# Metrology
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## Lecture – 31
## Interferometers

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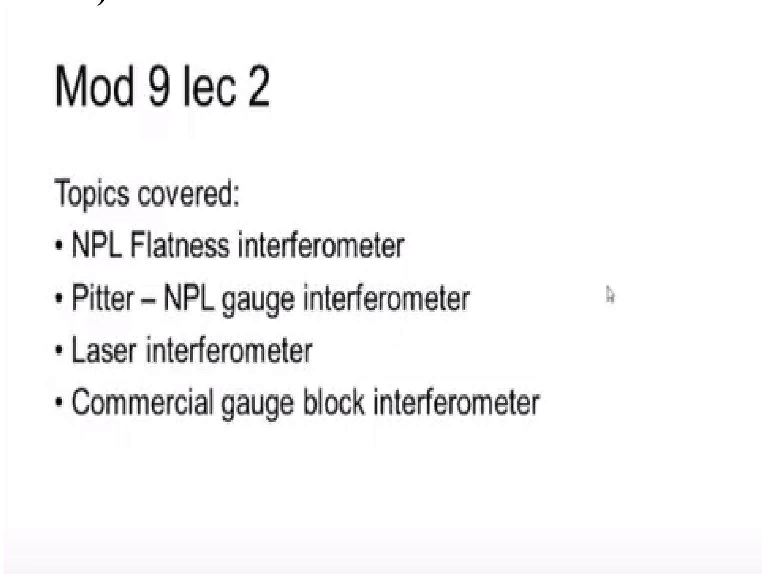


I welcome you all for module 9 lecture 2 on Interferometry in this second lecture we will discuss about the different types of it flow meter we will discuss the constriction and working of can be NPL flatness interferometer pitter-NPL gauge interferometer and also we will study about the laser based interferometer and then will see commercially viable gauge block interferometer.

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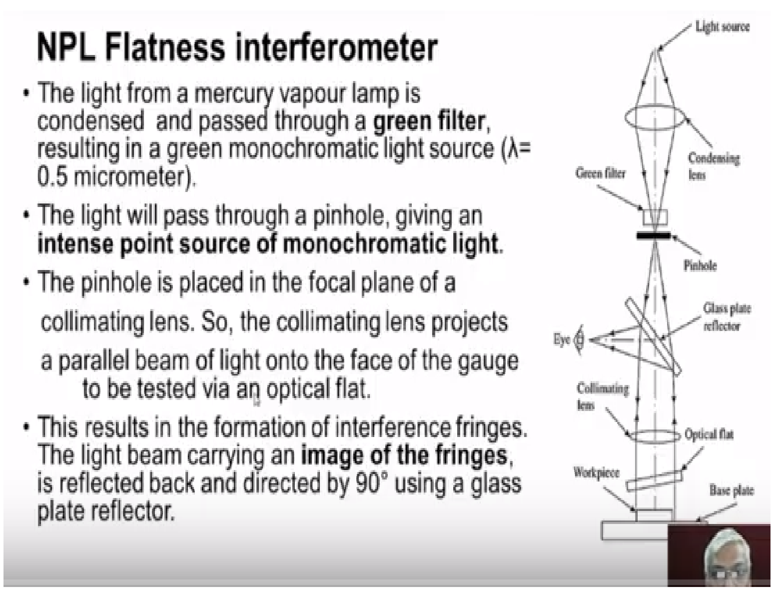

Now let us discuss on NPL flatness interferometer. We can now see the schematic diagram of NPL flatness interferometer, we have base plate on which the work piece to be inspected is placed and is a provision for keeping optical flat and other end is we have light source normally mercury vapor lamp is used with lambda of 0.5 micrometer and we can we will be condensing the lens to condense with the light to a point and then the condensed light will pass through a green filter.

So we get the green monochromatic light source with wave length of 0.05micrometer and at the focal point we have a pinhole through which the light will pass so here we get an intense point source of monochromatic light the pinhole is placed in the focal plane of the collimating lens, so we have a collimating lens here and pinhole is placed at the focal point of this collimating lens.

So we get a parallel beam of monochromatic light which will fall on the work piece to be inspected and then the light will pass through the optical flat fall on the work piece and the light will get reflected and displayed we have a glass plate reflector so reflected light will get deflected and it will fall at the detector. So through the eyepiece we can observe the fringe pattern.

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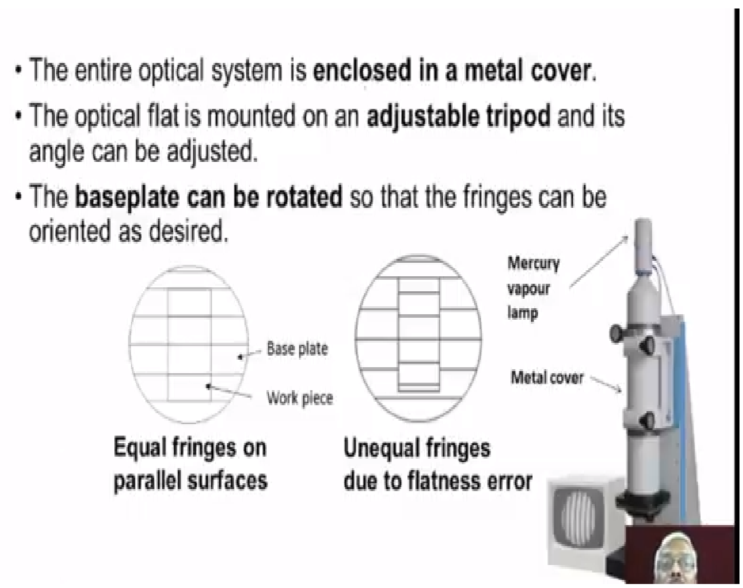


Now the entire optical system is enclosed in a metallic cover here. The mercury vapor lamp and then enter optical system is enclosed in a metal cover we can always adjust the height of this optical system to an adjustable tripod stand and its angle can be adjusted to get required fringe pattern the base plate can be rotated so that the fringes can be oriented as per the requirement.

So to the eyepiece you can see a display unit is interfaced with the interferometer, so that we can observe the fringe pattern in the monitor. Now when the surfaces of the work piece we have a work piece which is to be inspected to like this and the stop surface of the work piece is parallel to the bottom surface that means these 2 working surfaces of the work piece that parallel and if this is the case we can see here we can observe the fringe pattern like this.

Now we can observe that these fringes are obtain by the base plate and these fringes are obtained by surface of the work piece If the 2 surfaces of the work piece are parallel to each other and the surface to the base plate is parallel to these 2 surfaces then we obtain equal number of fringes from base data as well as work piece and the width of fringe will also be equal if the work piece surface is not parallel now we can observe here.

This surface of the work piece of the gauge not parallel to this then the number of fringes of time will be different from the number of fringes from base plane which indicates that the 2 surface of the gauge work piece are not parallel.

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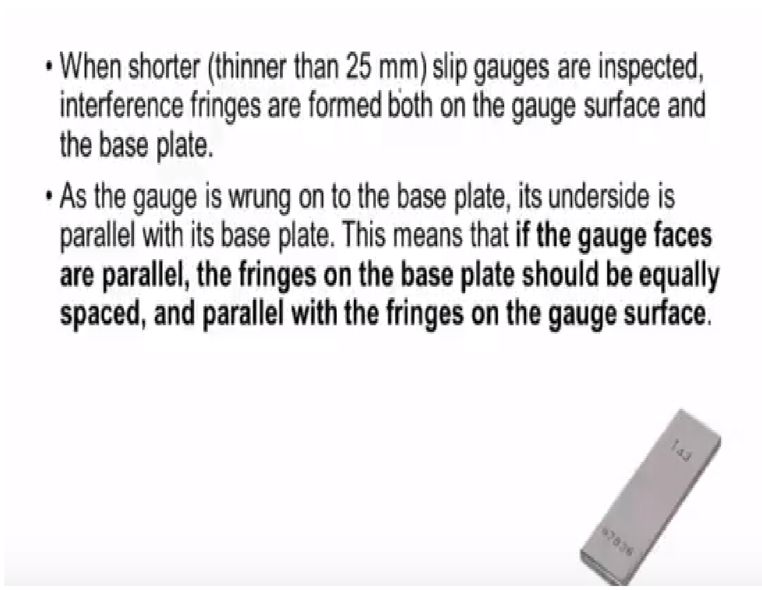

When thinner slip gauges are used which are thinner than 25 millimeter with interference fringes form are interference fringes are formed both on the gauge surface and the base plate as they observed in the previous slide as the gauge is wrung on the base plate, its underside is parallel with its base plate .This means this is the base plate and this is the work piece the underside is parallel that means the inter side of the work piece is parallel with the surface of the base plate.

This means that if the gauge faces are parallel, this surface and the bottom surface of the gauge if they are parallel the fringes of the base plate should be equally spaced and parallel to fringes on the gauge surface.

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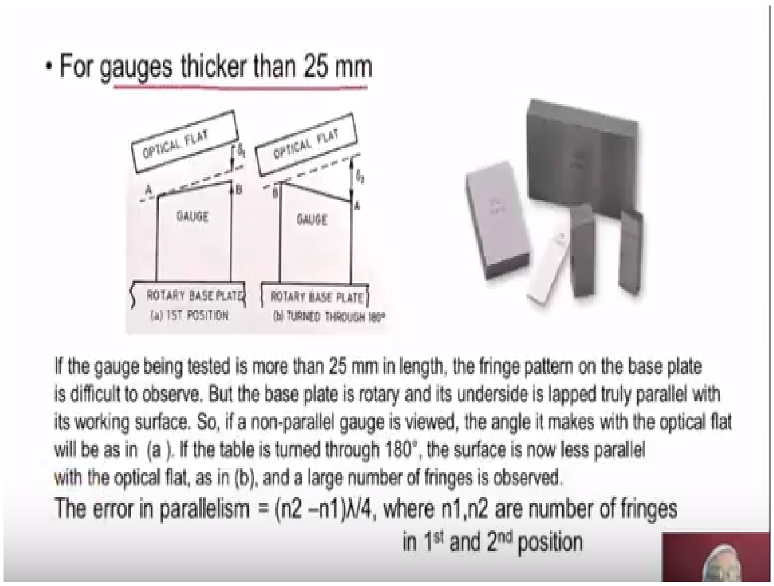


Now the gauges of the work pieces are thicker than the 25 millimeter now you can observe here we have place gauge which is thicker than the 25 millimeter this is the rotary base plate on which we have placed thicker gauge plate then the fringe pattern on the base plate is difficult to observe because this large distance but the base plate is rotary and its underside is lapped truly parallel with its working surface so if a non parallel gauges is viewed

Now you can see here this surface of the gauge is not parallel with this, with this surface if a non parallel gauges is viewed, the angle it makes with the optical flat so that is this angle, angle that makes the optical flat will be as in case (a).That means this is the angle that is made. If the turned through 180 degrees now you can observe here the table is completely turned through 180 degrees the surface is now less parallel with the optical flat that means.

We have greater angle between the gauge surface and optical flat and a large number fringes will be observed when the angle increases we know that number of fringes will increase. Now in error in parallelism that means the error parallelism between this surface and this surface can be calculated using this relationship (n2-n1)lambda/4, where n1 and n2 are number of fringes obtained in 1st and 2nd position

By setting n1 and n2 we can find what is the amount of error in parallelism between the surface of the bottom piece.

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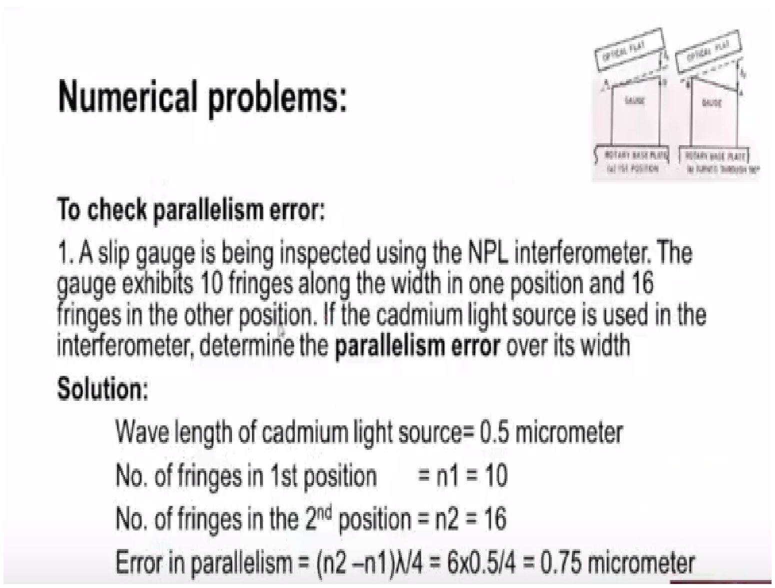


Now let us try to solve some numerical problem so that we understand the bases in a better manner. Now how do we check the parallelism error the error in the parallelism of the work piece surface. A slip gauge is inserted using the NPL interferometer. The gauge exhibits 10 fringes along the width in one position now we know the gauge is placed on the rotary base plate in one position the observe 10 fringes and it is rotated at 180 degree we observe 10 fringes and it is rotated through 180 degree at we observe 16 fringes in the second position.

If the cadmium light source is used in the interferometer, determined the parallelism error over its width, now the wave length of the cadmium light source is 0.05 micrometer, Number of fringes in the 1st position is n1=10, number of fringes in the 2nd position is n2=16.

Now error parallelism is obtained using this relationship (n2-n1)lambda/4 so in n2-n1 is 16-10 that is 6 and lambda is 0.05 micrometer/4 which gives 0.75 micrometer in the parallelism error between the 2 working surface of the gauge that means to use the NPL interferometer to count how many fringes are there in the 1st position how many fringes are there in 2nd position and by knowing the lambda value of the source we can find the error in parallelism.

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**To check height of slip gauge:**

**2.** An optical flat is used to check the height of the slip gauge against a standard gauge of height 20 mm. Cadmium light is used in the NPL interferometer. If the number of fringes on the gauge width of 15 mm is 12 and the distance between the two blocks is 30 mm, calculate the difference in **height of the gauge** being inspected.

**Solution:**

The difference in height is = $h = (n\lambda/2)L/l$

where n = number of fringes, L=distance between gauges,

l = width of gauge inspected, $\lambda = 0.5$ micrometer

$h = (12 \times 0.5) \times 30/(15 \times 2) = 6$ micrometer

Now let us see how we can check the height of slip gauges using interferometers the problem is like this an optical flat is used to check the height of slip gauge against the standard gauge of height 20 millimeter that means the given slip gauge is compared with the height of standard gauge of height 20 millimeter. Cadmium light is used in the NPL interferometer. If the number of fringes on the gauge width of 15 millimeter is 12 and the distance between the 2 blocks is 30 millimeter, calculate the difference in height of the gauge being inspected.

That means we have a gauge of 20 millimeter height and another gauge is placed on the base plate so this is the base plate, so this height we have to check the width of this gauge is 15 millimeters and distance between the 2 blocks is 30 millimeter that means is 30 millimeter. Now the difference in height h can be calculated using this relationship and (lambda/2)L/l, where n is number of fringes observed by the interferometer.

In this case the number of fringes on the gauge width of 15 millimeter is 12, so n=12 distance between the gauges that is L is 30 millimeter and small l is width of gauge inspected is 15 millimeter so (n lambda/2)Ll is l is 12 lambda is 0.5)x capital L is 30 small l is 15/2, so this gives 6 micrometer that means the difference in height of the given gauge when compared with this standard gauge of 20 millimeter of height is 6 micrometer.

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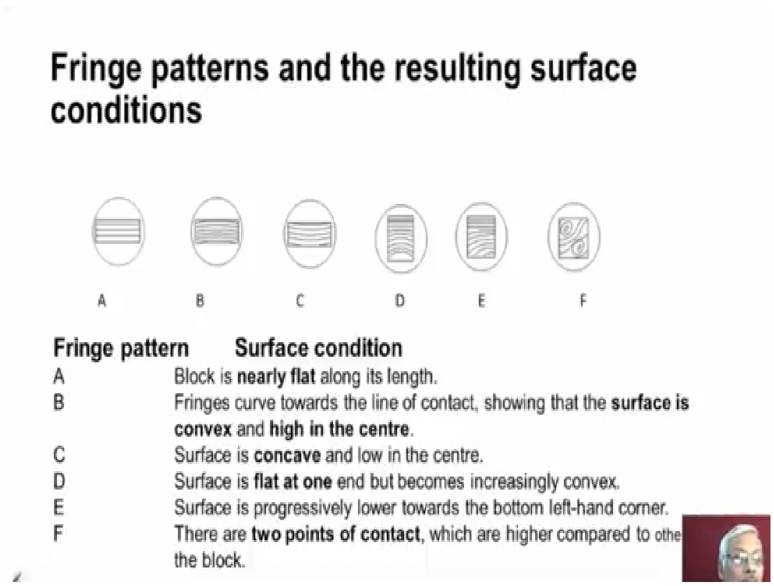


Now different fringe patters we get depending upon the surface and condition of the work piece can observe here. We have different fringe pattern A to F and the corresponding surface condition are mention here. We get the straight parallel fringes when the block surface of the work piece or the block nearly flat along its length, we get straight fringes parallel to one edge.

Now in this case we have convex fringes so this is case B fringes curve towards the line of contact so here this is the contact and this is the contact. Fringes curve towards the line of contact showing the surface is convex and high in the centre the surface is high in the centre. Now in C is surface is concave and low in the centre we can observe here this we get concave fringes and the they are low in the centre this is the case then the surface is concave.

In case of D surface is flat at one end so here the surface is flat and increasingly convex at the other end. Now here we are observing convex fringes indicating the surface is convex at the other end and in case of E surface is progressively lower towards the bottom left-hand corner here we observe that there are 2 peak points case F the 2 points of contact which are higher compare to the other area of the block. So like this depending upon the surface condition we get different fringe patterns.

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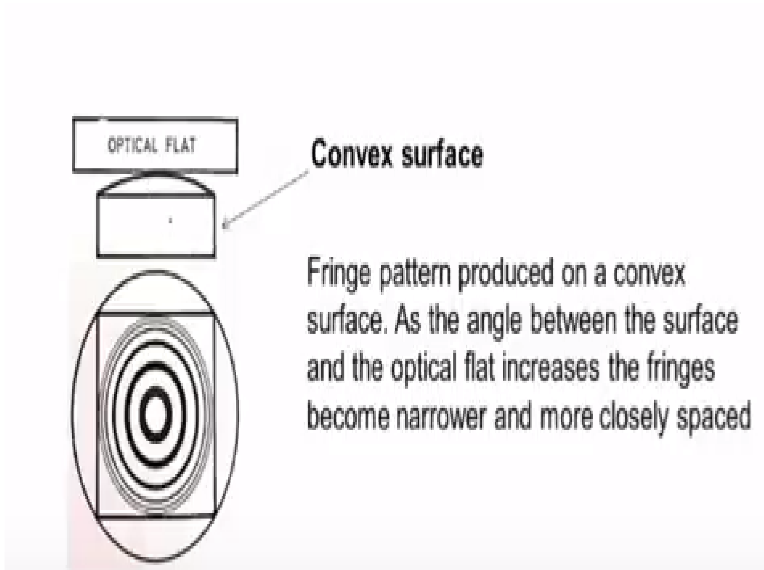


Now here we are observing the fringe pattern we have the work surface whose surface is convex and then we have placed an optical flat over the surface of the work piece and when we observe when the set when the pair is kept in a area where we have monochromatic light source we can observe circular fringes like this.

Now so this is the angle between the surface of the work piece and the surface of the optical flat has the angle between the surface ant the optical flat increases the number of the fringes become narrower see this angle increases we can observe here the fringes are narrower and they are closely packed as the angle increases the fringes become very closer.

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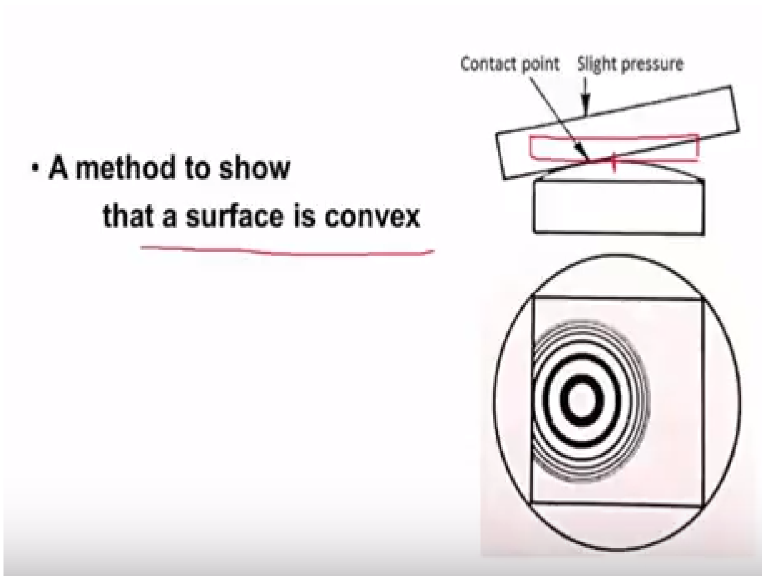


Now how do we test whether the surface is convex or concave here is a method to show that the surface is convex so initially the contact optical flat place like this there will be a contact here and we get the concentric fringes as shown in the previous slide so contact is here and we get concentric fringes like this now we have to apply slight pressure as shown here.

Then the contact point will move and now this is the fresh contact point that means the fringes will go the centre of fringes will move towards left when slight pressure is applied so this indicates that the surface is convex.

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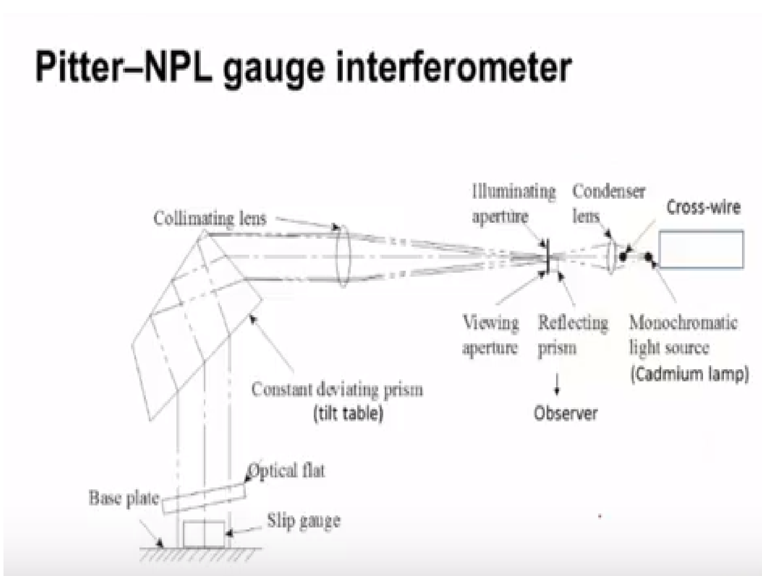

Now let us start a discussion on pitter-NPL gauge interferometer I can see the schematic we have the base plate over which the slip gauge which is inspected is placed and the optical flat is placed like this and we have monochromatic light source normally cadmium lamp is used so we get the monochromatic light source and using this condenser lens the monochromatic light source is condensed this point.

Where an illuminating aperture is placed and from here we get the light source monochromatic light source and by using this collimating lens again the make the light the obtain the parallel beam of light which will fall on the tilt table constant deviating prism and then the light is deflected and it falls on the slip gauge by a optical flag and the reflected light follow this almost same path and then here.

It deviates because of the slight inclination of the optical flat the reflected light will slightly get deflected and it will fall on viewing aperture and because of the presence of this reflecting prism the reflected light is deflected and will fall on the detector and then we can observe the fringes.

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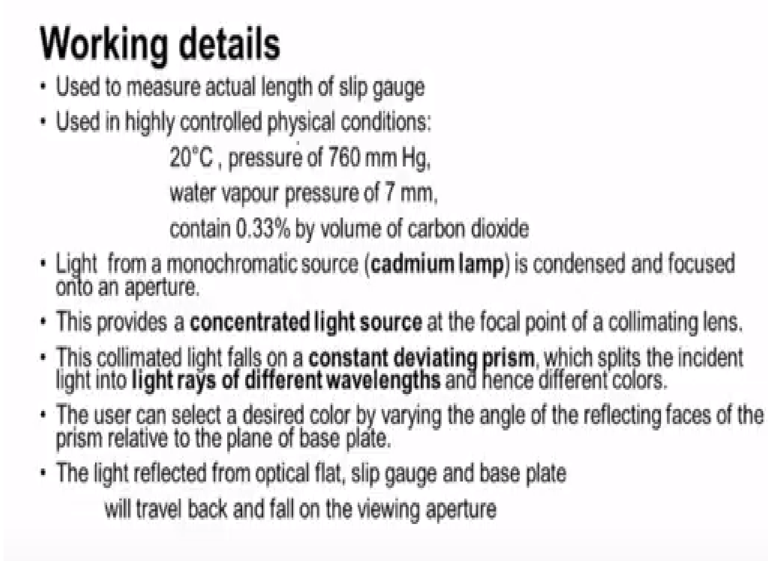


Now this type of interferometer used to measure the actual length of the slip gauge and these Interferometers are used in highly controlled physical conditions like the temperature will be20 degree celsius and the working pressure and chamber where the work piece is placed is of 760 millimeter mercury and water vapor pressure will be 7 millimeter containing 0.33 percent of the volume by carbon dioxide.

Light from the monochromatic source normally cadmium lamb is condensed and focused on an aperture and this aperture provides concentrated light source and the focal point of a collimating lens so we can see here this is the collimating lens and this is the focal point so we get the condensed light at this particular point the collimated light falls on the constant deviating prism which spilt the incident light into light rays of different wavelengths and hence different colors.

Now we can always select a desired color by varying angle of the reflecting faces of the prism so we can observe here this constant deviating prism can be tilted to obtain the monochromatic of desired color. The light reflected from the optical flat slip gauge and base plate will travel back and fall on the viewing aperture. at this place the viewing aperture where we obtain the fringe pattern.

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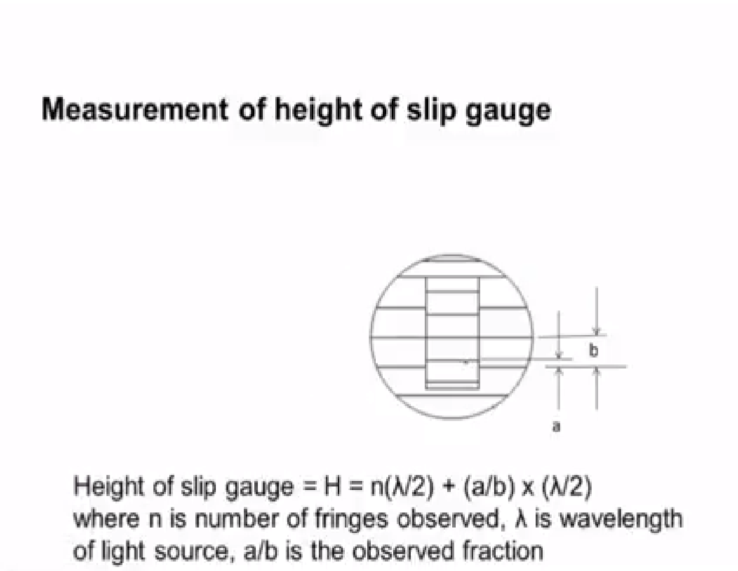


Now do we measure the height of the slip gauge so the fringe pattern is obtained if depending upon the height of the slip gauge the fringe pattern is obtained like this which is the fringe pattern obtained by the surface of the gauge and this is the fringe pattern obtain by the base plate now we see the height of the slip gauge is obtain by the using this relationship n(lambda/2)+(a/b)x(lambda/2).

Where b is the pitch of the fringe pattern obtain by the base plate and this a is the gap between the fringe and the base plate and fringe obtain by the gauge surface. So here n is number of fringes observed, lambda is wavelength of light source, a/b is the observed fraction so there to measure a and b and then we can calculate this fraction and then by inserting these values the relationship we can find the height of slip gauge.

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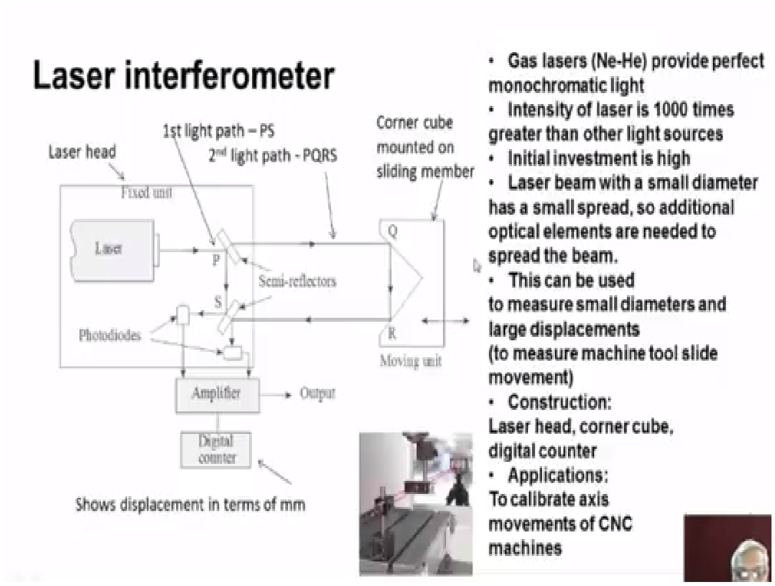


Now let us start the discussion on laser interferometer now a day laser is used in interferometer normally the gas lasers the system of helium Neon provide perfect monochromatic light and we can have an intensity 1000 times>the other light sources so that we can observe the fringes but fashion the drawback of laser interferometer is its high initial investment and another drawback is since the laser beam will have small diameter they spread up the laser work surface will be very small in order to cover the larger area of the work piece.

We need to have additional optical elements to spread the beam to cover the larger area of the work piece these laser interferometers can be used to measure the small diameters and also larger displacements can be measured. So these laser interferometers are used to measure the machine tool slide movement we can observe here we have machine tool slide on which the corner cube the part of the laser interferometer is fixed.

So when the table moves its movement is recorded in the interferometer like this the movement of the machine tool slides is measured. Now coming to the construction of laser interferometer mainly it has laser head and then the corner cube and then electronic unit and the distill counter the corner cube is the moving part of the laser interferometer which is mounted on the sliding member of the machine tool we can see here the light ray which falls on the corner cube it gets deflected by 180 degree.

Now coming to laser head it has the laser source with we get the laser light and then we have the 2 photodiodes and 2 semi reflectors are hosting the laser head and then we have the amplifier to amplify the signal and then there is a counter to count the number of fringes and the working of the laser interferometer is like this we get the laser light from the source which will fall on the semi reflector first semi reflector.

So light ray falling on the first semi reflector a part of it is deflected which moves in this direction again it is deflected by the semi reflector and then finally it falls on the first photodiode part of the light falling here will be transmitted and it moves in this direction it gets deflected by 180 degree and it falls on the semi reflector part of it is deflected and it falls on second photodiode and part of the reflected semi reflected light will pass through the semi reflector and it gets combined here.

Now when the corner cube moves along with the machine tool slide we can observe here the first light path is PS and second light path is PQRS so again depending upon the OPD optical path difference between these 2 rays if it is equal to odd number of wave length we get the dot band and if the OPD optical path difference is =even number of wave length we get bright band so like this depending upon the movement.

We get light band and bright band by counting the these bands like an measure the machine tool slide movement. So normally these laser interferometers are used to calibrate axis movement of CNC machine tools.

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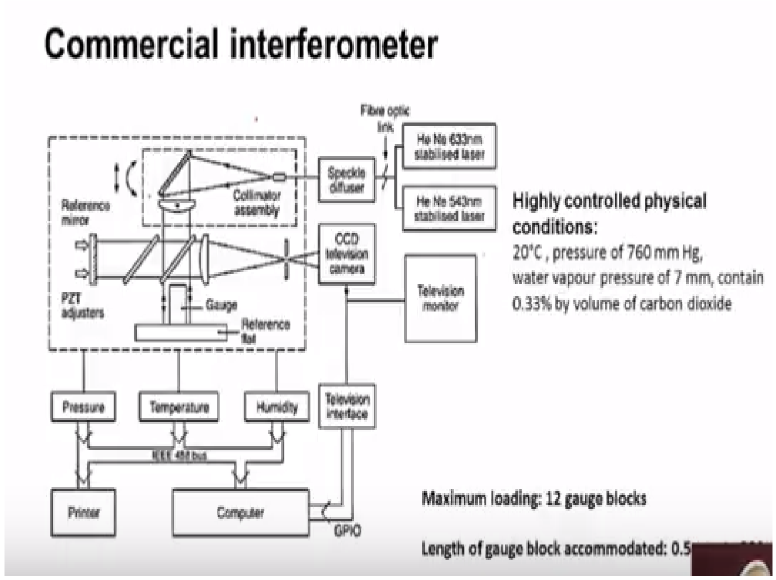


Now this diagram shows the arrangement of commercial interferometer which uses gas laser HeNe633 nanometer stabilized laser and it is dual laser system the other one is HeNe 543 nanometer stabilized laser and then we have the unit that optical elements in this chamber we have reference flat surface table surface on which the gauge to be inspected is placed and then we have a moving mirror.

And a tilting mirror we get the laser source and then the light will move in this fashion the collimated light which will fall on the gauge surface and then it is deflected back and then finally it falls on the CCD television camera and on the monitor we observe the fringes. Now it is important that this chamber gauge, the gauge is placed.

We should control the working environment like pressure, temperature, humidity so those things we need to control and another advantage of these interferometers is at a time we can load 12 gauge blocks so that the measurement through put is more and the length of gauge block can be accommodated the working chamber is 0.5 millimeter to 300 millimeter long gauges can be placed here.

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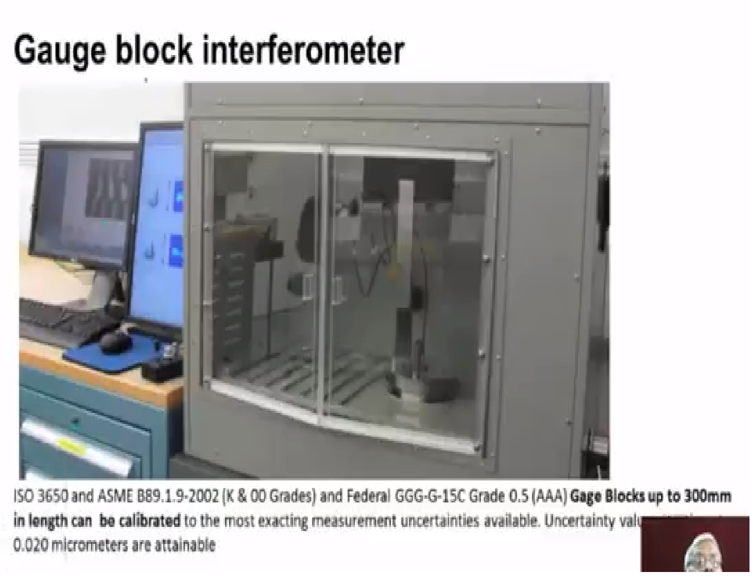


Now this shows photograph of the gauge block in PL gauge block interferometer which can house gauge blocks of 300 millimeter long gauges and uncertainty values in these gauge block interferometers starts at 0.2 micrometer so such a fine accuracy can be achieved in these gauge block interferometers

Now we can see the chamber were we can keep blocks to be inspected and in this chamber we need to working and on the monitor we can observe the fringes and we can make the process the signals received from the interferometer.

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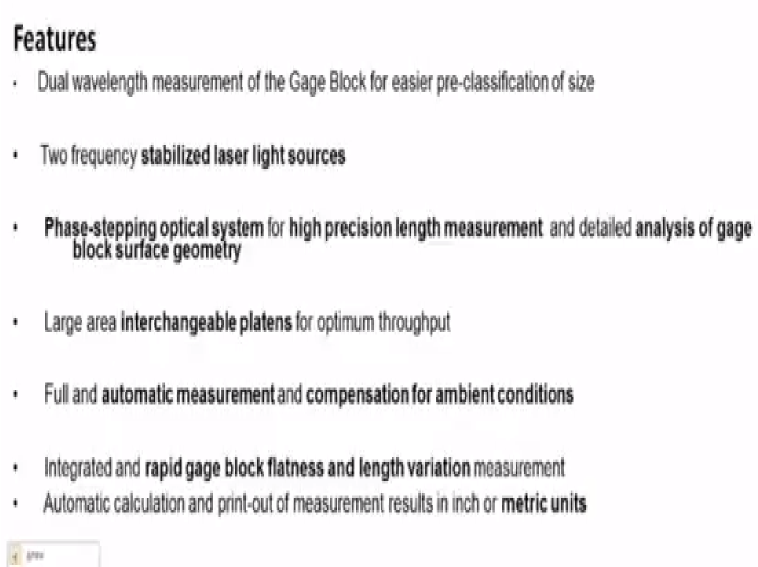

Now the features of the dual wave length measurement of the gauge block interferometer or like this. Dual wave length laser source is used and the pre classification of size of the gauge blocks is possible with such an arrangement and 2 frequency stabilized laser lights are used phase stepping optical system is used for high precision length measurement and detailed analysis of gauge blocks surface geometry is possible.

Large area interchangeable platens are provided in such a interferometer so that we have a optimum throughput in one platen we can mount the gauges to be inspected while the other platen will be inside the chamber wherein the measurement will be carried out and once the measurement of the gauge blocks placed on the platen which is inside is over it is the outside platen will move in so like this we can have the optimum throughput.

Full and automatic measurement is possible without intervention of the operator once the gauge blocks are loaded in the chamber all the gauge blocks are measured for the length as well as surface aspect and the result is printed and the compensation for the ambient condition if there is a change in the temperature or the pressure automatic compensation will be provided.

Integrated and rapid gauge block flatness and length variation measurement is possible so theses 2 frequency stabilized laser interferometers can be used for the analysis of the flatness of the gauge box surface as well as the length variation can be measured and automatic calculation and printout of measurement is possible in inch as well as metric units.

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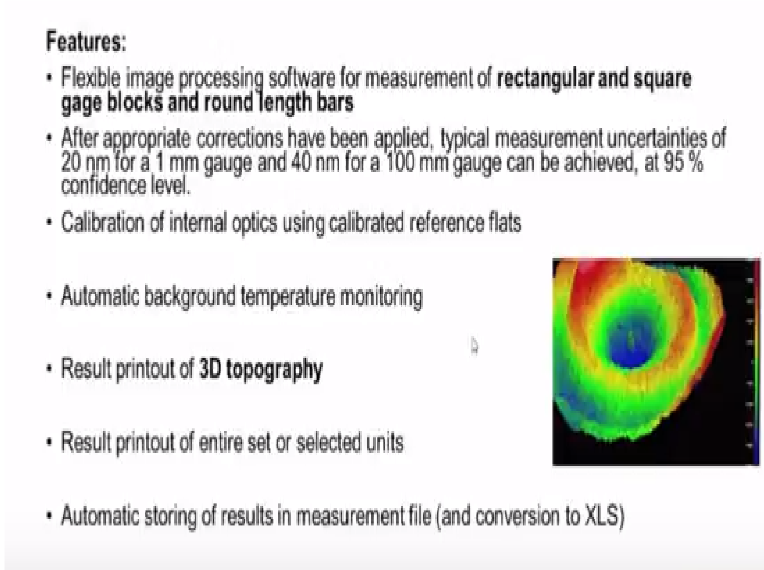


Now the other features of the laser interferometer are listed here flexible image processing software for measurement of rectangular gauge blocks, square gauge blocks and round gauge bars are possible with such a interferometers and after appropriate corrections have been applied, typical measurement and uncertainties of 20 nanometer for 1 mm gauge and 40 nanometer for a 100 mm gauge can be achieved at 95 percent confidence level.

Calibration of internal optics using calibrated reference flats is possible and it is also possible to have automatic background temperature monitoring if there is any variation in the temperature and it can be compensated automatically 3D topography of the work surface can be had. Result printout of entire set we can keep some 10 or 12 pieces at a time the result will out of all the gauges is possible or can have selected units.

Automatic storing of results in measurement file is possible so that can be retrieved at a later date for analysis purpose.

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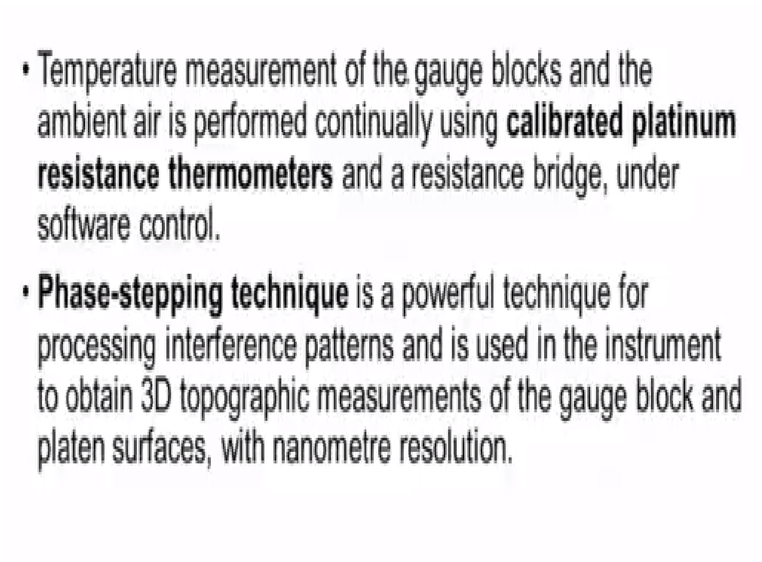


Now the temperature measurement of the gauge block which are placed in the working chamber and the it is possible using calibrated platinum resistance thermometers and a resistance bridge, and temperature adjustment or control of temperature is possible in software. Phase stepping technique is a powerful technique for processing interference patterns and such a systems is used in the instrument obtain 3 dimension topographic measurements of the gauge block surfaces and plated surfaces with nanometer resolution.

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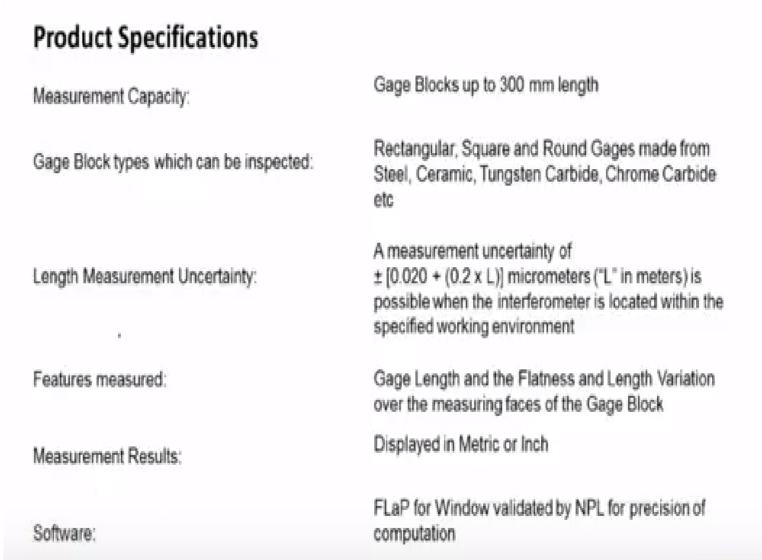


The product specifications are listed here the measurement capacity of the interferometers are gauge blocks up to 300millimeter long blocks can be loaded into the interferometer for measurement purpose gauge blocks which can be expected or like this rectangular, square and round gauges made of steel ceramic, tungsten carbide, chrome carbide can be inspected with these interferometers length measurement uncertainty is like this +/-[0.020+(0.2xL)]micrometers

Where L is in meters such a uncertainty is possible with the interferometers is located within the specified working environment and what are the features that will be measured with these interferometers gauge length can be measured flatness of the gauge block surface can be measured length variation over the measuring faces can be measured and measurement results can be displayed in metric units or inch units.

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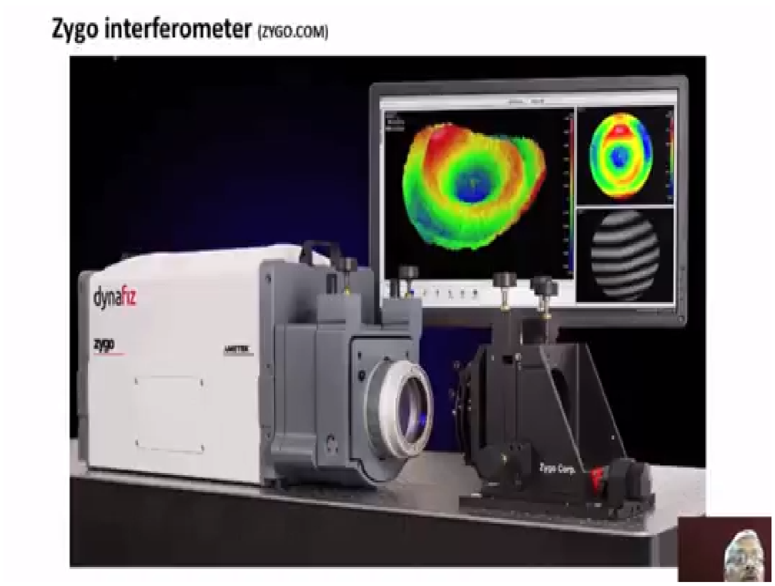


The software flat for window validated by NPL for precision of computation so flat software is used. Now here we can see another interferometer made by zygo interferometer we can see the table flat surface of which complete interferometer is placed this is the unit which can be mounted on the moving elementary machine tools and this is the measuring the laser sourced optical elements etc.

And then we have a monitor which will show the shape of interference and then the3 dimensional topography of the surfaces etc the details of such interferometer can be obtained by zygo.

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## Summary of module 9 lecture 2

- NPL Flatness interferometer
- Pitter – NPL gauge interferometer
- Laser interferometer
- Commercial gauge block interferometer

Now let us conclude the lecture number 2 in this lecture we discussion some of the interferometers like NPL flatness interferometer, pitter NPL gauge interferometer, interferometer based on laser monochromatic light sources and some commercially available commercial gauge block interferometers also discussed we discussed about the constructional features and then how they can be used for measurement of various features like the gauge block surface parameters length parameters etc.

What are the various applications of these interferometer. That also we discussed with this we will conclude this module number 9 on interferometer. Thank you.