Michelson Interferometer to Measure Coefficient of Thermal Expansion

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Aim:

To measure the thermal expansion co-efficient of a material using Michelson Interferometer

Apparatus:

- Laser source
- Mirrors
- Beam splitter
- Breadboard
- Copper rod

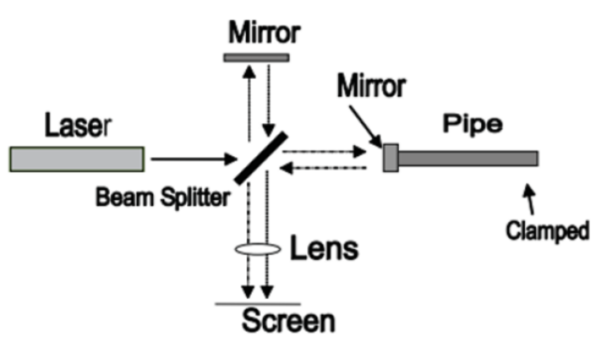

Figure 1: Setup of the experiment

Theory:

On heating, metal expands as:

$$\alpha = \frac{\Delta L}{L_0 \Delta T}$$

where:

- α is the linear coefficient of thermal expansion
- L_0 is the initial length of the rod
- ΔL is the change in length of the rod on heating
- ΔT is the change in temperature

The change in length is related to the number of fringes shifted (given by n) as:

$$\Delta L = \frac{n\lambda}{2}$$

Therefore, we get:

$$\alpha = \frac{n\lambda}{2L_0 \Delta T}$$

$\lambda = 650$ nm and the initial length of the rod is $L_0 = 75$ mm

Observations:

Table 1: Temperature Data for Aluminium

Temperature Range (°C)	ΔT	n
35-40	5	18
40-45	10	36
45-50	15	54
50-55	20	74
55-60	25	92
60-65	30	113

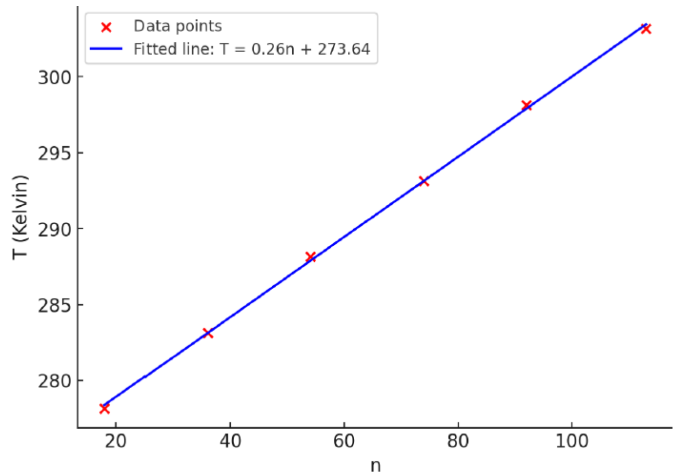

Figure 2: Temperature vs n for Aluminium

Table 2: Temperature Data for Copper

Temperature Range (°C)	ΔT	n
35-40	5	11
40-45	10	25
45-50	15	38
50-55	20	52
55-60	25	66

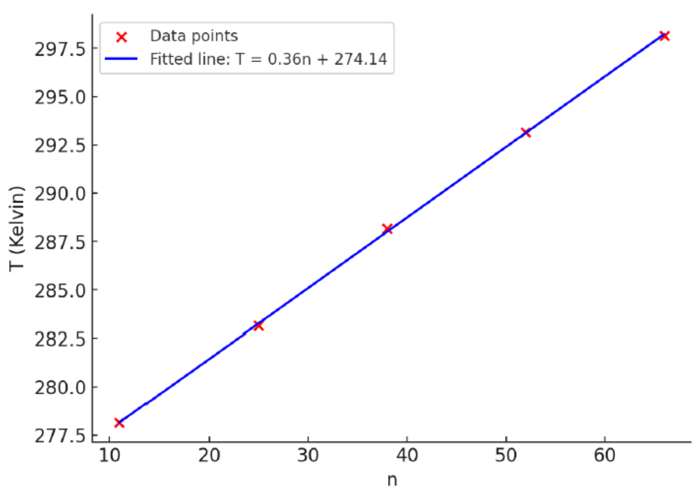

Figure 3: Temperature vs n for Copper

Calculations:

The slopes were determined from the temperature vs. n data:

Slope for Aluminium:

$$\frac{n}{\Delta T} = 3.8461$$

Slope for Copper:

$$\frac{n}{\Delta T} = 2.7777$$

Therefore:

$$\alpha_{Al} = 1.22 \times 10^{-6}\,\mathrm{K}^{-1} \quad \text{and} \quad \alpha_{Cu} = 0.65 \times 10^{-6}\,\mathrm{K}^{-1}$$

Error Analysis:

The uncertainty in α was determined using:

$$\frac{\Delta\alpha}{\alpha} = \frac{\Delta n}{n} + \frac{\Delta\lambda}{\lambda} + \frac{\Delta L_0}{L_0} + \frac{\Delta T}{T_0}$$

The relative uncertainty was found to be:

$$\frac{\Delta\alpha}{\alpha} = 0.32\%$$

Results:

The experimentally determined coefficients of linear thermal expansion were:

- Aluminium: $1.22 \times 10^{-6}\,\mathrm{K}^{-1} \pm 0.32\%$
- Copper: $0.65 \times 10^{-6}\,\mathrm{K}^{-1} \pm 0.32\%$

Discussion and Sources of Error:

- At extreme temperatures, materials exhibit non-linear expansion behavior due to phase transitions or changes in bonding forces at the atomic level. By extending the temperature range and incorporating high-resolution temperature sensors, this experiment could explore these effects in greater detail.
- Incorporating image-processing techniques to automatically track fringe shifts can reduce human error and enhance measurement precision.
- Improperly aligned optical components which can cause incorrect fringe counting.
- Human error in counting the fringes shifted on screen gives an error in n.

- Imperfections in the beam splitter and mirrors may lead to distortion in interference patterns.
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- Fringes are at times hard to see because of ambient light as well.