ME-372 : Heat transfer and Metrology lab

White Light Interferometer

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Introduction

- **AIM:** To study the roughness of a surface using white light interferometer

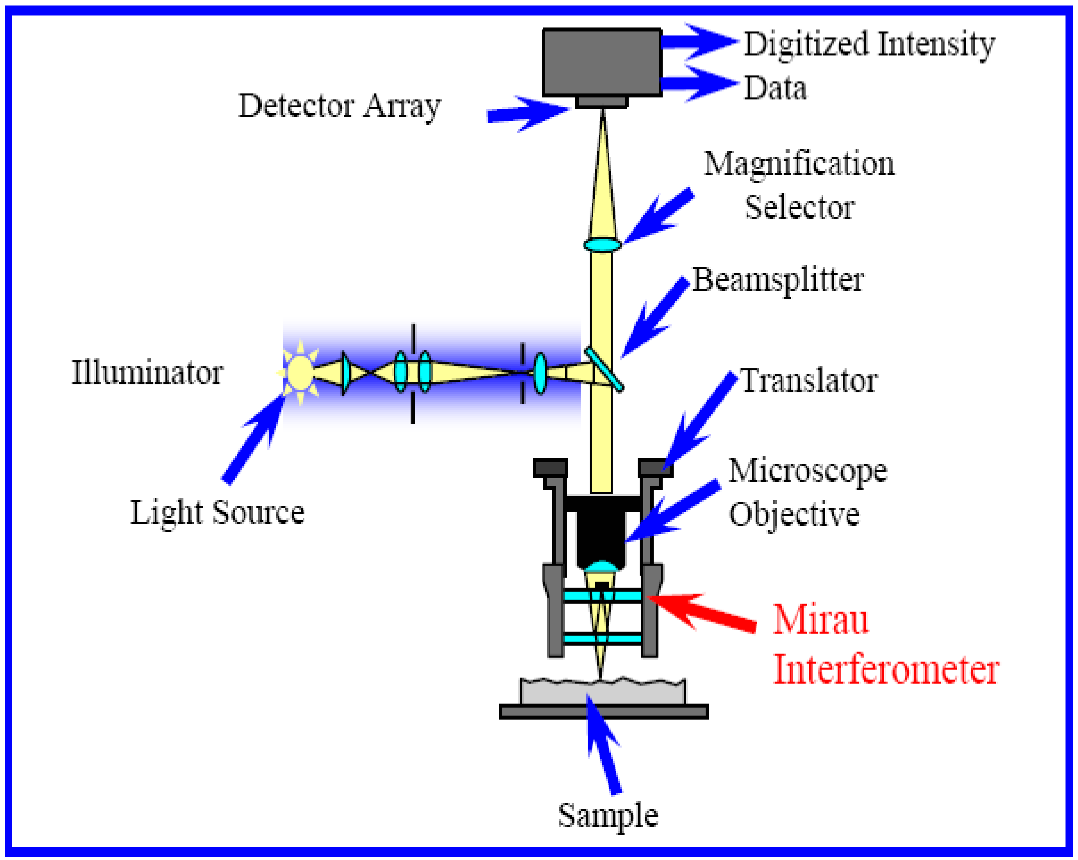
- **Methodology:** The roughness parameters (like Ra, Rq, Rz) will be measured for different kinds of surfaces (smooth and rough) and at different locations using an equipment named as White Light Interferometer. We will use white light as well as monochromatic light source to evaluate the roughness. For a smooth surface, an optical flat will be used.
- A sample surface with heights at different points will be given in order to manually calculate different roughness parameters. A critical analysis of the surface based on roughness parameters in expected. Further report writing instructions will be mentioned in the end of this presentation.

Theory and Principles

- Interferometry is the technique of analyzing the properties of two or more waves by studying the pattern of interference resulting from their superposition. The instrument that uses this concept is known as an interferometer.
- Light interference occurs when there is a difference in distance traveled by the light (light path) from the surface of a target object to a certain point; the **white light interferometer** uses this phenomenon to measure the surface roughness of a sample.
- By carefully selecting two wavelengths for operating, it is possible to greatly increase the dynamic range of the measurement over what can be obtained using a single wavelength. A better approach is to use a white light interferometer.

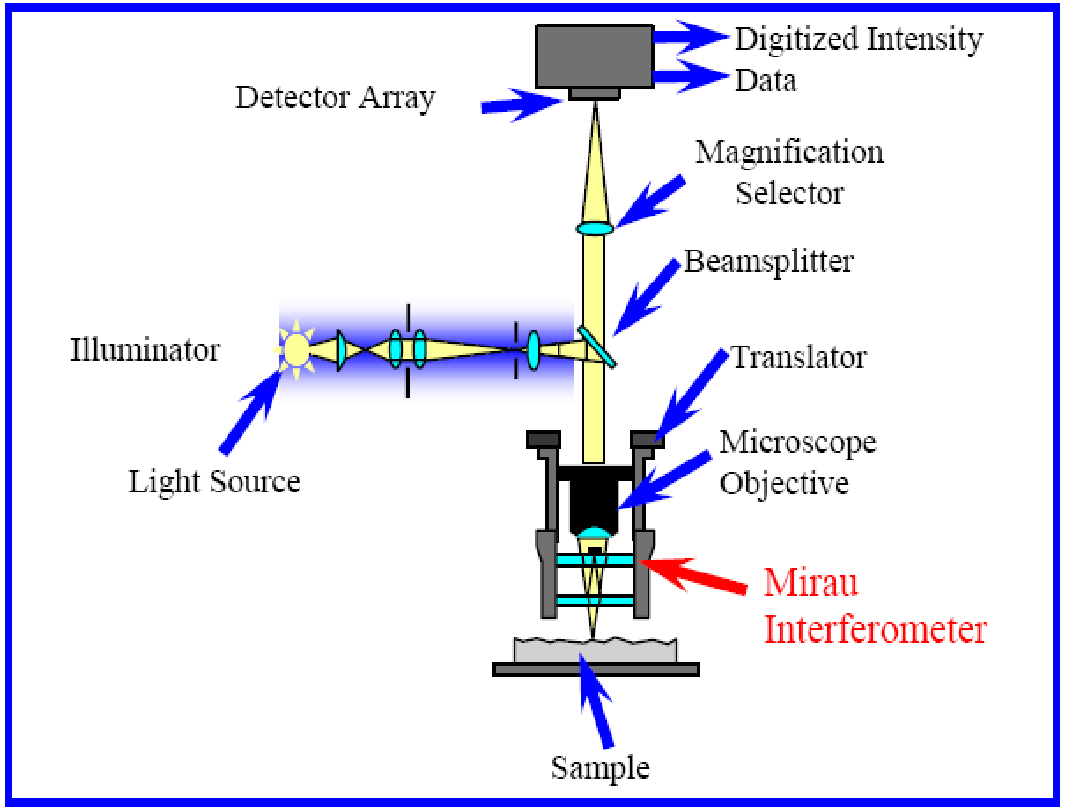
Structure of a White Light Interferometer

- The configuration shown in the figure utilizes a two-beam Mirau interferometer at the microscope objective.
- A tungsten halogen lamp is used as the light source. Light reflected from the test surface interferes with light reflected from the reference.
- The white light interferometer is designed so that the optical path length from the CCD element to the reference mirror and that from the CCD element to the sample surface are the same.



Working of a White Light Interferometer

- The light emitted from the source (semiconductor laser, etc.) is separated into reference and measurement beams. While the reference beam is passed through the reference mirror through a half mirror, the measurement beam is reflected and guided to the sample surface.
- The passed beam is reflected by the reference mirror to the CCD image sensor and forms an interference pattern. The other beam is reflected off the sample surface, passes the half mirror, and forms an image through the CCD image sensor.
- The resulting interference pattern is imaged onto the CCD array. Also, output from the CCD array is digitized and read by the computer.
- The asperity on the sample surface causes these path lengths to be unequal, which results in forming an interference pattern at the CCD element. The number of lines in the interference pattern is translated to peaks and troughs (heights) on the sample surface



A simplified schematic of a coherence peak sensing interference microscope.

Review of Roughness Parameters

Ra

y(x) = profile height from mean line

$$R_a = \frac{1}{L}\int_0^L |y(x)|dx$$

Digitized Profile

$$R_a = \frac{1}{N}\sum_{i=1}^{N} |y_i|$$

N = Number of points

Rq

R_q = RMS = σ

$$\sigma^2 = \frac{1}{L}\int_0^L (y(x))^2 dx$$

$$= \frac{1}{N}\sum_{i=1}^{N} |y_i{}^2|$$

Review of Roughness Parameters

Skewness-Sk

$$Sk = \frac{1}{\sigma^3 L} \int_0^L (y(x))^3 dx$$

$$= \frac{1}{\sigma^3 N} \sum_{i=1}^{N} (y_i)^3$$

Kurtosis

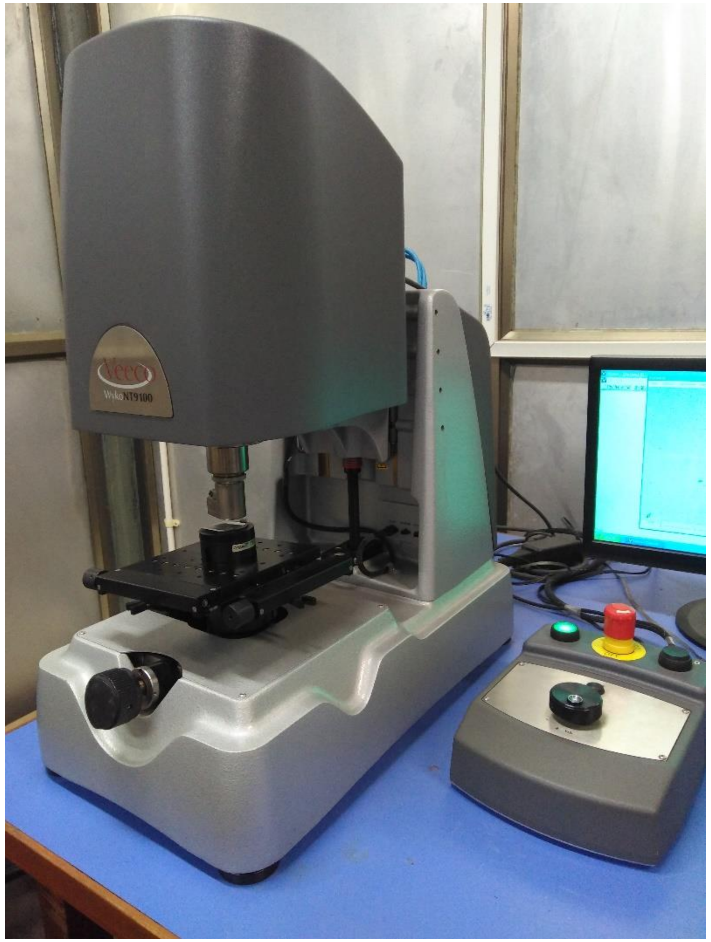
$$k = \frac{1}{\sigma^4 L} \int_0^L (y(x))^4 dx$$

$$= \frac{1}{\sigma^4 N} \sum_{i=1}^{N} (y_i)^4$$

Experimental Set up

- The set up will look similar to the schematic mentioned in the first figure.
- There will two samples, one smooth (an optical flat) and another one a comparatively rough surface.
- An Optical flat is a smooth surface with very low values of roughness parameters like Ra and Rq.
- The WLI apparatus is controlled through the computer connected with it. The control software enables the operations as well as visualization of the surfaces.
- The rough surface would be a micro-milled surface which will have many asperities at microscopic scale and also a few at meso scale
- These two samples are chosen to give a realisation on the values of the values of roughness parameters for different conditions of the surface.

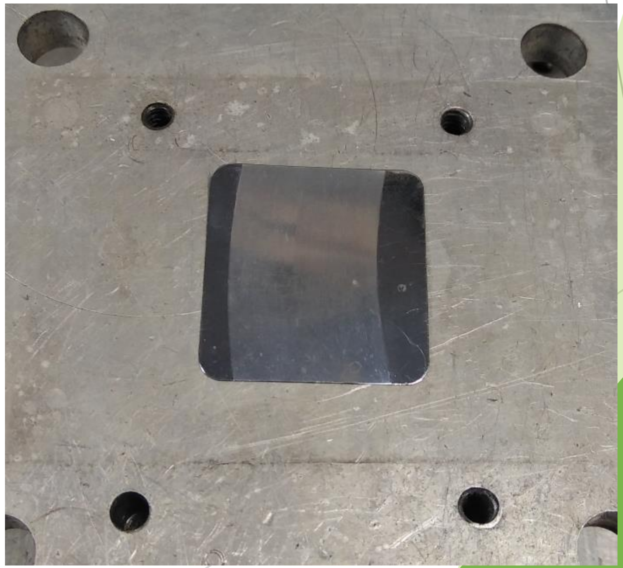
Experimental Setup (MTL laboratory)



White Light Interferometer with controller

Optical Flat used:

Calibration sample: With 5 micron roughness

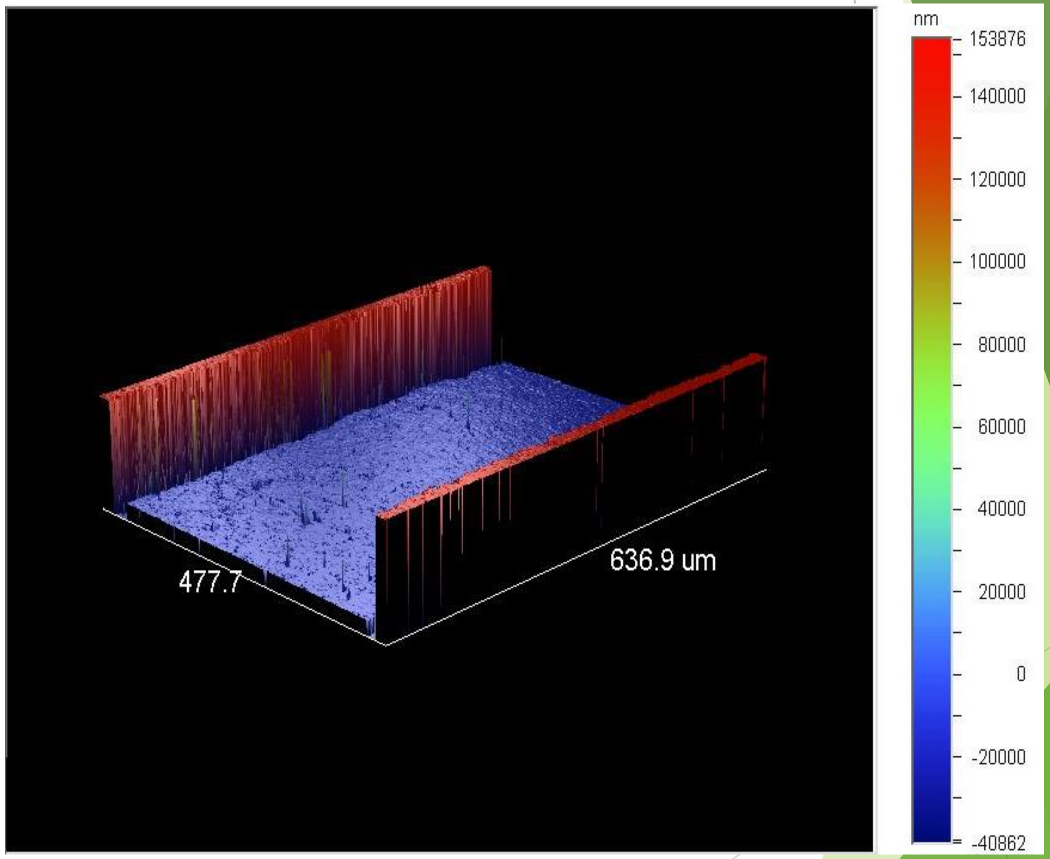


Procedure

1. Place the sample on the top of the table for measurement.
2. Open the intensity window by clicking the intensity button.
3. After this psi or vsi mode can be selected based on the sample. For rough surfaces vsi mode and for very smooth surfaces psi mode is best suited.
4. Using the slider bar at the bottom of the intensity window, adjust the light intensity to be as bright as possible to make focusing easier. If the intensity window shows red pixels, use the slider bar to lower the intensity until the image appears just below saturation.
5. Now use the rotating button to focus the object. For better focusing use slow motion while setting the focus. Fringes will appear at best focus, set the focus for 2-3 fringes.
6. Now click on new file button to start scan.
7. Repeat the same procedure for other samples.

Results

- System window will give the surface roughness of the sample.
- Values of different roughness parameters can be evaluated
- The software produces a 3D profile of the surface and can be visualized on the computer screen, an example is shown here.
- A sample data set will be provided, which will contain the heights at different location of a surface. Students are expected to analyse the data and calculate the values of roughness parameters asked in the problem statement.



Expectations from the Report

General Instructions & info

- Please watch the video and get acquainted with experimental setup and working
- Refresh your fundamentals about roughness parameters, like:

i. Ra, Sa

ii. Rq, Sq

iii. Rz

iv. Skew

- Analyse the data set provided, and solve the problem statement mentioned

Report Writing

- Following sections must be included:

- Objectives
- Setup & Working (with schematics)
- Theory (Roughness Parameters)
- Samples
- Procedure
- Results & Discussion (from data analysis)
- Conclusions and Applications

Sample Data

Problem statement

- The adjacent matrix has 25 entries, which are to be taken as the height of a sample (0.5mm x 0.5mm) at grid points. Here, the horizontal and vertical distance between adjacent points are both 0.1 mm)
- Calculate the following :

i. Average Ra value

ii. Sq

Height Matrix (values in µm)

34	48	36	25	25
31	43	47	21	34
32	24	25	28	47
36	36	25	35	42
44	44	44	34	39