Vidyavardhini's College of Engineering and Technology, Vasai (West)

First Year Engineering

Academic Year: 2024-2025

Problem Set 2: Measurements by light – Wave Interference

Subject: BSC2023/EP **Date: 01/02/2025**
Max Marks: 30 **Duration: 1 Hr**

CO2: To explain the basic importance of interference in the field of measurements.

1 Significance of Monochromatic Light in Interference

Problem 1: A monochromatic light sources of wavelength 600 nm produce interference fringes. If the fringe separation is 0.5 mm, calculate the distance between the two slits, given that the screen is placed 2 m away.

Solution: The fringe width is given by:

$$\beta = \frac{\lambda D}{d} \tag{1}$$

Rearranging for d:

$$d = \frac{\lambda D}{\beta} = \frac{600 \times 10^{-9} \times 2}{0.5 \times 10^{-3}} = 2.4 \text{ mm} \tag{2}$$

Problem 2: If the path difference between two monochromatic waves is 1200 nm and the wavelength is 600 nm, determine whether constructive or destructive interference occurs.

Solution: The condition for constructive interference is:

$$\Delta x = m\lambda \tag{3}$$

Since $\Delta x = 1200\,\text{nm}$ and $\lambda = 600\,\text{nm}$:

$$m = \frac{1200}{600} = 2 \tag{4}$$

Since m is an integer, constructive interference occurs.

2 Interferometry Applied to Flatness Testing

Problem 1: An optical flat is used to test the flatness of a surface. The wavelength of light used is 500 nm, and the fringe spacing observed is 0.2 mm. Determine the height difference between two adjacent fringes.

Solution: The height difference is given by:

$$h = \frac{\lambda}{2} = \frac{500}{2} = 250 \text{ nm} \tag{5}$$

Problem 2: A Michelson interferometer produces circular fringes. If the mirror is displaced by 1.5μm, how many fringes cross the field of view? Assume wavelength $\lambda = 600\,\text{nm}$.

Solution: The number of fringes displaced is:

$$N = \frac{2d}{\lambda} = \frac{2 \times 1.5 \times 10^{-6}}{600 \times 10^{-9}} = 5 \tag{6}$$

Problem 3: An optical flat is placed on a metal surface to test its flatness using monochromatic light of wavelength $\lambda = 600\,\text{nm}$. The interference fringe pattern observed has a fringe spacing of 2.5 mm. It is noted that the contour lines of the fringes represent height variations of $\lambda/2$.
1. Calculate the height difference between two successive fringes.
2. If the fringes curve outward in the middle, determine whether the surface is convex or concave.
3. If the surface has a localized high spot of $0.75\,\mu$m, estimate how many additional fringes would appear around this high spot.

Solution: Step 1: Height Difference Between Successive Fringes The height difference between successive fringes is given by:

$$\Delta h = \frac{\lambda}{2} \tag{7}$$

Substituting the given value of λ:

$$\Delta h = \frac{600 \times 10^{-9} \text{ m}}{2} = 300 \text{ nm} = 0.3\mu\text{m} \tag{8}$$

Step 2: Surface Shape Determination

- If the fringes curve outward in the middle, it means that the optical flat is making more contact with the middle region, implying that the test surface is **concave**. - If the fringes curve inward in the middle, it would indicate a convex surface.

Step 3: Estimating Additional Fringes Due to a High Spot

The number of additional fringes formed due to a localized height variation h is given by:

$$N = \frac{h}{\Delta h} \tag{9}$$

Substituting $h = 0.75\,\mu$m and $\Delta h = 0.3\,\mu$m:

$$N = \frac{0.75}{0.3} = 2.5 \tag{10}$$

Since the number of fringes must be an integer, we approximate to **3 additional fringes**.

Final Answer

- The height difference between successive fringes is **0.3 μm**.
- Since the fringes curve outward in the middle, the surface is **concave**.
- Around the high spot, approximately **3 additional fringes** would appear.

3 Surface Contour Test

Problem 1: In a surface contour test, the interference fringe separation is measured as 0.3 mm for a wavelength of 550 nm. Find the height variation of the surface.

Solution: The height difference is given by:

$$h = \frac{\lambda}{2} = \frac{550}{2} = 275 \text{ nm} \tag{11}$$

Problem 2: A scratched surface is tested using an optical flat. If the distance between two fringes is 0.5 mm and the depth of the scratch is 0.15μm, determine the wavelength of light used. Given distance due to scratch is 0.5μm. **Solution:** Using the relation, depth of scratch

$$depth = \frac{d}{D} \times \frac{\lambda}{2} \tag{12}$$

Solving for λ:

$$\lambda = \frac{2dD}{depth} = \frac{2 \times 0.15 \times 10^{-6} \times 1 \times 10^{-3}}{0.5 \times 10^{-6}} = 600\mu m \tag{13}$$