Chapter 7
Optical Measurement and Interferometry
Introduction

✓ Optical measurement provides a simple, easy, accurate and reliable means for carrying out inspection and measurements in the industry

✓ the projected image should be clear, sharp and dimensionally accurate.

✓ Application of interference of light is extreme interest in metrology

✓ Lasers are also being increasingly used in interferometers for precision measurement.
Optical magnification is one of the most widely used techniques in metrology.

The primary requirement is visual magnification of small objects to a high degree with the additional provision for taking measurements.
A tool maker’s microscope supports a wide range of applications from shop-floor inspection, measurement of tools and machined parts, to precision measurement of test tools in a measuring room.
Tool Maker’s Microscope

https://www.youtube.com/watch?v=SxvCOAbLfOg
✓ It features a vertical supporting column, which is robust and carries the weight of all other parts of the microscope

✓ The work-piece is loaded on an XY stage, which has provision for translatory motion in two principal directions in the horizontal plane

✓ The entire optical system is housed in the measuring head

✓ When the image is viewed through the eye-piece, a reticle provides the reference or datum to facilitate measurement
Optical Interference

✓ When two light waves interact with each other, the wave effect leads to the phenomenon called *interference* of light.

✓ The instruments designed to measure with interference are known as *interferometers*.

✓ Let us consider two monochromatic light rays from the same light source, but originating from two point sources A and B.

✓ the distances AO₁ and BO₁ are equal, the two rays are in phase, and results in maximum illumination at point O₁.

✓ On the other hand, at point O₂, the distance BO₂ is longer than the distance AO₂. Therefore, by the time the two rays arrive at the point O₂, they are out of phase

✓ Suppose the phase difference \( \delta = \lambda / 2 \), where \( \lambda \) is the wave length of light, then it leads to complete interference and formation of a dark spot.
This process repeats on either side of $O_1$ on the screen, resulting in the formation of alternate dark and bright areas.
Optical Interference
The phenomenon of interference is made use of for carrying out precise measurements of very small linear dimensions, and the measurement technique is popularly known as interferometry.

This technique is used in a variety of metrological applications such as inspection of machine parts for straightness, parallelism, flatness, measurement of very small diameters, and so on.

The instrument used for making measurements using interferometry technique is called an interferometer.
Optical Flats

Fig. 7.10 Fringe formation in an optical flat
Optical Flats

✓ An optical flat is a disk of high quality glass or quartz

✓ When an optical flat is laid over a flat reflecting surface, it orients at a small angle $\theta$, because of the presence of air damper between the two surfaces.

✓ When light from a monochromatic light source is made to fall on an optical flat, which is oriented at a very small angle with respect to a flat reflecting surface, alternate band of light and dark patches are seen by the eye

✓ In case of a perfectly flat surface, the fringe pattern is regular, parallel and uniformly spaced. Any deviation from this pattern is a measure of error in the flatness of the surface being measured
Optical flats in case. About 1 inch (2.5 cm) in diameter
• Fig. shows photos of reference flats being used to check two test flats at different stages of completion, showing the different patterns of interference fringes.
• The reference flats are resting with their bottom surfaces in contact with the test flats, and they are illuminated by a monochromatic light source.
• The light waves reflected from both surfaces interfere, resulting in a pattern of bright and dark bands.
• The surface in the left photo is nearly flat, indicated by a pattern of straight parallel interference fringes at equal intervals.
• The surface in the right photo is uneven, resulting in a pattern of curved fringes.
Interferometers

- Whereas an interferometer works on the same basic principle as that of an optical flat, it is provided with arrangements in order to control the lay and orientation of fringes.

- It is also provided with a viewing or recording system, which eliminates the measurement errors.
The light from a mercury vapour lamp is condensed and passed through a green filter, resulting in a green monochromatic light source.

The light will now pass through a pin hole, giving an intense point source of monochromatic light.

The pin hole is positioned such that it is in the focal plane of a collimating lens. Therefore, the collimating lens projects a parallel beam of light on to the face of the gauge to be tested via an optical flat.

This results in the formation of interference fringes.
Fig. 7.15  Example of fringe patterns (a) Equal fringes on parallel surfaces (b) Unequal fringes due to flatness error
Interference fringes can be observed with a light intensity that is 1000 times more than any other monochromatic light source.
Laser Interferometers

✓ In interferometry, laser light exhibits similar properties as that of any ‘normal’ light.

✓ The fixed unit called the laser head consists of laser, a pair of semi-reflectors and two photo-diodes. The sliding unit will have a corner cube mounted on it.

✓ The corner cube is a glass disk whose back surface has three polished faces mutually at right angles to each other.

✓ The photo-diodes will electronically measure the fringe intensity and provide an accurate means for measuring displacement.
Laser Interferometers

– the instrument used for high precision measurements (distance, angles…. etc.)
– it uses the very small, stable and accurately defined wavelength of laser as a unit of measure.
Other Applications
flatness, straightness, velocity and vibrations, etc.

Loudspeaker vibrating at 1500 Hz

Source: www.optonor.no