UNIT-IV

LASER METROLOGY

PRECISION INSTRUMENT BASED ON LASER:

- Laser stands for **Light Amplification by Stimulated Emission of Radiation.**
- Laser instrument is a device to produce powerful, monochromatic, collimated beam of light in which the **waves are coherent**.
- Laser development is for production of clear coherent light. The advantage of coherent light is that whole of the energy appears to be emanating from a very small point.
- The beam can be focused easily into either a parallel beam or onto a very small point by use of lenses A major impact on optical measurement has been made by development in elector optics, providing automation, greater acuity of setting and faster response time.
- Radiation sources have developed in a number of areas, the most important developments are light emitting diodes and lasers.
- The laser is used extensively for interferometry particularly the He- Ne gas type. The laser distance measuring interferometer has become an industry standard.
- This produces 1 to 2mm diameter beam of red light power of 1MW and focused at a point of very high intensity. The beam begins to expand at a rate of 1mm/m. The laser beam is visible and it can be observed easily.
- This is used for very accurate measurements of the order of 0.lμm is 100m.

LASER METROLOGY

- Metrology lasers are low power instruments. Most are helium-neon type. Wave output laser that emit visible or infrared light. He-Ne lasers produce light at a wavelength of 0.6μm that is in phase, coherent and a thousand times more intense than any other monochromatic source.
- Laser systems have wide dynamic range, low optical cross talk and high contrast.
- Laser fined application in dimensional measurements and surface inspection because of the properties of laser light.
- These are useful where precision, accuracy, rapid non-contact gauging of soft, delicate or hot moving points.

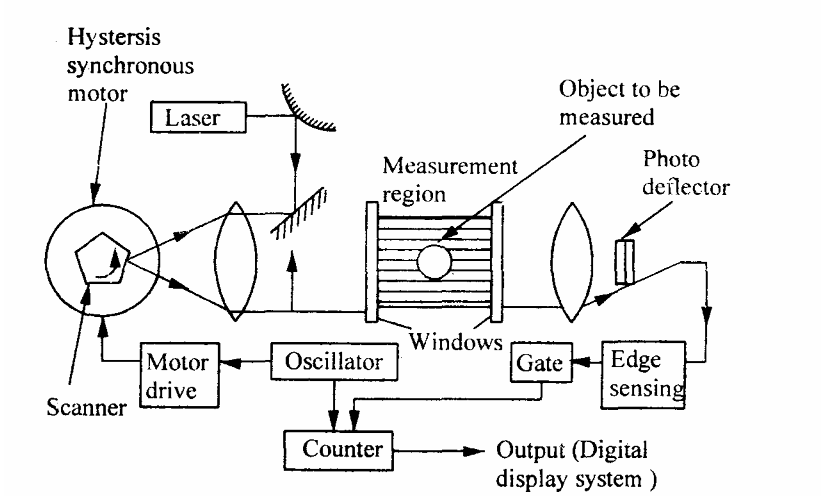
USE OF LASER

1. Laser Telemetric system:

- Laser telemetric system is a non-contact gauge that measures with a collimated laser beam. It measures at the rate of 150 scans per second.
- It basically consists of three components, a transmitter, a receiver and processor electronics. The transmitter module produces a collimated parallel scanning laser beam moving at a high constant, linear speed.
- The scanning beam appears a red line. The receiver module collects and photoelically senses the laser light transmitted past the object being measured.
- The processor electronics takes the received signals to convert them 10 a convenient form and displays the dimension being gauged.
- The transmitter contains a low power helium-neon gas laser and its power supply, a specially designed collimating lens, a synchronous motor, a multi faceted

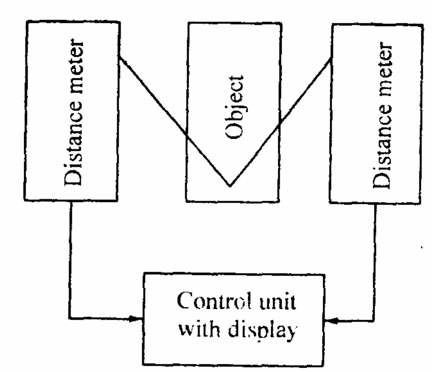
reflector prism, a synchronous pulse photo detector and a protective replaceable window.

- The high speed of scanning permits on line gauging and thus it is possible to detect changes in dimensions when components are moving on a continuous product such as in rolling process moving at very high speed.
- There is no need of waiting or product to cool for taking measurements. This system can also be applied on production machines and control then with closed feed back loops.
- Since the output of this system is available in digital form, it can run a process controller limit alarms can be provided and output can be taken on digital printer.



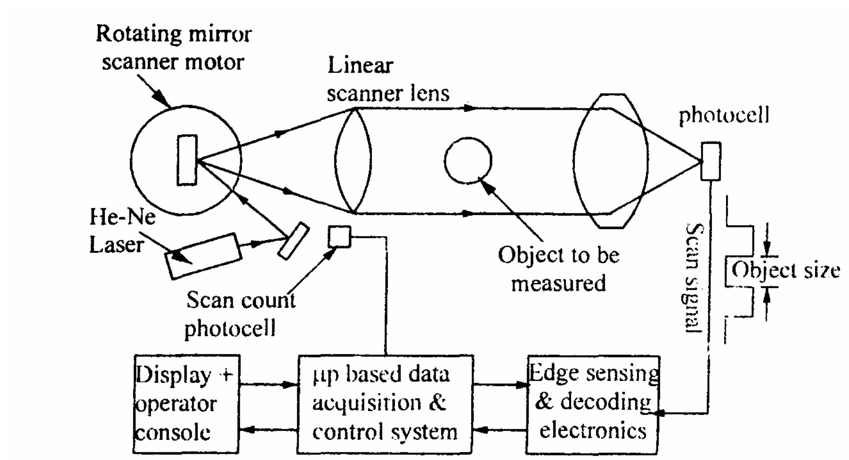
2. Laser and LED based distance measuring instruments

- These can measure distances from I to 2in with an accuracy of the order of 0. 1 to 1% of the measuring range When the light emitted by laser or LED hits an object, scatter and same of this scattered light is seen by a position sensitive detector or diode array.
- If the distance between the measuring head and the object changes. the angle at which the light enters the detector will also change.
- The angle of deviation is calibrated in terms of distance and output is provided as 0-2OmA. Such instruments are very reliable because there are no moving parts their response time is milliseconds.
- The measuring system uses two distance meters placed at equal distance on either side of the object and a control unit to measure the thickness of an object. The distance meter is focused at the centre of the object.



3. Scanning Laser gauge

- Fig shows a schematic diagram of a scanning laser gauge. It consist of transmitter, receives and processor electronics.
- A thin band of scanning laser light is made to pass through a linear scanner lens to render it parallel beam. ‘The object placed in a parallel beam, casts a time dependent shadow.
- Signal from the light entering the photocell (receiver) arc proc by a microprocessor to provide display of the dimension represented by the time difference between the shadow edges.
- It can provide results to an accuracy of0.25 for 10—50mm diameter objects. It can be used for objects 0.05mm to 450mm diameter; and offers repeatability of 0.1μm



4. Photo diode away imaging

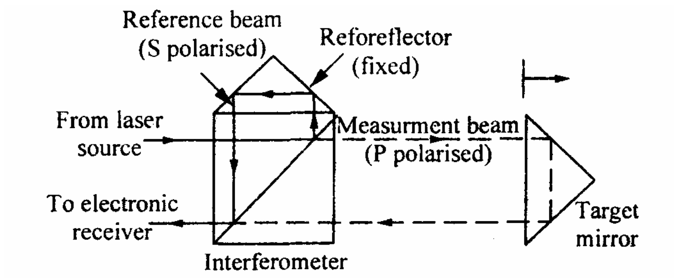
- The system comprises of laser source, imaging optics. photodiode array. signal processor and display unit.
- For large parts, two arrays in which one for each edge are used. Accuracies as high as 0.05 μm have been achieved.

5. Diffraction pattern technique

- These are used to measure small gaps and small diameter parts. A parallel coherent laser beam is diffracted by a small part and a lens on a linear diode array focuses the resultant pattern.
- Its use is restricted to small wires. The measurement accuracy is more for smaller parts. The distance between the alternating light and dark hands in the diffraction pattern is a (tired function of the wile diameter, wavelength of laser beam and the focal length of the lens.

6. Two- frequency laser interferometer

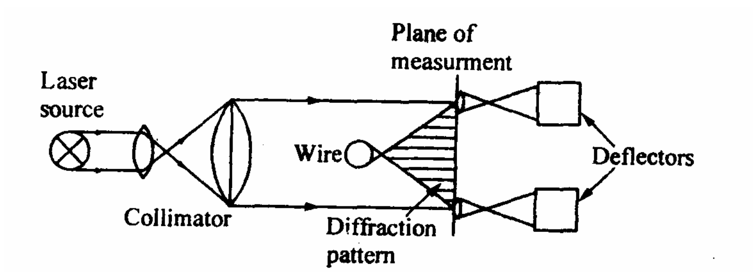
- Fig. shows schematic arrangement. This consists of two frequency laser head, beam directing and splitting optics, measurement optics, receivers, and wavelength compensators and electronics.
- It is ideally suited for measuring linear positioning straightness in two planes, pitch and yaw.



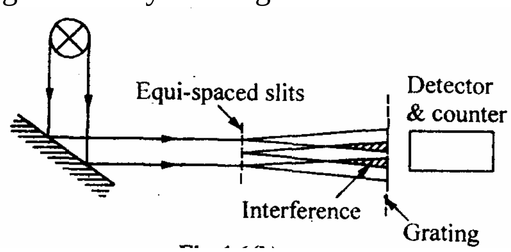
- The two-frequency laser head provides one frequency with P polarisation and another frequency with S-polarisation.
- The laser beam is split at the polarizing beam splitter into its two separate frequencies.
- The measuring beam is directed through the interferometer to reflect off a target mirror or retro reflector attached to the object to be measured.
- The reference beam is reflected from fixed retro reflector. The measurement beam on its return path recombines with the reference beam and is directed to the electronic receiver.

7. Gauging wide diameter from the diffraction pattern formed in a laser

- Fig.(1) shows a method of measuring the diameter of thin wire using the interference fringes resulting from diffraction of the light by the wire in the laser beam.
- A measure of the diameter can be obtained by moving the photo detector until the output is restored to its original value.
- Changes in wire diameter as small as 0.2% over wire diameter from 0.005 to 0.2mm can be measured..



- Fig. (2) shows the length measurement by fringe counting. The laser output, which may be incoherent illumines three slits at a time in the first plane which form interference fringes.
- The movement can be determined by a detector. The total number of slits in the first plane is governed by the length over which measurement is required



- The spacing between the slits and distance of the slit to the plane of the grating depend on the wavelength of the light used.

PRINCIPLE OF LASER

- The photon emitted during stimulated emission has the same energy, phase and frequency as the incident photon.
- This principle states that the photon comes in contact with another atom or molecule in the higher energy level E2 then it will cause the atom to return to ground state energy level E1 by releasing another photon.
- The sequence of triggered identical photon from stimulated atom is known as stimulated emission. This multiplication of photon through stimulated emission leads to coherent, powerful, monochromatic, collimated beam of light emission. This light emission is called laser.

LASER INTERFEROMETRY

Brief Description of components

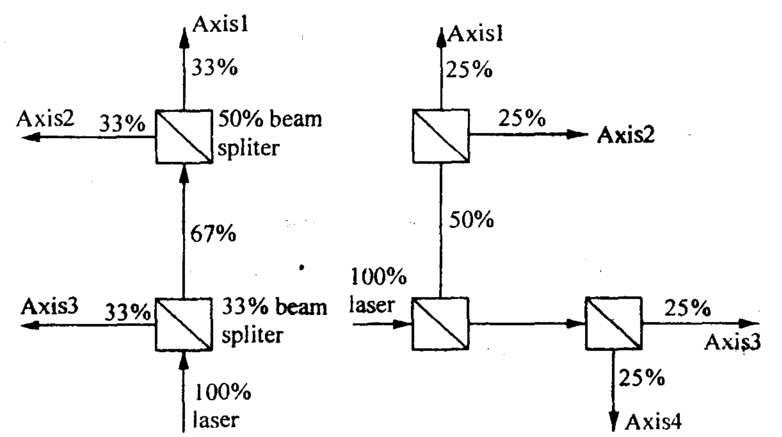
(i) Two frequency Laser source

- It is generally He-Ne type that generates stable coherent light beam of two frequencies. one polarized vertically and another horizontally relative to the plane of the mounting feet.
- Laser oscillates at two slightly different frequencies by a cylindrical permanent magnet around the cavity. The two components of frequencies are distinguishable by their opposite circular polarization
- Beam containing both frequencies passes through a quarter wave and half wave plates which change the circular polarizations to linear perpendicular polarisations, one vertical and other horizontal. Thus the laser can be rotated by 90° about the beam axis without affecting transducer performance.
- If the laser source is deviated from one of the four optimum positions, the photo receiver will decrease. At 45° deviation the signal will decrease to zero.

(ii) Optical elements:

(a) Beam splitter:

- Fig shows the beam splitters to divide laser output along different axes. These divide the laser beam into separate beams.
- To avoid attenuation it is essential that the beam splitters must be oriented so that the reflected beam forms a right angle with the transmitted beam.
- So that these two beams: are coplanar with one of the polarisation vectors of the input form.



b) Beam benders:

- These are used to deflect the light beam around corners on its path from the laser to each axis.
- These are actually just flat mirrors but having absolutely flat and very high reflectivity. Normally these are restricted to 90° beam deflections to avoid disturbing the polarizing vectors.

c) Retro reflectors:

- These can be plane mirrors, roof prism or cube corners. Cube corners are three mutually perpendicular plane mirrors and the reflected beam is always parallel to the incidental beam.,'
- Each ACLI transducers need two retro reflectors. All ACLI measurements are made by sensing differential motion between two retro reflectors relative to an interferometer.
- Plane mirror used as retro reflectors with the plane mirror interferometer must be flat to within 0.06 micron per cm.

(iii) Laser head' s measurement receiver

- During a measurement the laser beam is directed through optics in the measurement path and then returned to the laser head is measurement receiver which will detect part of the returning beam and a doppler shifted frequency component.

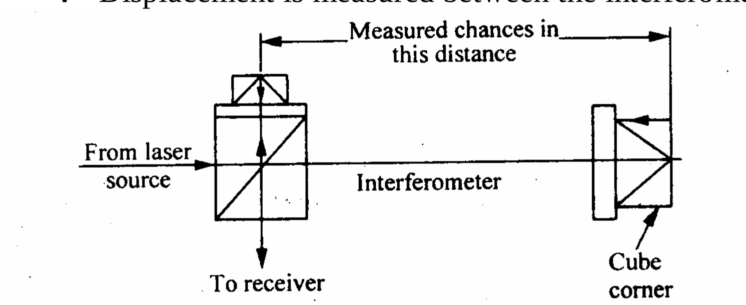
(iv) Measurement display

- It contains a microcomputer to compute and display results. The signals from receiver and measurement receiver located in the laser head are counted in two separate pulse converter and subtracted.
- Calculations are made and the computed value is displayed. Other input signals for correction are temperature, co-efficient of expansion, air velocity etc., which can be displayed.

(v) Various version of ACLI

a) Standard Interferometer:

- Least expensive.
- Retro reflector for this instrument is a cube corner.
- Displacement is measured between the interferometer and cube corner.

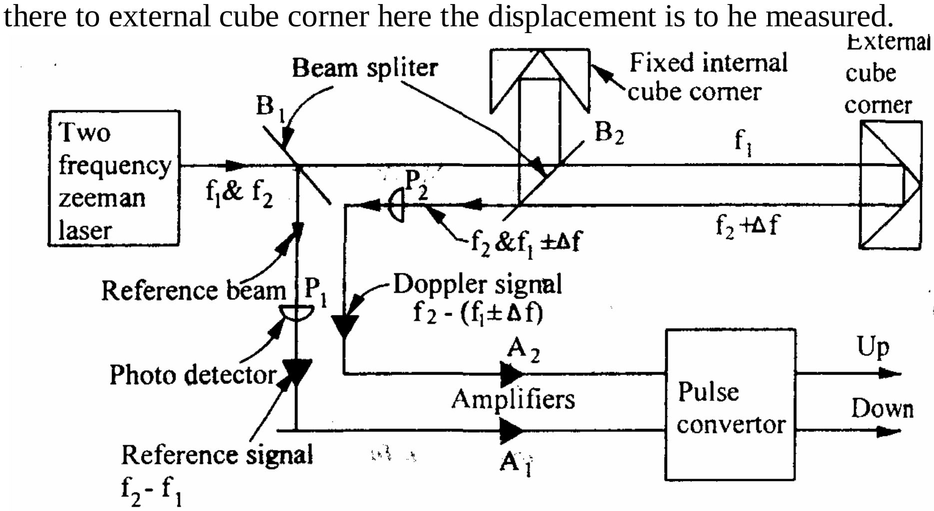


b)Signal beams Interferometer:

- Beam traveling between the interferometer and the retro reflector.
- Its operation same as standard interferometer.
- The interferometer and retro reflector for this system are smaller than the standard system.
- Long range optical path
- Easy installation
- Wear and tear.

LASER INTERFEROMETER

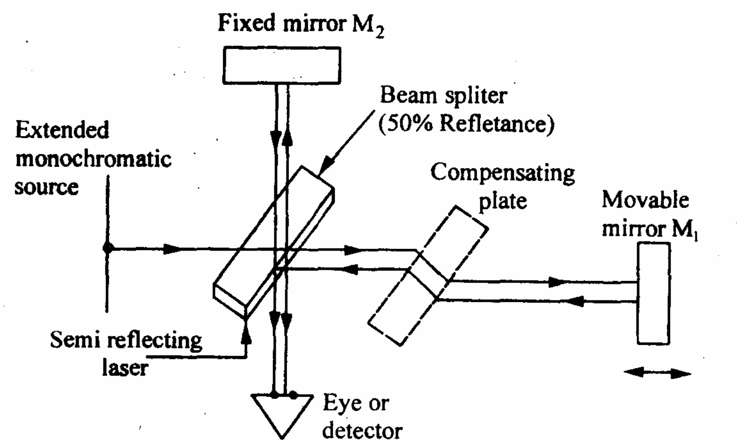
- It is possible to maintain the quality of interference fringes over longer distance when lamp is replaced by a laser source:
- Laser interferometer uses AC laser as the light source and the measurements to be made over longer distance.
- Laser is a monochromatic optical energy, which can be collimated into a directional beam AC. Laser interferometer (ACLI) has the following advantages.
    - High repeatability
    - High accuracy
    - Long range optical path
    - Easy installations
    - Wear and tear
- Schematic arrangement of laser interferometer is shown in fig. Two-frequency zeeman laser generates light of two slightly different frequencies with opposite circular polarisation.
- These beams get split up by beam splitter B One part travels towards B and from there to external cube corner here the displacement is to he measured.



- This interferometer uses cube corner reflectors which reflect light parallel to its angle of incidence. Beam splitter B_2 optically separates the frequency J which alone is sent to the movable cube corner reflector.
- The second frequency from B_2 is sent to a fixed reflector which then rejoins f1 at the beam splitter B_2 to produce alternate light and dark interference flicker at about 2 Mega cycles per second. Now if the movable reflector moves, then the returning beam frequency Doppler-shifted slightly up or down by Δf
- Thus the light beams moving towards photo detector P_2 have frequencies f_2 and ($f_1 \pm \Delta f_{1)}$ and P_2 changes these frequencies into electrical signal.
- Photo detector P_2 receive signal from beam splitter B_2 and changes the reference beam frequencies f_1 and f_2 into electrical signal.
- An AC amplifier A separates frequency. difference signal $f_2 - f_1$ and A_2 separates frequency difference signal.
- The pulse converter extracts i. one cycle per half wavelength of motion. The up-down pulses are counted electronically and displayed in analog or digital form.

MICHELSON INTERFEROMETER

- Michelson interferometer consist of a monochromatic light source a beam splitter and two mirrors.
- The schematic arrangement of Michelson interferometer is shown in fig. The monochromatic light falls on a beam splitter, which splits the light into two rays of equal intensity at right angles. One ray is transmitted to mirror M_1 and other is reflected through beam splitter to mirror M_2,.
- From both these mirrors, the rays are reflected back and these return at the semi-reflecting surface from where they are transmitted to the eye.
- Mirror M_2 is fixed and mirror M_1 is movable. If both the mirrors are at same distance from beam splitter, then light will arrive in phase and observer will see bright spot due to constructive interference.
- If movable mirror shifts by quarter wavelength, then beam will return to observer 180^0 out of phase and darkness will be observed due to destructive interference



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- Each half-wave length of mirror travel produces a change in the measured optical path of one wavelength and the reflected beam from the moving mirror shifts through 360° phase change.
- When the reference beam reflected from the fixed mirror and the beam reflected from the moving mirror rejoin at the beam splitter, they alternately reinforce and cancel each other as the mirror moves Thus each cycle of intensity at the eye represents $\lambda/2$ of mirror travel.
- When white light source is used then a compensator plate is introduced in each of the path of mirror M_1 So that exactly the same amount of glass is introduced in each of the path.
- To improve the Michelson interferometer
  - **(i)** Use of laser the measurements can be made over longer distances and highly accurate measurements when compared to other monochromatic sources.
  - **(ii)** Mirrors are replaced by cube-corner reflector which reflects light parallel to its angle of incidence.
  - **(iii)** Photocells are employed which convert light intensity variation in voltage pulses to give the amount and direction of position change.

DUAL FREQUENCY LASER INTERFEORMETER

- This instrument is used to measure displacement, high-precision measurements of length, angle, speeds and refractive indices as well as derived static and dynamic quantities.

- This system can be used for both incremental displacement and angle measurements. Due to large counting range it is possible to attain a resolution of 2mm in 10m measuring range.
- Means are also provided to compensate for the influence of ambient temperature, material temperature, atmospheric pressure and humidity fluctuation.

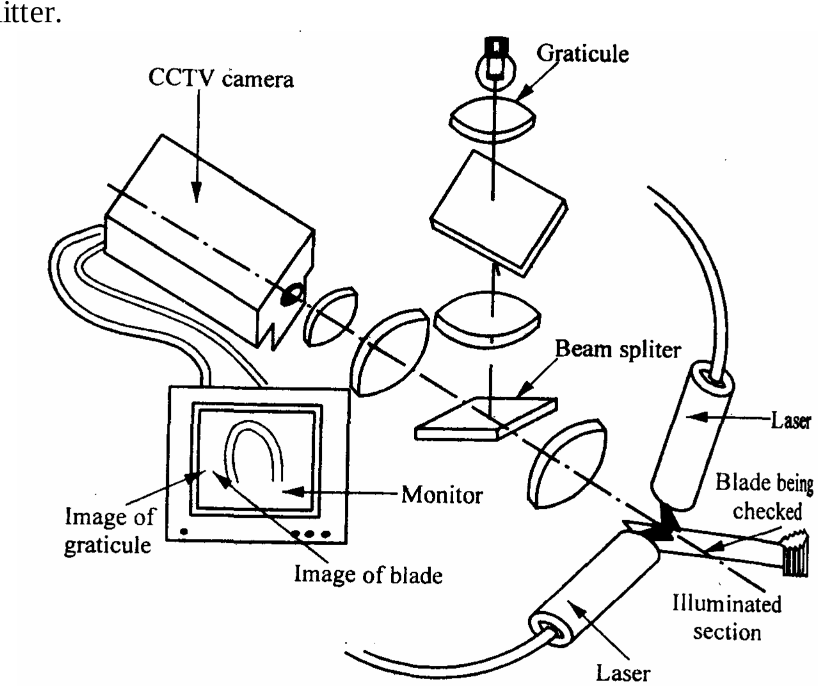
TWYMAN-GREEN INTERFEROMETER

- The Twyman-Green interferometer is used as a polarizing interferometer with variable amplitude balancing between sample and reference waves.
- For an exact measurement of the test surface, the instrument error can be determined by an absolute measurement. This error is compensated by storing the same in microprocessor system and subtracting from the measurement of the test surface.
- It has following advantages

1. It permits testing of surface with wide varying reflectivity.
2. It avoids undesirable feed back of light reflected of the tested surface and the instrument optics.
3. It enables utilization of the maximum available energy.
4. Polarisation permits phase variation to be effected with the necessary precision.

LASER VIEWERS

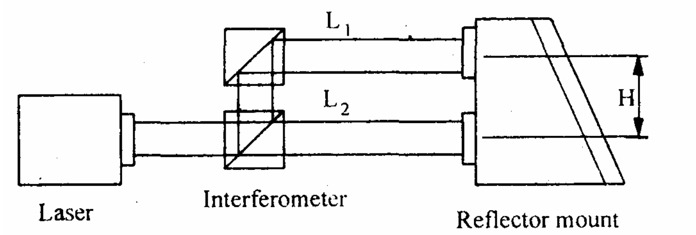
- The profile of complex components like turbine blades can be checked by the use of optical techniques. It is based on use of laser and CCTV.
- A section of the blade, around its edge is delineated by two flat beam of laser light. This part of the edge is viewed at a narrow angle by the TV camera or beam splitter.



- Both blade and graticule are displayed as magnified images on the monitor, the graticule position being adjustable so that its image can be superimposed on the profile image.
- The graticule is effectively viewed at the same angle as the blade. So, distortion due to viewing angle affects both blade and graticule. This means that the graticule images are direct 1:1.

INTERFEROMETRIC MEASUREMENT OF ANGLE

- With laser interferometer it is possible to measure length to an accuracy of 1 part in 106 on a routine basis.
- With the help of two retro reflectors placed at a fixed distance and a length measuring laser interferometer the change in angle can be measured to an accuracy of 0.1 second. The device uses sine Principle.
- The line joining the poles the retro-reflectors makes the hypotenuse of the right triangle. The change in the path difference of the reflected beam represents the side of the triangle opposite to the angle being measured.
- Such laser interferometer can be used to measure an angle up to ± 10 degrees with a resolution of 0. 1 second. The principle of operation is shown in fig.



LASER EQUIPMENT FOR ALIGNMENT TESTING

- This testing is particularly suitable in aircraft production, shipbuilding etc. Where a number of components, spaced long distance apart, have to be checked to a predetermine straight line.
- Other uses of laser equipment are testing of flatness of machined surfaces, checking square ness with the help of optical square etc.
- These consist of laser tube will produces a cylindrical beam of laser about 10mm diameter and an auto reflector with a high degree of accuracy.
- Laser tube consist of helium-neon plasma tube in a hea aluminum cylindrical housing. The laser beam comes out of the housing from its centre and parallel to the housing within 10" of arc and alignment stability is the order of 0.2" of arc per hour.
- Auto reflector consists of detector head and read out unit. No. of photocell are arranged to compare laser beam in each half horizontally and vertically.
- This is housed on a shard which has two adjustments to translate the detector in its two orthogonal measuring directions perpendicular to the laser beam. The devices detect the alignment of flat surfaces perpendicular to a reference line of sight.

MACHINE TOOL TESTING

- The accuracy of manufactured parts depends on the accuracy of machine tools.
- The quality of work piece depends on Rigidity and stiffness of machine tool and its components.
- Alignment of various components in relation to one another Quality and accuracy of driving mechanism and control devices.
- It can be classified into
  1. Static tests
  2. Dynamic tests.

Static tests:

- If the alignment of the components of the machine tool are checked under static conditions then the test are called static test.

Dynamic tests:

- If the alignment tests are carried out under dynamic loading condition. The accuracy of machine tools which cut metal by removing chips is tested by two types of test namely.
  1. Geometrical tests
  2. Practical tests.

Geometrical tests:

- In this test, dimensions of components, position of components and displacement of component relative to one another is checked.

Practical tests:

- In these test, test pieces are machined in the machines. The test pieces must be appropriate to the fundamental purpose for which the machine has been designed.

PURPOSE OF MACHINE TOOL TESTING

- The dimensions of any work piece, its surface finishes and geometry depends on the accuracy of machine tool for its manufacture.
- In mass production the various components produced should be of high accuracy to be assembled on a non-sensitive basis.
- The increasing demand for accurately machined components has led to improvement of geometric accuracy of machine tools. For this purpose various checks on different components of the machine tool are carried out.

TYPE OF GEOMETRICAL CHECKS ON MACHINE TOOLS.

Different types of geometrical tests conducted on machine tools are as follows:

1. **Straightness.**
2. **Flatness.**
3. **Parallelism, equi-distance and coincidence.**
4. **Rectilinear movements or squareness of straight line and plane.**
5. **Rotations.**

Main spindle is to be tested for

1) Out of round.
2) Eccentricity
3) Radial throw of an axis.
4) Run out
5) Periodical axial slip
6) Camming

VARIOUS TESTS CONDUCTED ON ANY MACHINE TOOLS

1) Test for level of installation of machine tool in horizontal and vertical planes.
2) Test for flatness of machine bed and for straightness and parallelism of bed ways on bearing surface.
3) Test for perpendicularity of guide ways to other guide ways.
4) Test for true running of the main spindle and its axial movements.
5) Test for parallelism of spindle axis to guide ways or bearing surfaces.
6) Test for line of movement of various members like spindle and table cross slides etc.

USE OF LASER FOR ALIGNMENT TESTING

- The alignment tests can be carried out over greater distances and to a greater degree of accuracy using laser equipment.

- v Laser equipment produces real straight line, whereas an alignment telescope provides an imaginary line that cannot be seen in space.
- v This is important when it is necessary to check number of components to a predetermined straight ‘ line. Particularly if they are spaced relatively long distances apart, as in aircraft production and in shipbuilding.
- v Laser equipment can also be used for checking flatness of machined surface by direct displacement. By using are optical square in conjunction with laser equipment squareness can be checked with reference to the laser base line.

PART-A

1What is interferometer? And its types/
2.Name the common source of light used for interferometer?
3.Define-Crust and Rough?
4.Define- Wavelength
5. What is meant by alignment test on machine tools?
6. State the basic principle of Laser
7. State the use of Laser
8. What is the other name for alignment test on machine tools/
9. List the various geometrical checks made on machine tools.
10.Define-LASER?
11. Define-Beam splitters
12. Define-Beam benders
13. Define-Retro reflectors

PART-B

1. What is meant by alignment test on machine tools? Why they are necessary? Explain.
2. State the basic principle and use of Laser.
3. Distinguish between geometrical and practical test on machine
4.Sketch and explain the Michelson interferometer in detail.
5.Sketch and describe the optical system in any two of the following.
    a. Laser interferometer.
    b. N.P.L. Flatness interferometer.
6. Sketch and explain the Two frequency interferometer in detail.
7.State the applications of Lasers in Linear and Angular measurements
8. State the applications of Laser Interferometer in testing of machine tools?