Surface Measurement

User Manual

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Contents

1 Introduction

1.1 Overview

As part of the Akrometrix Studio software platform, Surface Measurement is designed as the data acquisition package for any Akrometrix hardware utilizing the shadow moiré, fringe projection, or DIC techniques. It features a multiple document interface where the user interacts with child windows and context menus allowing many types of information to be displayed and compared on screen at one time.

This manual describes the interface and functions of the Surface Measurement software. Automated data acquisition during a thermal profile is described in the **Thermal Profiler User Manual** and analysis is described in the **Surface Analysis User Manual**. Surface Measurement requires system hardware to operate and, thus, will only be installed on computers attached to Akrometrix measurement equipment. Surface Analysis may reside on the measurement equipment computer and/or on a remote computer.

A user unfamiliar with shadow moiré, fringe projection, and DIC and their application in Akrometrix measurement systems is advised to first read **Akrometrix Techniques and Analysis 101**.

Section 2 describes the program interface and its functions. **Section 3** describes the program functionality while in MP10 mode. **Section 4** describes the program functionality while in DIC mode. **Section 5** describes common problems and troubleshooting. **Appendix A** describes software file formats and keyboard shortcuts.

1.1 Warnings and Notes

1.1.1 Warnings and Notes in this Manual

Warnings and Notes are marked throughout the manual with these icons:

Figure 1.1 Warning Icon

Figure 1.2 Note Icon

Warnings are specific health hazards for the operator or potential sources of system damage. Notes highlight system limitations or automatic responses that may require corrective action by the operator for successful operation.

1.2 Technical Support

For technical support, contact Akrometrix:

Akrometrix	404-486-0880	support@akrometrix.com
2700 NE Expressway	404-486-0890 (fax)	http://www.akrometrix.com
Building B, Suite 500		
Atlanta, GA 30345		

When contacting Akrometrix, please provide the system serial number, the version numbers of the Akrometrix software being used, a description of the problem or question, and contact information for reply. If the question concerns a particular measurement or analysis, please provide electronic copies of the phase images, reference images, and final results and a description of data acquisition and/or analysis conditions. If the problem concerns changes or failure in general system operation, please describe any events or system modifications that occurred immediately before the problem arose.

2 Surface Measurement

2.1 Start-up

1. Run Surface Measurement by clicking the Surface Measurement button in the Studio Manager bar on the left side of the screen. Alternatively, the program can be run from the desktop shortcut or by pointing to **Start→All Programs→Akrometrix→Surface Measurement**. A start-up splash screen appears while the software initializes.

2. When asked whether or not to home the grating stage, ensure that all obstructions are removed from the stage path and press **Yes**. If **No** is pressed, the application will continue to load without homing the sample support motors.

   Note: Pressing No will decrease program startup time. In this case, however, absolute sample support position will not be available.

3. The main Surface Measurement screen will display. The parent window contains a camera view and all other windows that the program spawns.

2.2 Acquiring Data

1. Position the sample under the grating, using the Camera window (see **Figure 2.1**) to line up edges of the part so that they are more or less parallel with the edges of the camera view.

2. Adjust the region of interest, or ROI, such that it fully encompasses the part to be measured.

3. Adjust the sample/grating height using the Sample Height Adjust Window (see **Figure 2.2**) so that there is adequate fringe contrast on the sample. It may also be necessary to adjust the camera iris settings to get adequate brightness on the sample. Use the highlight saturated and dark pixels options to avoid getting saturation in the fringe image. These can be activated by going to the Camera Control window described in **Section 2.3.2**.

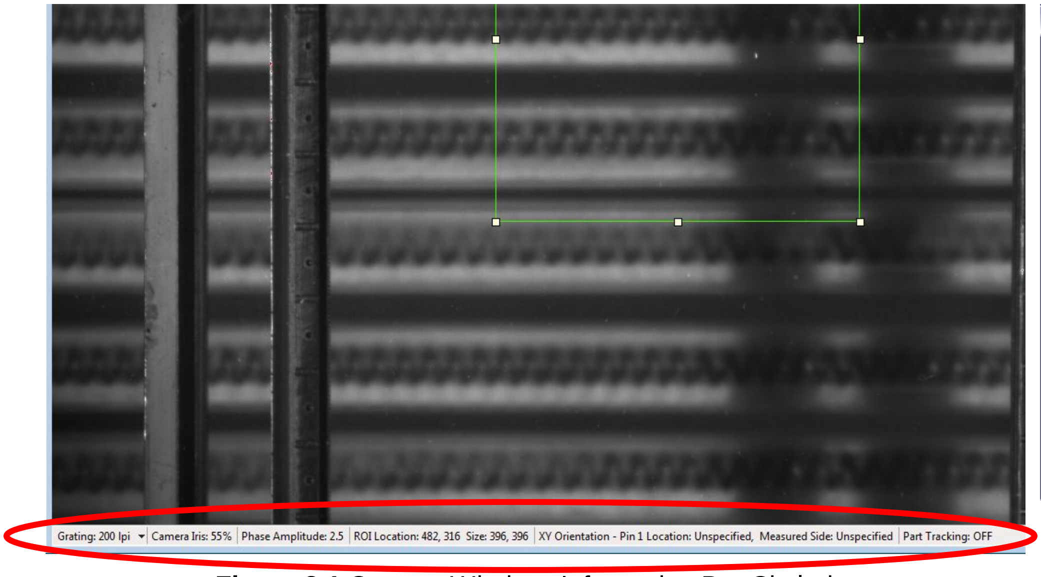


Figure 2.1 Camera Window, Information Bar Circled

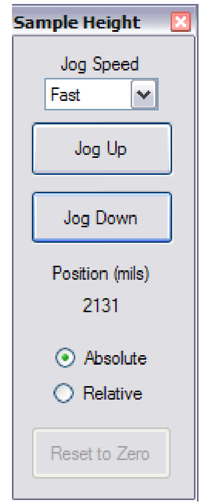


Figure 2.2 Sample Height Adjust Window

4. Right-click on the Camera window (inside the ROI) to bring up a context menu (see **Figure 2.9**) that contains the Acquire… command. Click Acquire… or, alternatively, press the **F12** key.

2.3 Information Bar

At the bottom of the Camera window (see **Figure 2.1**), an information bar displays relevant acquisition parameters for quick user reference. These include

- which grating is selected (if more than one is installed on the system)
- the camera iris setting
- the phase amplitude
- the ROI location and size, in pixels
- the XY Orientation; Pin 1 Location and Measured Side
- the Part Tracking ON/OFF setting

Each one of these parameters can be edited by clicking on the desired parameter. See the following sections for a brief description of each parameter and how it can be edited.

2.3.1 Grating

The grating parameter area has an arrow on the right side. When clicked, it opens a window containing the calibration routines for a grating as well as a grating editor screen. See **Section 2.8** for instructions on using the calibration routines.

When more than one grating is installed on the system, clicking directly on the grating information area brings up a grating selection menu. The user can select among the available gratings to be the active grating.

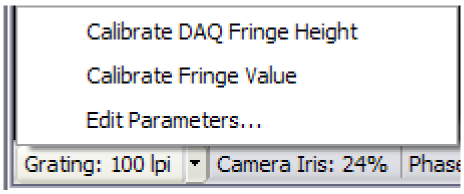


Figure 2.3 Grating Pop-Up Menu

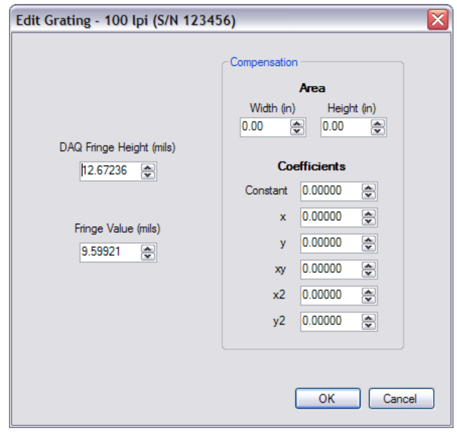


Figure 2.4 Edit Grating Window

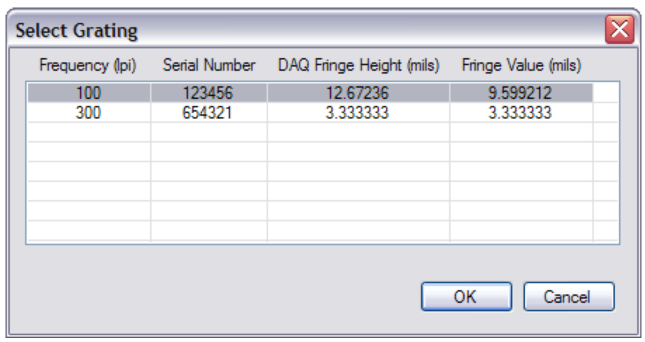


Figure 2.5 Select Grating Menu

2.3.2 Camera Iris

To the right of the Grating Parameters section is the Camera Iris setting. This area shows the current camera iris setting in percentage form. A Camera Control dialog can be opened by clicking on the Window menu at the top of the main screen. This dialog can control the camera iris setting as well as turn on and off highlighting of dark or saturated pixels.

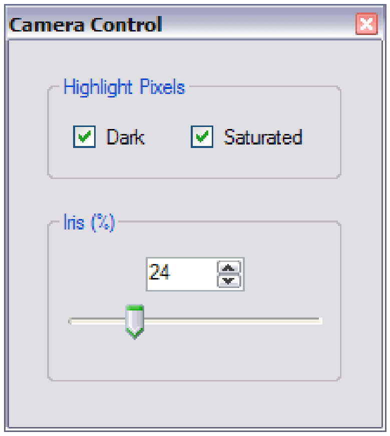


Figure 2.6 Camera Control Window

2.3.3 Phase Amplitude

This section displays whether or not Phase Amplitude Thresholding is turned on, and, if so, what its value is set to. Again, this parameter can be edited by clicking on the phase amplitude area to open a setting dialog.

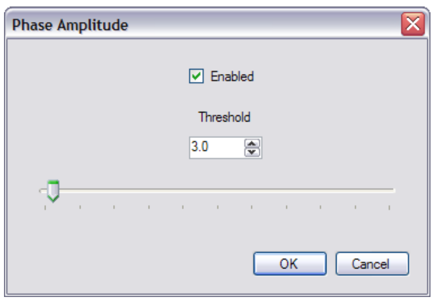


Figure 2.7 Phase Amplitude Adjustment Window

2.3.4 ROI Location

This section describes where in the field of view the ROI, or region of interest, is located and what its size is in pixels. Clicking on this area brings up a dialog that allows precise adjustment of the position and size of the ROI.

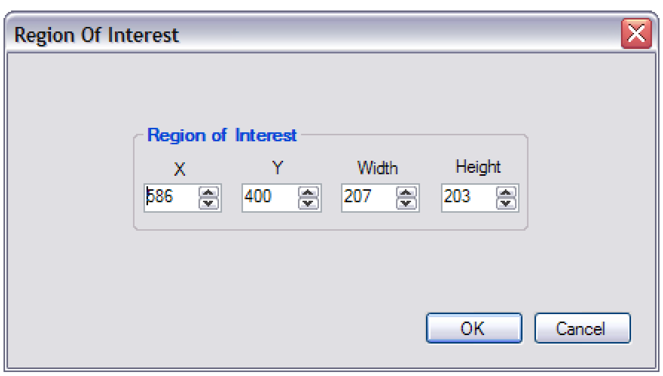


Figure 2.8 ROI Adjustment Window

The ROI can also be adjusted using the following keyboard shortcuts when it has focus. Shifting can be done using the arrow keys or the outer number keys located on the NumPad. Each press of a key results in one pixel shift of the ROI.

For example:

Up Arrow or **8** on NumPad	Move ROI up one pixel
7 on NumPad	Move ROI up one pixel and left one pixel

Holding down **Ctrl** while pressing any of these keys will now increase the ROI size in the desired direction. **Ctrl+5** will make the ROI its maximum size. Holding down **Alt** while pressing any of these keys will decrease the ROI size in the desired direction. **Alt+5** will make the ROI half of the maximum length and width and position it in the center of the field of view.

2.3.5 XY Orientation

For purposes of orienting and registering surface data in Interface Analysis, a new section has been added to the Camera Window Information Bar. Clicking on this area brings up a dialog where the user can input Pin 1 Location and Measured Side of the phase image that is captured on Acquire.

2.3.6 Part Tracking: ON/OFF

This section of the Information Bar simply shows whether Part Tracking is currently On or Off.

2.4 Camera Window Context Menu

There are several different commands that can be issued when interacting with the Camera window in Surface Measurement. These commands can be accessed by right-clicking within the Camera window and include:

- Acquire… **F12**
- Shrink To Fit
- Fill ROI… **F3**
- Export Full Field Image…
- Open Thermal Profiler… **Ctrl+T**

The acquire command will only be available if the user right-clicks inside of the ROI.

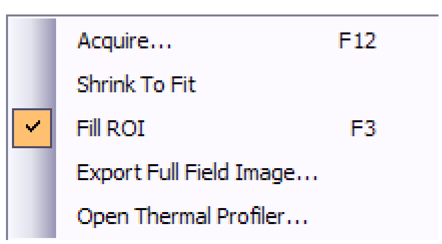


Figure 2.9 Camera Window Context Menu

2.4.1 Acquire

The Acquire command performs a onetime phase image capture.

2.4.2 Shrink To Fit

If checked, the camera image is forced to the window size.

2.4.3 Fill ROI

Toggles whether or not the region of interest appears as a transparent square or as a square outline.

2.4.4 Export Full Field Image

This command will perform an export of exactly what the user sees within the Camera window, ROI included. The following image export formats are supported: .bmp, .gif, .jpg, .png, and .tif.

2.4.5 Open Thermal Profiler

This command opens a separate application in the Studio Suite called Thermal Profiler. This allows automated data capture while subjecting the sample to a thermal profile. For more details please see the Thermal Profiler User Manual.

2.5 Phase Image Context Menu

There are several different commands that can be issued when interacting with a Phase Image in **Surface Measurement**. These commands can be accessed by right-clicking within the Phase Image window and include:

- Save… **Ctrl+S**
- Save Image… **Ctrl+I**
- Open in Surface Analysis… **Ctrl+O**
- Properties…

2.5.1 Save

Saves the phase image as a *.akx_phase file which can be analyzed using **Surface Analysis**. The phase image name is constructed from the date and time at acquisition, but can be changed by the user.

2.5.2 Save Image

Saves the phase image as either a *.bmp or *.jpg image file.

2.5.3 Open in Surface Analysis

Opens the phase image in the **Surface Analysis** application.

2.5.4 Properties

Views phase image properties in a separate window.

2.6 3D Surface Image Context Menu

There are several different commands that can be issued when interacting with a 3D Surface Image in Surface Measurement. These commands can be accessed by right-clicking within the 3D Surface window and include:

- Scale Z-Axis…
- Save…
- Save Image…
- Copy View **Ctrl+C**
- Paste View **Ctrl+V**
- Print…
- Create Legend…
- Properties…

2.6.1 Scale Z-Axis

Allows the user to scale the Z axis of the graph and change the display units as well.

2.6.2 Save

Saves the 3D surface in one of the following data formats: *.akx_disp, *.dat, *.txt, or *.bin. Only the *.akx_disp file can be loaded back into **Surface Analysis**.

2.6.3 Save Image

Saves the phase image as either a *.bmp or *.jpg image file.

2.6.4 Copy View

Copies the current 3D Surface Image view parameters (Rotation, Altitude, and Zoom) so that they can be applied (pasted) to another 3D Surface Image.

2.6.5 Paste View

This command is only available if the user has a copied a 3D view to the clipboard. If it is available, it pastes a copied view from the clipboard onto a 3D Surface Image.

2.6.6 Print

Prints a 3D Surface Image.

2.6.7 Create Legend

Allows the user to select the min and max for and create a legend image.

2.6.8 Properties

Views 3D Surface Image properties in a separate window.

2.7 File Menu Bar

At the top of the Surface Measurement application window there is a standard Windows File Menu bar (see **Figure 2.10**). It contains the following menu categories:

- File
- Tools
- Window
- Help

2.7.1 File

The File menu will change depending on what type of window has focus. It will have relevant commands for the currently selected window type. For example, if the Camera window is selected, it contains an Acquire command, a Save Full Field Image command and an Exit command.

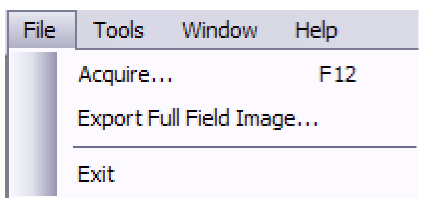


Figure 2.10 File Menu

2.7.2 Tools

The tools drop down menu contains four items. The first, a grating manager, allows the user to add or remove gratings from the system. The second opens the Thermal Profiler app. The third allows the user to check the measurement accuracy of a normal step height block (see **Section 2.8.3**). The last selection opens system options as described in **Section 2.9**.

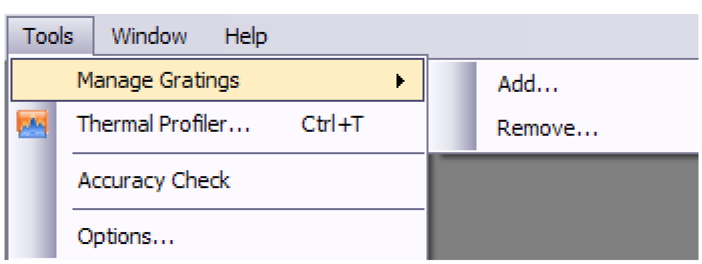


Figure 2.11 Tools Menu

2.7.3 Window

This menu item contains commands for managing the child windows that are present within the parent Surface Measurement window at any time. Windows that may be hidden behind other windows can be brought to the foreground by selecting them in this drop down menu. All open windows can also be closed by selecting the **Close All Windows** command. The Camera (**Section 2.2**), Sample Height (**Section 2.2**), and Camera Control (**Section 2.3.2**) windows are always available in this menu.

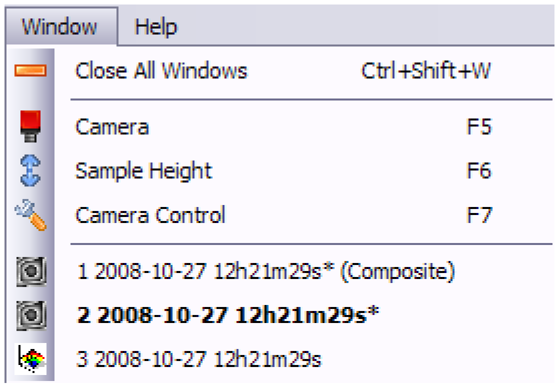


Figure 2.12 Window Menu

2.7.4 Help

This menu item contains a link to the **Surface Measurement User Manual** as well as an **About** command for determining program version information.

2.8 Grating Calibration Routines

The grating calibration routines can be accessed by clicking the small arrow to the right of the Grating information area on the Information bar (see **Figure 2.13**). Clicking on either one of these items will put the system in the respective calibration mode. The user must deselect the calibration mode when calibration is complete.

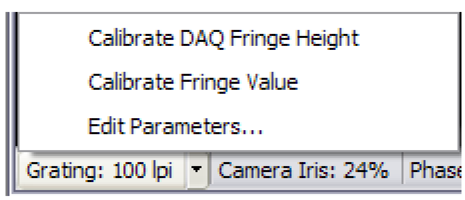


Figure 2.13 Grating Pop-Up Menu

2.8.1 DAQ Fringe Height

In the **Calibrate DAQ Fringe Height** mode, a uniform white colored continuous surface sample is used to determine the optimal phase step distance based on the optical configuration of the system. The calibration sample is provided by the user and can be any white colored, continuous surface sample that is at least 100mm x 100mm. The sample must also be sufficiently stiff so as to maintain its shape while phase stepping occurs.

1. When **Calibrate DAQ Fringe Height** mode is enabled the ROI bounding box becomes a dashed outline.

2. After placing a uniform white colored continuous sample in the measurement system, adjust the ROI such that it only encompasses a continuous part of the sample.

3. Right click to select **Start Calibration…** from the Camera window context menu. A series of images is taken with different step heights to determine the best calibrated phase step distance, or **DAQ Fringe Height**. While the images are being taken a dialog (see **Figure 2.14**) pops up showing the captured images and a plot of the intensity standard deviation for each step height trial.

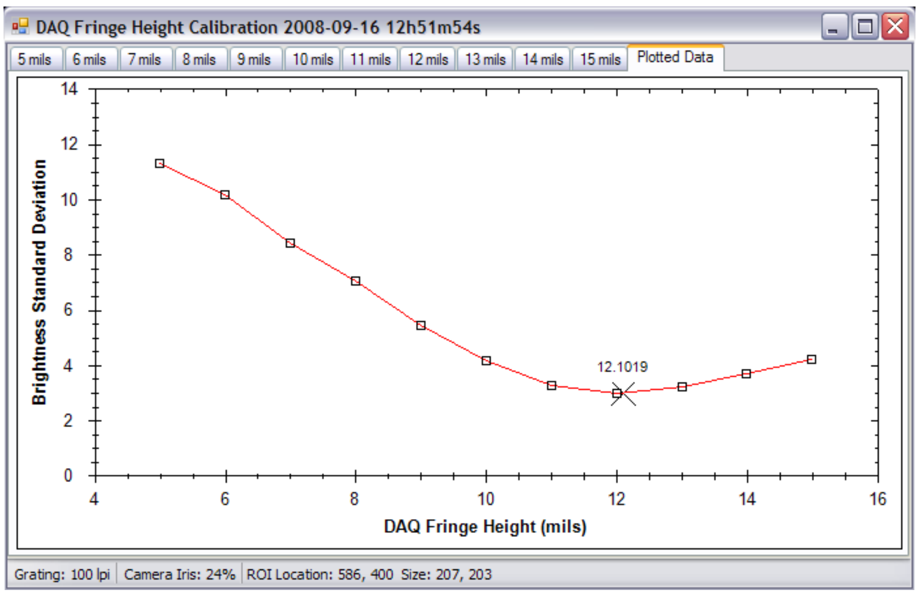


Figure 2.14 DAQ Fringe Height Cal Dialog

4. At the completion of the calibration routine a dialog pops up asking the user to update the **DAQ Fringe Height**.

5. Press **Yes** to approve and save the new **DAQ Fringe Height**. If an error is suspected (refer to **Section 5.1**), press **No** to discard the new calibration value.

2.8.2 Fringe Value

In the **Calibrate Fringe Value** mode, a single step calibration block is used to determine the **Fringe Value** calibration constant for the system. This block is provided with the measurement system. See **Akrometrix Techniques and Analyses 101** for more details on this calibration constant.

1. Enter the calibration offset value in the Calibrate Fringe Value dialog box that pops up and click OK. The calibration offset value for the block is on the Calibration Certificate provided with each block. Please note that the relevant number will either be listed as “Distance” or “DIST_A_to_B” depending on what

independent lab was used to calibrate the block. Please see **Figure 2.15**, **Figure 2.16**, and **Figure 2.17**.

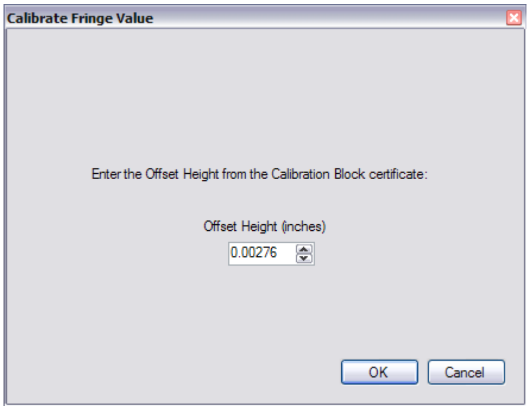
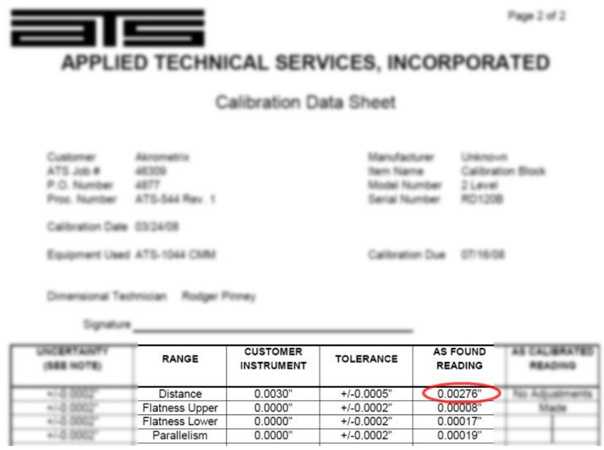


Figure 2.15 Offset Value Dialog



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APPLIED TECHNICAL SERVICES, INCORPORATED

Calibration Data Sheet

Customer Akrometrix
ATS Job # 46309
P.O. Number 4877
Proc. Number ATS-544 Rev. 1

Manufacturer Unknown
Item Name Calibration Block
Model Number 2 Level
Serial Number RD1208

Calibration Date 03/24/08

Equipment Used ATS-1044 CMM

Calibration Due 07/16/08

Dimensional Technician Rodger Pinney

Signature ______

UNCERTAINTY (SEE NOTE)	RANGE	CUSTOMER INSTRUMENT	TOLERANCE	AS FOUND READING	AS CALIBRATED READING
+/-0.0002"	Distance	0.0030"	+/-0.0005"	0.00276"	No Adjustments Made
+/-0.0002"	Flatness Upper	0.0000"	+/-0.0002"	0.00008"	
+/-0.0002"	Flatness Lower	0.0000"	+/-0.0002"	0.00017"	
+/-0.0002"	Parallelism	0.0000"	+/-0.0002"	0.00019"	

Figure 2.16 Offset Value from Certificate (ATS)

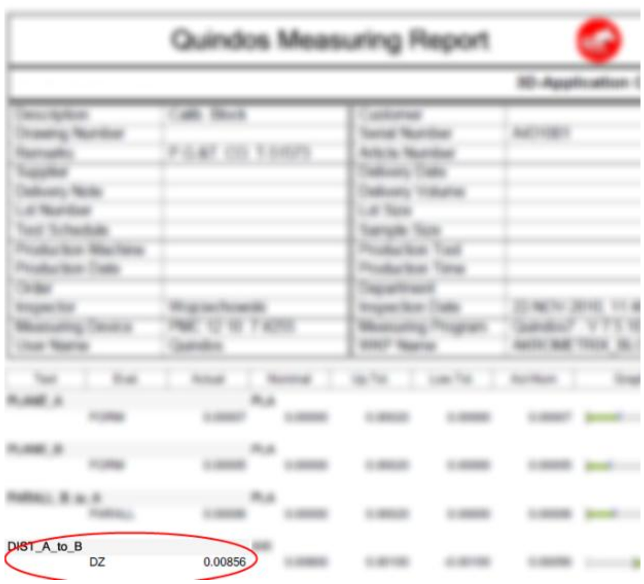

Figure 2.17 Offset Value from Certificate (Quindos)

2. Adjust the ROI such that the outside square approximately outlines the calibration block. Exact alignment is not required because measurements are made only within the inner two rectangles, which are inset from the outside boundary.

3. Right click within the ROI and click **Start Calibration…** The calibration process is initiated and three windows pop up afterward. These windows show the phase image, the displacement data, and a Confirm Calibration Results dialog.

4. Press **Yes** to approve and save the new Fringe Value. If an error is suspected (refer to **Section 5.1**), press **No** to discard the new calibration value.

2.8.3 Accuracy Check

Under the **Tools** menu at the top of the program there is an **Accuracy Check** function, which is used for checking the normal height between two surfaces. This is useful for checking system accuracy against a cal block with a machined step height in it. Typically, the accuracy check measurement is compared with that of a CMM or laser based profilometer measurement.

2.9 Software Options

Surface Measurement options can be accessed by going to Tools → Options. A Dialog appears as in **Figure 2.18**.

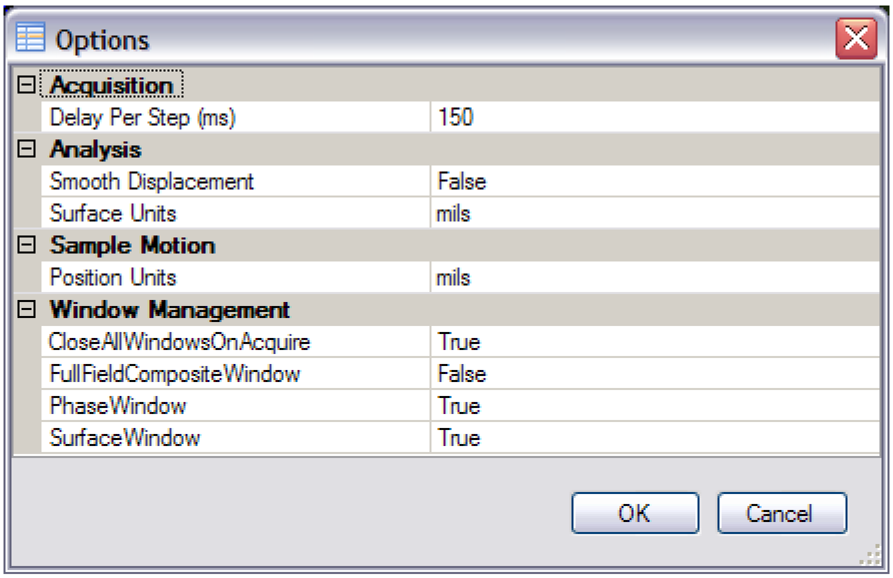

Figure 2.18 Options Dialog

2.9.1 Delay per Step

Determines the amount of time in milliseconds the software waits between each phase step. Increasing this value can be useful for samples that exhibit excessive vibration between each phase step. Keep in mind, however, that increasing this value will increase total data acquisition time.

2.9.2 Smooth Displacement

Runs a smoothing algorithm on the displacement data. See Akrometrix Optical Techniques and Analyses 101 for more details.

2.9.3 Surface Units

Determines what units the Surface Windows display in. Options are mils or microns.

2.9.4 Position Units

Determines what units the Sample Height dialog displays the current motor travel position in. Options are mils or microns.

2.9.5 Close All Windows on Acquire

On Acquire, closes all open phase images and surface windows within the Surface Measurement parent window. Setting this to false will spawn a new phase image window and/or displacement window on each Acquire.

2.9.6 Full Field Composite Window

On Acquire, displays a window showing the entire camera FOV with the phase data overlaid on top.

2.9.7 Phase Window

On Acquire, displays a window showing the phase image captured.

2.9.8 Surface Window

On Acquire, displays a window showing the 3D surface calculated from the captured phase image.

2.10 Part Tracking

Part Tracking is the revolutionary new feature in Akrometrix Studio which has the potential to reduce analysis time of multiple part runs by more than 90%. It is designed to find and track rectangular parts of a user defined size at room temperature and during a temperature profile. Traditionally, if a part happened to shift or rotate during a thermal run, the user would need to spend many painstaking minutes manually partitioning and rotating the data such that the resulting displacement plots did not have any artifacts. With Part Tracking, all the resulting data at the end of a thermal run should automatically be partitioned and rotated to the same starting orientation, greatly speeding analysis time. Part Tracking even improves work flow and productivity when only one sample is tested and moves due to thermal expansion. The more samples tested at once, the more productivity will be improved.

2.10.1 Part Tracking Window

- **Rectangle** – Defines the Rectangle Model size that Part Tracking will try to find parts with. This can be buttoned in manually or set from the ROI/Search Area context menu. The rectangle model size is represented by the white box on the right side of the Part Tracking window.
- **Search Settings**
  - **Number of Instances** – Defines the number of parts which Part Tracking should expect to find. In order to eliminate finding “ghost” parts, Akrometrix recommends setting this to the exact number of parts in the oven. The max number of instances is 99.
  - **Rotation** – Defines the rotation tolerance for finding a part. This will allow parts to be found which aren’t perfectly aligned with the camera pixels. Akrometrix recommends setting parts up such that they are within 10° of normal to the camera and using as little rotation tolerance

as possible. Increasing this value can increase the risk of finding "ghost" parts. The max rotation tolerance is 30°.

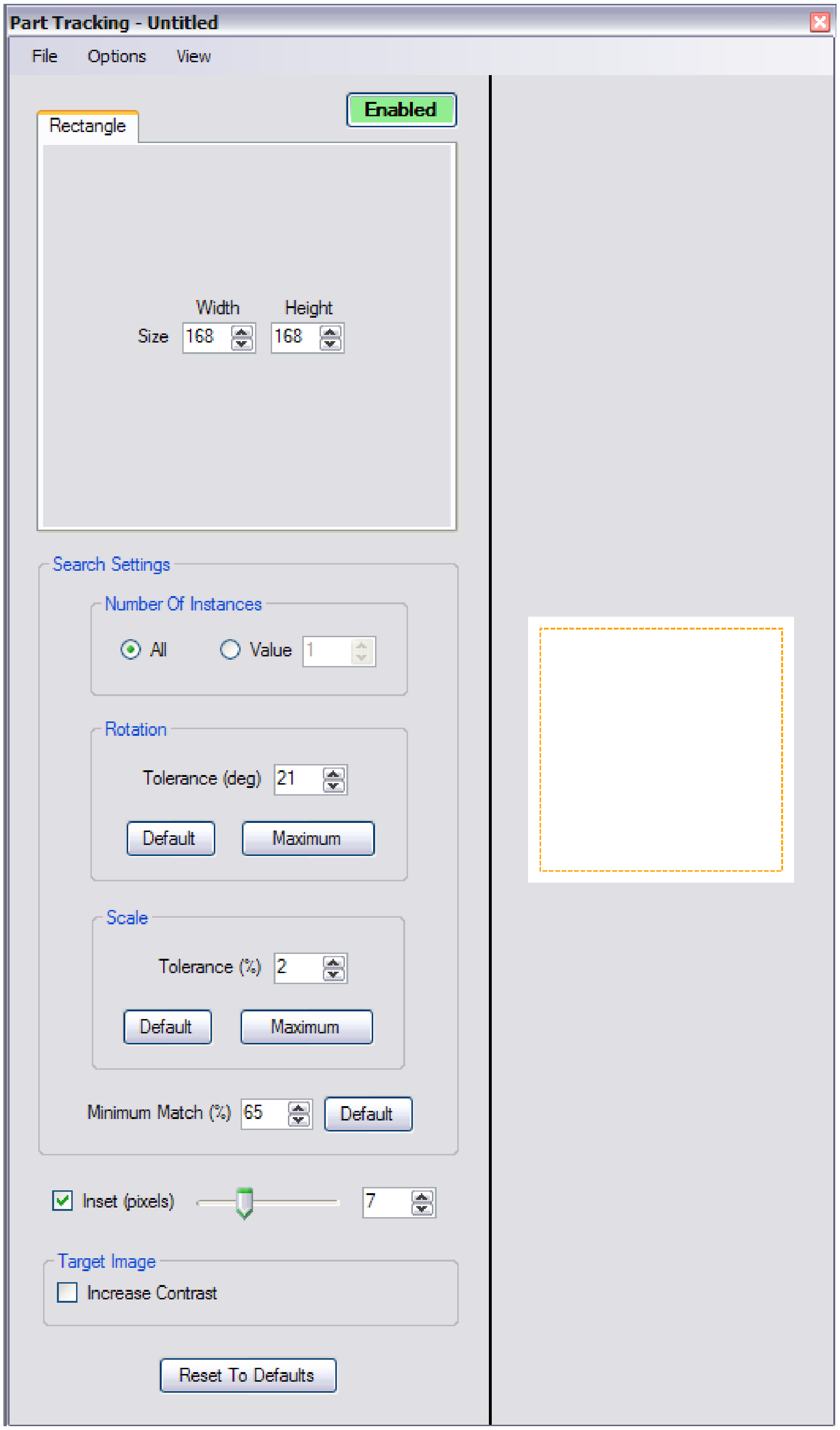

Figure 2.19 Part Tracking control window in Surface Measurement

- **Scale** – Defines the scale tolerance for finding a part. This will allow parts to be found which aren't exactly the same size as the rectangle model. This can be useful when comparing results between systems that have ever so slightly different zoom factors. In **Figure 2.19** above, the scale tolerance of 2% on a rectangle model of 168 x 168 pixels will allow Part Tracking to find parts which are anywhere from 165 x 165 to 171 x 171. Increasing this value can increase the risk of finding “ghost” parts.

    - **Minimum Match** – This defines the percentage of edge which Part Tracking has to find to determine that a feature in the camera image is a part. Decreasing this setting will increase the risk of finding “ghost” parts.

- **Inset (pixels)** – Determines the number of pixels to crop in on found parts. This will effectively reduce the ROI on a part and can be useful for reducing or eliminating edge displacement artifacts.
- **Target Image**
    - **Increase Contrast** – Increases the contrast of a surface image before tracking parts on it. This can be useful for finding parts which have low contrast with their background in the oven.

All of the settings above can be saved in a part tracking file known as *.akx_track. This allows settings to be reused from run to run and site to site without having to button in every last setting.

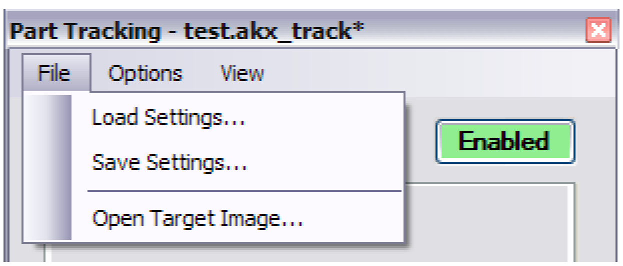

Figure 2.20 Part Tracking File Menu

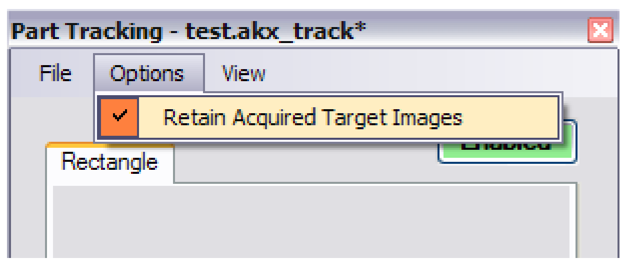

Figure 2.21 Part Tracking Options Window

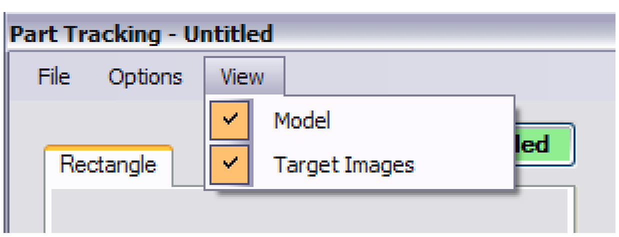

Figure 2.22 Part Tracking View Menu

- **File Menu** – Load and Save *.akx_track files as well as Open previously saved Target Images which can be either *.bmp or *.akx_phase
- **Options** – Allows the user to retain acquired target images in memory so that the part finding options can be experimented with to find the appropriate number and location of parts.

- **View** – Allows the user to show or hide the Rectangle Model and Target Images display. See the result with both being shown in **Figure 2.23**.

Figure 2.23 Part Tracking window with Target Images

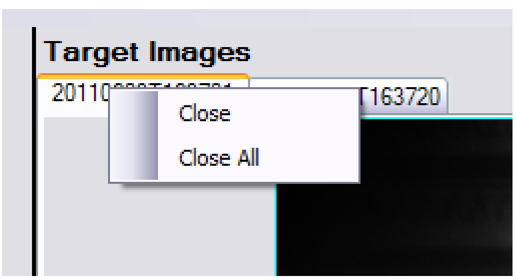

Figure 2.24 Target Image Tab Menu

Figure 2.25 Target Image Context Menu

In the Target Images display section of the Part Tracking window, there are two more right-click context menus available to the user. The user can close tabs using the context menu shown in **Figure 2.24**, as well as search and save Target Images using the menu shown in **Figure 2.25**.

2.10.2 Multi-ROI Results Window

In order to display Part Tracking results, a separate Multi-ROI results window was developed. This window allows the user to see the following items in one result window.

- **Surface Image**
- **Phase Image**

- **Displacement Plot**
- **Camera/ROI Selection**

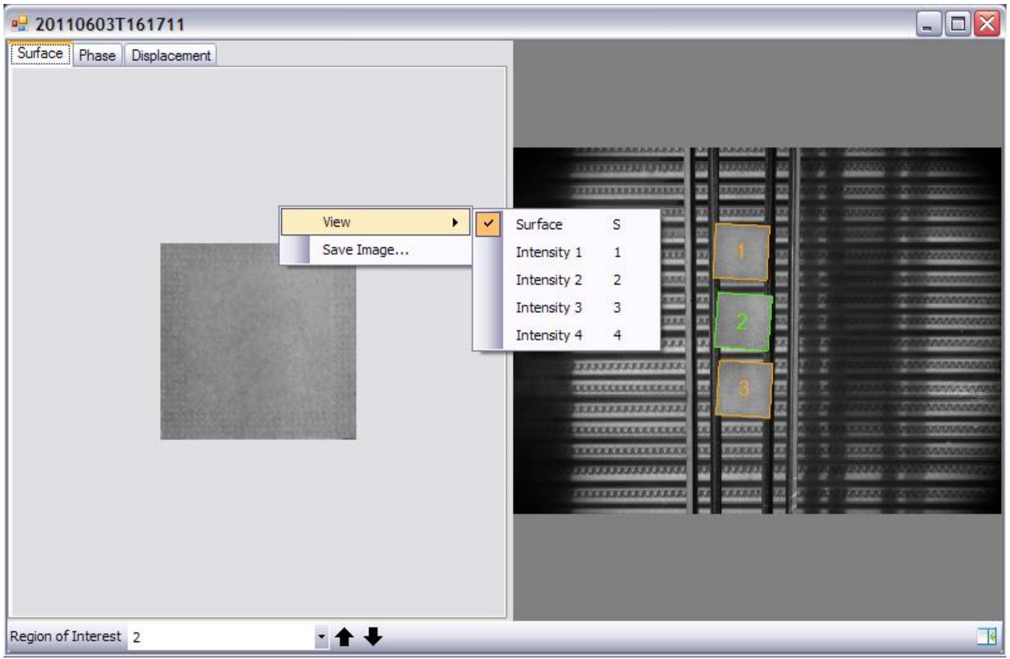

Figure 2.26 Multi-ROI Surface View

- **Surface Image View** – Shows the Surface Image (average of 4 intensity images) or any of the 4 intensity images for the selected ROI. A save Image option is available in the context menu.

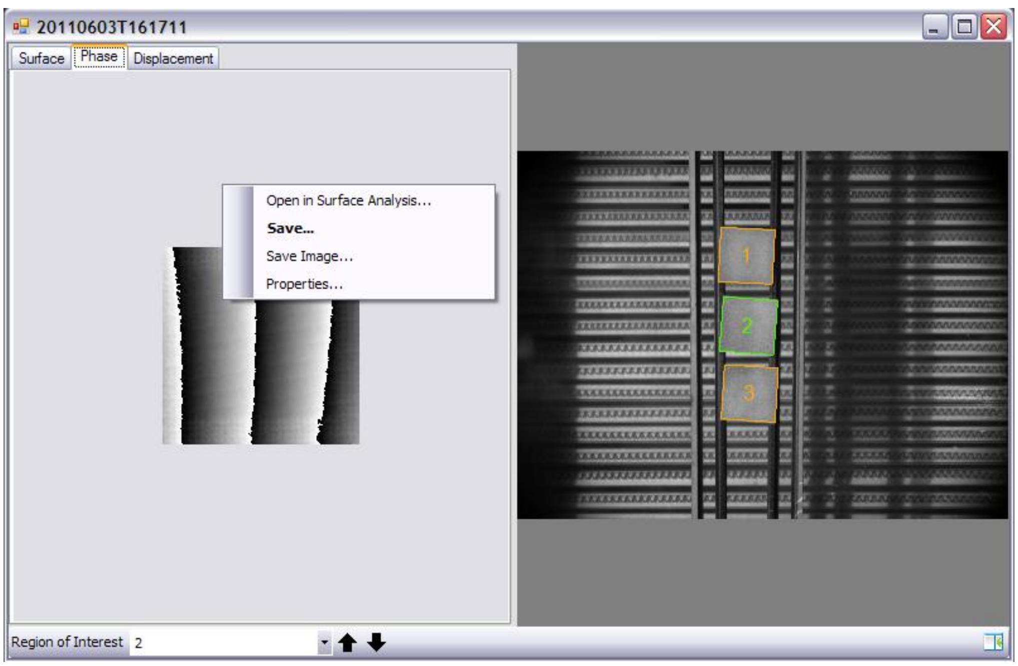

Figure 2.27 Multi-ROI Phase View

- **Phase Image View** – Shows the Phase Image for the selected ROI. The same context menu options that are available in a single phase image are available in this Multi-ROI Results window.

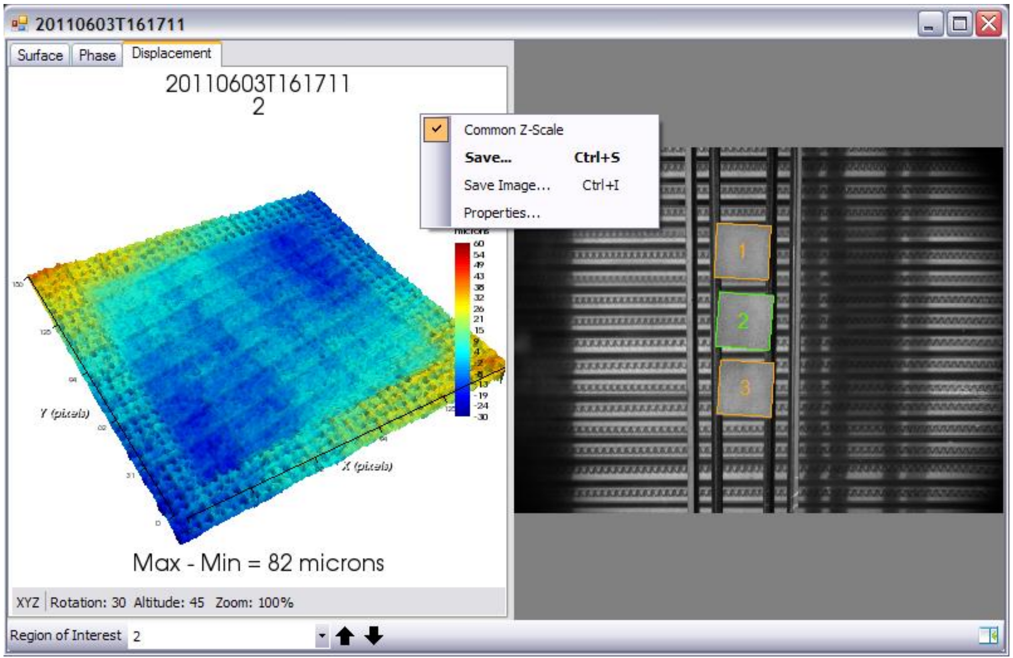

Figure 2.28 Multi-ROI Displacement View

- **Displacement Plot View** – Shows the resulting 3D displacement from the measurement. The same context menu options that are available in a single displacement plot are available in the Multi-ROI Results window.

Figure 2.29 Camera/ROI Selection Context Menu

- **Camera/ROI Selection Window** – Click on a found part ROI to display the data from that ROI in the left window pane. Right-click to bring up the context menu which allows zooming to the found ROI extents, or toggling the Overlay Phase function.

3 MP10 Surface Measurement

The interface and operation of the **MP10 Surface Measurement** program are very similar to the **Surface Measurement** program. A user unfamiliar with the **Surface Measurement** software should read **Section 2** first or refer to it where necessary for operation of the MP10 software. In this section, only MP10 specific functions will be described.

In the MP10 module, a new grating located at the projection path needs to be controlled for phase shifting. Therefore, in the MP10 software, there are some additional functions for homing and moving this grating stage.

Note: The sample height adjustment stage is still in use. Instead of executing phase shifting, it is used to move the sample vertically for focusing purposes.

3.1 Start-up

1. Remove the TherMoiré grating from the oven lid if it is in place.
2. Install the MP10 module. (Refer to the **MP10 User Manual**).
3. Run the **MP10 Surface Measurement** program by clicking the corresponding button on the Akrometrix Studio Manager toolbar on the left side of the screen. A start-up splash screen appears while the software initializes.
4. When the Homing Sequence Confirmation Dialog is displayed (**Figure 3.1**), check whether or not to home the main system sample support and press Continue to home the MP10 motor stage.

Note: If the main system sample support is not homed, absolute sample support position will not be available.

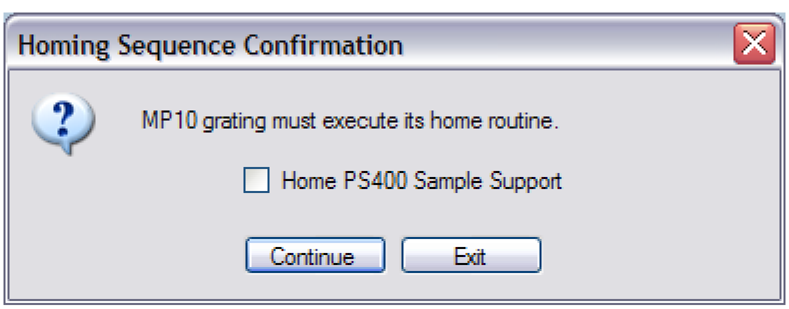

Figure 3.1 Homing Sequence Confirmation

5. The main screen will display and it looks just like the normal **Surface Measurement** interface.

3.2 MP10 Grating Motion

In the **Options** window (**Figure 3.2**), there are a few different parameters when compared to normal Surface Measurement:

3.2.1 Algorithm

Determines what phase unwrapping algorithm is applied to the 4 intensity images captured at acquisition. See Akrometrix Optical Techniques and Analyses 101 for more details.

3.2.2 Backlash Distance

This parameter defines how far the projection stage will travel past its start point in order to prevent any backlash from affecting an acquisition.

3.2.3 Home Return Distance

This parameter defines the homing position of the grating stage along its 12 mm travel distance. It is set to an optimal value by Akrometrix and cannot be adjusted by the user.

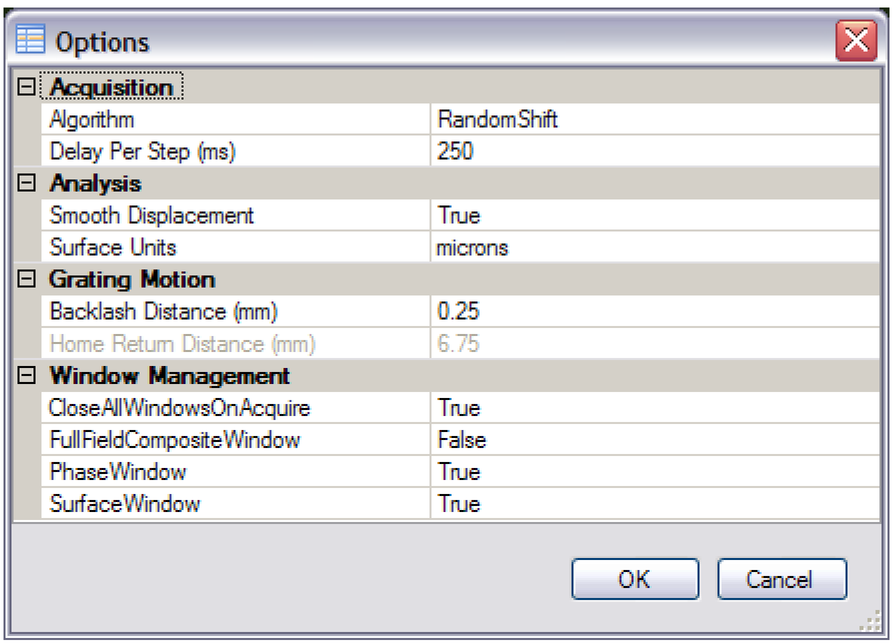

Figure 3.2 MP10 Options Dialog

3.2.4 MP10 Grating Position

An **MP10 Grating Position** window (**Figure 3.3**) is added to the software to control the position of the projection grating stage. It can be accessed from the menu item **Window→MP10 Grating Position**.

1. In this window, the current position of the grating stage is displayed in millimeters. Each time the program starts, this number will be initialized as the value set for **Home Return Distance** item in the Options window (**Figure 3.2**).

2. Use the **Jog Near** and **Jog Far** buttons to move the grating laterally on the sample surface, if necessary. It is not recommended to move the grating stage significantly away from its home position. Operation of the translation stage near either end of its 12-mm travel range can cause the actuator to stop moving if one of the limit switches is reached.

Note: If the system is in E-Stop, the **Jog** buttons will operate while the Motion Enabled button is pressed and held.

3. The **Absolute/Relative** option allows the **Position** indicator to display either the grating's absolute position with respect to one end of travel or the relative distance the grating has moved. The relative position is initialized to zero each time **Relative** or **Reset to Zero** is clicked.

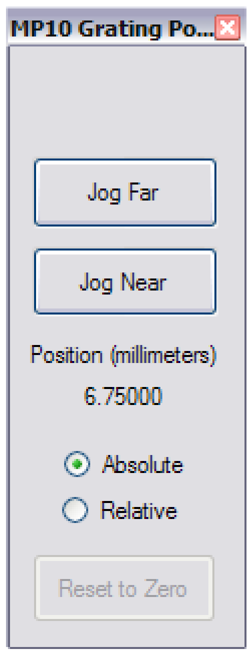

Figure 3.3 MP10 Grating Position Adjust Window

3.3 Calibration

Akrometrix believes that calibration should be performed whenever:

- The MP10 system is initially installed
- A new grating is used for the first time
- Individual optical components, such as the projection lens, or video camera have moved

3.3.1 Calibration Parameters

The primary calibration parameter is the **Fringe Value**, defined as the change in surface height represented by the lateral movement of one complete projected fringe with respect to that of the reference plane (see **Akrometrix Optical Techniques and**

Analyses 101). Each calibrated grating has a unique **Fringe Value**, which is saved with each measurement result and can be loaded during analysis.

A secondary calibration parameter is the **Reference Plane**, defined as an unwrapped phase matrix of a flat surface. This matrix is also unique for each calibrated grating. During measurement, the **Reference Plane** will be cropped according to the Region of Interest (ROI) defined for measurement. The cropped reference plane matrix is stored together with each phase image for data analysis. Displacement values are then calculated from the phase image by subtracting the **Reference Plane** and multiplying by the **Fringe Value**.

3.3.2 Reference Plane and Calibration Block

To calibrate the MP10 system, a flat reference plane and a calibration block with a known-size step are needed (**Figure 3.4**). The reference plane is a steel block with a diffuse white flat top surface. The calibration block is a NIST-traceable steel block with a step machined on its top surface.

Note: Never touch the top surface of either block. Doing so could leave fingerprints or scratches on the surfaces and result in rust or measurement errors. Carry the blocks by their edges.

Figure 3.4 Reference Plane and Calibration Blocks

The reference plane is measured first and stored as a base for the next step. The calibration block is then measured and the height of the points within the two large planar step areas relative to the reference plane is calculated. Next, the software fits the points within each area to an ideal best-fit plane, and calculates the offset between the two planes. This offset is compared with the known step height. As a result, a new **Fringe Value** is derived and a new **Reference Plane Matrix** is generated based on the new **Fringe Value**. Both of the calibrated parameters will be stored or updated by the software.

3.3.3 Software Operation

1. To calibrate the grating, click the small arrow to the right of the Grating information area on the information bar. Select **Calibrate…** to open a calibration wizard as shown in **Figure 3.5**. This is a 3-step wizard for MP10 calibration.

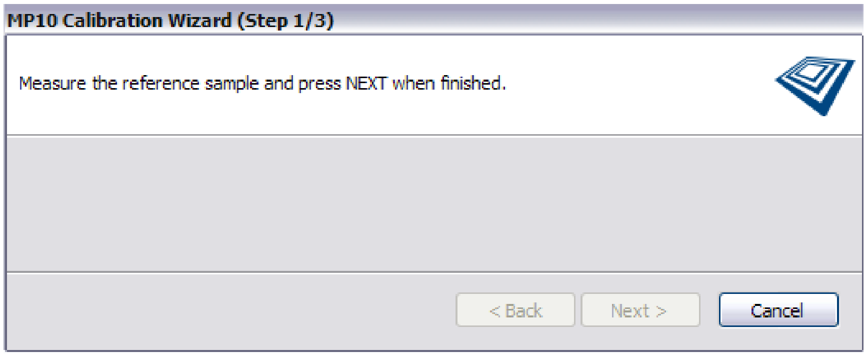

Figure 3.5 MP10 Calibration Wizard

2. In step 1 of the wizard, the reference plane is measured. Place the reference plane in the center of the oven chamber under the camera view. Use the **Sample Height Adjust** window (see **Figure 2.2**) to focus the sample surface in the camera view. Once the sample is in focus, move the sample along its plane so that the projected area is approximately located in the center of the reference plane surface.

3. Turn the light source up to its maximum intensity and adjust the iris ring of the projection lens to achieve the best Depth of Field (DOF) and contrast for the fringe image. Closing the iris will increase the DOF but reduce the brightness of the image. The user should make sure to achieve optimal contrast across the full camera view. Use the highlight pixels options in the **Camera Control** window to avoid getting saturated or dark values in the fringe image.

   Note: Do not adjust other parts of the MP10 system such as the camera focus ring or stage and the distance between each individual component. Doing so will require a recalibration.

4. After an optimal fringe image is achieved, right click on the image and select **Acquire…** (or **F12**). A phase image and 3D plot of the reference plane appear on the screen. Verify the quality of the displayed results. A good phase image should show smooth gradients from black to white within each fringe. Be sure areas around the edges aren’t noisy; this may indicate insufficient contrast (see **Figure 3.6** and **Figure 3.7**). The 3D plot should also look smooth and show no noisy or empty areas. Press **Next** in the wizard window if the displayed data is satisfactory. Otherwise, adjust the settings and acquire another image.

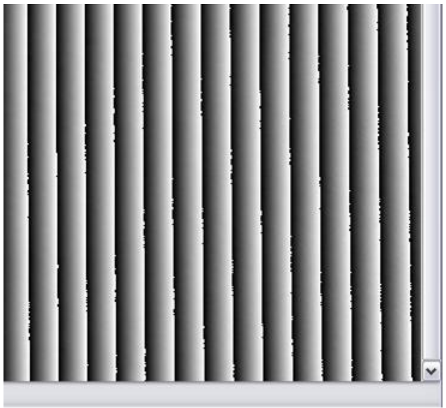

Figure 3.6 Good Phase Image

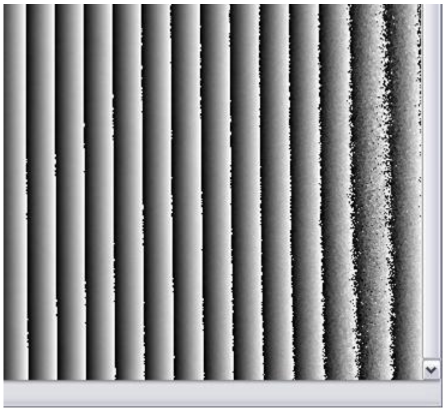

Figure 3.7 Bad Phase Image

5. Enter the cal block Offset Height value in the next window and click **OK** (**Figure 3.8**). This value can be found on the Calibration Certificate provided with each block (**Figure 3.9** or **Figure 3.10** depending on what independent lab was used to calibrate the block).

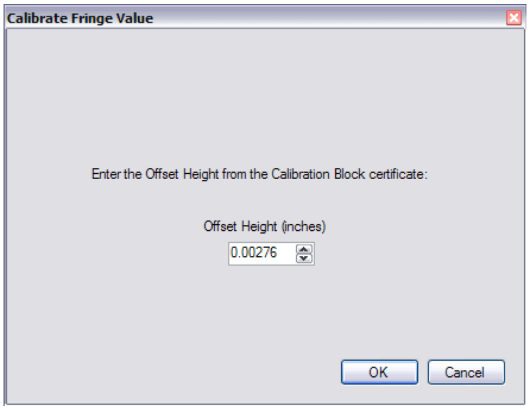

Figure 3.8 Offset Value Dialog

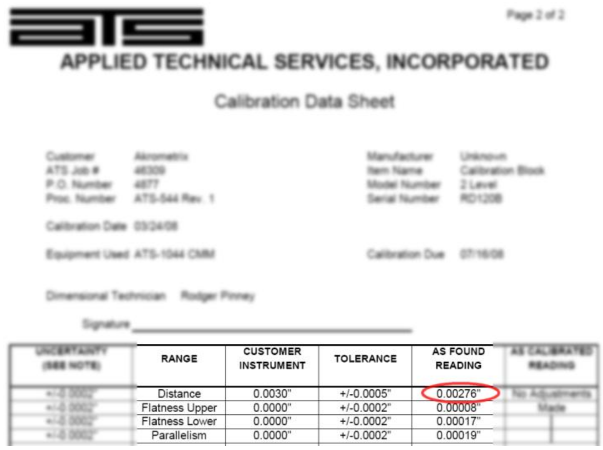

Figure 3.9 Offset Value from Certificate (ATS)

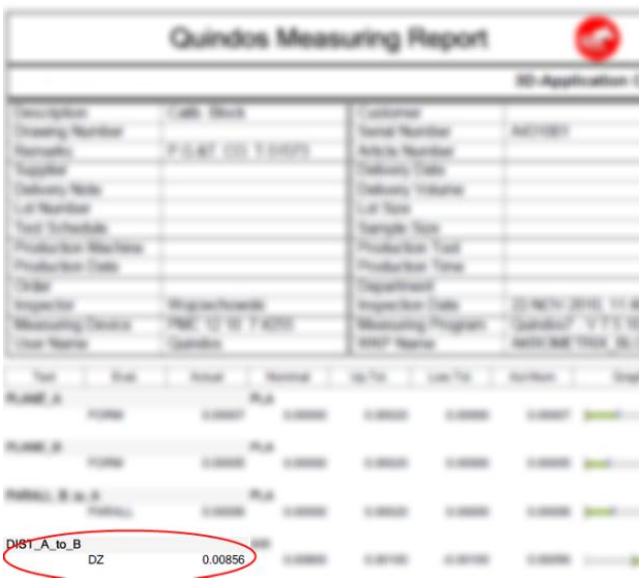

Figure 3.10 Offset Value from Certificate (Quindos)

6. In step 2 of the wizard, the calibration block is measured. Remove the reference plane from the oven and place it back in its box. Place the calibration block in the oven where the reference plane was located and orient the block such that the step line runs from left to right. The serial number engraved on the edge should face the user (**Figure 3.11**). The thickness of the calibration block and the reference plane are designed to be same. Therefore, the surface should be in focus. If not, slightly adjust the sample stage up or down using the **Sample Height Adjust** window (see **Figure 2.2**).

Figure 3.11 Calibration Block in the Oven

7. In this step, a large rectangle with two inner rectangles is shown on the screen. The two small rectangles define the two surface areas used to calculate the step height. Move the sample along its plane so that the intermediate step line is between the two inner rectangles (**Figure 3.12**). Exact alignment is not required because the calculation is only based on the inner two rectangles. Adjust the iris ring of the projection lens to achieve optimal fringe contrast.

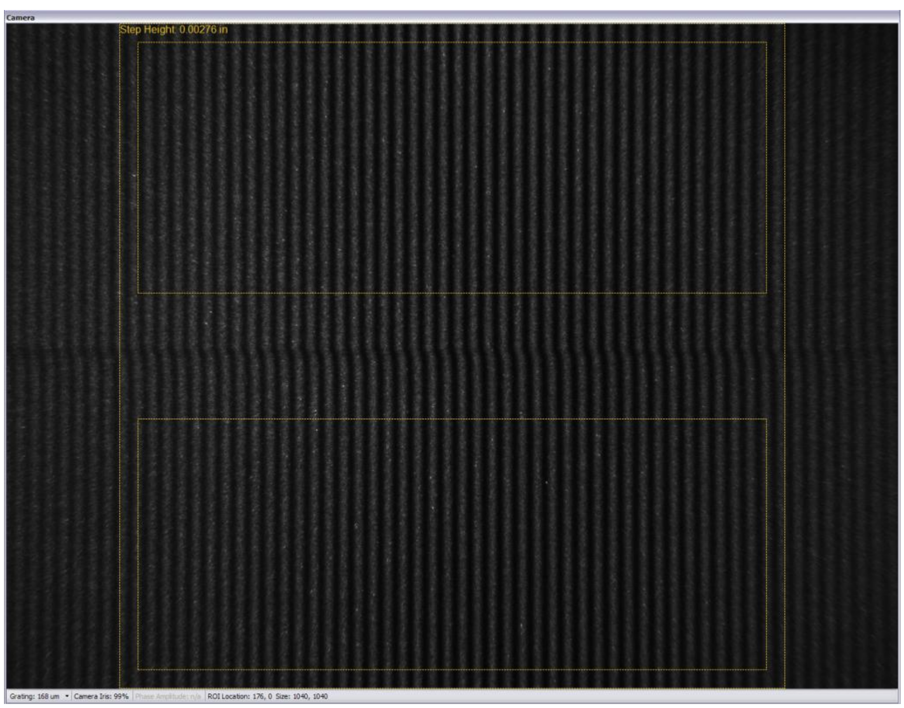

Figure 3.12 Calibration Block Image

8. Right click on the image and select **Acquire…** (or **F12**). A phase image and 3D plot of the calibration block appear on the screen. Verify the quality of the displayed result as in step 4. Press **NEXT** in the wizard window if the displayed data is satisfactory. Otherwise adjust the settings and acquire another image.

9. In step 3 of the wizard, a series of parameters appears in the wizard window:
   a. Actual step height input by the user
   b. Step height calculated using the current calibration value
   c. Current fringe value before calibration
   d. New calibrated value that would adjust the measurement to the correct calibrated value.

   If the calibrated fringe value has less than ±10% variation from the previous calibrated value, press **Next** to approve. If an error is suspected (refer to **Section 3.3.4**), press **Cancel** to discard the new calibration value. On the next page, press **Finish** to end the calibration procedure. The software will switch from the calibration mode to measurement mode automatically.

10. After calibration, the **Fringe Value** is added for the new grating or updated for the existing grating. This can be verified by clicking the small arrow to the right of the Grating information area on the information bar and selecting **Edit Parameters…** (see **Figure 3.13**). The **Reference Plane** is also stored in memory and on the hard drive.

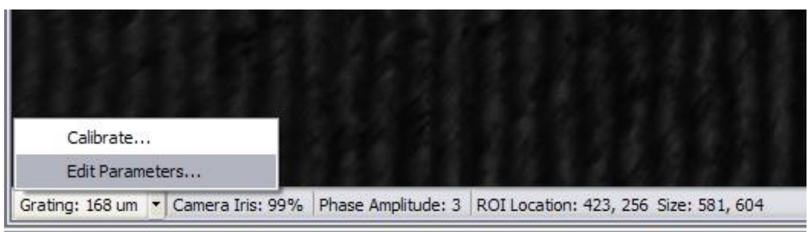

Figure 3.13 Edit Grating Parameters

11. Remove the calibration block from the oven and store it in its box.

3.3.4 Troubleshooting Calibration

Problems

Calibration value varies more than ±10% from the previous calibrated value.

Solutions

1. Check that correct grating was selected by clicking on the grating bar located at the bottom left of the information bar. A **Select Grating** window pops up showing a list of gratings added to the system. The desired grating should be highlighted (see **Figure 3.14**).

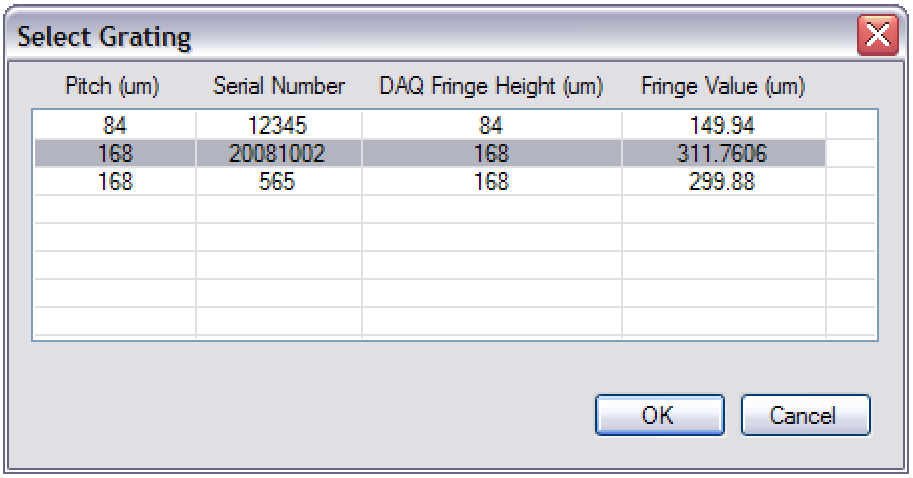

Figure 3.14 Select Grating Window

2. Check sample set-up
   a. Check sample height. Sample surface should be in focus.
   b. Check sample brightness. Sample surface should not be entirely black or saturated white

Problems with set-up are usually easy to observe in the phase image. A good phase image shows one or more smooth gradients from black to white within each fringe. Random noise, monotone gray, or strong black and gray bands within the phase image are indicators of improper setup.

3. If individual optical components have been moved, the optical system needs to be re-aligned before calibration. Refer to the **MP10 User Manual**.

4. If the camera height or focus ring is changed, the system FOV (Field of View) or magnification will be changed. In this situation, it is possible to obtain a variation of more than 10% on calibration value even if the optical system is re-aligned. Consult with Akrometrix for validation of the system.

4 DIC Surface Measurement

The interface and operation of the **DIC Surface Measurement** program are very similar to the **Surface Measurement** program. A user unfamiliar with the **Surface Measurement** software should read **Section 2** first or refer to it where necessary for operation of the DIC software. In this section, only DIC specific functions will be described.

Because the DIC technique is fairly different than that of shadow moiré or fringe projection, the program interface is much simpler than for those techniques. No analysis or calibration functions exist in this software. The only major function available is to acquire images from both cameras simultaneously.

Note: The system sample height adjustment stage is still in use. Instead of executing phase shifting, it is used to move the sample vertically for focusing purposes.

4.1 Start-up

1. Remove the TherMoiré grating from the oven lid if it is in place.

2. Install the DIC module. (Refer to the **DIC User Manual**).

3. Run the **DIC Surface Measurement** program by clicking the corresponding button on the Akrometrix Studio Manager toolbar on the left side of the screen. A start-up splash screen appears while the software initializes.

4. When the Homing Sequence Confirmation Dialog is displayed (**Figure 4.1**), press **Yes** to continue program initialization. The TherMoiré sample support stage will home.

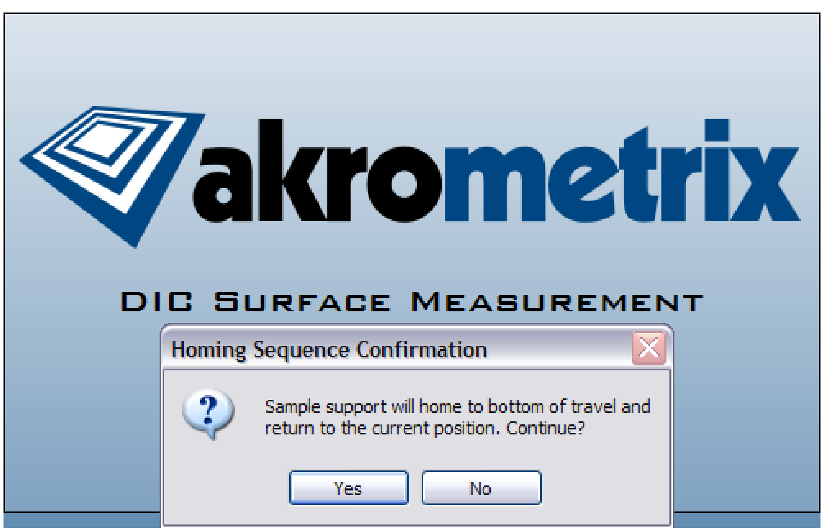

Figure 4.1 Homing Sequence Confirmation

5. The main screen will display and it looks very similar to the normal Surface Measurement interface, except that it has two camera views instead of one (**Figure 4.2**).

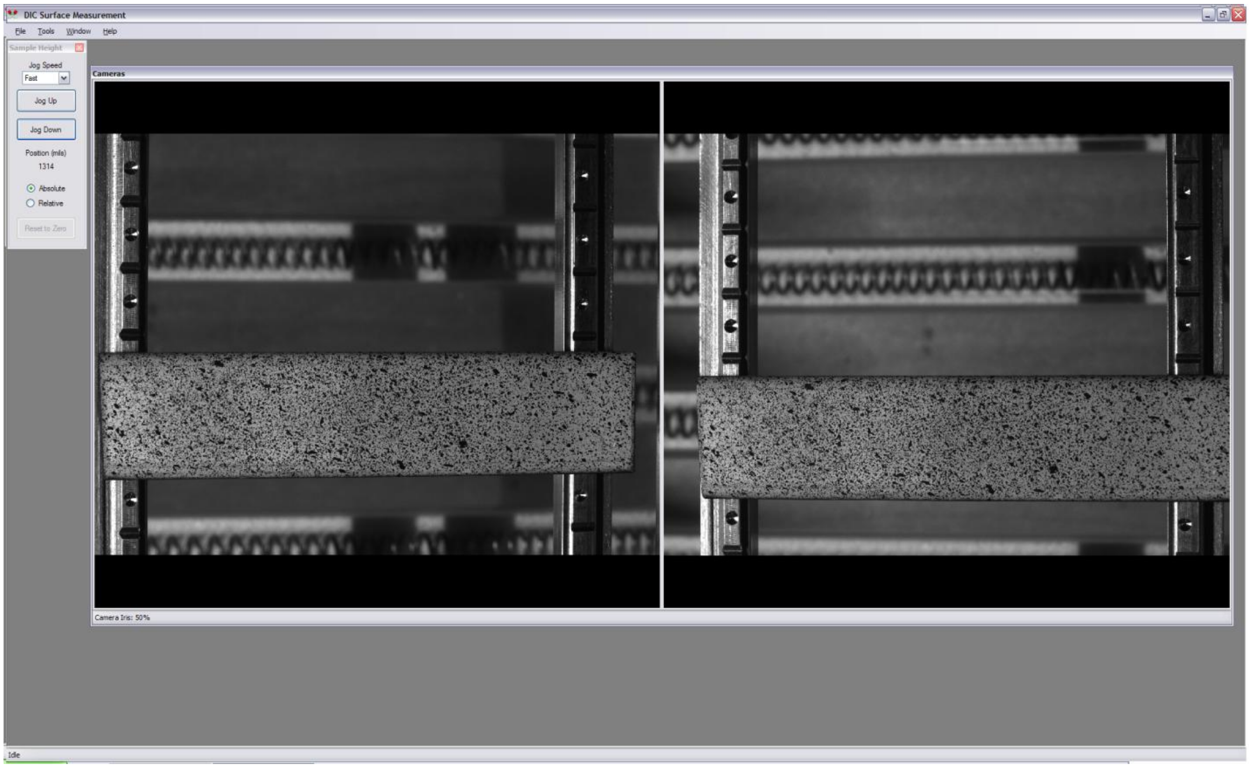

Figure 4.2 DIC Surface Measurement

6. Right-click anywhere in the Camera window to Acquire data or change the camera zoom factor.

4.2 Software Options

A simplified options dialog (see **Figure 4.3**) is available in **Tools→Options**, just as in normal Surface Measurement. There are no new options. The only difference with respect to normal Surface Measurement is that options that do not apply have been removed.

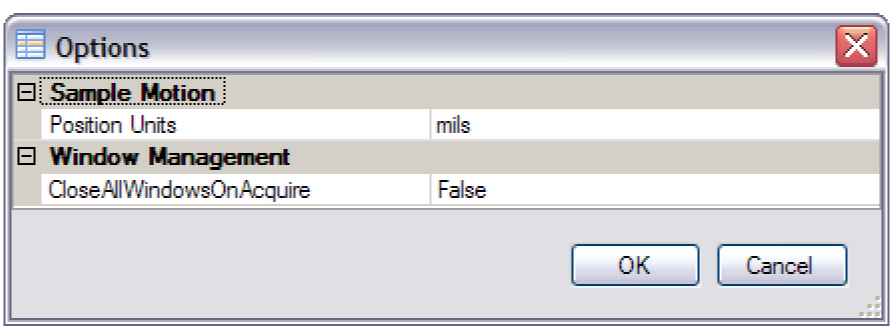

Figure 4.3 DIC Options Dialog

4.3 System Calibration

Calibration of the stereo system requires capturing 15-20 images of a calibration target in different rotations for each image. This is accomplished by the following procedure:

1. Setup the DIC system as described in the DIC User Manual.
2. Position the calibration target underneath the cameras' FOV.
3. Capture an image of the calibration target, then rotate the target. Repeat 15-20 times. The images will pop up, one on top of the other.
4. Save the images into a project folder by using the **File→Save All…** command.

5 Troubleshooting

5.1 Troubleshooting Data Acquisition

As with any measurement system, Akrometrix TherMoiré products have their limitations. These limitations exist because the shadow moiré technique with phase stepping analysis is sensitive to the optical properties of the samples measured. The optical and analytical limitations of the system include:

- Failure to obtain good fringe phase information.
- Loss of resolution on samples with a wide range of reflectivity.

5.1.1 Failure to Obtain Quality Phase Information

Phase information is obtained for each pixel in an image by combining four images on a pixel-by-pixel basis. In general, quality phase information can be obtained anywhere good fringe contrast is observed in the raw video image. Frequently, good phase information can be calculated even where the human eye cannot resolve fringes; for example, against a permanent background pattern such as circuit traces. However, there are situations where quality fringes cannot be obtained:

Symptoms:

- An extremely noisy grayscale signal appears in the phase image. (**Figure 5.1**)
- A banding pattern of grayscale values appears in the phase image.(**Figure 5.2**)
- Discontinuities exist in the calculated displacement data. (**Figure 5.3**)

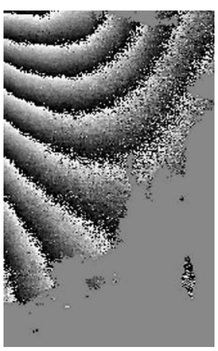

Figure 5.1 Noisy Phase Image

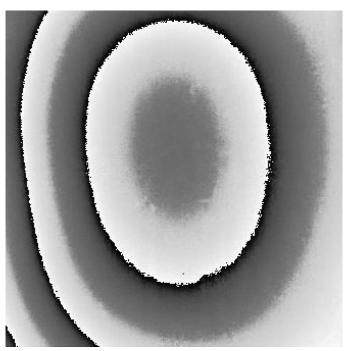

Figure 5.2 Banded Phase Image

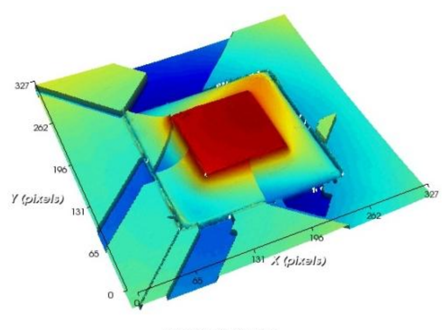

Figure 5.3 Discontinuity Errors in Displacement Data

Cause: Discontinuous Sample

Fringes are not generated at holes and cutouts or where the sample surface is shadowed by components or other obstructions; fringes can only appear on the sample surface itself. While these are obvious statements, the problems resulting from nonsense phase calculations within such localized regions frequently cause incorrect interpretation of the phase image.

Surfaces with abrupt discontinuities, such as steps, components, or solder balls, can create analysis errors characterized by sharp diagonal edges in the calculated displacement surface (**Figure 5.3**). For shadow moiré, abrupt implies adjacent pixels with a height difference greater than half the fringe value, e.g. greater than 0.005" (0.127 mm) for a 100 line per inch grating or 0.0017" (0.043 mm) for a 300 lpi grating.

Solution:

a. Use the Phase Amplitude option with an appropriate threshold value to automatically eliminate bad pixels from the phase image.

b. Use a grating with a larger pitch, e.g. a 100 lpi grating instead of a 300 lpi.

c. Apply a user-defined mask over holes and slots using Surface Analysis. See the Surface Analysis User Manual for more details.

d. Within the Surface Analysis program, vary the filter conditions.

Cause: Incorrect Phase Step Distance

An incorrectly assigned phase step size results in the incorrect calculation of phases. This is due to incorrect software grating selection, incorrect calibration values, or physical contact between the sample and the grating. If the sample support frame is raised so that the sample is touching the grating, the sample is not uniformly translated relative to the grating during the phase stepping data acquisition.

The grating is touching the sample (more generally, some point on the lid is touching some point on the sample support fixture), so that the grating does not translate independently of the sample during phase stepping. The phase image frequently has the appearance of **Figure 5.2**. Use the Sample/Grating Height adjustment dialog to manually raise and lower the sample at Slow Speed. If the sample is touching, the fringe pattern is frozen at some or all points on the sample.

Solution:

a. Lower the sample, or raise the grating, so that they are not touching.

b. Check to make sure the correct grating is selected from the drop down list in the software.

c. Open the calibration file and check that the grating value is within ±10% of the theoretical value. If not, perform calibration.

Cause: Sample-Grating Distance

A fringe pattern is not visible when the distance between the sample surface and the grating is too large. There is an effective working distance below the grating within which fringes on the sample surface can be observed. The shadow of the grating loses sharpness as the distance from the grating increases due to diffraction effects and finite thickness of the light source. As a rule of thumb, these distances are approximately:

- 0.8 in (20 mm) for the 50 lpi grating
- 0.2 in (5 mm) for the 100 lpi grating, and
- 0.02 in (0.5 mm) for the 300 lpi grating.

Solution:

Adjust the height of the sample, either with the servomotor stages or by changing the sample support fixture. Position the sample so that it shows a high contrast fringe pattern on the raw video feed, but is not touching. If the sample is translated from this point using the servomotor stages, the user observes that the fringe pattern moves smoothly and uniformly across the sample. If some part of the fringe pattern does not move during translation, this usually indicates that that part of the sample is touching the grating.

In some cases, it may not be possible to bring the sample surface within working distance of the grating, e.g. with a tall component or connector on the sample surface. Approaches Akrometrix has used under these circumstances include:

- Inverting the sample and measuring the back surface, or
- Using a lower resolution grating with a larger working distance.

Cause: Unfavorable Surface Optical Properties

The surface has unfavorable optical properties. Shadow moiré is based on diffuse reflection from the sample surface, which allows the interference patterns between the shadow grating and the reference grating to be observed. Surfaces that provide poor diffuse reflection include:

- transparent surfaces, such as glass
- specular reflecting surfaces, such as polished metal or solder pads
- black or other dark-colored surfaces

Solution:

a. Using the Phase Amplitude option with an appropriate threshold value automatically masks regions with such unfavorable optical properties, excluding these bad pixels from the phase image and subsequently the analysis calculation.

b. Painting the sample with a thin coat of high temperature white paint provides optimal surface properties for shadow moiré without significantly affecting mechanical properties. Other surface treatment methods may be used, depending on the sample, including creating a matte finish on a metal surface by etching or abrasion.

c. Blurring the focus of the camera can help in some circumstances. For example, blurring allows a strong fringe signal from the terminal ring around a through-hole to combine with the weak fringe signal from adjacent regions of solder mask. This technique does reduce the lateral resolution of the measurement.

Cause: Stray Sample Illumination

Illumination of the sample by any light other than the linear fiber optic light source decreases the shadow contrast. In addition to ambient light, frequent sources of additional light are reflections inside the sample chamber and light from the infrared heating source.

Solution:

a. Close system doors & turn off room lights.

b. Shield off as much of the heater light as possible by laying black paper or cloth shields on top of the oven window.

c. Make sure that the IR filter is in place on the camera lens. In extreme cases, shield off as much of the heater light as possible by laying black metal, paper or cloth shields on top of the oven window.

5.1.2 Additional Sources of Error

Several second-order effects have been observed in phase-stepped shadow moiré measurements that can affect results, particularly for extremely small and/or flat samples. Periodic structures in the apparatus or samples can introduce corresponding periodic errors in the phase image. In addition, the phase calculation algorithms inside Akrometrix software can introduce small periodic errors.

High magnification of the sample can cause the grating lines themselves to be resolved, which can cause a periodic error in the phase calculation. Choose a combination of magnification and grating frequency so that the lateral resolution is at least one full grating pitch. The general guidelines below minimize this problem:

1. If the full field of view of the video image is less than 160 mm in width, use a 100 lpi or higher grating.

2. If the full field of view of the video image is less than 60 mm in width, use a 300 lpi or higher grating.

Even when these guidelines are used, interference between camera pixel spacing and grating line spacing can produce aliasing in the video image. This initially appears as low contrast vertical (or near vertical) fringes across the image that vary in pitch and rotation as the zoom lens magnification is varied. This effect can be minimized by varying the lens magnification.

Interference between a periodic structure on the sample surface (e.g. a field of solder pads on a BGA substrate) and the grating line spacing can introduce a periodic phase calculation error. This effect can generally be observed by eye in the live video image of the sample and may be eliminated by re-orienting the sample or changing the grating (e.g. from 100 lpi to 300 lpi).

A second problem related not to system hardware, but to system software is caused by the breakdown of the sinusoidal approximation used in the phase calculation (see **Akrometrix Techniques and Analysis 101**). This appears as a series of ripples superimposed on the final displacement results. The ripples are characteristically parallel to the fringes appearing in the shadow moiré fringe pattern, but at four times the fringe frequency (a similar effect occurs when an incorrect step height is used, but the frequency of ripples is two times the fringe frequency).

In general, the amplitude of the ripples is comparable to the resolution of the system and the effect on accuracy is within the system specification. However, saturation of the video camera by regions of high reflectivity can enhance this effect to higher levels. If observed, this effect may be reduced through elimination of camera saturation by closing the lens iris or reducing light source power. In some cases, the effect may also be reduced by slightly increasing the distance between sample and grating. Consult with Akrometrix technical support if this effect is creating significant measurement problems.

5.1.3 Loss of Contrast and Resolution

A more subtle concern in making phase-stepped shadow moiré measurements deals with the relationship between the digital resolution of the intensity measurements and the precision of the vertical displacement data. The high resolution of the phase stepping method is based on the number of grayscale levels available when the fringe pattern is digitized. Using an 8-bit digitizer, there are 256 grayscale levels to encompass the fringe pattern from its brightest to darkest pixel. These 256 levels directly relate to the claim that vertical height measurement resolution is 100 times better than the grating pitch. If there are fewer levels available for digitization, the measurement resolution is proportionately reduced.

The manual lens iris should be adjusted so that maximum sample brightness is just below the saturation level of the digitizer. This is generally sufficient when the illumination and diffuse reflectivity of the surface is uniform across the sample. However, when the sample contains regions of high and low reflectivity, the fringe intensity signals from the two regions each cover only a small amplitude at the extreme high and low ends of the digitization range. In order to encompass both the dark fringe pixels in the low reflectivity region and the bright fringe pixels in the high reflectivity regions, each of the two signals spans a smaller range of digitization levels and the vertical displacement resolution in each region is reduced.

Painting the surface is the simplest procedure to eliminate this problem. If the surface cannot be painted, useful phase and displacement information can still be obtained for many samples, but the resulting loss of precision should be kept in mind.

Appendix A - Miscellaneous Information

A.1 File Formats

Akrometrix Surface Measurement saves data in a format with extension .akx_phase. These files should automatically be associated and can only be opened with the Surface Analysis application. Other image file formats can be exported from the program but cannot be loaded back into any Akrometrix software. Image export formats include: .bmp, .gif, .jpg, .png, and .tif.

A.2 Keyboard Shortcuts

F3	Toggle Fill ROI behavior
F5	Bring Camera Window to foreground (will not hide Camera Window)
F6	Show/Hide Sample Height Window
F7	Show/Hide Camera Control Window
F12	Perform an Acquire (capture data)
Ctrl+T	Open Thermal Profiler application
Ctrl+S	Save as *.akx_*
Ctrl+I	Save as image
Ctrl+W	Close
Ctrl+O	Open in Surface Analysis
While the ROI has focus the following keyboard shortcuts apply:	
Ctrl+5	make ROI its maximum size.
Alt+5	make ROI half of maximum size and position in center of field of view.
Up Arrow or 8 on NumPad	Move ROI up one pixel
Down Arrow or 2 on NumPad	Move ROI down one pixel
Left Arrow or 4 on NumPad	Move ROI left one pixel
Right Arrow or 6 on NumPad	Move ROI right one pixel
1 on NumPad	Move ROI down one pixel and left one pixel
3 on NumPad	Move ROI down one pixel and right one pixel
7 on NumPad	Move ROI up one pixel and left one pixel
9 on NumPad	Move ROI up one pixel and right one pixel
Ctrl plus any of the above will increase the ROI size in the desired direction.	
Alt plus any of the above will decrease the ROI size in the desired direction.	