# Surface analysis

User Manual

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Contents

1 Introduction

1.1 Overview

Surface Analysis is a program designed to analyze and display the results of shadow moiré and fringe projection measurements produced by Akrometrix warpage measurement systems. The program typically resides on the measurement system computer. If additional site licenses are purchased, **Surface Analysis** may also be installed as a stand-alone application on other computers, offloading analysis tasks from the measurement system.

The analysis of interferometric data from shadow moiré and fringe projection systems is a rich and complex subject. The main text of this manual emphasizes the operation of the **Surface Analysis** program. The principles of interferometric techniques and analysis will be discussed in **Akrometrix Optical Techniques and Analyses 101** (**AOTA101**). This paper should be read first by users unfamiliar with these techniques.

The output of the data acquisition program and thus the input of the **Surface Analysis** program is an Akrometrix-defined file with the extension of either *.akx_phase or *.akx_disp (displacement images). These files can contain measurement and reference data as well as some measurement parameters and conditions. **Surface Analysis** converts data from the *.akx_phase and *.akx_disp file into height data, and if required, Akrometrix gauges.

The main analysis functions on shadow moiré acquired data in **Surface Analysis** are based on the phase image in the *.akx_phase file. A phase image is a two-dimensional grayscale image (computed from several intensity source images) containing a value at each point related to the surface height at that point. Many of the options available in the **Surface Analysis** program originate from two challenges in phase image analysis.

- First, the phase data must be analyzed as a whole and errors due to poor quality data in one region of the surface can affect the results in other regions. The *Phase Smoothing*, *Cropping* and *Masking* functions allow bad data to be smoothed or excluded from analysis.

- Second, the surface contour does not have an absolute frame of reference. The *Rotation*, *Grating Compensation*, and *Reference/Relative* functions allow the user to define the reference plane in a way most useful for understanding the experimental results.

A second group of options control the display and output of experimental results. **Surface Analysis** provides a suite of display formats, which can each be further customized to the user's preference. In addition, the displacement data can be exported in tabular form for plotting or further analysis by other software packages.

Finally, four features allow repetitive functions to be automated:

- **Batch Analysis** allows the user to quickly analyze a set of related measurement data (e.g. the same sample at different temperatures)

- **Batch Masking** allows the user to quickly mask more than one phase or displacement image.

- **Batch Rotation** allows the user to quickly rotate more than one phase or displacement image.

- **Batch Cropping** allows the user to quickly crop multiple regions of interest from more than one phase or displacement image.

- **Batch Edit X/Y Orientation** allows the user to assign Pin1 location and Measured Side Metadata to a phase or displacement image.

1.2   Warnings and Notes

1.2.1   *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.

1.3   Technical Support

Akrometrix	404-486-0880	support@akrometrix.com
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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 *.akx_phase files, 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 Loading Measurement Data

2.1 Starting the Program

The **Surface Analysis** program can be started in four different ways:

A. Right click on the phase or displacement image in Surface Measurement and choose **Open in Surface Analysis…**.

B. Double-click on a valid *.akx_phase file

C. Launch the **Surface Analysis** executable file directly from its shortcut (e.g. via the Start menu)

D. Click the **Surface Analysis** button listed on the Akrometrix **Studio Manager** bar on the left side of the screen.

> **Note:** Only one instance (copy) of the software can run at a time; subsequent calls to the program will activate the open instance.

2.2 Loading Measurement Data

Once the **Surface Analysis** program starts, a GUI (Graphical User Interface) frame will appear. The contents of the display frame depend on how the application was launched:

A. If called from the measurement software via clicking on a phase image, the current phase or displacement window from the data acquisition program is shown.

B. If an *.akx_phase file was double-clicked, the phase image contained in the selected *.akx_phase file is shown.

C. If the EXE is launched from a shortcut or **Studio Manager**, no image is shown and the user needs to select a file to open.

New measurement data files can be loaded into memory with the **File→Open** menu item. A standard **Open** dialog box appears prompting the user to select a valid *.akx_phase or *akx_disp file. Multiple files can be opened at one time by highlighting multiple selections using the Shift or Control keys. Phase images and displacement images can also be dragged and dropped into the Surface Analysis program in order to open them.

> **Note: Surface Analysis** can be configured to analyze the image and display results immediately upon opening the *.akx_phase file, using the **Tools→Options…** menu item. See **Section 4.2**

2.3 Working with the Phase Image

An *.akx_phase file may contain a variety of information such as measurement data (phase images, intensity images, etc.), reference data, as well as measurement

parameters and conditions. When the *.akx_phase file is loaded, all the information in the file is loaded in memory. For display purposes, only the phase image will be shown in the GUI of the **Surface Analysis** program. Modification (**Section 0**) and Analysis (**Section 4**) on the measurement data will be mainly applied to the phase image and any associated reference data that exist.

2.3.1 Resizing a Phase Image

The phase image window may be resized in the normal fashion by dragging along any edge or corner. The image in the window can be zoomed by using **Ctrl+** or **Ctrl-** (**Figure 2.1** and **Figure 2.2**). Each action doubles or halves the size of the phase image.
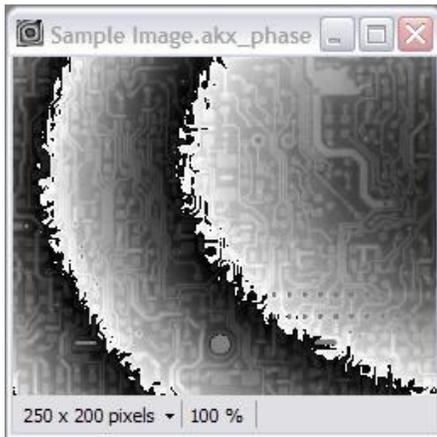
Figure 2.1 Phase Image 100% Magnification
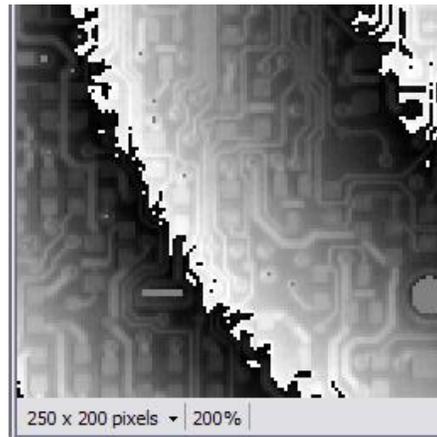
Figure 2.2 Phase Image 200% Magnification

2.3.2 Data Information

When a phase image is displayed in **Surface Analysis**, some data information can be present as well. First of all, the full path of the *.akx_phase file can be shown by hovering the cursor over the title bar of the phase image. Second, the image size and magnification ratio information are shown on the status bar located at the bottom of the image (**Figure 2.3**).
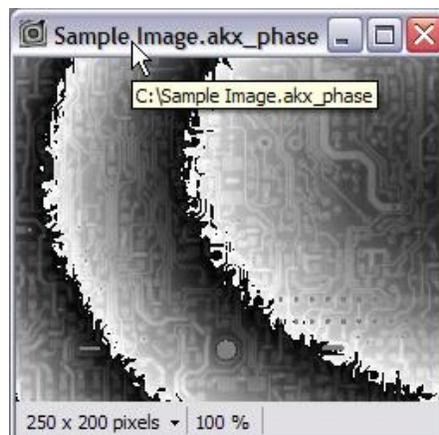
Figure 2.3 Data Information Shown on the Phase Image

2.3.3 Measurement Information

In addition to the data information described in **Section 2.3.2**, the measurement parameters and conditions can be displayed by right-clicking on the image and choosing **Properties…** (**Figure 2.4**). In the Properties window, information about the intensity images, phase image, and grating can be found.
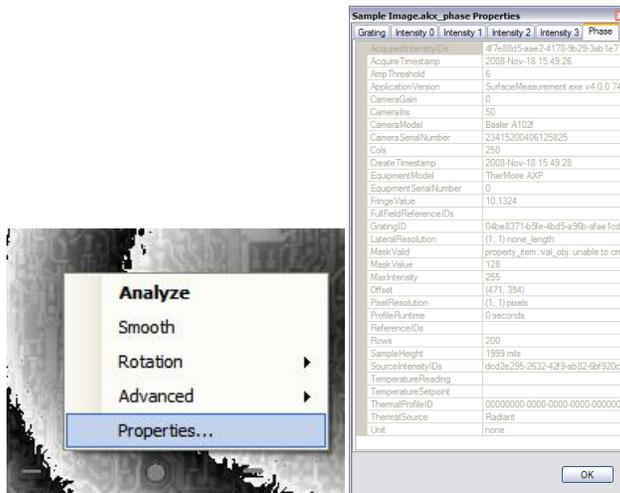
**Figure 2.4** Displaying Measurement Parameters and Conditions

2.3.4 Assigning Physical Size

Surface Analysis (and the TherMoiré measurement system in general) has no internal means of knowing the physical ROI (Region of Interest) size, but physical dimensions can be assigned by the user. Click the "Image Size" area on the status bar at the bottom left of the phase image. Select **Assign Size…** from the pull-up menu (**Figure 2.5**). In the Physical Size window, assign the unit as inches or millimeters, then enter the Width and Height of the image and click OK.

After physical dimensions have been assigned, the user can choose whether X and Y axes are displayed in pixels, inches or millimeters using the same pull-up menu on the status bar. The selected unit will appear on the X and Y axes of all graphs created after analysis.
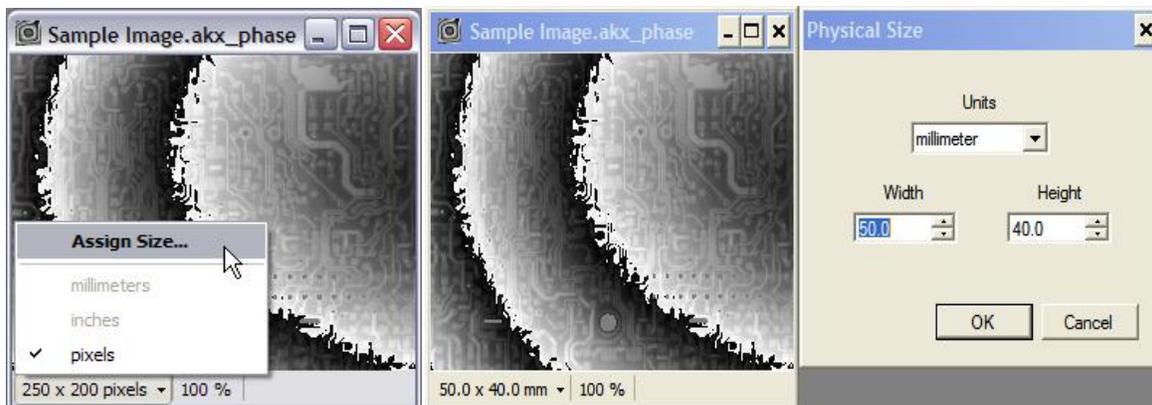
Figure 2.5 Assigning Physical Size for a Phase Image

Note: Physical dimensions are required for Compensation (**Section 4.5**) and calculation of Bow and Twist gauges (See **Akrometrix Optical Techniques and Analyses 101**).

2.3.5 *Showing Surface or Intensity Images*

Phase images have fringes across the whole field, hiding features on the sample surface. If the user wishes to make masks, partitions, or chords on the surface or intensity images, they can be shown by right-clicking on the phase image and selecting **Advanced→View→Surface Image** (or, alternatively, any one of the 4 intensity images). The image can also be quickly changed without the context menu by using the keyboard shortcuts **P**, **S**, and the numbers **1-4**. The currently viewed image can be saved to disk in the .bmp format by selecting **File→Save Image…** or **Ctrl+I**.
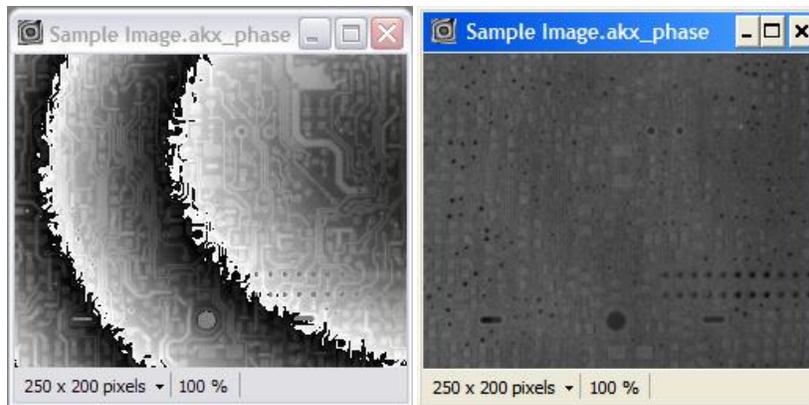
Figure 2.6 Phase and Surface Image Views
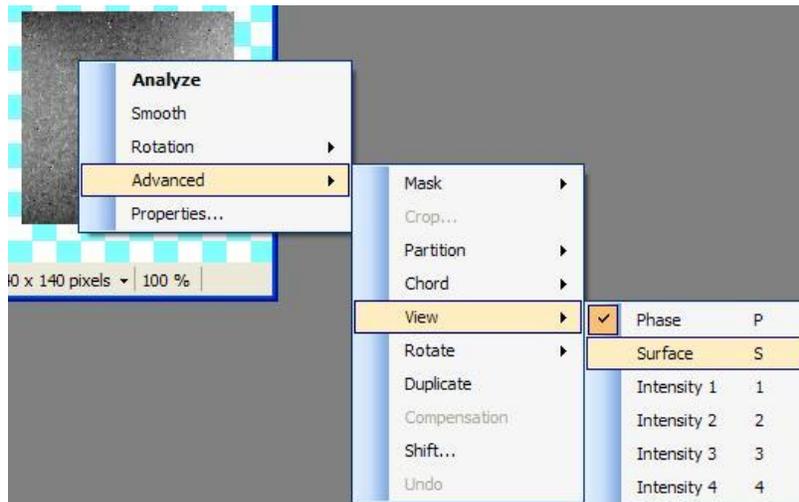
Figure 2.7 Menu Command for Showing Surface or Intensity Images

2.4 Working with Displacement Data

When a *.akx_disp image is loaded in Surface Analysis, a different window type is created as shown in **Figure 2.8**.
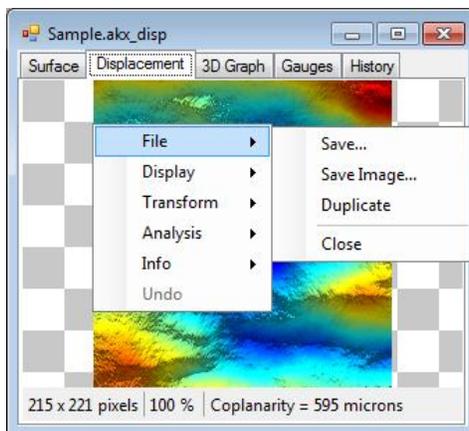
**Figure 2.8** Loaded Displacement Window

This window shows the displacement data, average surface image, 3D graph, gauge results, as well as a history of operations performed on one tabbed interface. The interaction with this window happens via context menu, just as with the phase image window. There is now a File entry for saving the data in either its original format or as an image. The data can also be duplicated or closed from this menu item.

Other functions present in the phase image window are rearranged in this window to accommodate new functionality. The organization is described in the following sections.

2.4.1 File

Save…	Saves the data in *.akx_disp format
Save Image…	Allows display window to be saved in graphical format (*_3D.png or *_3D.jpg).
Duplicate	Makes a copy of the current displacement window in memory.
Close	Closes the displacement window. Prompts to save if any changes are detected.

2.4.2 Display

Zoom	Allows a reset of the image zoom that has been changed by the mouse wheel.
Z-Axis	Allows the Z-Axis units to be changed between microns and mils as well as to change the Z-Axis scale.
XY Size	Allows the X and Y data dimensions to be mapped to physical dimensions in either mm or inches.

2.4.3 Transform

Mask	Allows the data to be masked. All functions are the same as described for phase images in **Section 3.2**.
Crop…	Allows the data to be cropped. All functions are the same as described for phase images in **Section 3.3**.
Smooth	Applies a smoothing function to the 3D data. This command can be repeated multiple times. See **AOTA101** for more information.
Plane Rotation	Allows the user to change the data rotation as in **Section 4.3**.
Fit Data…	Opens a dialog where a polynomial fit can be calculated based on the data set. See **Figure 5.2**. Alternatively, if physical dimensions are assigned to the phase image, a spherical fit can be calculated.
Subtract	Displays the relative displacement data calculated by subtracting a selected 3D data from the current 3D data in a new window.
Rotate	Allows the data to be rotated about its Z-axis as in **Section 3.6**.
Shift…	Allows the data to be shifted in its plane as in **Section 3.7**.

2.4.4 Analysis

Generate Results	Produces graph outputs as selected in the Options window.
Step Height	Allows the user to define two ROIs and calculate the height difference between them. See **Section 2.4.5**.
Partition	Shows the same commands under the **Advanced→Partition** menu for phase images. See **Section 3.4**.
Chord	Shows the same commands under the **Advanced→Chord** menu for phase images. See **Section 5.4**.

2.4.5 Step Height Calculation

Clicking on **Step Height→Add Step** (**Figure 2.9**) will add a pair of boxes to the displacement view that can be moved around and resized. The step height difference is calculated as the difference in average heights between the two regions (1A-1B). The step height sign will vary depending on whether the A region is higher or lower than B and the result is shown at the bottom of the displacement window (See **Figure 2.10** and **Figure 2.11**). Multiple step height pairs can be added. They can also be saved for loading onto other displacement windows or used with batch processing.
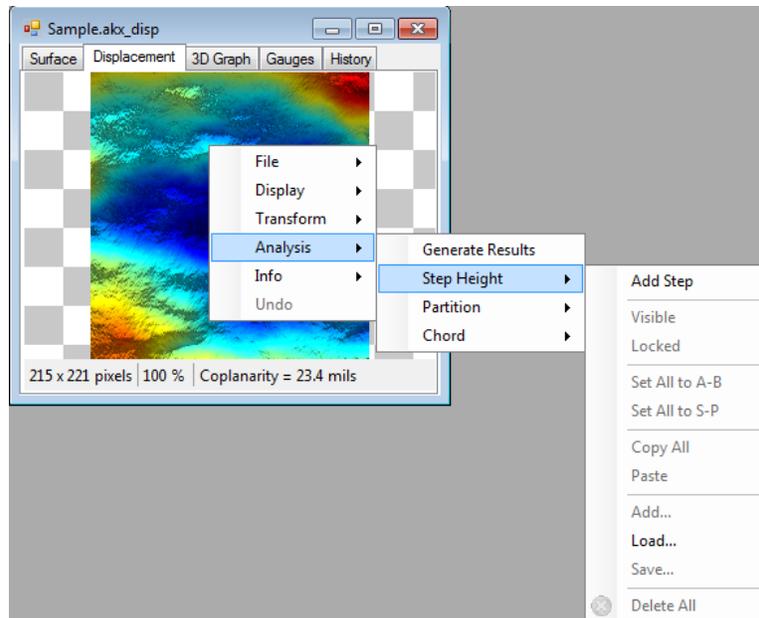
Figure 2.9 Step Height Menu
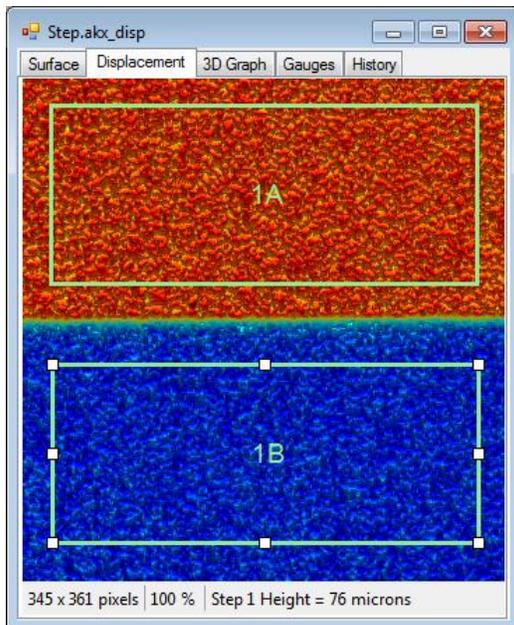
Figure 2.10 Step Height Calculation A>B
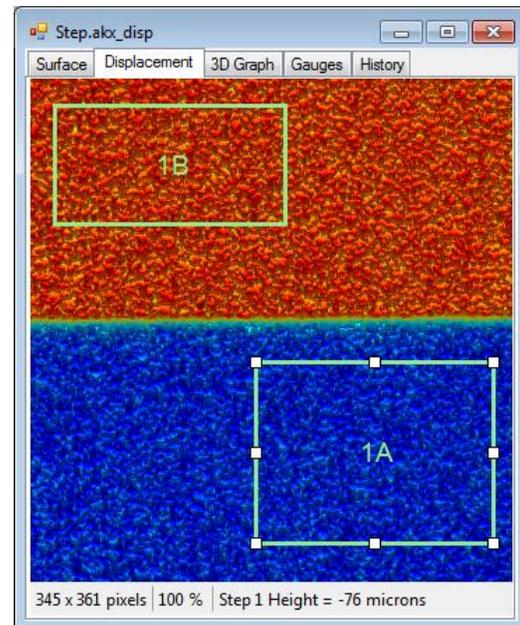
Figure 2.11 Step Height Calculation A<B

The step height pair mode can also be changed by right clicking on either of the boxes and going to **Switch to S-P**. S-P mode uses the 1P box for its LSF reference plane and is most useful when analyzing a calibration block with flat planes and known step heights between them. A-B mode uses the reference plane that is already applied to the surface. See **Figure 2.12** and **Figure 2.13** for an example.
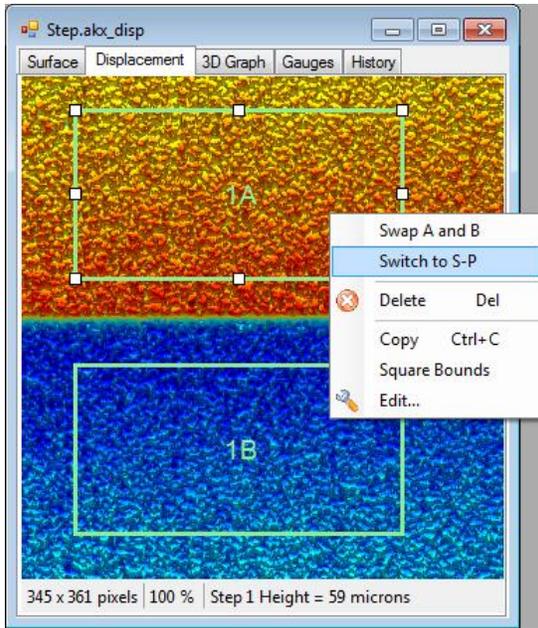
Figure 2.12 A-B Mode
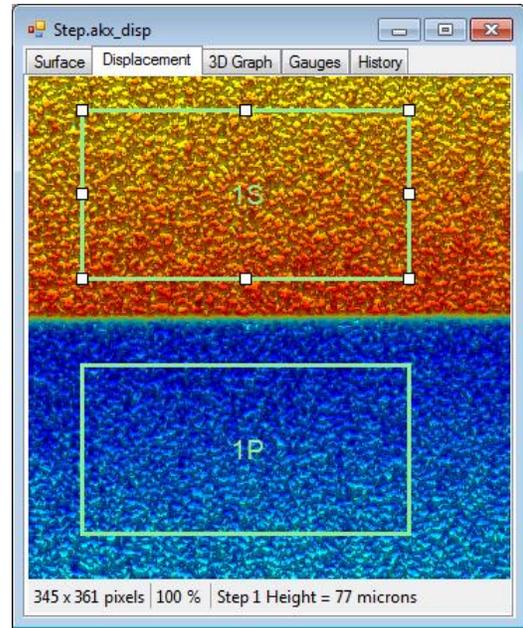
Figure 2.13 S-P Mode

3 Modifying Measurement Data

Note: Context menu paths described in this section and references to phase images will be different for *.akx_disp files. Behavior of the functions such as masks/partitions/etc. remains the same for displacement images. Reference Section 2.4, Working with Displacement Data for correct context menu paths.

3.1 Setting the ROI

The Mask, Crop, and Partition functions in **Surface Analysis** create one or more graphically defined ROIs (Regions of Interest) on the phase image where these functions can be applied. ROIs can be different shapes such as rectangle, ellipse, triangle, etc. The default shape of an ROI is a rectangle. Choose a new shape by opening the Shape Selector window from the **View→Shape Selector** menu item. Choose the shape before selecting the Mask, Crop, or Partition function (**Figure 3.1**).

Draw an ROI inside the image by picking the first corner and dragging the cursor to another corner and letting go of the button. When an ROI region is selected, it can be repositioned by dragging anywhere within its region and resized by dragging on any of the eight "Handles" on the periphery. The shape, location, and size of the ROI can also be changed by using the ROI Properties Window (**Figure 3.2**). To access this window, right-click inside the ROI and choose **Properties…**. This window is useful for drawing a pre-defined ROI.
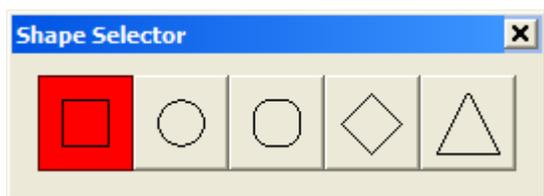
Figure 3.1 ROI Shape Selector
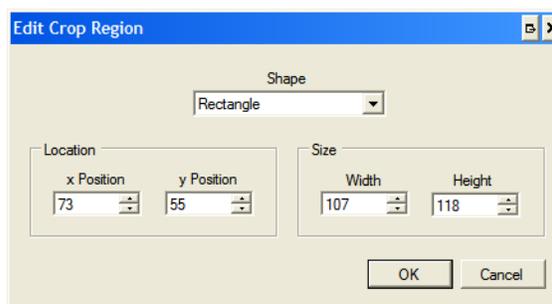
Figure 3.2 Edit ROI Region Size and Position

Other common functions for Masking, Cropping, and Partitioning can be called by right-clicking inside an ROI:

Copy (**Ctrl+C**) creates a copy of the active ROI on the Windows Clipboard. It may be pasted (**Ctrl+V**) inside the original phase image or in a different phase image (Not available for Crop function)

Square Bounds equalizes the horizontal and vertical dimensions of the ROI as the shorter value of the two

Delete deletes the active ROI (Not available for Crop function)

Delete All deletes all ROIs within the current phase image window (Not available for Crop function)

> **Note:** The ROI functions for Mask, Crop, and Partition modes are all slightly different. See the following sections.

3.2   Masking a Phase Image

Masking excludes regions inside the phase image from the analysis. Regions that lack good phase data (e.g. holes, steps) can create errors in the analysis that extend beyond the bad phase region. When using a mask, there is no displacement information generated within the masked-out regions, and the remainder of the phase image can be analyzed without interference.

3.2.1 Creating a Mask

A mask file is a binary graphical image containing only black and white colors. The white color represents valid data while the black color represents points or areas that need to be masked out. In most cases, the mask shapes shown in **Figure 3.1** are sufficient. However, if the user needs to define an irregularly shaped mask, they can also be generated from an external graphical tool such as *MS Paint®*. The file format needs to be *.bmp, *.png, or *.tif in order to be loaded in **Surface Analysis**.

A mask can be created and saved in **Surface Analysis** by the following steps:

1. To create a new mask, right-click in the selected phase image and choose **Advanced➔Mask➔New** (or use the keyboard shortcut, **Ctrl+M**).

2. To create the first ROI in the new mask, hold down the left mouse button; draw a rectangle on the phase image and then release. The ROI will appear as a transparent red shape. All the ROI commands described in **Section 3.1** apply to the mask ROI.

3. Additional mask ROIs can be added by repeating steps 1 and 2. Mask ROIs may overlap.

4. When the mask is complete, it may be saved to a file (*.bmp, *.png, or *.tif) by right-clicking inside the phase image (but not inside an editable mask ROI) and choosing **Advanced➔Mask➔Save…**.

5. Masking function can be turned on and off without deleting the mask from memory by right-clicking inside the phase image (but not inside an editable mask ROI) and choosing **Advanced➔Mask➔Enable**. Alternating this command will turn the current mask(s) on and off. This is useful when evaluating masks between phase image and 3D surface plot during a trial. When the masking function is disabled, all mask ROIs are hidden.

3.2.2 Loading and Editing a Mask

A previously created mask that was saved in the *.bmp, *.png, or *.tif formats can be recalled and applied to any phase image. To load the mask file, right-click inside the phase image, choose **Advanced→Mask→Load…,** and select the desired mask file. More than one mask file can be loaded on the same phase image. A loaded mask is shown in solid yellow color.

A loaded mask cannot be edited but can be turned on and off by toggling the **Advanced→Mask→Enable** function. To delete the loaded mask, choose **Advanced→Mask→Clear**. The **Clear** command does not apply to mask ROIs which are not loaded from a file; these can be removed using the **Delete** or **Delete All** commands. New mask ROIs may be added by right-clicking inside the phase image and choosing **Advanced→Mask→New**.

The modified mask, including both old and new components, can be saved by right-clicking inside the phase image (but not inside an editable mask ROI) and choosing **Advanced→Mask→Save…**.

Note: If a mask is applied to a phase image with different pixel dimensions than the one on which it was created, it will be located on the new phase image with the upper left corner as the origin. Any mask ROIs that lie entirely outside the boundaries of the new phase image will not appear. Mask ROIs lying partially outside the phase image boundaries will be truncated.

3.2.3 Burning a Mask

Burning a mask combines the current phase image with one or more mask ROIs created in memory or loaded from a file. The mask pattern will be permanently embedded in the phase image as the grayscale value 128. This function prevents the future separation and loss of mask files used during analysis.

A mask can be burned by:

- right-clicking inside an editable mask ROI and choosing **Burn** or,

- right-clicking inside the phase image (but not inside an editable mask ROI) and choosing **Advanced→Mask→Burn**.

The burned mask ROIs appear as a gray color as shown in **Figure 3.3**.
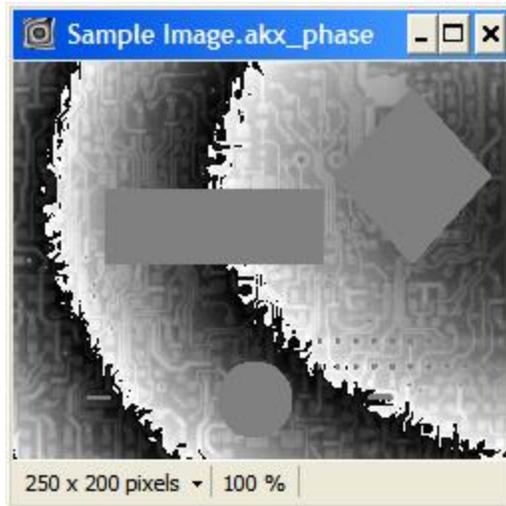
Figure 3.3 Burned Mask Areas

3.3 Cropping a Phase Image

Cropping an image allows the user to extract and save a smaller portion of the current phase image. This is useful for defining a smaller region inside the original phase image or eliminating bad phase data at an image edge.

1. Inside the phase image to be modified, right-click and go to **Advanced→Crop…**

2. Draw an ROI inside the image using the cursor.

3. Size and position the ROI to enclose the desired region with the mouse or the ROI Properties Window (**Figure 3.2**).

4. To abort the crop operation, right-click and go to **Cancel** inside the ROI or use **Esc** on the keyboard.

5. To execute the cropping operation, right-click and select **Crop** inside the ROI. The enclosed cropped region is now shown in the display.

> **Note:** After cropping, the source phase image will be removed and replaced with a new cropped phase image. To keep both the old and new images, use the partition function (**Section 3.4**).

3.4 Partitioning a Phase Image

Partitioning is a function where one or more ROIs are cropped from a phase image while leaving the original phase image intact. This function is useful for measuring multiple samples in a single run, and later extracting the individual samples from each phase image recorded. The same partition can be applied to multiple phase images using the Batch Cropping tool described in **Section 6**.

3.4.1 Creating a Partition

1. To create a new partition, right-click in the selected phase image and choose **Advanced➔Partition➔New** (or **Ctrl+R**).

2. To create the first domain in the new partition, draw a rectangle on the phase image with the mouse.

3. An ROI properties window will appear to allow the user to modify domain properties. Like the other ROI property windows, this can be used to edit the shape, location, and size of the domain. It can also be used to rename the domain and change the font and alignment of the label inside the domain (**Figure 3.4**). Click **OK** when complete. A green ROI appears and all the ROI commands described in **Section 3.1** apply to the partition ROI.
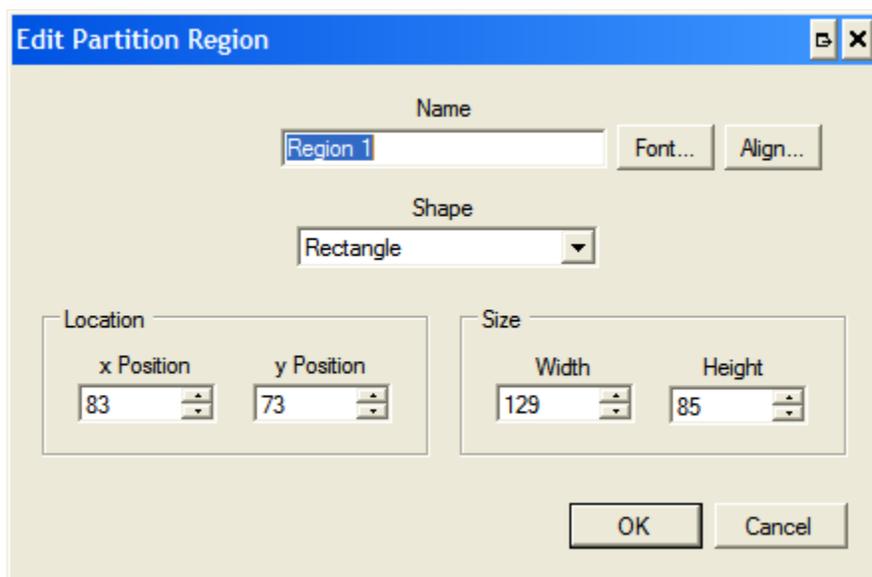

Figure 3.4 A Partition ROI Properties Window

4. Additional domains can be added to the partition (**Figure 3.5**) by repeating steps 1 through 3. Domains may overlap.
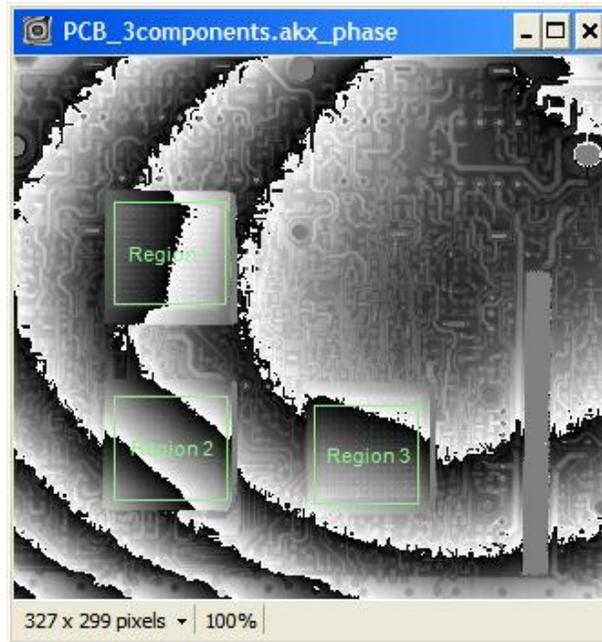
Figure 3.5 Multiple Domains on One Phase Image

5. When the partition is complete, it can be saved to a file (*.akx_partition) by right-clicking inside the phase image (but not inside a domain) and choosing **Advanced→Partition→Save…**.

6. Even if it has not been saved, a partition may be used until it is cleared. It may be cleared by right-clicking inside the phase image (but not inside a domain) and choosing **Advanced→Partition→Clear**.

3.4.2 Loading and Editing a Partition

A previously created partition that was saved in an *.akx_partition file can be recalled and applied to any phase image. To load the partition file, right-click inside the phase image, choose **Advanced→Partition→Load…**, and select the desired partition file.

Any domain in the partition may be modified or deleted by right-clicking inside the domain and using the ROI commands described in **Section 3.1**. It may also be edited graphically using the cursor. New domains may be added by right-clicking inside the phase image (but not inside a domain) and choosing **Advanced→Partition→New**.

The modified partition, including both old and new domains, may be saved by right-clicking inside the phase image (but not inside a domain) and choosing **Advanced→Partition→Save…**.

> **Note:** If a partition is applied to a phase image with different pixel dimensions than the one on which it was created, it will be located on the new phase image with the upper left corner as the origin. Any domains that lie entirely or partially outside the boundaries of the new

phase image will be excluded.

3.4.3 *Extracting Domains*

To extract a domain as an independent phase image in its own window, right-click inside the domain and choose **Extract**. To extract all domains, right-click inside any domain and choose **Extract All**. Unlike the crop function, where the source image was replaced by the new image, the partition function retains both old and new images.
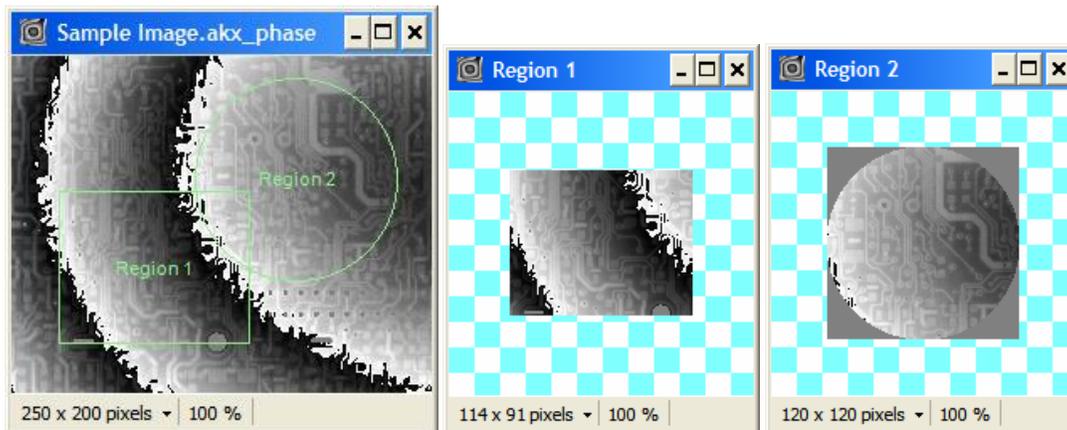
Figure 3.6 Extracted Domains from a Phase Image

3.5   Smoothing a Phase Image

The **Smooth** command applies a smoothing function to the active phase image to reduce noise in the data. This is useful for reducing analysis error due to fringe miscounting and increasing reproducibility in gauge values. Warpage gauge values, such as coplanarity, are frequently determined by a small number of data points, e.g. the highest and lowest displacement values. Therefore, they are extremely sensitive to statistical outliers in the data set. Smoothing, by reducing statistical noise, can make these values more repeatable from measurement to measurement.

To apply the smooth function, right-click inside the phase image and choose **Smooth**. This command can be repeated multiple times. For further information about the smooth function, refer to **Akrometrix Optical Techniques and Analysis 101**.

Note: Smoothing may cause errors when applied to images where the fringes are very tightly spaced or at boundaries of mask ROIs. Therefore, it is not recommended to apply the smooth function on data acquired with the **MP10 Surface Measurement** system which produces a closely spaced fringe pattern on a phase image.

3.6   Rotating a Phase Image

Rotating a phase image is a feature useful when a sample does not have the desired orientation in the original phase image (e.g. a part has rotated on the sample support fixture during a temperature profile).

To rotate a phase image, right-click on the image, choose **Advanced→Rotate** and select the desired rotation.

Note: Phase image rotation is different from reference plane rotation that is discussed in **Section 4.3**. The former rotates a 2D image while the latter rotates a 3D surface. To choose the method of rotating a reference plane, right-click on the phase image and choose **Rotation** (**Figure 3.8**).
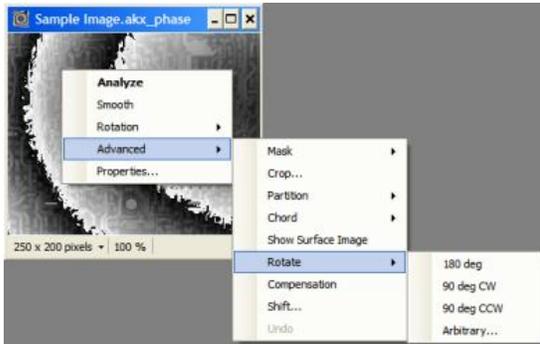
Figure 3.7 Phase Image Rotation
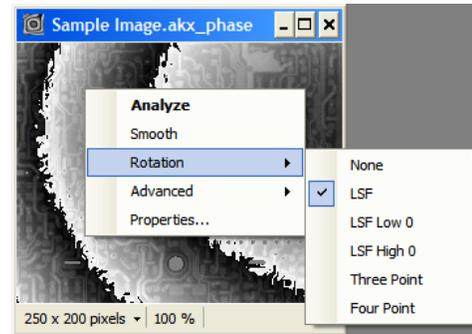
Figure 3.8 Reference Plane Rotation

3.7 Shifting a Phase Image

Shifting a phase image is a feature useful when a sample does not have the desired position in the original phase image, e.g. a part has shifted to one side of the sample support fixture during a temperature profile.

To shift a phase image, right-click on the phase image, choose **Advanced→Shift…** and select the desired shift in either the X (left-right) or Y (up-down) direction. The image will shift with respect to an origin that is defined as the top left of the phase image. Areas shifted from outside the boundaries of the phase image will be filled with mask (see **Figure 3.9**).
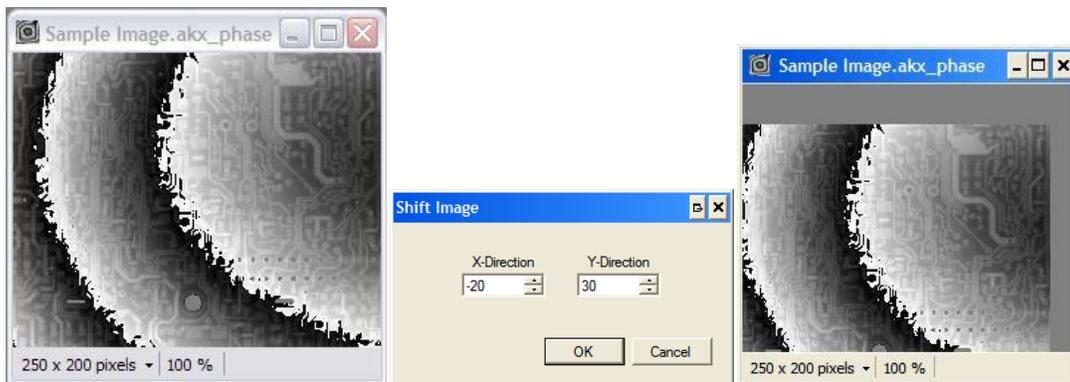
Figure 3.9 Shifting a Phase Image

3.8   Undoing a Phase Image Modification

To undo phase image modification from masking, cropping, smoothing, rotating or shifting, right-click and select **Advanced→Undo**; select the action to undo from the available list.

There can be up to 99 actions on the undo list. The latest action will be shown at the top of the list. Clicking on the latest action will remove this single action and move the phase image back one state. Clicking on any item in the middle of the list will remove all the actions from the top to this item.

3.9   Saving Phase Images

A modified phase image is **NOT** automatically saved to the hard drive. It can be saved using the **File→Save…** menu item. If the modified image is not saved, the user will be prompted again to save it when the phase image window is closed or the program is shut down.

4 Analyzing Measurement Data

Analysis is the mathematical conversion of the measurement data (e.g. phase image) into displacement data (the height of the surface at each image pixel in physical units). **Surface Analysis** is normally set to display displacement data graphically as soon as the analysis is complete. The graphical *output* options will be described in **Section 5**. This section describes how to initiate the analysis process and a key factor in the analysis, the choice of reference plane.

4.1 Analysis

There are three methods to trigger analysis of the measurement data

A. To trigger analysis manually, right-click on the phase or displacement image to be analyzed and select **Analyze**.

B. To trigger analysis automatically when a *.akx_phase file is opened, select the **Tools→Options…** menu item and check **Analyze on Open**.

C. To analyze multiple measurement data in parallel, use the **Batch Analysis** function described in **Section 6.2**.

> **Note:** If no graphical display options are checked in the options window, there will be no visible indication that analysis has taken place in cases A and B above.

4.2 The Options Window

The settings on the options window (**Figure 4.1**) determine the reference plane and display options when the measurement data is analyzed. These settings will be applied to all the measurement data, either manually or automatically on opening.

To open the options window, select the **Tools→Options…** menu item. All the settings are explained below:

Units XY	Displays the in-plane dimensions in English (inches) or metric units (millimeters).
Units Z	Displays the out-of-plane dimensions in English (mils, 1 mil = 0.001 inches) or metric units (microns, or μm).
Initial Physical Size	Assigns the specified physical dimensions for Width (X) and Height (Y) to the phase image when loaded. The unit of X and Y is assigned in **Units XY**.
Smooth Phase on Open	Checking this box causes the phase image to be smoothed one time immediately after loaded.
Analyze on Open	Checking this box causes the measurement data to be analyzed immediately after loaded.

Normalize Chords	Checking this box causes all 2D chord plots to be displayed with the endpoints referenced to zero.
Grating Compensation	Checking this box applies compensation to all measurement data that contain compensation parameters(See **Section 4.5** for a discussion of grating compensation). It may be turned on or off for individual measurement data by right-clicking on a phase image and choosing **Advanced→Compensate**.
Smooth Displacement	Checking this box caused all phase images to be displacement smoothed when analyzed.
Rotation	Pull-down list sets the reference plane rotation to be applied during the analysis. See **Section 4.3**.
Gauges	Select which gauges (numerical values quantifying flatness) are displayed at the bottom of the graphical display windows. A gauge on the list may be highlighted by clicking on it once. Checking a box means that gauge will be displayed. The up and down arrows move the highlighted gauge up and down the list, changing the order in which gauges are displayed.
Graphs	Selects which graph formats (see **Sections 5.1** through **5.4**) are displayed after analysis. A graph on the list may be highlighted by clicking on it once. Checking a box means that graph will be displayed. The up and down arrows move the highlighted graph up and down the list, changing the order in which graphs are displayed.
Configuration File	Allows the user to load a non-default display format for graphs. The 3D configuration file has an extension of *.akx_3Dconfig and is used for 3D plots. See **Section 5.1**. The 2D configuration file has an extension of *.akx_2Dconfig and is used for any 2D chords. See **Section 5.3** and **5.4**.
Graph Size	Sets the initial size for all graphical displays created during analysis.
Gauge Display	Gauge values listed at the bottom of the 3D or 2D display window may be arranged horizontally or vertically.
Use Latest 3D View	Applies the perspective of the most recently modified 3D surface plot to all subsequently spawned 3D surface plots. In other words, if the user changes the altitude or rotation from which the surface is viewed in one graph, new graphs will automatically be shown from the same viewpoint. The zoom factor of the most recent graph will also be inherited.

Fixed Z-Scale   When checked, this allows the user to adjust the data scale for all 3D or 2D plots. When unchecked, each image is plotted on a scale set by its own data set. This option is also available in Batch Analysis (**Tools→Batch Processing…→Analysis Tab**).

OK   Any changes to the settings are saved and the window is closed.

Cancel   The window will close without changes to the settings.
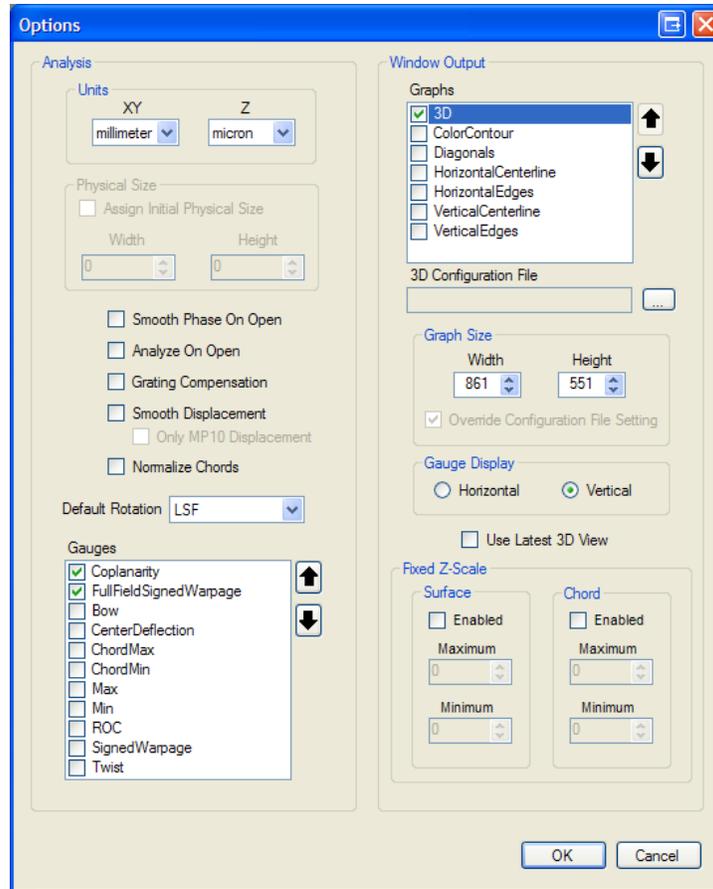
Figure 4.1 Options Window

Note: If no options are checked on the Graphs list, there will be no visible indication that analysis has taken place.

4.3   Reference Plane – Rotation

In order to display the displacement data, the user may define a coordinate system with a zero reference plane. This is especially useful when calculating gauges. To set the reference plane rotation to be used during analysis, select **Tools→Options…** and choose from the **Default Rotation** pull-down list.

The rotation choice can also be made before analysis by right-clicking on the phase image and choosing **Rotation** or **Transform→Plane Rotation** on a displacement image, then selecting from the list. The selected option is checked.

> **Note:** The rotation option chosen in the options window will be applied to all the measurement data when loaded. The rotation option chosen from an individual phase or displacement image will only be applied to that particular data.

Surface Analysis provides the user with several options for defining the zero reference plane:

- **None:** The displacement data is not rotated and thus the reference plane is parallel to the grating. The zero value on the data does not correspond to any specific feature of the displacement surface.
- **LSF:** The displacement data is rotated so that the zero reference plane is the best fit plane calculated from all displacement points.
- **LSF Low 0:** LSF rotation option with the lowest displacement point set equal to zero (all others are positive displacement values).
- **LSF High 0:** LSF rotation option with the highest displacement point set equal to zero (all others are negative displacement values).
- **Three Point:** The displacement data is rotated so that the zero reference plane is defined by three corners (upper left, lower left, upper right).
- **Four Point:** The displacement data is rotated so that the zero reference plane is the best fit plane calculated from all four corners.

When analyzing a displacement image, the User Defined rotation option is also available. This allows the user to specify a region on the sample surface to fit a LSF plane to. This LSF plane is then use to rotate the entire surface.
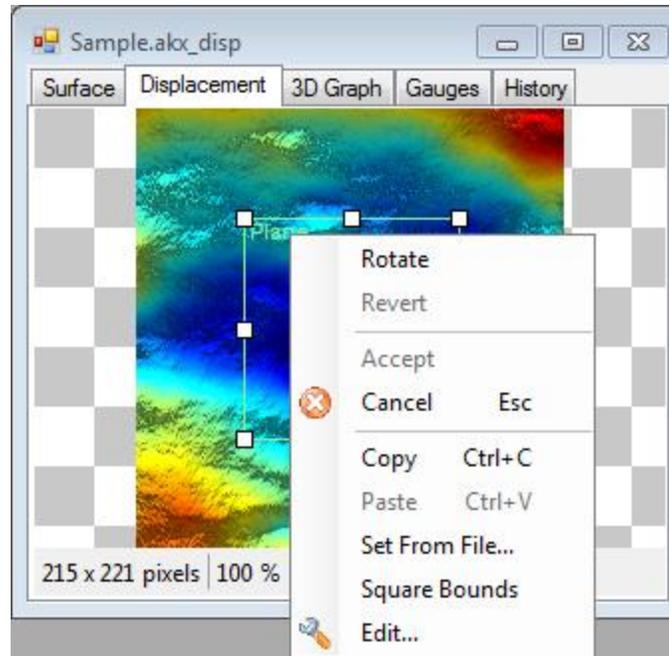
Figure 4.2 User Defined Plane Rotation

In **Figure 4.2** the green box can be dragged around and resized to cover the area that represents the desired rotation. In the context menu, Rotate will perform the rotation. If the rotation is deemed acceptable, Accept will complete the operation and remove the green box. Revert will undo the rotation. In addition, the green box can be copied from one displacement window to another using the Copy/Paste commands. Lastly, the box size and location can be set from another *.akx_disp file as well as edited using the Square Bounds and Edit commands.

The values of the individual data points change as a function of rotation (choice of reference plane), so gauges (e.g. coplanarity) and other calculated values are also a function of rotation. See **Akrometrix Optical Techniques and Analyses 101** for further discussion.

4.4   Reference Surface – Relative Displacement

A relative displacement measurement is calculated by taking the difference between two absolute displacement measurements with the same image pixel size. It is useful for observing the change in sample warpage as a function of sample history. The baseline displacement surface is set to be reference surface. The relative displacement surface is the current active surface minus the reference surface.

To define a reference surface, right-click on a 3D graph analyzed from a phase image and check **Reference Surface**. This surface data will then act as a reference to all other displacement data. After identifying the reference surface, right-click on a second phase image of the same pixel dimensions. An additional menu item, **Analyze Relative**, appears on the list below **Analyze**. To obtain the relative displacement data, select **Analyze Relative**. Otherwise, choose **Analyze** to obtain the absolute displacement data. The relative displacement display can be turned off by right-clicking

on the reference surface image and unchecking **Reference Surface**. After that, **Analyze Relative** will disappear from the menu list for the phase images.

> **Note: Analyze Relative** only compares data with the same pixel dimensions. If the second phase image is of different pixel dimensions than the reference phase image, the user will be shown an error message.

4.5   Reference Surface – Grating Compensation

The non-planar surface of a grating can be compensated by a reference surface (see **Akrometrix Optical Techniques and Analyses 101**). To enable grating compensation during analysis, check the **Enabled** box under **Grating Compensation** in the options window.

The compensation choice can also be made for individual phase images by right-clicking on the phase image and checking **Advanced→Compensation**. To turn off compensation, repeat the process and uncheck the selection by clicking it again.

> **Note:** In the options window, the **Grating Compensation** option can be enabled or disabled regardless of whether the grating has been compensated or not. This option will be applied to all opened phase images that contain compensation data.

> **Note:** The compensation option on an individual phase image will be grayed out if no compensation parameters can be found in the *.akx_phase file. Otherwise, this option is shown in black and can be checked or unchecked. The compensation option chosen for each phase image will only be applied to that particular image.

> **Note:** In order to apply grating compensation, physical dimensions have to be assigned to the phase image (see **Section 2.3.4**). The grating compensation calculation assumes that the ROI is centered with respect to the grating. The accuracy of the compensation will be reduced if the ROI is not centered, particularly if it lies outside the central 4" by 4" area of the grating.

5 Displaying Results

After analysis, the information is displayed in a choice of four graphical formats:

- 3D Surface (**Section 5.1**)
- 3D Contour (**Section 5.2**)
- 2D Diagonal (**Section 5.3**)
- 2D Chord (**Section 5.4**)

The data displayed in each graph can be exported in numerical form (**Section 5.5**). In the meantime, gauges (single values representing the warpage) can be displayed at the bottom of the 3D graphs (**Section 5.6**).

5.1   Graphical Output – 3D Surface Plot

5.1.1 3D Display Window

To display the 3D Surface plot after analysis, check the box next to **3D** on the **Graphs** list in the options window (**Section 4.2**). After right-clicking and selecting **Analyze** on the phase image or **Analysis→Generate Results** on a displacement image, a new 3D display window is opened and the 3D height map represented in color is shown in the center of this window. Interaction with the 3D display when generated from a displacement image is similar to that of the original image. Further details on the 3D display window generated from a phase image are discussed in this section 5.1. The name of the data file will be shown on the top and gauges selected in the options window will be displayed below the 3D image. The caption of the 3D display window can be renamed by right-clicking on its title bar and selecting **Rename Window…**. Additional information including cursor coordinate position, viewpoint and zoom ratio can be found in the status bar at the bottom left. See **Figure 5.1**.

5.1.2 Key/Mouse Interactions with the Graph

There are five interactions that can be done with the 3D graph:

1. **Coordinates** of each individual data points are shown live in the status bar by hovering the cursor over the 3D image.

2. **Rotate** adjusts the angle from which the surface is viewed. Press the left mouse button and drag the plot to the desired orientation in the display window. The current Rotation and Altitude parameters will be displayed in the status bar.

3. **Zoom** adjusts the scale of the plot. Scroll the mouse wheel and change the plot to the desired scale in the display window. The current 3D graph magnification level will be displayed in the status bar.

4. **Pan** adjusts the plot center point. Simultaneously press the Ctrl key and left click on the plot to set the center point. Subsequent rotate and zoom functions will rotate and zoom about this new point.

5. **Esc** key brings the 3D graph back to its original size (zoom ratio of 100%) and center point.
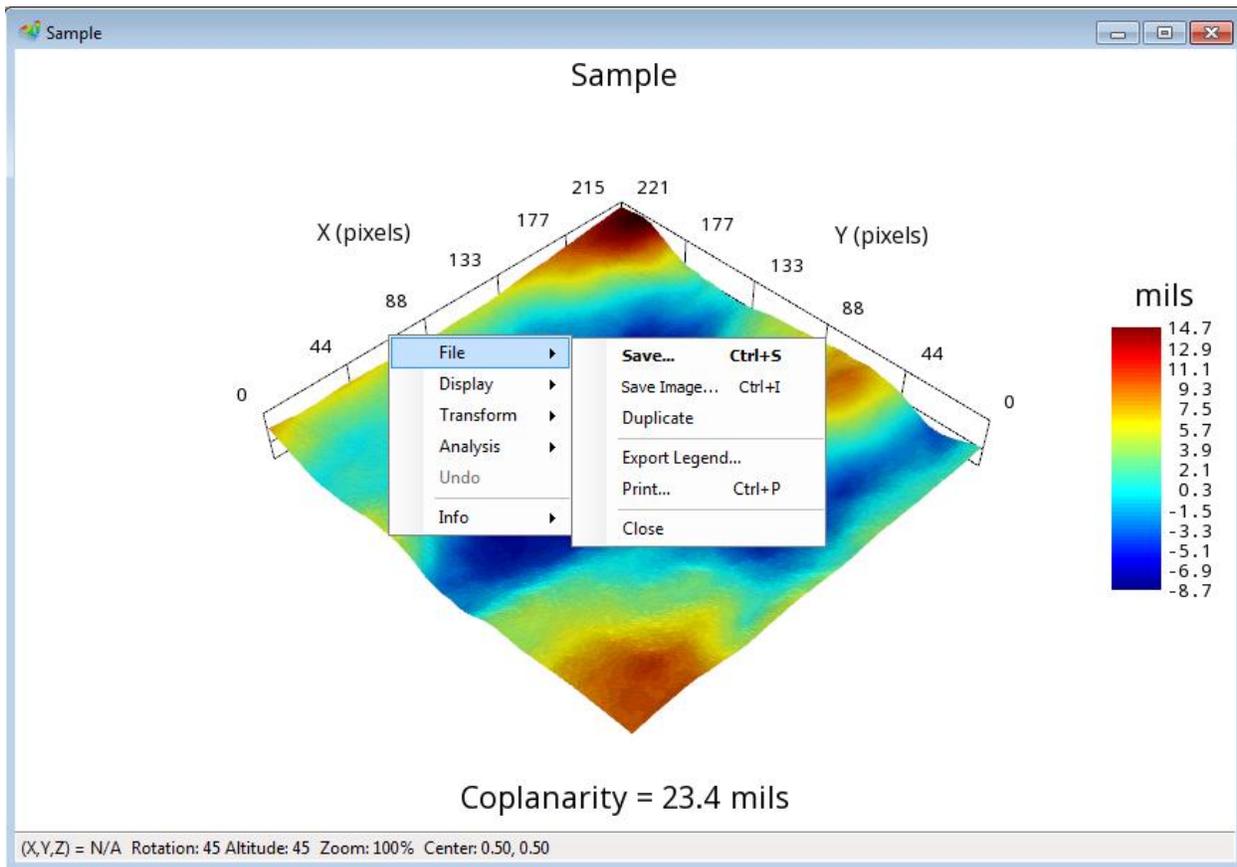
Figure 5.1 3D Surface Plot

5.1.3 Changing Viewpoint

The viewpoint of a 3D graph can be set using four different approaches:

- **Use Latest 3D View** box in the options window (**Section 4.2**)
- **Rotate** and **Pan** operations (**Section 5.1.2**)
- **Copy View** and **Paste View** in the 3D display command list (**Section 5.1.4**)
- The display **Configuration** window (**Section 5.1.5**)

5.1.4 Graph Command List

Right-clicking on the display window will show the same command list available on the tabbed *.akx_disp window. See **Section 2.4**.
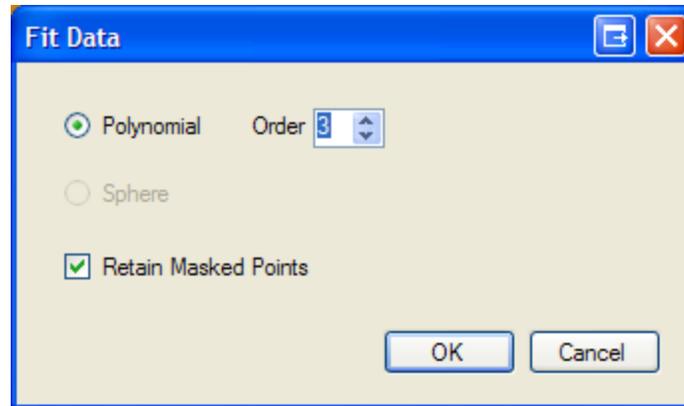
Figure 5.2 Fit Data Dialog

5.1.5 *Display Configuration Window*

The display configuration window (**Figure 5.3**) gives the user access to a very flexible system for customizing the graph display format. The custom format can be saved and re-used, and set as the default format for all 3D plots. To display the configuration window, right-click inside the graph window and select **Configure…**.

In the configuration window, to load a previously saved display configuration, choose **File→Open…** (**Ctrl+O**). To save the current display configuration, choose **File→Save….** (**Ctrl+S**).

> **Note:** The display configuration file (*.akx_3Dconfig) loaded from the display properties window is applied to the current display window (**Figure 5.1**). Configuration files loaded from the Options window (see **Section 4.2**, **Figure 4.1**) will be applied to all newly created display windows.
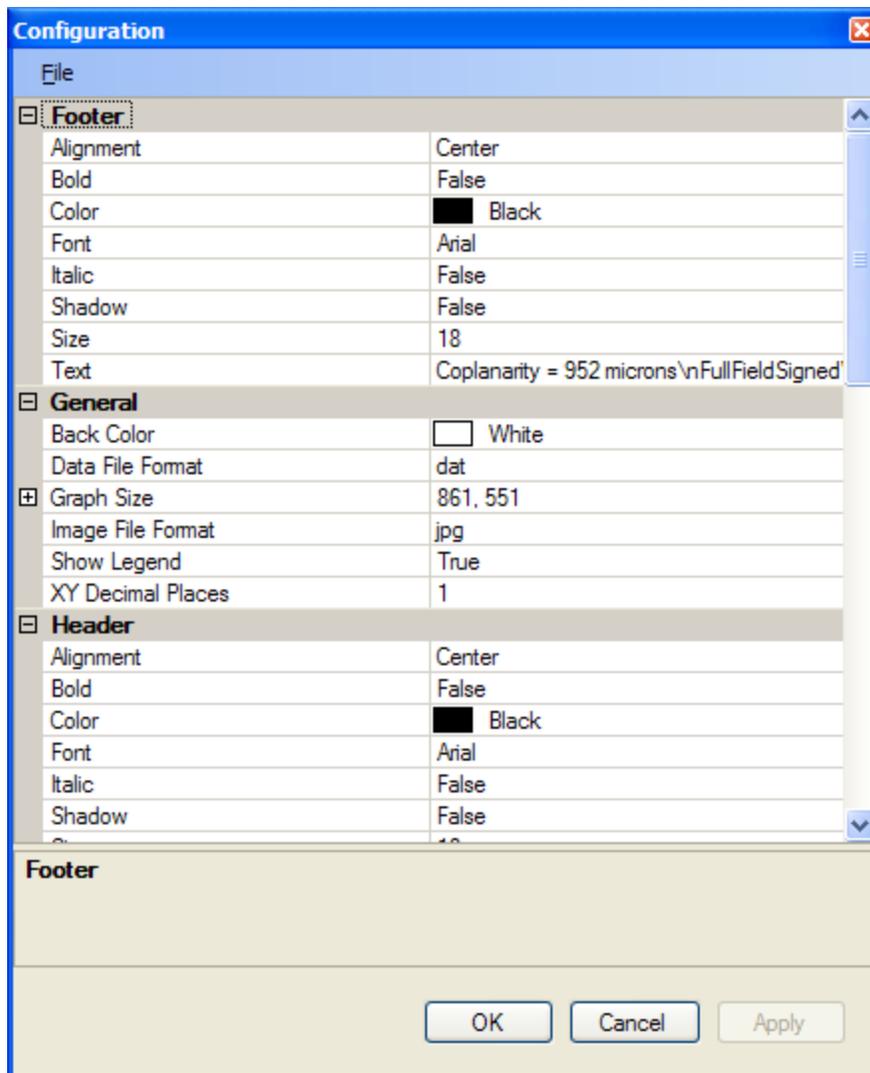
Figure 5.3 Display Configuration Window

5.2 Graphical Output – 3D Contour Plot

To display the 3D Contour plot after analysis, check the box next to **ColorContour** on the **Graphs** list in the options window. Most of the contour plot commands and features are identical to those described in **Section 5.1** (**Figure 5.4**).
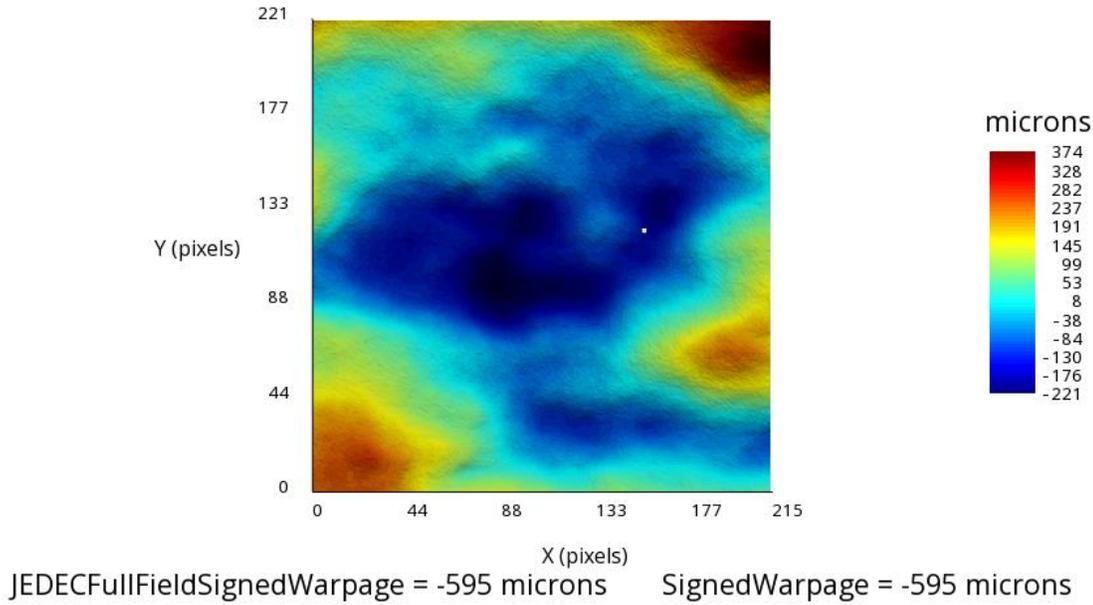
Figure 5.4 Contour Plot

5.3   Graphical Output – Diagonal Plot

The diagonal plot (**Figure 5.5**) represents two cross-sections of the surface along diagonal lines connecting the corners. To display the 2D diagonal plot after analysis, check the box next to **Diagonals** on the **Graphs** list in the options window. If it is not checked, the 2D diagonal plot window can also be opened by right-clicking on the 3D display window and selecting **Plot→Diagonals**. The caption of the 2D display window can be renamed by right-clicking on its title bar and selecting **Rename Window…**.
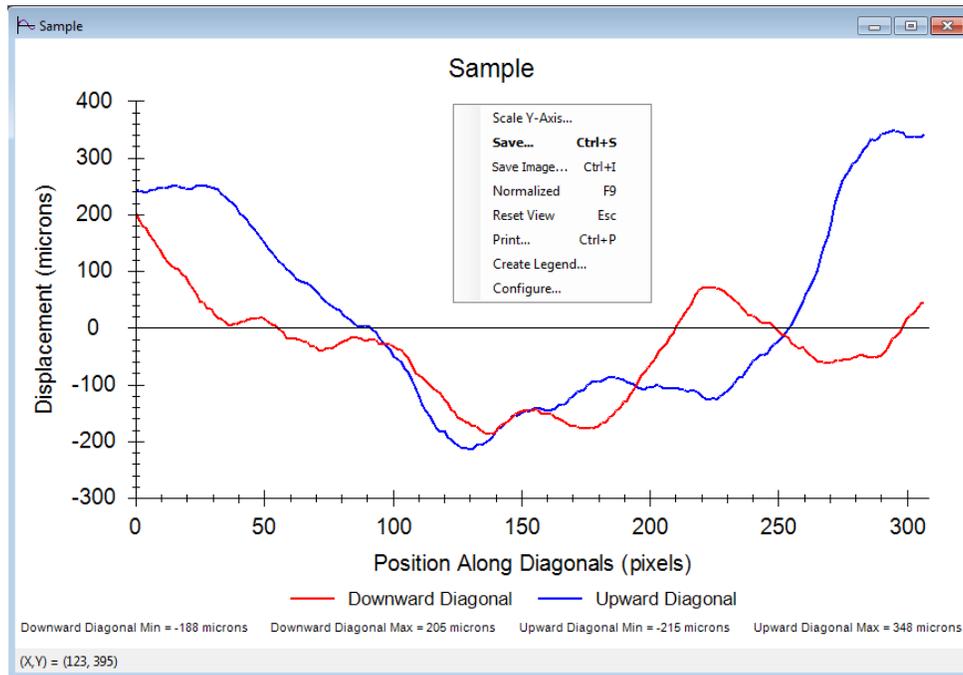
Figure 5.5 Diagonal Plot

5.3.1 Display Command List

Right-click inside the display window to show the command list.

Scale Y-Axis…   Displays a window where the minimum and maximum values of the Y axis may be modified. Defaults are the min and max values of the data plus a software determined buffer.

Save…   Exports the data in numerical format (**Section 5.5**)

Save Image…   Allows display window to be saved in graphical format (*_dia.bmp or *_dia.jpg).

Normalized   Causes all diagonal plots to be displayed with the endpoints for each diagonal set to zero.

Reset View   Resets the graph view after it has been zoomed.

Print…   Allows display window to be printed to any available system printer.

Create Legend…   Allows the legend to be saved as a separate picture file for reporting purposes.

Configure…   The 2D display properties window is very similar to the 3D version described in **Section 5.1.5**.

5.4 Graphical Output – Chord Plot

In addition to the diagonal plot, four special chord options are defined as follows

- Vertical Edges (from top to bottom)
- Horizontal Edges (from left to right)
- Vertical Centerline (from top to bottom)
- Horizontal Centerline (from left to right)

They can be accessed by right-clicking on the 3D display window and selecting **Plot**. In more general cases, an arbitrary chord or chord set can be defined, where out-of-plane displacement data along any line(s) can be displayed. The following sub sections will describe how to draw a generic chord or chord set.

5.4.1 Creating a Chord

Right-click inside a phase image and select **Advanced→Chord→New Chord (Ctrl+K) or Analysis→Chord→New Chord (Ctrl+K)** on a displacement image. Using the mouse, draw a line across the phase or displacement image, holding down the left mouse button at the start point and releasing it at the end point.

Several preset chords can be added to the phase or displacement image using keyboard shortcuts.

- **Shift+T**: Top Edge
- **Shift+B**: Bottom Edge
- **Shift+L**: Left Edge

- **Shift+R**: Right Edge
- **Shift+D**: Downward diagonal (upper left to lower right corner)
- **Shift+U**: Upward diagonal (lower left to upper right corner)
- **Shift+H**: Horizontal centerline
- **Shift+V**: Vertical centerline

> **Note:** Preset chords can be removed by hitting the keyboard shortcut a second time.

5.4.2 Editing a Chord

To reposition the endpoints of a chord, click on the chord. Square white handles will appear on either end of the chord, which can be moved with the cursor.

> **Note:** Preset chords defined in **Section 5.4.1** cannot be selected or edited.

Right-click on a chord to show the chord command options list:

Reverse Direction	Reverses the direction of the data along the chord when plotted.
Align	Aligns the chord horizontally or vertically.
Plot	Plots the current chord in a new 2D display window.
Plot Set	Plots all chords appearing on the phase or displacement image (only available when more than one chord is shown on the image).
Delete	Deletes the selected chord.
Edit…	Allows the endpoint positions to be set to specific pixel values using text boxes. Also allows renaming of the chord.

5.4.3 Plotting a Chord

Right-click on the chord and choose **Plot** or **Plot Set**. Calculation is performed and a display window appears. All display commands available for Diagonal plots are applicable here, including exporting the chord displacement data in numerical form. See **Section 5.3**.

5.4.4 Using a Chord Set

One or more chords form a set, which can be saved, re-used, and plotted collectively. A set is started automatically when the first chord is drawn on the phase or displacement image. Additional chords added using **Advanced→Chord→New Chord** become part of this set.

A set can be saved by right-clicking on the phase image and choosing **Advanced→Chord→Save Set…** and a saved set can be loaded by choosing **Advanced→Chord→Load Set…**. A saved set has a filename ending in *.akx_chordset.

> **Note:** If a loaded chord set was generated from a larger phase or displacement image than the current one, only the chords with both ends falling within the current image in that set will be loaded.

All the chords in a set can be plotted on the same graph by right-clicking on any of the chords and selecting **Plot Set**.

A new set can be started by right-clicking on the phase image and choosing **Advanced→Chord→New Set (Ctrl+G) or Analysis→Chord→New Set (Ctrl+G)** on a displacement image. Up to 9 sets can be created for one image.

Multiple sets can be in memory at the same time. The sets are numbered 1 through 9, depending on the order in which they are created or loaded. A particular set can be displayed by typing Shift + its number on the keyboard or choosing **Advanced→Chord→Set** and selecting the desired set number.

5.4.5 Saving a Chord Image

After a chord or chord set is plotted, the graphical image can be saved by right-clicking on the 2D image and choosing **Save Image…**. The image may be saved either in BMP or JPG format with different suffixes as listed below:

Chord Type	File Suffix	File Extention
Diagonal	_dia	.png or .jpg
Horizontal Centerline	_hzc	.png or .jpg
Horizontal Edges	_hze	.png or .jpg
Vertical Centerline	_vtc	.png or .jpg
Vertical Edges	_vte	.png or .jpg
Arbitrary	_crd	.png or .jpg

5.5 Numerical Output

Numerical data from all display windows can be exported by right-clicking on the display window and selecting **Save…**. A standard **Save** window appears with three choices for the save format in the **Save as type** pull-down list at the bottom.

Akx_disp   Exports data in the Akrometrix akx_disp format

Dat files   Exports data in tab-delimited text format

Text files   Exports data in space-delimited text format

5.6   Gauge Output

Gauges can be selected in the **Gauges** list in the options window and are displayed at the bottom of 3D Surface, Contour or Chord plots where appropriate. Gauge definitions are available in **Akrometrix Optical Techniques and Analyses 101**.

6 Batch Processing

6.1 Batch Processing

Batch processing allows most of the one-off functionality in Surface Analysis to be performed on multiple data files with no user interaction. This functionality is very helpful when performing large experiments with multiple ROIs and/or multiple temperature points. There are five batch functions available:

- Batch Analyze
- Batch Mask
- Batch Rotate
- Batch Crop
- Edit XY Orientation

To access the batch processing functions, select the **Tools→Batch Processing…** menu item. This will open a batch processing window (**Figure 6.1**). Five tabbed screens appear for the five batch processing functions. Common menu items for these functions appear on a menu bar above the tabs.

> **Note:** Multiple batch processing windows can be opened to process different data or process the same data with different settings.
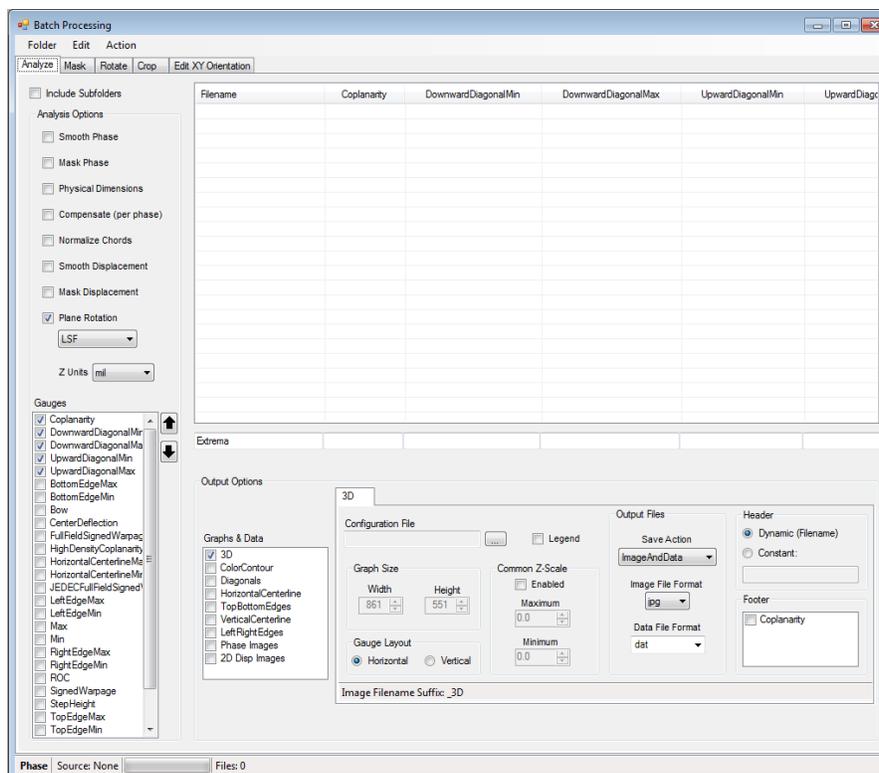

Figure 6.1 Batch Processing Screen

Folder → Select…	Identifies the folder of *.akx_phase or *.akx_disp files on which the batch processing functions will be applied
Edit → File Type	Switches between analyzing phase images (*.akx_phase) and displacement data (*.akx_disp).
Edit → Refresh Source Folder (F5)	Allows the user to update the file count since the folder was originally selected.
Edit → Save Settings	Saves settings of all four batch functions to the User Configuration.xml file.
Edit → Load Settings	Loads settings from the User Configuration.xml file.
Edit → Set From Preferences	Loads settings defined in the Options window.
Action	Initiates the batch processing function, depending on which tabbed screen is showing.

6.2   Batch Analysis

The batch analysis function opens the image or displacement files in the selected folder, analyzes the data, and saves the results in graphical and/or numerical format. This is useful, for example, for analyzing all the warpage measurements taken during a temperature profile and plotting the results on the same scale. The batch analysis tab window shows the conditions to be applied during analysis and display, while the action is initiated using the **Action** menu item.

6.2.1   Using Batch Analysis

The key steps in using batch analysis are:

1. Select a folder to be analyzed (**Folder→Select…** menu item)

2. Select analysis options (**Section 6.2.3**)

3. Analyze the measurement data (**Action→Analyze** menu item)

4. Select output options (**Section 6.2.4**)

5. Create and save results (**Action→Generate Output** menu item)

After Step 3, a table of summary results appears, with one row for each measurement analyzed. The extreme values of each parameter in the table are shown below, which will provide the default scale for plotting results in the final step. The user can open any of the phase or displacement images listed in the table by right-clicking on a row and clicking **Open**.

6.2.2   Using Batch Analysis to Create Relative Plots

In order to set one of the images in the selected folder as reference image (**Section 4.4**), double-click on one file in the summary table and confirm that all analysis should

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use its 3D data as reference. The program will then save all graphs and numeric data as relative to this reference surface. All other steps remain the same.

6.2.3 Analysis Options

Note: Phase operations listed below will not be available if the file type is set to *.akx_disp.

Include Subfolders	Applies the batch processing function to subfolders within the selected folder in addition to the original folder.
Smooth Phase	Applies a smoothing function once to phase images before analysis (see **Section 3.5**)
Mask Phase	Applies a previously-created mask to phase images before analysis (see **Section 3.2**). A Load Mask window appears when the box is checked.
Physical Dimensions	Assigns a specific physical size to each data (see **Section 2.3.4**).
Compensate	Enables a compensation for the non-planar surface of the grating.
Normalize Chords	Causes all chord plots to be displayed with the endpoints set to zero after analysis (see **Section 5.3.1**).
Smooth Displacement	Applies a smoothing function to the surface data. See Optical Techniques and Analyses 101 for an explanation of this smoothing function.
Mask Displacement	Applies a previously-created mask to displacement files before analysis (see **Section 3.2**). A Load Mask window appears when the box is checked.
Plane Rotation	Selects the reference plane rotation option to be used during analysis (see **Section 4.3**). Can be turned off to use the grating tilt as reference.
Z Units	Selects English or metric units for out-of-plane displacement results.
Gauges	Selects which gauges (numerical values quantifying flatness) are displayed at the bottom of the graphical display windows. A gauge on the list may be highlighted by clicking on it once. Checking a box means that gauge will be displayed. The up and down arrows move the highlighted gauge up and down the list, changing the order in which gauges are displayed.

6.2.4 Output Options

Graphs & Data Selects which graph formats (see **Sections 5.1** through **5.4**) are saved after analysis. A graph on the list may be highlighted by clicking on it once. Checking a box means that graph will be saved. The up and down arrows move the highlighted graph up and down the list, changing the order in which graphs are displayed.

Configuration File Allows the user to load a non-default display format for saved graphs. The 3D configuration file has an extension of *.akx_3Dconfig and is used for 3D plots (3D and Contour). See **Section 5.1**. The 2D configuration file has an extension of *.akx_2Dconfig file and is used for 2D Chord plots. See **Section 5.3**.

Graph Size Sets the initial size for all display windows to be saved.

Gauge Layout Gauge values listed at the bottom of the 3D or 2D display window may be aligned horizontally or vertically.

Legend Selects if a legend is displayed on each graph.

Common Z-Scale When checked, causes all 3D or 2D plots generated by batch analysis to use the same vertical scale. Default min and max values are determined by the extremes in the combined data sets, but may be edited using the text box. When unchecked, each image is plotted on a scale set by its own data set.

Output Files Data can be saved in graphical and/or numerical format. The user can select the image file format and data file format to be saved as well.

Header Allows the graph to use a dynamic header created from the file name or a constant header typed by the user.

Footer Allows user to choose the footer from the available items in the list.

6.3 Batch Masking

The Batch Mask feature allows the user to automate mask-burning for multiple image files contained in a specified folder (**Figure 6.2**).
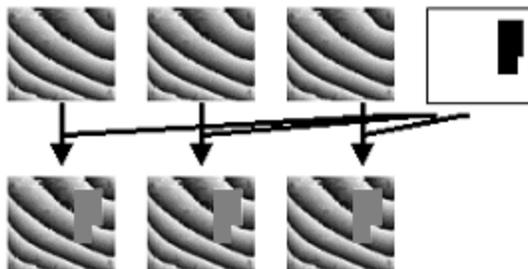
Figure 6.2 Batch Burn

6.3.1 Using Batch Masking

This function uses a mask file, as described in **Section 3.2**. The mask file must be created and saved prior to the batch masking operation. The batch masking screen is shown in **Figure 6.3**.
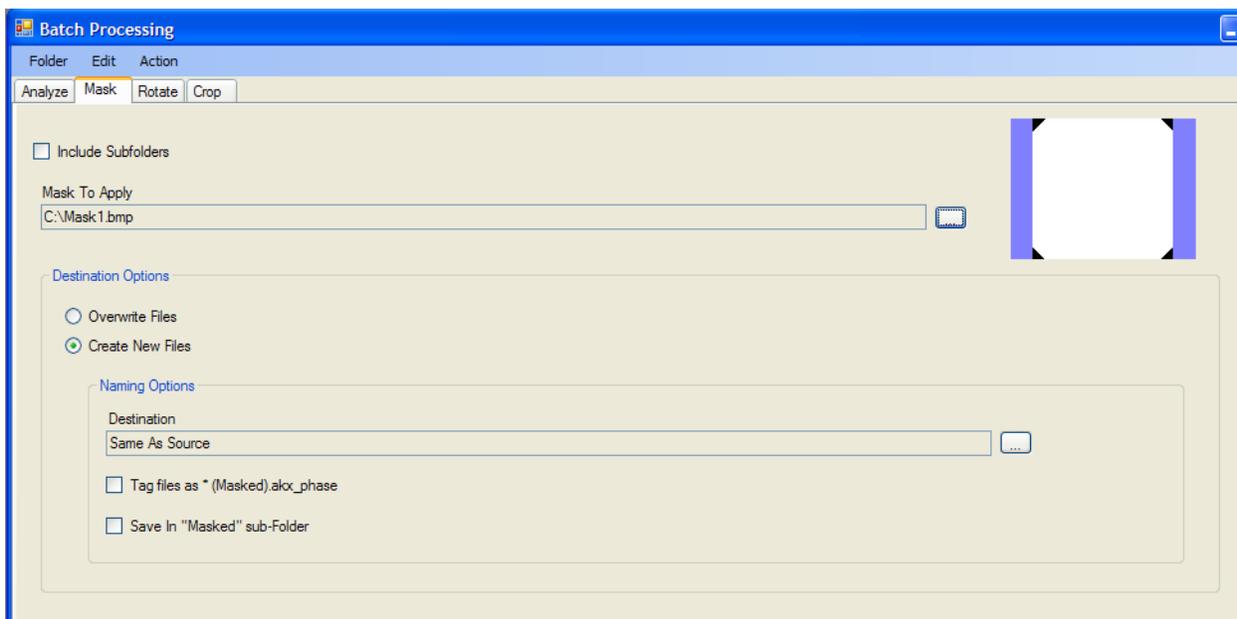

Figure 6.3 Batch Masking Screen

The key steps in using batch masking are:

1. Select a folder containing data files to be masked (**Folder→Select…** menu item)

2. Select a mask (see **Section 3.2** to create and save masks) to be applied.

3. Select destination options (**Section 6.3.3**)

4. Create and save results (**Action→Mask** menu item)

6.3.2 Source Directory

Include Subfolders   Applies the batch processing function to subfolders within the selected folder in addition to the original folder.

Mask to Apply   Click on [...] button on the right to browse for a mask file.

6.3.3 Destination and New Naming Options

Overwrite Files   Causes masked files to overwrite original data files.

Create New Files   Saves masked images to a new destination and/or with a new name. The original data files are unchanged.

Destination   Selects the folder to which the masked images will be saved. Click on the [...] button to the right to browse for the destination folder.

Tag files as *(Masked).akx_phase (disp)   Appends the string "(Masked)" to the end of the original filename for the masked file.

Save In "Masked" sub-Folder   A single new folder named "Masked" will be created in the destination folder and all masked files will be saved in this subfolder.

6.4   Batch Rotation

6.4.1 Using Batch Rotation

Phase image rotation is described in **Section 3.6** and also applies to displacement files. This batch function rotates all the images in the selected folder according to the options set in the batch rotation tab window. The batch rotation screen is shown in **Figure 6.4**.

Note: Rotation angle options are fixed at multiples of 90 degrees when working with displacement files due to artifacts arising from arbitrary angles.
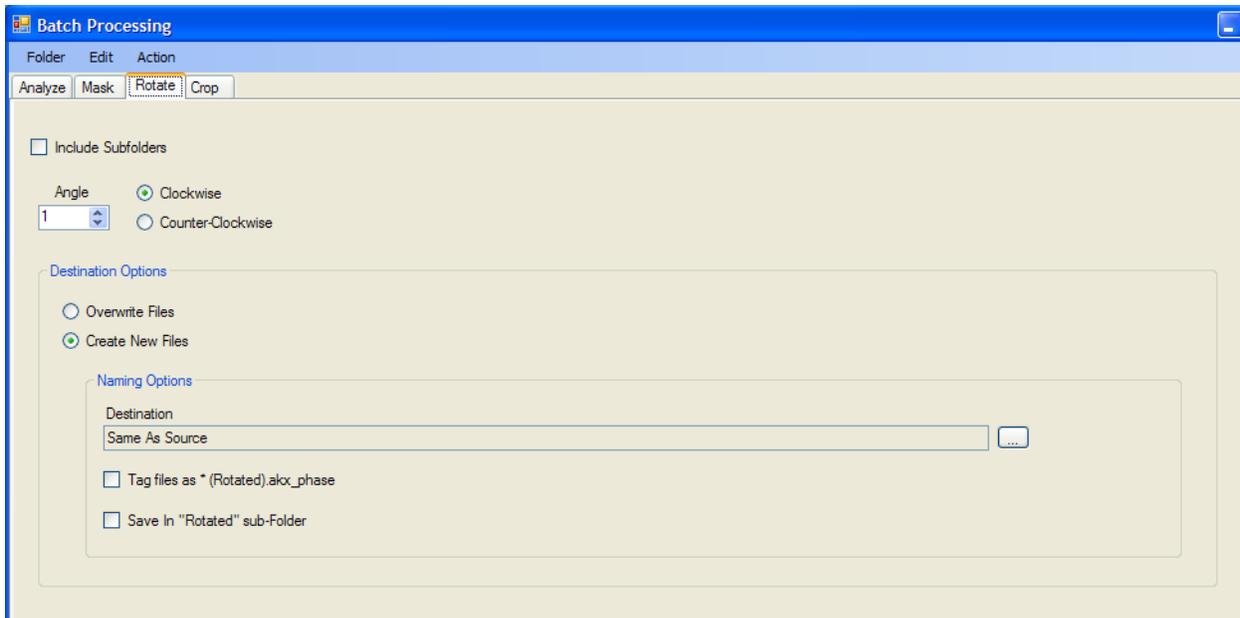
Figure 6.4 Batch Rotation Screen

The key steps in using batch rotation are:

1. Select a folder containing images to be rotated (**Folder→Select…** menu item)

2. Select rotation options (see **Section 6.4.2**)

3. Select destination options (see **Section 6.4.3**)

4. Create and save results (**Action→Rotate** menu item)

6.4.2 Rotation Options

Include Subfolders	Applies the batch processing function to subfolders within the selected folder in addition to the original folder.
Angle	Enter number of degrees to rotate the image clockwise or counterclockwise.

6.4.3 Destination and New Naming Options

Overwrite Files	Causes rotated data to overwrite original data files.
Create New Files	Saves rotated data to a new destination and/or with a new name. The original data files are unchanged.
Destination	Selects the folder to which the rotated data will be saved. Click on the […] button to the right to browse for the destination folder.

Tag files as *(Rotated).akx_phase (disp)	Appends the string "(Rotated)" to the end of the original filename for the rotated file.
Save In "Rotated" sub-Folder	A single new folder named "Rotated" will be created in the destination folder and all rotated files will be saved in this subfolder.

6.5   Batch Cropping

Batch cropping allows the user to extract multiple regions of interest from multiple phase or diplacement images. For example, a measurement test which produces measurement data at three temperature points, with each phase or displacement image containing four regions of interest (3 × 4 = 12 measurements), can be easily analyzed in a two step procedure: batch cropping, followed by batch analysis (**Figure 6.5**).
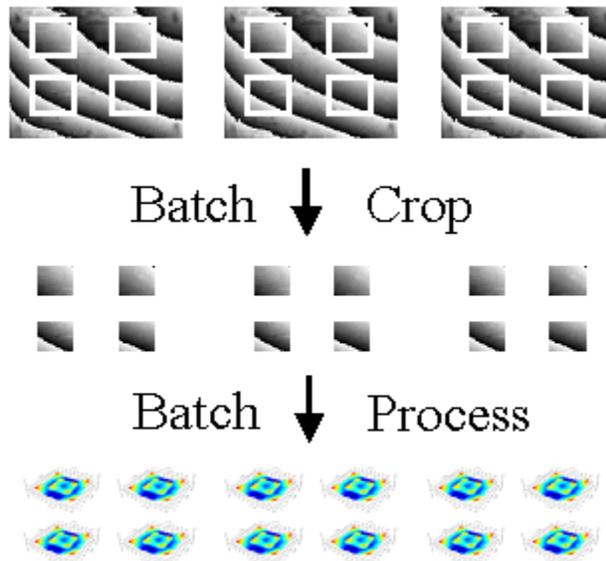

Figure 6.5 Batch Cropping and Analysis

6.5.1   Using Batch Cropping

Batch cropping requires that the user has created a partition file as described in **Section 3.4**. This must be created and saved prior to the batch cropping operation. The partition may contain only one domain, in which it becomes equivalent to the crop function (**Section 3.3**). Each domain from all the phase or displacement images in the selected folder are permanently saved as new, independent files, organized according to the **Destination Options** on the batch crop tab. The resulting image files can then be batch processed in a second step to complete the analysis. The batch cropping screen is shown in **Figure 6.6**.
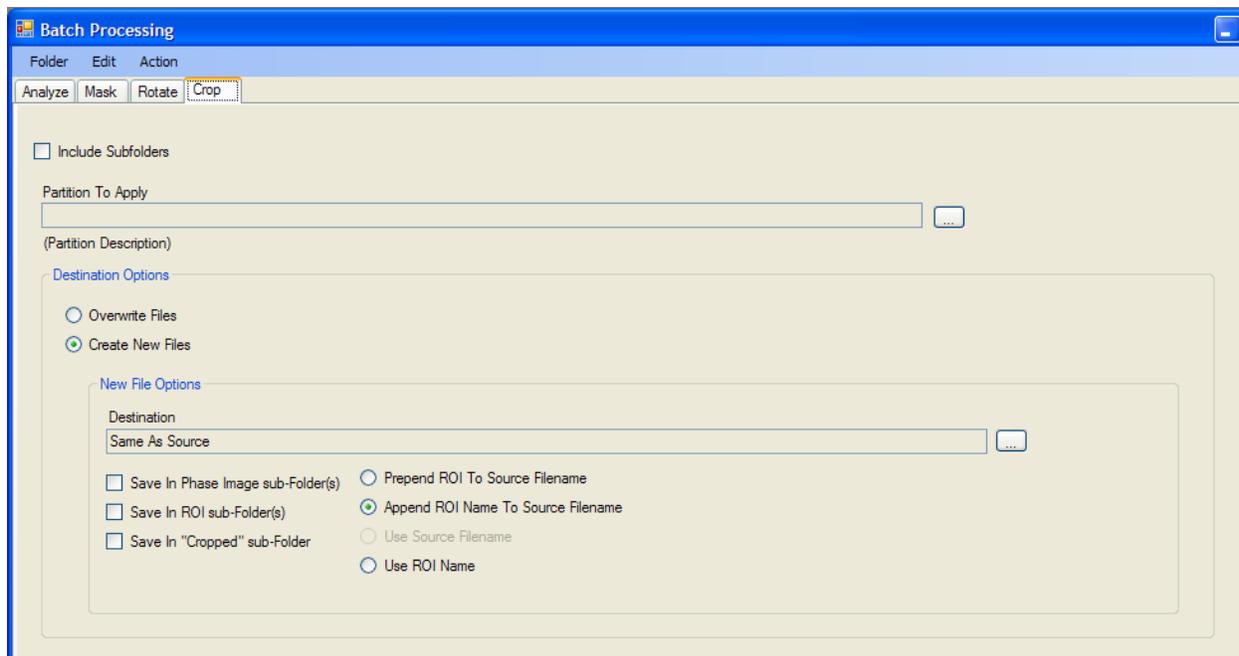
Figure 6.6 Batch Cropping Screen

The key steps in using batch cropping are:

1. Select a folder containing images to be cropped (**Folder➔Select…** menu item)

2. Select a partition (see **Section 3.4** to create and save partitions) to be applied

3. Select destination options (**Section 6.5.3**)

4. Create and save results (**Action➔Crop** menu item)

6.5.2 Source Directory

Include Subfolders — Applies the batch processing function to subfolders within the selected folder in addition to the original folder.

Partition to Apply — Click on the [...] button to browse for a partition file.

6.5.3 Destination and New File Options

Overwrite Files — Causes cropped files to overwrite original data files. This should only be used if the partition contains only one domain.

Create New Files — Saves cropped data to a new destination and/or with a new name. The original data files are unchanged.

Destination — Selects the folder to which the cropped data will be saved.

Click on the [...] button to the right to browse for a destination folder.

Save In Source Filename sub-Folder(s)	A new folder will be created for each file in the source folder and all cropped images derived from each file will be collected in this subfolder.
Save In ROI sub-Folder(s)	A new folder will be created for each ROI in the partition and all cropped data derived from this ROI for all files will be collected in this subfolder.
Save In "Cropped" sub-Folder	A single new folder named "Cropped" will be created in the destination folder and all cropped files will be collected in this subfolder.
Prepend ROI To Source Filename	Cropped data will be uniquely named with a combination of ROI name and original data file name, the ROI name coming first.
Append ROI Name to Source Filename	Cropped data will be uniquely named with a combination of ROI name and original data file name, the data file name coming first.
Use Source Filename	Cropped data will be named with the original filename. This option is disabled if the destination folder is the same as the source folder. In addition, this should only be used if the partition contains only one domain.
Use ROI Name	Cropped data will be named with the ROI name from the partition file. This can create a problem if there are multiple files in the source folder.

6.6   Batch Edit XY Orientation

For purposes of orienting and registering surface data in Interface Analysis, a new tab has been added to the Batch Processing window. This tab allows multiple data files to be tagged with Pin 1 location and Measured Side information.
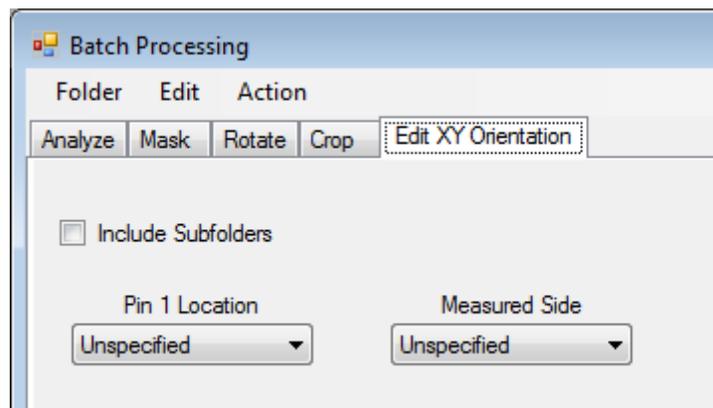

Figure 6.7 Edit XY Orientation Screen

The key steps in using batch cropping are:

1. Select a folder containing data to be edited (**Folder→Select…** menu item)

2. Select a Pin 1 Location and Measured Side to be applied.

3. Perform the Batch Edit operation (**Action→Edit XY Orientation** menu item)

7 Troubleshooting

As with any measurement system software, the **Surface Analysis** program has its limitations. These limitations exist mainly because the analysis software is sensitive to patterns it was not designed to interpret, which is typical of any software using pattern recognition.

7.1 Failure to Correctly Interpret the Phase Image

After acquiring a phase image, a procedure called "unwrapping" is applied to the phase data (See **Akrometrix Optical Techniques and Analyses 101**). The unwrapping process removes the 2π discontinuity by examining the nearest neighbors' pixel phase values starting at the center pixel. With the sequential dependent nature of the unwrapping process, the height at all the pixels in an entire image can be related to one origin pixel. Conversion from the unwrapped phase image to vertical displacement is simply multiplication of each pixel phase value by the calibration factor.

Problems arise when an error occurs at one point in the unwrapping process, either by incorrectly identifying a phase discontinuity or missing a discontinuity that has occurred. Once a problem occurs, all pixels downstream of the error point are offset from their correct value by the same increment of one full fringe cycle.

7.1.1 Symptoms

Unwrapping errors are propagated downstream of the error point. These errors appear in the 3D surface plots as ridges, troughs, or plateaus in the displacement surface. Two examples of such cases are shown in **Figure 7.1**, where the error originates from a step condition on the sample surface.

7.1.2 Cause

Unwrapping errors can occur at steps (i.e. vertical discontinuities in the sample surface). A step may be defined as a region where fringes are so closely spaced that they cannot be resolved by the video camera due to a rapid height change on the sample surface. Typically, fringes less than 5 pixels in width cannot be resolved. The **Surface Analysis** program is unable to determine the height at a step larger than approximately half a fringe height since the relative order of the fringes on the two surfaces cannot be determined. Unwrapping errors can also occur in regions where there is poor fringe information or at the transition from such regions to regions of good phase information; including holes, shadows, pieces of tape, etc.

7.1.3 Solutions

1. The simplest solution is to exclude error-causing features from the ROI. Adjust the position and size of the ROI to exclude these features.

2. Use the filtering option to help eliminate some unwrapping errors. Filtering smoothes the phase image before unwrapping. Because filtering can smear out

fine detail in the displacement surface, it should be applied to the analysis only to the extent necessary to eliminate extended phase unwrapping defects.

3. Apply a mask to the data analysis and eliminate unwrapping errors by excluding problematic areas from being analyzed. Follow the directions given in **Section 3.2**.
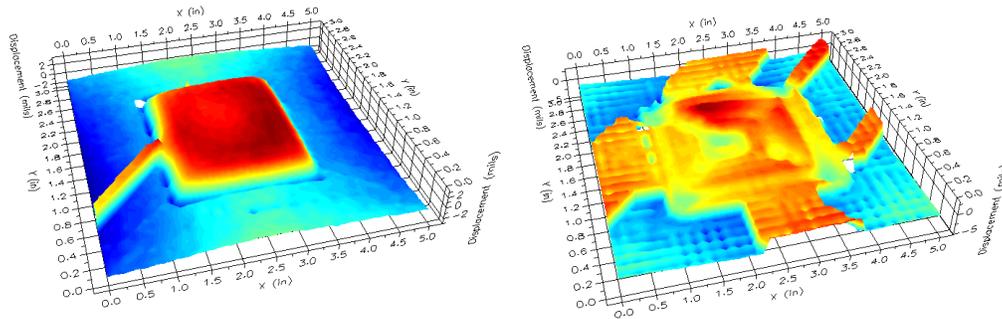

Figure 7.1 Surface Plots with Unwrapping Errors

Appendix A Miscellaneous Information

A.1   File Formats

Akrometrix Surface Analysis loads and saves data with the *.akx_* extension. For a more detailed breakdown of **Surface Analysis** specific formats please see the table below. Image export formats include .bmp and .jpg with varying filename postfixes to further denote their origins.

Extension	Contents
*.akx_phase	A single phase image with associated metadata. May optionally contain cropped versions of supporting data: intensity, and/or reference displacement
*.akx_disp	A single displacement data matrix with associated metadata. May optionally contain cropped versions of supporting data: phase, intensity, and/or reference displacement
*.akx_partition	Partition file (standard XML format)
*.akx_3Dconfig	Configuration file for 3D plot
*.akx_2Dconfig	Configuration file for 2D plot
*.akx_chordset	Chord set (standard XML format)

A.2   Keyboard Shortcuts

Shortcut	Command	Action
Main Window Shortcuts		
Ctrl+O	**File→Open**	Open a new *.akx_phase or *akx_disp file
Alt+F+X	**File→Exit**	Exit the Surface Analysis program
F1	**Help→User Manual**	Open the User Manual
Phase Window Shortcuts		
Ctrl+C	**Copy (Mask or Partition Region)**	Copy Mask or Partition Region
Ctrl+V	**Paste (Mask or Partition Region)**	Paste Mask or Partition Region
1-4	**Advanced→View→Intensity 1-4**	Show Intensity Images 1-4
P	**Advanced→View→Phase Image**	Show Phase Image
S	**Advanced→View→Surface Image**	Show Surface Image

Ctrl+			Zoom in to phase image
Ctrl-			Zoom out of phase image
Ctrl+M	**Advanced➔Mask➔New**		Create a new mask
Ctrl+R	**Advanced➔Partition➔New**		Create a new partition
Ctrl+K	**Advanced➔Chord➔New Chord**		Create a new chord
Ctrl+G	**Advanced➔Chord➔New Set**		Create a new chord set
Shift+1-9	**Advanced➔Chord➔1-9**		Show Chord Sets 1-9
Shift+T		Create a chord along top edge of the image	
Shift+B		Create a chord along bottom edge of the image	
Shift+L		Create a chord along left edge of the image	
Shift+R		Create a chord along right edge of the image	
Shift+D		Create a chord along the downward diagonal line (upper left to lower right corner) of the image	
Shift+U		Create a chord along the upward diagonal line (lower left to upper right corner) of the image	
Shift+H		Create a chord along the horizontal centerline of the image	
Shift+V		Create a chord along the vertical centerline of the image	
3D Window Shortcuts			
Ctrl+C	**Copy View**		Copies the current display window viewing angle and magnification to the Clipboard.
Ctrl+V	**Paste View**		Applies the viewing angle and magnification saved to the Clipboard to the current display window (only appears after **Copy View** is used).
Batch Processing Window Shortcuts			
F5	**Edit➔Refresh Source Folder**		Allows the user to update the list of source files since the folder was originally selected