfaces.

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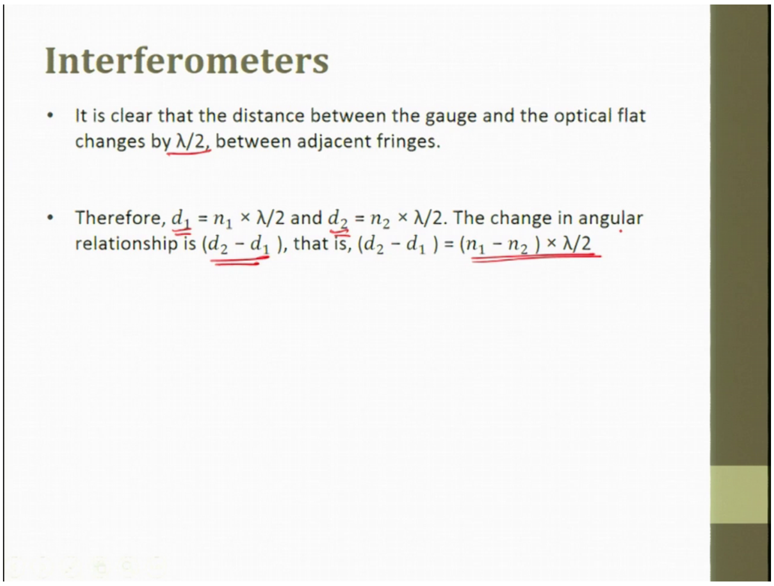

So, it is clear the distance between the gauge and the optical flat changes by lambda 2 by adjusting fringes therefore, d 1 is given as n 1 lambda by 2 d 2 is given as n 2. So, d 2 minus d 1 is this, which we already seen. So, by this relationship is used to measure the flatness error on the surface.

Thank you.