


OPTICAL PROFILOMETER

Getting Started:

- **SIGN THE LOG BOOK!!!** If you are the first person to use the instrument for the day, you will need to calibrate both VSI and PSI modes. Also if you calibrate the instrument please note it in the logbook.
- The instrument is ON, you will need to turn ON the two monitors (computer and the black/white)
- Open Vision 32 software
- Raise objective using the Z-Axis control knob and the speed button
- Calibrate the instrument. (Note: Both modes of measurement should be calibrated on a daily basis to ensure accuracy.)

Calibrations:

1. Select **MEASUREMENT OPTIONS** from the toolbar, 
2. Select **CALIBRATE** (Lower left end of box) → choose **AUTOCALIBRATION** (Fig. 1-2)
3. Select **ALL MODES** from the measurement mode box., (see Fig. 2) VSI mode will be calibrated first, followed by PSI mode.
4. Select **NEXT**

B. VSI: (Vertical Scanning Interferometry)

1. Place calibration step under the objective (not important to find the feature immediately). (**5x**)
2. Lower the objective until it reaches close to, but not touching the surface.
3. Select **INTENSITY** → set the intensity and find the best focus at the TOP of the step. (Fig. 3-4) HINT: Focus on the surface first, (i.e. locate fringes on surface) then attempt to find features.
Begin initial focusing by going under **HARDWARE** →

FILTER → PSI LOW MAG and HARDWARE → FOV → 1x, this is the COARSE focus (larger range of focus). Once you have found the feature, you should use the COARSE “Tilt and Tip” knobs to orient 3-4 fringes perpendicular to the step. After orienting the fringes, change the filter for a final focus (**HARDWARE → FILTER → VSI**) and then double-check your focus and intensity. (Double check FOV is 1x)

* All step height measurements should be done using the VSI filter.



Figure 1. Measurement Options

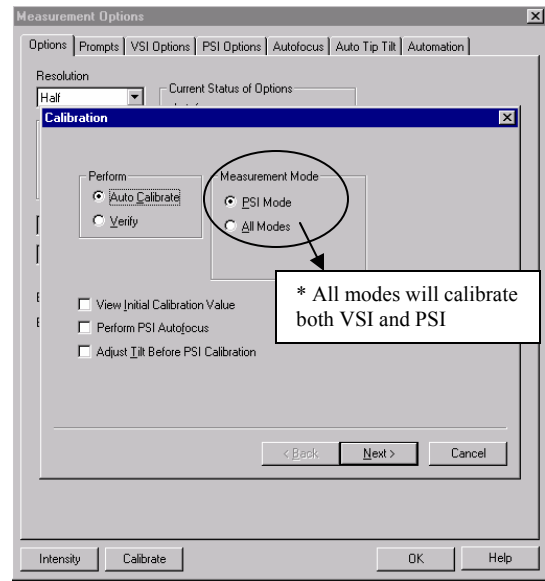


Figure 2. Calibration

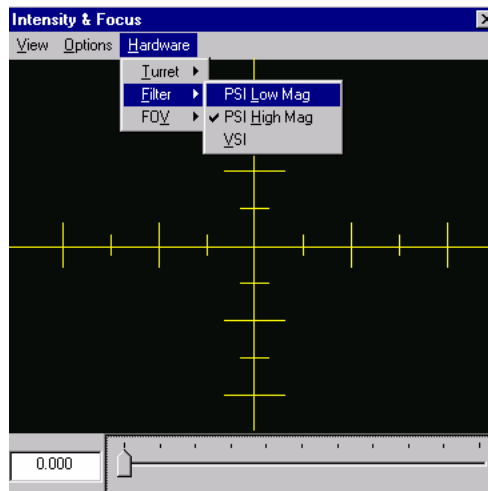


Figure 3. Filter Settings

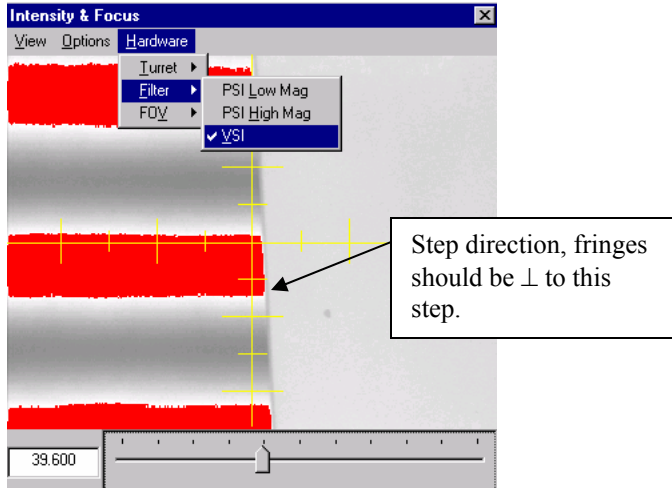


Figure 4. Fringe Pattern for VSI

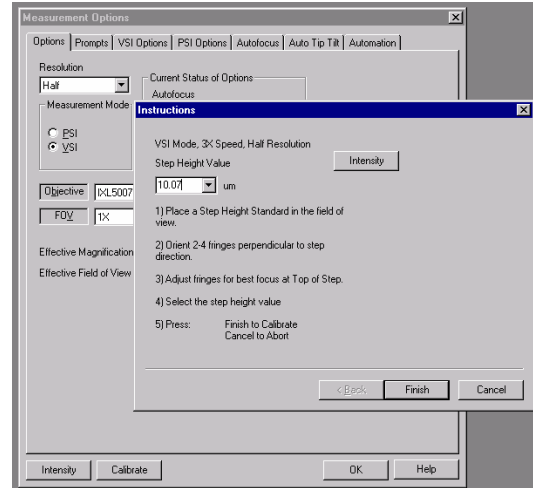


Figure 5. VSI Calibration

4. Close the **INTENSITY** window.
5. Type in the **STEP HEIGHT VALUE** that is written on the calibration standard, (should be 10.07 μm) (Fig. 5)
6. Select **FINISH** to complete the calibration.
7. To accept the new calibration number, Select **OK**.

C. PSI: (Phase Shifting Interferometry)

1. Place polished mirror under objective (**20x**)
2. Lower the objective until it reaches close to, but not touching the surface.
3. Select **INTENSITY** → set the intensity and find the best focus at the surface. (Fig. 6) HINT: 2-4 fringes should be oriented at a 45° angle with respect to the X-Y coordinates in the intensity box. Begin initial focusing by going under **HARDWARE** → **FILTER** → **PSI LOW MAG** and **HARDWARE** → **FOV** → **1x**, this is the **COARSE** focus (larger range of focus). Once you have the surface in focus, you should use the **COARSE** “Tilt and Tip” knobs to orient the fringes as described above, then change the filter for a final focus (**HARDWARE** → **FILTER** → **PSI HIGH MAG**)

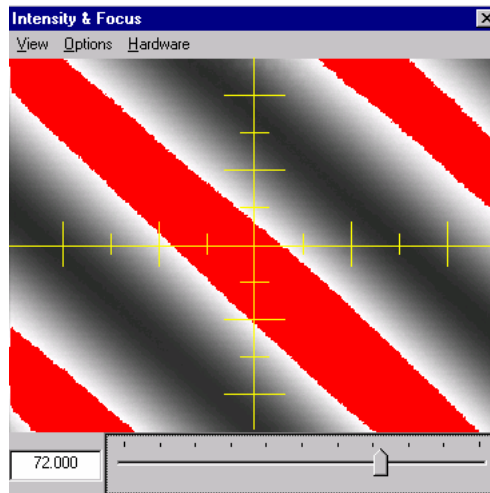


Figure 6. Fringe Pattern for PSI



and double-check your focus and intensity. (See Fig. 6) (Double check that the FOV is still 1x).


- * All surface roughness measurements should be done using the PSI HIGH MAG filter.
 4. Close the **INTENSITY** window.
 5. Select **FINISH** to complete the calibration.
 6. To accept the new calibration number, Select **OK**. (If calibration fails → repeat steps 3-5 until it is acceptable.)

Tips for Making Measurements:



- Check the limitations and resolution section of the reference page to determine which measurement is best for your sample.
- Transparent materials (i.e. PDMS, PMMA, Parylene, etc.) must be placed on top of a reflective material (i.e. wafer, glass with metal, mirror, etc.)
- The limitations for transparent materials, i.e. Silicon dioxide and Silicon Nitride, are a minimum of 2 μm for measuring the step height.

Measurements:**VSI:**

- Place sample on a support (objective will not focus sample that is lying directly on the stage...use one of the plastic lids that is next to the instrument).
- **CAUTION:** Lower objective until it reaches close to, but not touching the sample surface.
- If calibration was not done, please refer to above instructions for calibrating the instrument.
- Open the **INTENSITY** window 
- **HARDWARE →FILTER→PSI LOW MAG**, use this setting for your initial focus and intensity settings. Focus on the surface and then find your feature. Fringes should be oriented perpendicular to the step. (See figure 4)
- **HARDWARE →FILTER→VSI**, final focus and intensity setting for making a measurement. Intensity should be set to just below the saturation limit of the CCD camera (saturation is indicated by red fringes).
- After you have found the best focus and intensity, you can close the intensity window.
- Choose **MEASUREMENT OPTIONS** from the toolbar. 
Be sure that you set the appropriate options:
 - **Options:** Resolution
 - Mode of Measurement (VSI)
 - Correct objective/FOV

- **VSI Options:** Speed of measurement
 - Back scan (usually good to leave default value)
 - Length of scan
 - Modulation Threshold (see definitions)
- After you have set all of the options, Select **OK**
- To measure your sample, Select **NEW** 

PSI:

- Place sample on a support (objective will not focus sample that is lying directly on the stage...use one of the plastic lids that is next to the instrument).
- **CAUTION:** Lower objective until it reaches close to, but not touching the sample surface.
- If calibration was not done, please refer to above instructions for calibrating the instrument.
- Open the **INTENSITY** window 
- **HARDWARE →FILTER→PSI LOW MAG**, use this setting for your initial focus and intensity settings. Focus on the surface and then find your feature. Fringes should be oriented at a 45 ° angle with respect to the X-Y coordinates of the intensity window.
- **HARDWARE →FILTER→PSI HIGH MAG**, final focus and intensity setting for making a measurement. Intensity should be set to just below the saturation limit of the CCD camera (saturation is indicated by red fringes).
- After you have found the best focus and intensity, you can close the intensity window.
- Choose **MEASUREMENT OPTIONS** from the toolbar 
- Be sure that you set the appropriate options:
 - **Options:** Resolution
 - Mode of Measurement (VSI)
 - Correct objective/FOV
 - **PSI Options:**
 - For multiple measurements, under Averaging check the **ON** box.

Modulation Threshold (see definitions)

- After you have set all of the options, Select **OK**
- To measure your sample, Select **NEW**



Tips for Analyzing Data:

Processed Options allow you to remove terms, applying filtering, and perform data operations to enhance the measurement data. Processed options can be applied to the current dataset only. To access these options, Select the **PROCESSED OPTIONS** button on the toolbar.



(See Fig. 7)

After each measurement, the software will automatically remove any **TILT** that is introduced to produce fringes. If you find that your data is not level, you can create a “TERMS MASK” to level the data. (Please see next section for detailed instructions for leveling data)

For images that have many dropout points, you can use the **DATA RESTORE** under the **OTHER** heading. This option fills in the small areas of bad pixels using the height data surrounding the dropout area. **CAUTION**, it should not be used to replace large areas of bad data- results based on such data may be misleading or meaningless!!!

If you are interested in analyzing small portions of a larger dataset, use the **MASK EDITOR** button from the toolbar. Decide which type of tool is best for creating your mask (crosshair, box, circle, etc.), and highlight the region you want to mask. If you want to analyze a small region it is best to mask off the area for analysis and then choose **OUTSIDE** → **TERMS MASK** check **ON** → **SAVE** → **OK**

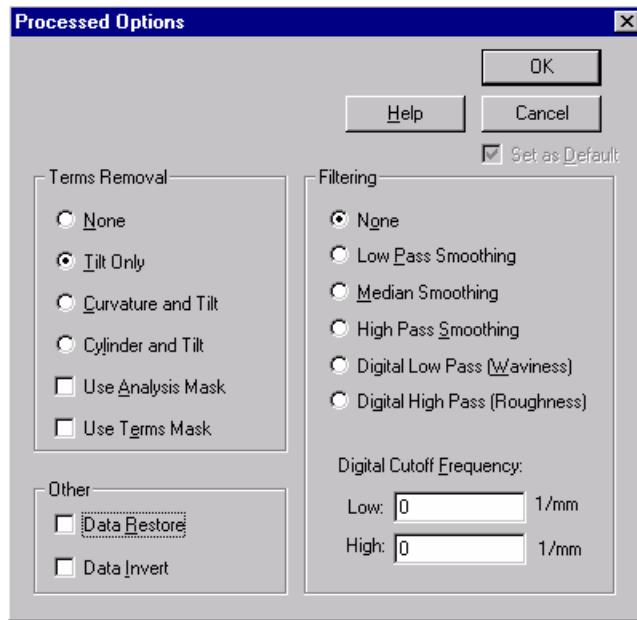


Figure 7. Processed Options

The following are a list of graphics options on the toolbar:



Contour Plot: False color scheme depicting the height of your surface features or step.



2-D Analysis: Profile slices taken from the surface height data. You can adjust the locations and size of the region from which the slices are taken.



3-D Analysis: Creates a 3-Dimensional image of the surface data.



Filtered Histogram: A plot that shows the distribution of individual surface parameters.



Bearing Ratio: The ratio of the bearing length to the sampling length.



3-D Interactive: Creates a 3-D contour map, which can be rotated into any position (view) by clicking on the contour map and dragging the cursor.

Leveling Data Using a “Terms Mask”:

A terms mask defines a dataset sub-region from which the tilt, curvature, or cylinder of the dataset will be calculated. The “term” (tilt, curvature, cylinder) will then be removed from the entire dataset.

Why use a terms mask? Take, for example, the stepped surface shown in Figure 8A. You would likely want to remove tilt from the dataset, aligning the steps with a true horizontal plane.

The dotted line in Figure 8A shows the “best-fit” plane for the whole dataset. If tilt is removed based on that line, the result would look like Figure 8B.

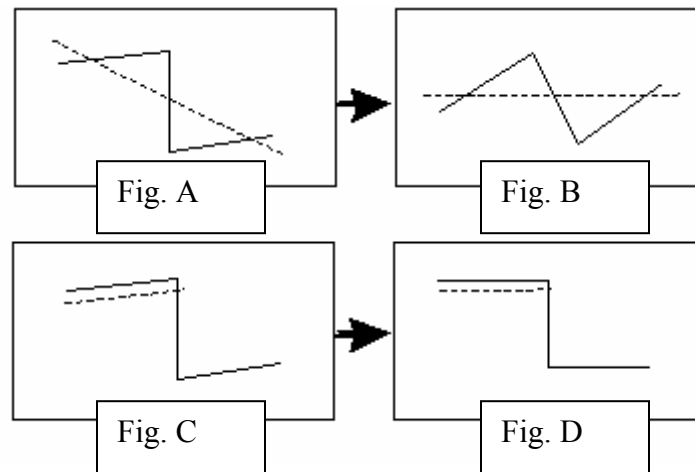



Figure 8.

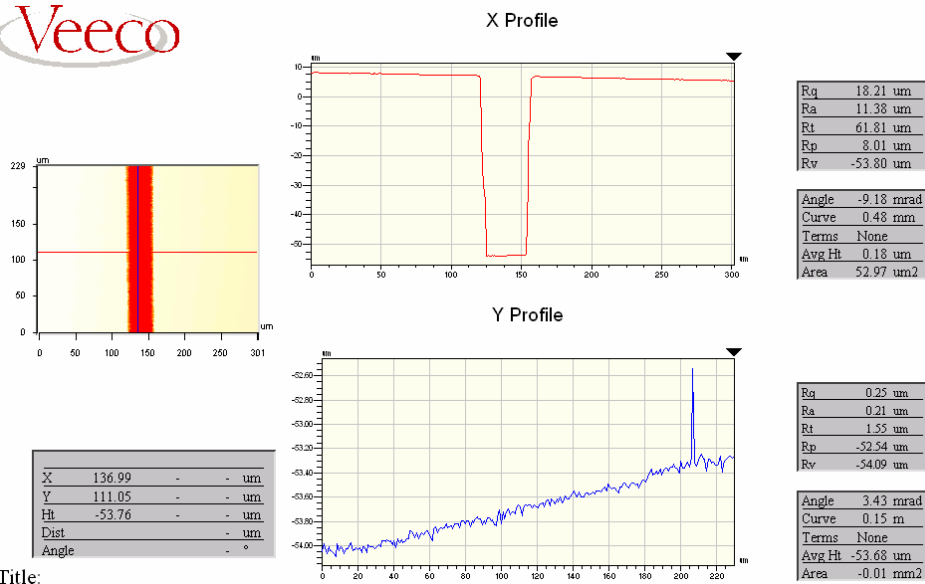
If you define a terms mask, however, to block the right side of the step, then the best-fit plane will be based on only the upper surface, as in Figure 8C. When tilt is removed, the result will be much more representative, as in Figure 8D.

Note: The terms mask simply defines an area; it does not appear as a blocked area on display plots. It also does not affect any calculations except terms removal.

(Note: See Help section for additional information; Post-measurement processing – Masking – Terms Mask)

Step-by-step instructions:

1. After measuring the step height, open a 2-D plot of the data. (See Fig. 9)
2. Open the “Mask Options (or mask editor)” (See Fig. 10) 
3. Place the desired cursor (in example it is a crosshair) on the image of your step (See Fig. 11)



Title:

Figure 9 – 2-D plot of step height data

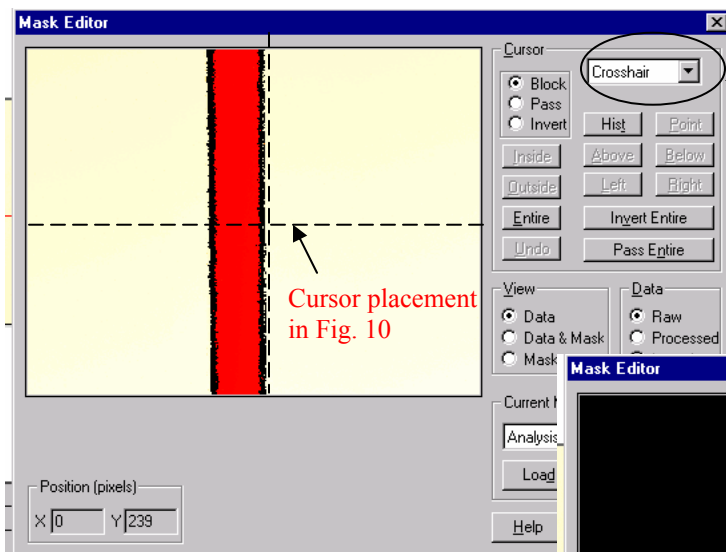
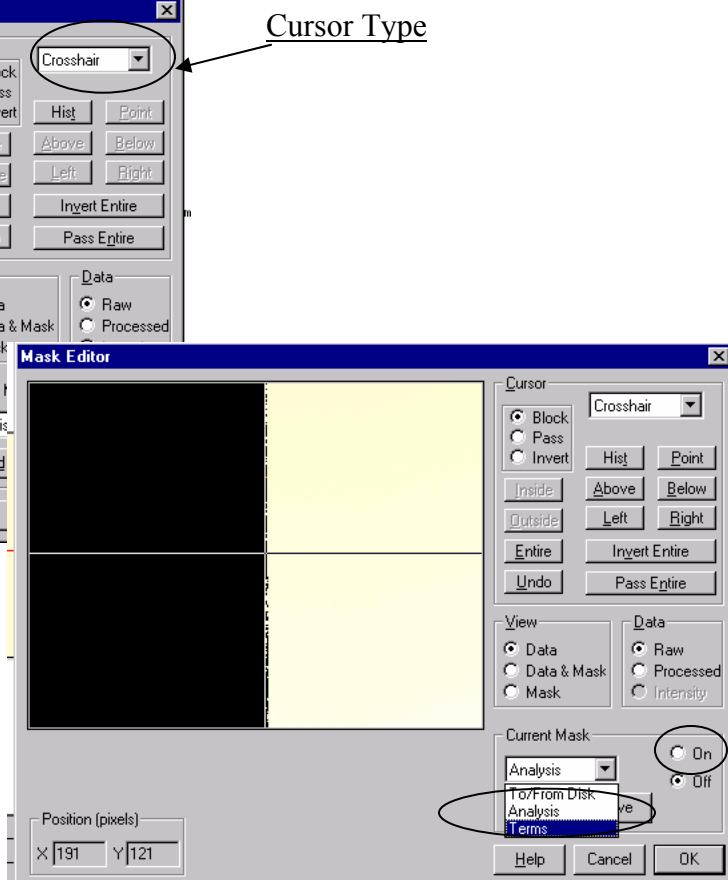


Figure 10 – Mask Editor

Figure 11 – Creating a ref. point for leveling by blocking left-hand side of step.



Leveling steps cont'd:

4. To create a reference in which to level the step, you must place the desired cursor in the screen and block the area that you want to level with the unblocked area. For example if you refer to Fig. 10, you can see that the step along with one side is blocked. This area will be referenced to the unblocked area using a “TERMS MASK” (See Fig. 11)
5. After blocking the desired area, select the TERMS mask from the pull down menu (Under CURRENT MASK). (See Fig. 11)
6. Select “ON” to activate this mask (See Fig. 11)
7. Choose “SAVE” (See Fig. 11)
8. OK
 - Now when the screen appears again with your step, the two edges should be level allowing for a more accurate measurement of the step height. (Compare Fig. 9 to Fig. 12)

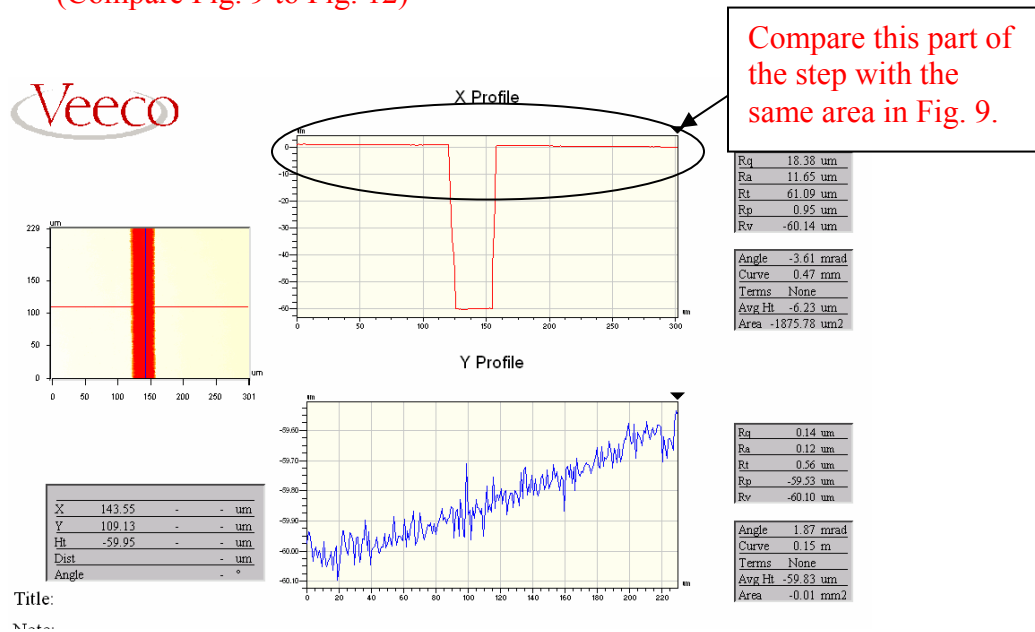


Figure 12 – Step height data after leveling (using terms mask)

Definitions:

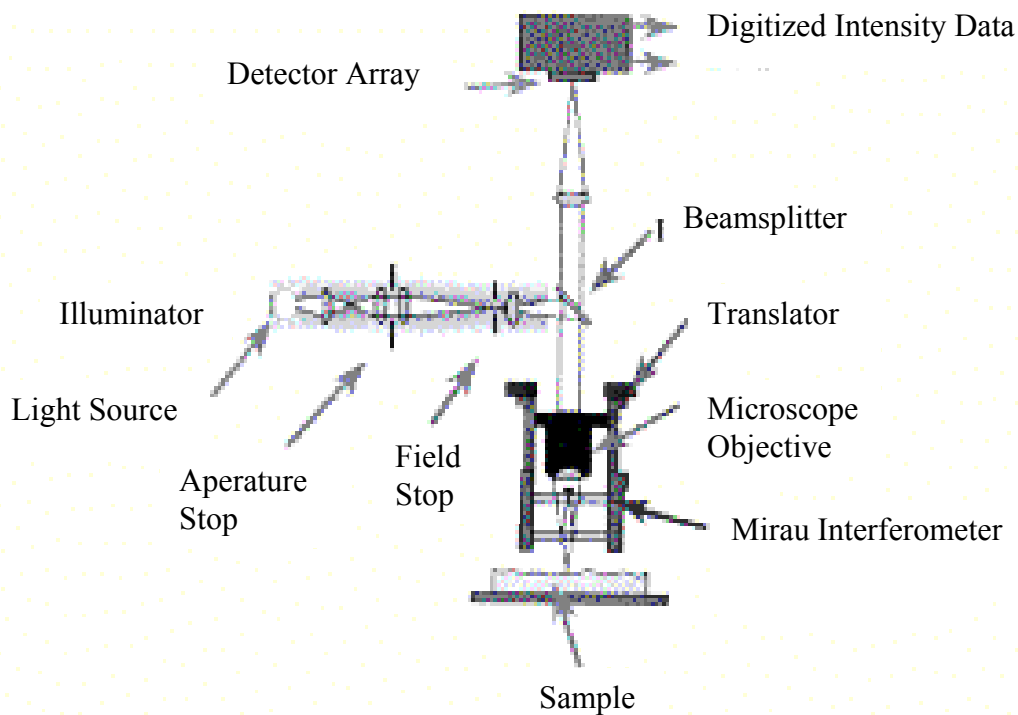
For PSI and VSI definitions, see microscope setup below.

PSI: Phase Shifting Interferometry; a white light beam is filtered and passed through an interferometer objective to the test surface. The interferometer beamsplitter reflects half of the incident beam to the reference surface within the interferometer. The beam reflected from the test surface and the reference surface recombine to form interference fringes. The fringes are the alternating light and dark bands you see when the surface is in focus.

During the measurement, a piezoelectric transducer (PZT) linearly moves the reference surface a small, known amount to cause a phase shift between the test and reference beams. The system records the intensity of the resulting interference pattern at many different relative phase shifts, and then converts the intensity into wavefront (phase) data by integrating the intensity.

VSI: Vertical Scanning Interferometry; light reflected from a reference mirror combines with light reflected from a sample to produce interference fringes, where the best-contrast fringe occurs at the best focus. In VSI mode, the white-light source is filtered with a neutral density filter, which preserves the short coherence length of the white light, and the system measures the degree of fringe modulation, or coherence, instead of the phase of the interference fringes.

Modulation Threshold: Determines the acceptable signal-to-noise level for which a given pixel is considered valid. Data points that do not meet the modulation threshold are marked as invalid and are not considered for analysis. If you are measuring an exceptionally rough sample, decrease the minimum modulation threshold to avoid having too many data points excluded from the analysis. If you are measuring an exceptionally smooth, reflective sample, such as a wafer surface, increase the modulation threshold to 10%.



An Interference Microscope

Objective: 5x

FOV	Effective Magnification	Effective FOV (mm)
0.5x	2.54	2.434 x 1.853
1x	5.088	1.215 x 0.925
2x	10.24	0.604 x 0.460

Objective: 20x

FOV	Effective Magnification	Effective FOV (mm)
0.5x	10.22	0.605 x .460
1x	20.48	0.302 x 0.230
2x	41.218	0.150 x 0.114

Limits and Resolution

PSI (Phase Shifting Interferometry): Surface Roughness

- Maximum height: 160 nm
- Resolution: 3 Å

VSI (Vertical Scanning Interferometry): Step Heights

- Maximum: 1.5 mm
- Resolution: 3 nm

Parameters

- R_a \equiv Roughness Average
- R_q \equiv RMS Roughness
- R_p \equiv Maximum Profile Peak Height
- R_v \equiv Maximum Profile Valley Depth
- R_t \equiv Maximum Height of the Surface
- R_z \equiv Avg. Maximum Height of the Profile
- R_{SK} \equiv Skewness (Measures asymmetry of plane)