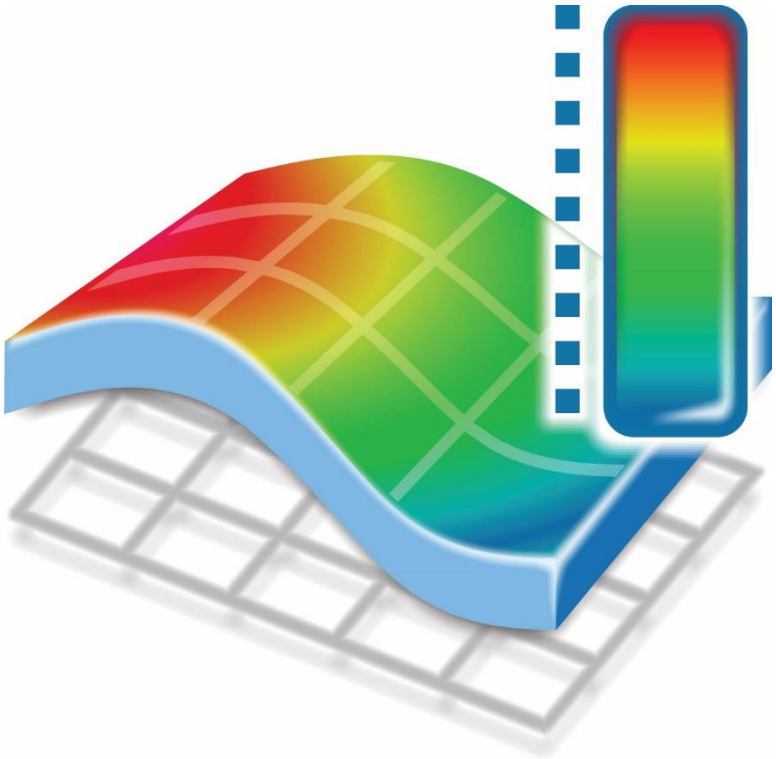
akrometrix

Surface Analysis



User Manual

Akrometrix Proprietary Information

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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. This manual is intended for use with Akrometrix Studio 8.0.

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 *Smoothing*, *Partitioning* 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, Batch Processing allows 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

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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 *.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 or *.akx_disp 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 or *akx_disp file was double-clicked, the phase or displacement image contained in the selected 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 3**) 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.

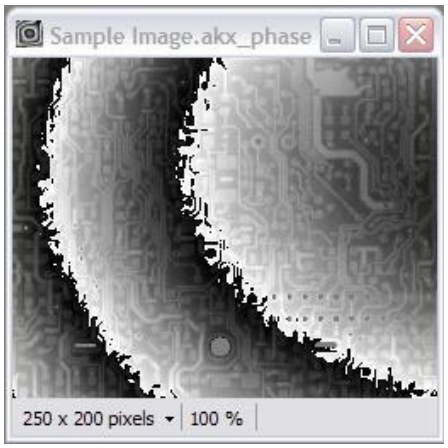

Figure 2.1 Phase Image 100% Magnification

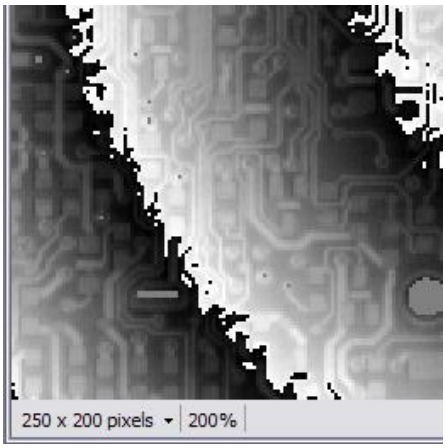

Figure 2.2 Phase Image 200% Magnification

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**).

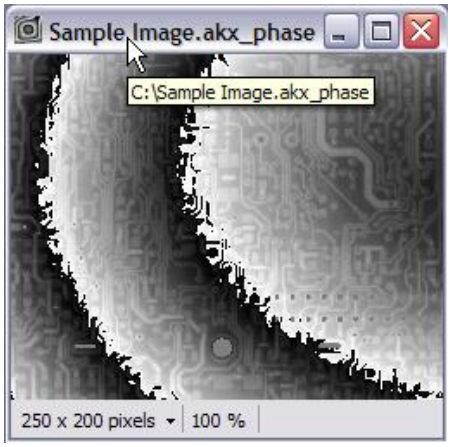

Figure 2.3 Data Information Shown on the Phase Image

2.3.3 Measurement Information

In addition to the data information described in **Section 2.3.2**, the measurement metadata can be displayed by right-clicking on the image and choosing **Properties…** (**Figure 2.4**). For a displacement image, the menu structure is **Info→Properties…**. In the

Properties window, information about the intensity images, phase image, and grating can be found, along with many other test parameters.

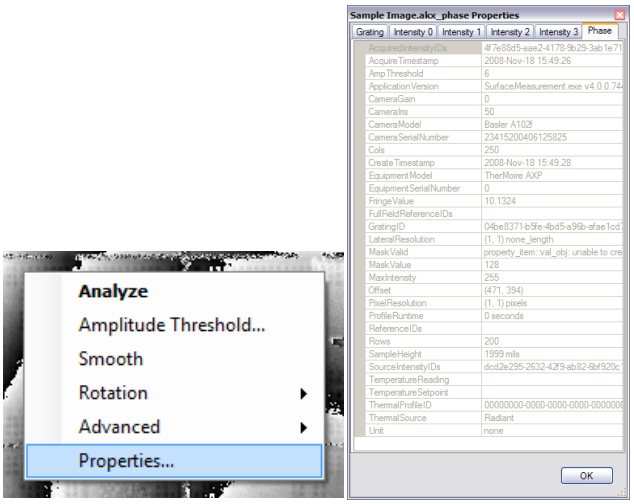

Figure 2.4 Displaying Measurement Metadata

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.

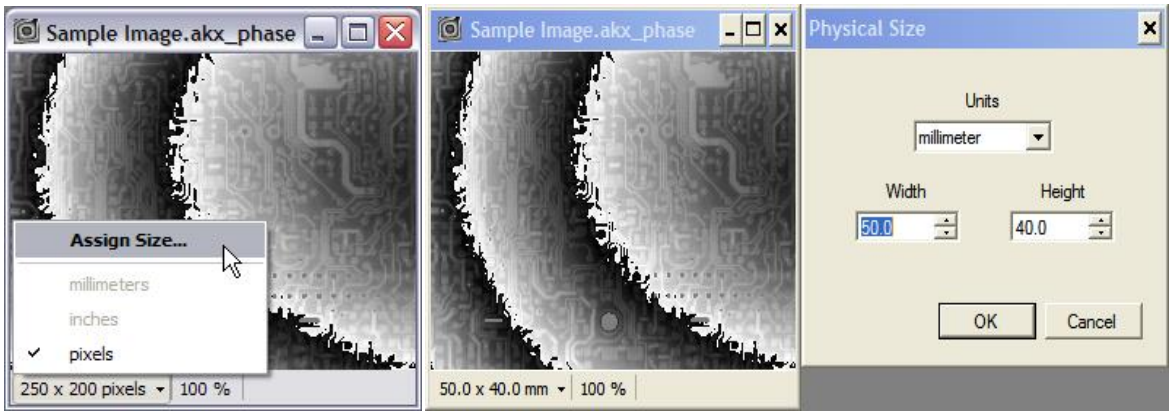

Figure 2.5 Assigning Physical Size for a Phase Image

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**.

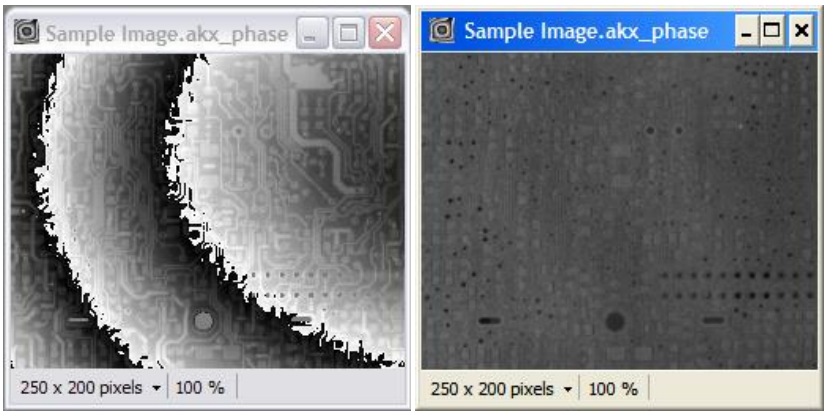

Figure 2.6 Phase and Surface Image Views

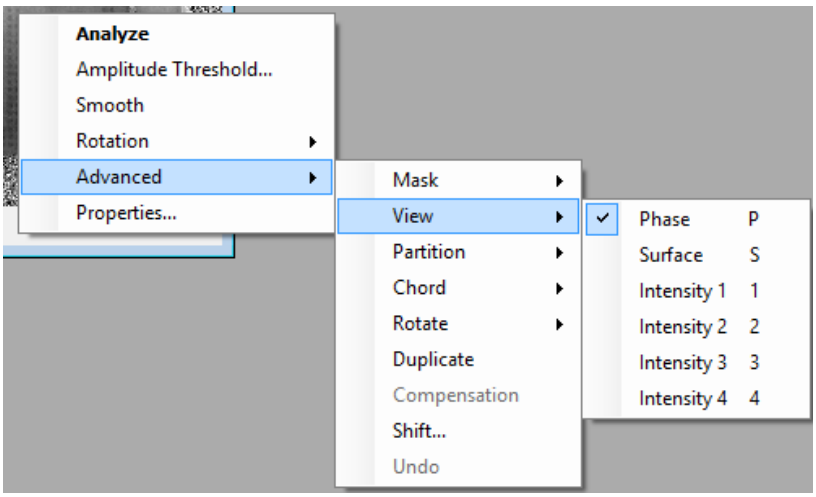

Figure 2.7 Menu Command for Showing Surface or Intensity Images

2.4 Working with Displacement Data

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

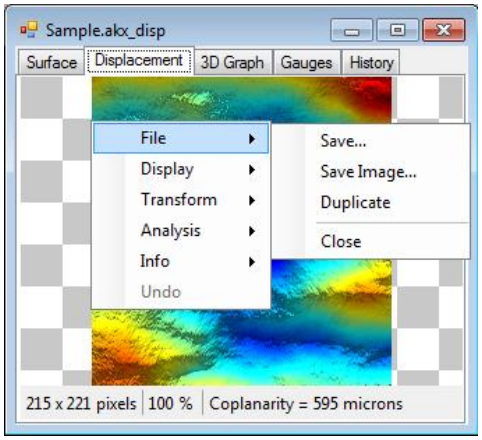

Figure 2.8 Loaded Displacement Window

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**.

Smooth	Allows the user to apply either a default smoothing function to the 3D data or a custom one. The default smooth 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 3.7**.
Shift…	Allows the data to be shifted in its plane as in **Section 3.8**.

2.4.4 Analysis

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 as a gauge in batch processing.

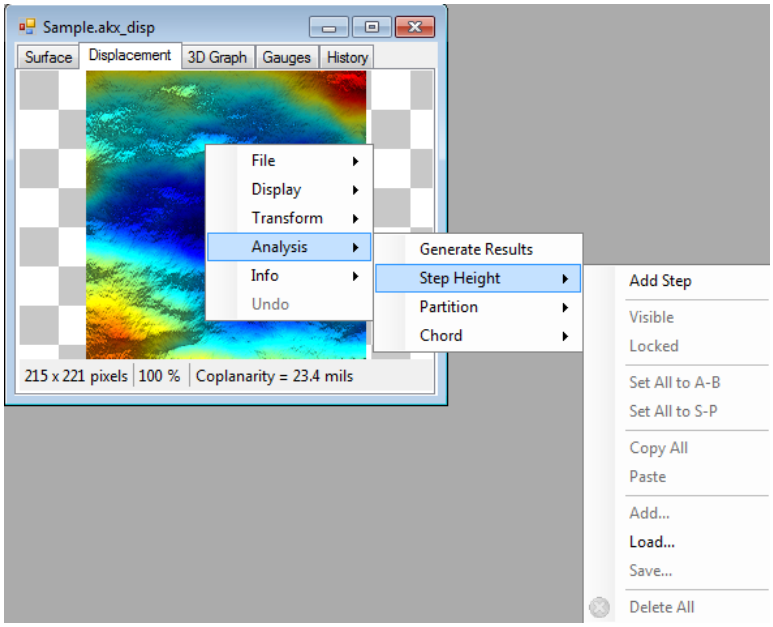

Figure 2.9 Step Height Menu

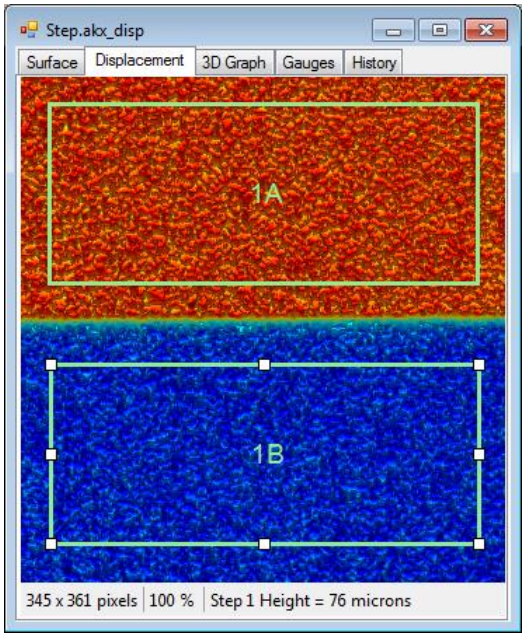

Figure 2.10 Step Height Calculation A>B

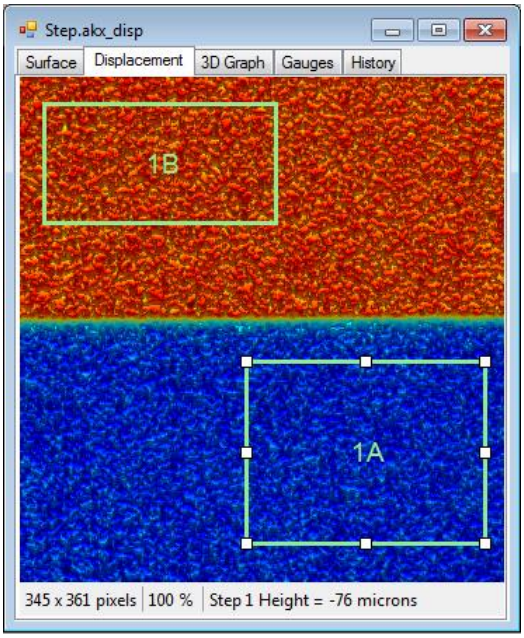

Figure 2.11 Step Height Calculation A<B

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.

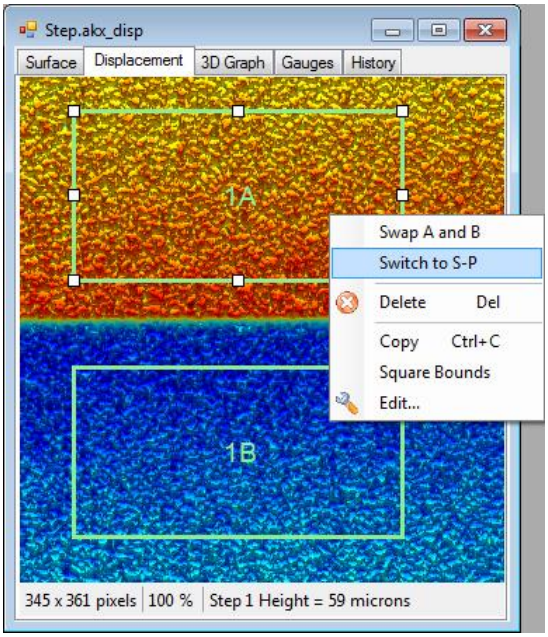

Figure 2.12 A-B Mode

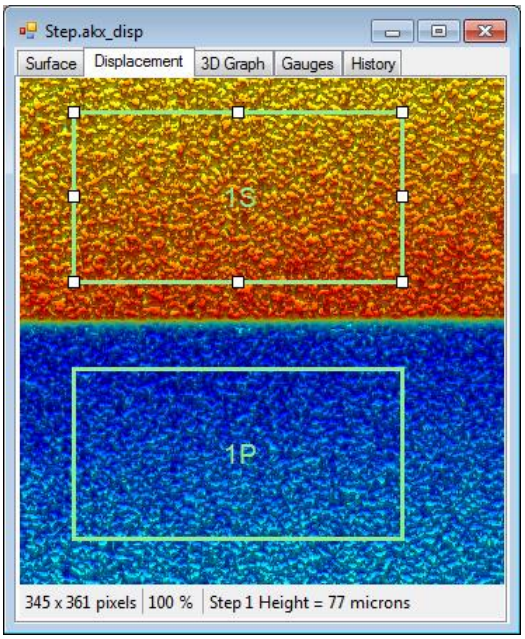

Figure 2.13 S-P Mode

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 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 or Partition function (**Figure 3.1**).

After activating the desired function (Mask or Partition), click and drag the mouse cursor from one corner of the desired ROI to the other. 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. Size can be defined in either absolute (pixel) terms or fractional terms (relative to the phase image dimensions).

Figure 3.1 ROI Shape Selector

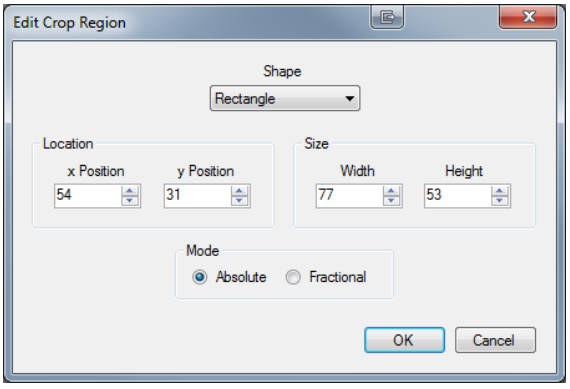

Figure 3.2 Edit ROI Region Size and Position

Other common functions for Masking 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.

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

Delete deletes the active ROI

Delete All deletes all ROIs within the current phase image window

Note: The ROI functions for Mask and Partition modes are 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.

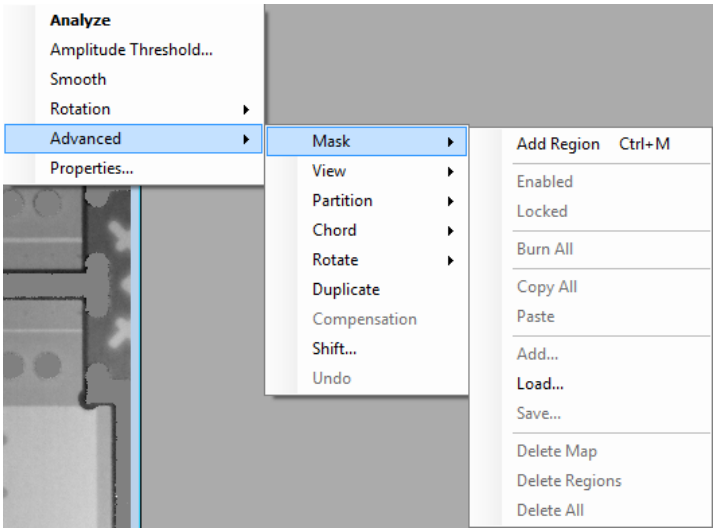

Figure 3.3 Mask Menu

3.2.1 Creating a Mask

A mask file can be either a binary graphical image (*.png) containing only black and white colors or a *.akx_mask file representing the location, shape, and size of the regions added during a mask operation. In the case of an image mask, 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 or *.png 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→Add Region** (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 (*.akx_mask or *.png) by right-clicking inside the phase image (but not inside an editable mask ROI) and choosing **Advanced→Mask→Save…**.
5. The mask 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→Enabled**. 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 analysis. When the masking function is disabled, all mask ROIs are hidden.
6. The mask can be locked by going to **Advanced→Mask→Locked**. This setting will prevent the user from interacting with any editable (red transparent) mask regions.

3.2.2 Loading and Editing a Mask

A previously created mask that was saved in the *.akx_mask, or *.png, 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. An image mask is shown in solid yellow color while a *.akx_mask file is shown as editable transparent red regions.

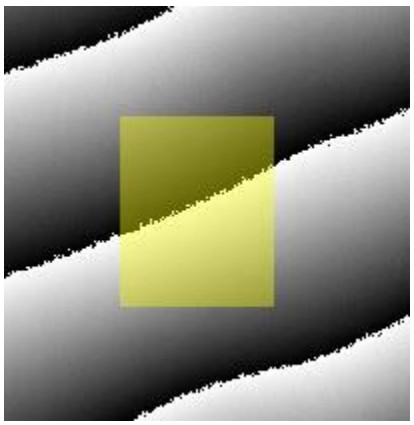

Figure 3.4 Loaded Image Mask in Yellow

A loaded image mask cannot be edited but can be turned on and off by toggling the **Advanced→Mask→Enable** function. To delete a loaded image mask, choose **Advanced→Mask→Delete Map**. To delete a loaded *.akx_mask mask, choose **Advanced→Mask→Delete Regions**. New mask ROIs may be added by right-clicking inside the phase image and choosing **Advanced→Mask→Add Region**.

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 *.akx_mask is loaded onto a phase image with different pixel dimensions than the one on which it was created, a dialog will appear, as shown and discussed below.

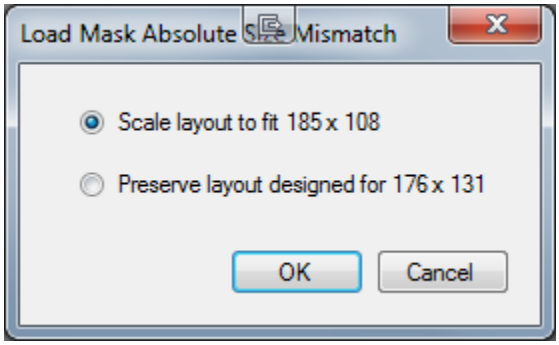

Figure 3.5 Abolute Size Mismatch Dialog

Scale layout will use the fractional values from the mask relative to the original phase image dimensions. Preserve layout will load the regions using the raw pixel dimensions and coordinates.

Note: If a *.png or *.bmp is loaded onto a phase image with different pixel dimensions than the one on which it was created, a dialog will appear, as shown and discussed below.

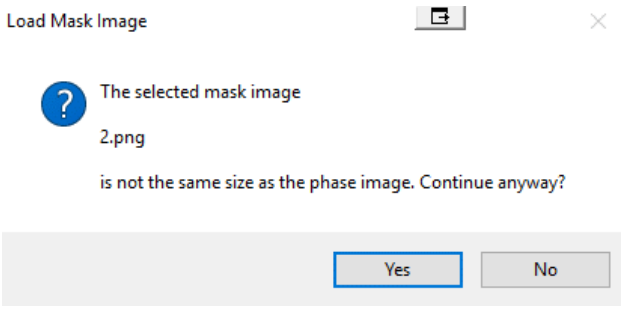

Figure 3.6 Load Image Mask Mismatched Size Dialog

Hitting continue on this dialog will load the image mask regardless of the mismatch, scaling the masked regions to the aspect ratio of the current phase image.

3.2.3 Copying and Pasting Masks

A mask can be copied by going to **Advanced→Mask→Copy All**. Alternatively, individual mask regions can be copied and pasted by right clicking on them and going to **Copy**. When a region is selected the shortcut **Ctrl+C** also works here.

Pasting a mask is similar. Once a mask region has been copied, right click on the target phase image and go to **Paste Mask**. When the target phase image has focus, the shortcut **Ctrl+V** also works for this function.

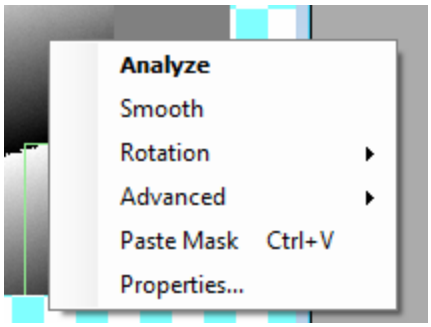

Figure 3.7 Paste Mask Option in Phase Image Context Menu

Note: If a mask is pasted onto a phase image with different pixel dimensions than the one on which it was created, the mask will be scaled fractionally in location and size.

3.2.4 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. 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 All**.

The burned mask ROIs appear as a gray color as shown in **Figure 3.8**.

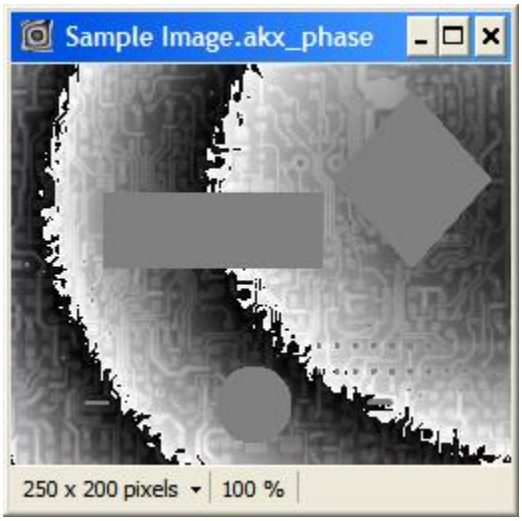

Figure 3.8 Burned Mask Areas

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.

Note: As of Studio 8.0, the crop function has been removed in favor or creating a partition file with only one region. Please see **Section 3.5**.

3.4 Phase Amplitude Thresholding

As of Studio 8.0 Surface Analysis now has the ability to adjust the phase amplitude threshold used to auto-mask a phase image after it has been saved by Surface Measurement. Previously, this value could only be changed by re-acquiring data during testing. This works by virtue of the fact that *.akx_phase files typically store the raw intensity images used to build phase data. By resetting the phase amplitude value, areas of the image that were above the acquisition PAT can be recovered and data that should have been masked can be removed.

In order to adjust the Phase Amplitude Threshold, right click on the phase image and select the Amplitude Threshold… menu option. A dialog will pop up asking the user whether or not they want to keep existing masked points. Clicking Yes will create a map of the already masked out points that will not be affected by any PAT adjustments. This is particularly useful if the user has already created a mask of data that had good phase amplitude but was simply not needed in the measurement. Saying No will recalculate mask on all areas of the image.

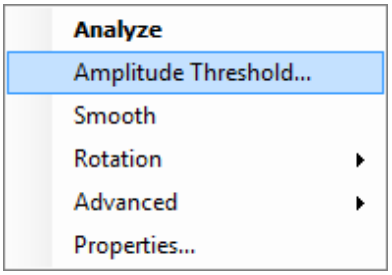

Figure 3.9 Amplitude Threshold Menu Option

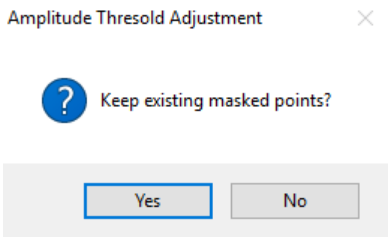

Figure 3.10 PAT Keep Existing Masked Points?

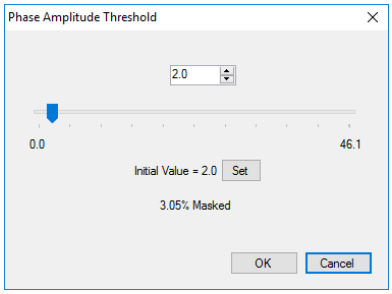

Figure 3.11 Phase Amplitude Thresholding Adjustment Window

When the adjustment window pops up, move the slider to adjust mask calculation. The Min and Max values on this slider are pulled directly from the phase amplitude of the image.

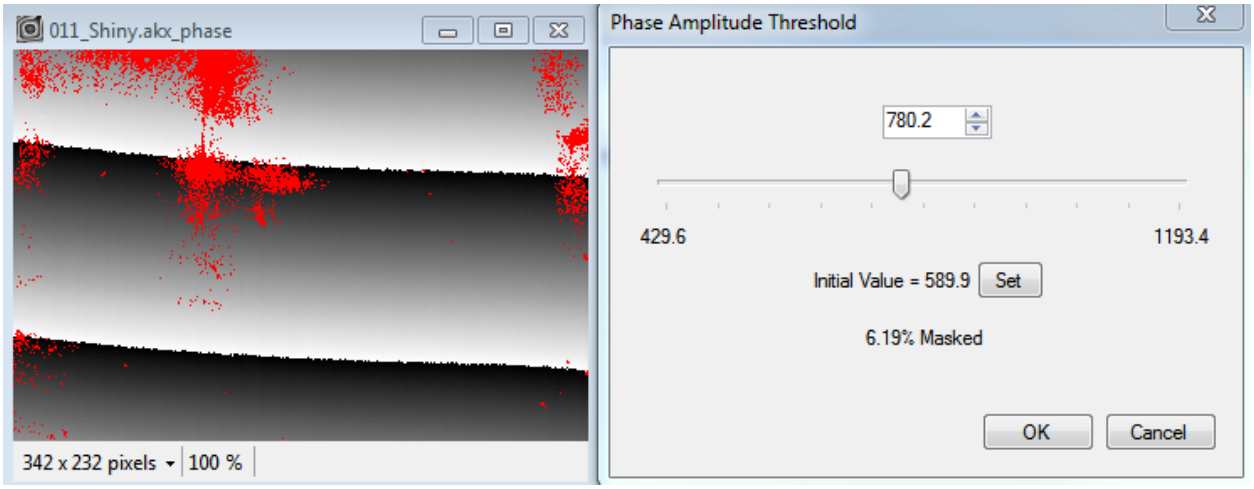

Figure 3.12 Phase Amplitude Thresholding

Masked areas will increase and decrease, and be highlighted red on the phase image. To go back to the original PAT value, click the Set button.

Note: Dragging the slider quickly or large distances may cause some delay in recalculating mask areas. This is particularly true with large phase images and/or slower computers.

In Batch Processing, the Phase Amplitude Threshold dialog has both absolute and relative threshold settings, as well as both 8-bit and 12-bit scales, depending on which type of image is being processed.

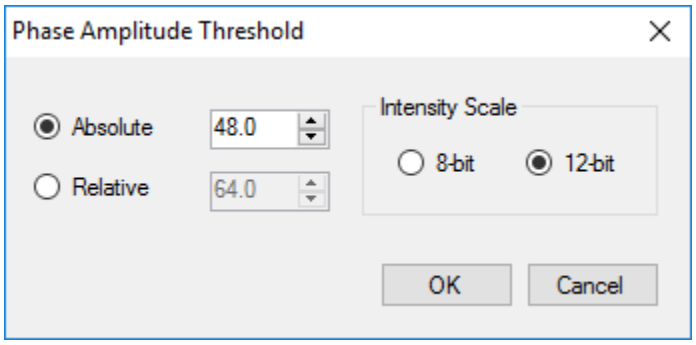

Figure 3.13 Phase Amplitude Threshold Batch Dialog

3.5 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**.

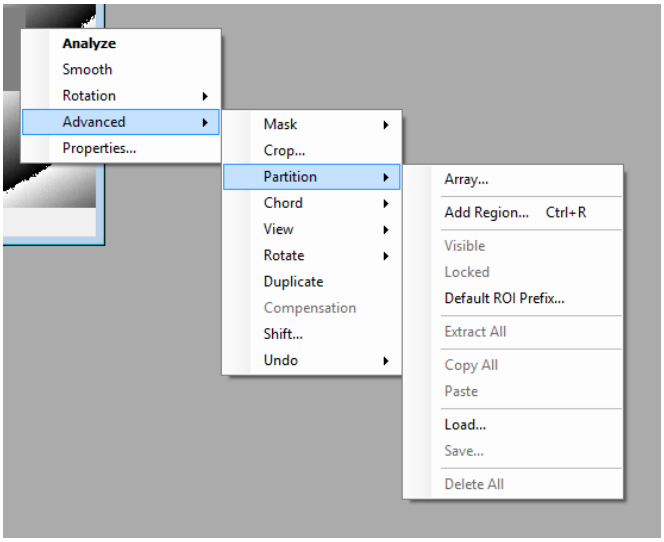

Figure 3.14 Partition Menu

3.5.1 Creating a Partition

1. To create a new partition, right-click in the selected phase image and choose **Advanced→Partition→Add Region…** (or **Ctrl+R**).
2. To create the first domain in the new partition, draw a rectangle on the phase image with the mouse.
3. A green ROI appears and all the ROI commands described in **Section 3.1** apply to the partition ROI. By default, the regions will be named “Region 001”, “Region 002”, etc, but the default can be changed by going to **Advanced→Partition→Default ROI Prefix…** Previously used ROI names will be saved in a list for recall later.

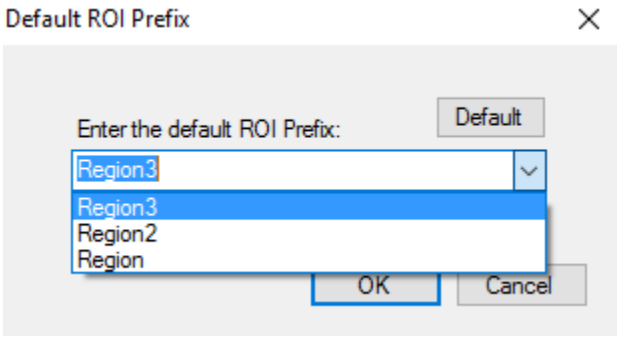

Figure 3.15 Default ROI Prefix Dialog

4. Right-clicking inside any ROI and choosing **Edit…** allows the region name to be changed as well as the shape, location, size, and Mode of the domain (**Figure 3.16**). Click **OK** when complete.

Note: The Mode selection determines whether the partition location and size are displayed in absolute pixels or fractions. The location is relative to the top left

corner of the phase image. The size is relative to the full x and y dimension of the phase image.

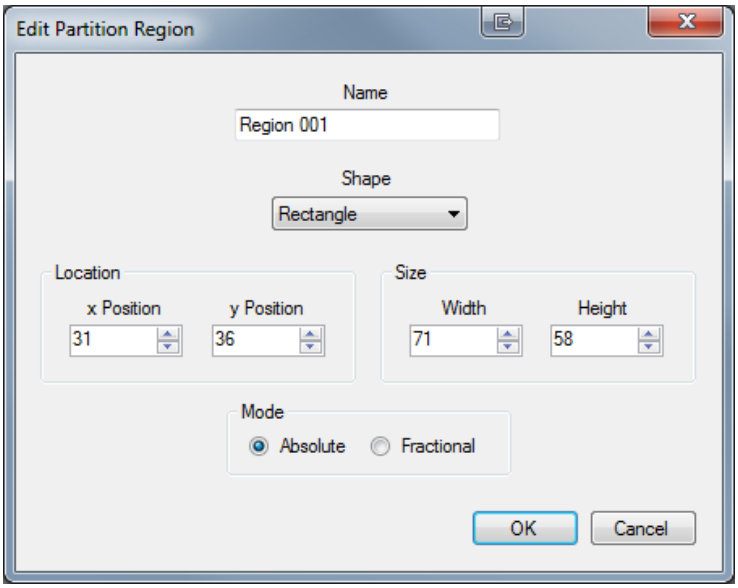

Figure 3.16 A Partition ROI Properties Window

5. Additional domains can be added to the partition (**Figure 3.17**) by repeating steps 1 through 3. Domains may overlap.

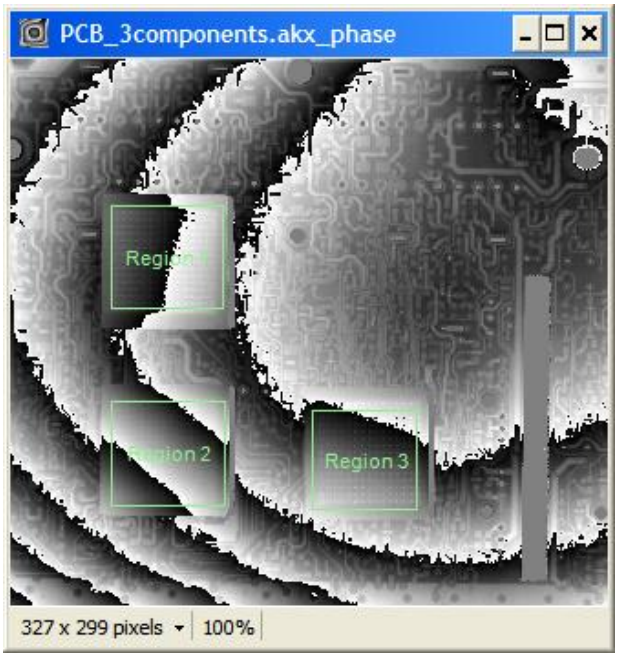

Figure 3.17 Multiple Domains on One Phase Image

6. 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…**.

7. 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→Delete All**.

3.5.2 Loading and Editing a Partition

A previously created partition that was saved in a *.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→Add Region…**.

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 loaded onto a phase image with different pixel dimensions than the one on which it was created, a dialog will appear, as shown and discussed below.

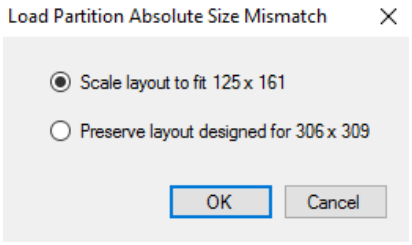

Figure 3.18 Load Partition Absolute Size Mismatch

Scale layout will use the fractional values from the mask relative to the original phase image dimensions. Preserve layout will load the regions using the raw pixel dimensions and coordinates. If Preserve is chosen, a dialog will let the user know how many regions were discarded because they were entirely outside of the data bounds as well as how many regions extend outside of the data bounds. Only regions with their top left corner present in the target image pixel bounds will be loaded.

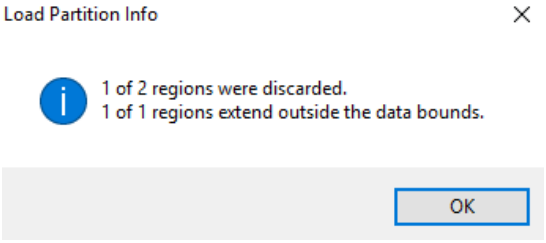

Figure 3.19 Load Partition Preserve Layout Info

3.5.3 Copying and Pasting Partition Regions

A mask can be copied by going to **Advanced→Partition→Copy All**. Alternatively, individual partition regions can be copied and pasted by right clicking on them and going to **Copy**. When a region is selected the shortcut **Ctrl+C** also works here.

Pasting a partition is similar. Once a partition region has been copied, right click on the target phase image and go to **Paste Partition Region**. When the target phase image has focus, the shortcut **Ctrl+V** also works for this function.

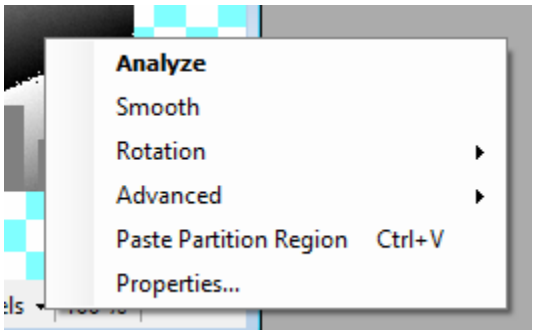

Figure 3.20 Paste Partition Region Option in Phase Image Context Menu

Note: If a partition is pasted onto a phase image with different pixel dimensions than the one on which it was created, the region will be scaled fractionally in location and size.

3.5.4 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**. A new window will pop up for each ROI.

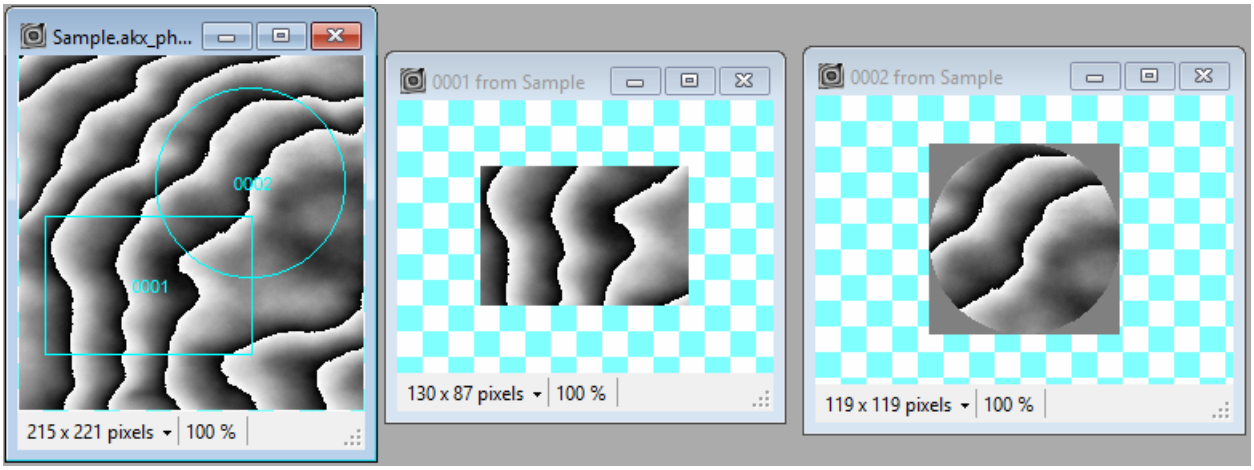

Figure 3.21 Extracted Domains from a Phase Image

3.5.5 Adding an Array

An array is a grid of ROIs. This function is useful for automatically creating a large quantity of regions on a phase image. Common use cases include examining die level warpage on wafers and package level warpage on strips.

Figure 3.22 Example of an Array

1. To create a new array right click in the selected phase image and choose

Advanced→Partition→Array…

2. By default, a grid of ROIs appear on the phase image. Also, a box with various array parameter options appear (**Figure 3.23**). The **height** and **width** refer to the individual dimensions of a single ROI. The **center offset** is the distance of the center of the full array from the center of the image. The **inset** refers to how much of the region is analyzed (useful if the solder array is smaller than the part border for instance). Each option affects all ROIs in the same way.

Note: There is no way to independently edit one region through the menu at this stage. Later in the process there is a way to independently change the shape and location of each of the partitions.

3. Click **Update** to view the changed array inside the phase image.

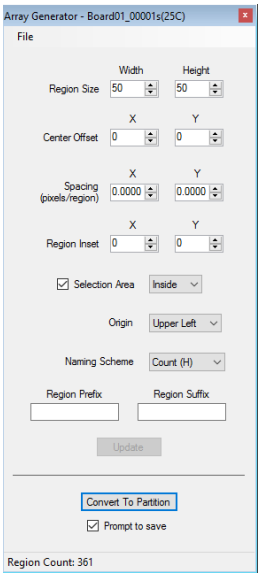

Figure 3.23 Array Parameters

4. To save the partitions, use the green array bounds box to select the specific partitions to be saved. Note that only partitions whose whole areas are enclosed by the green rectangle will be saved, as seen in the figure below. Click on **Convert To Partition** to save the partition file.

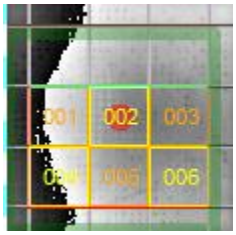

Figure 3.24 Green Array Bounds Box

5. To extract the regions, right click on the phase image and choose **Advanced→Partition→Locked** and uncheck locked. This will separate the ROIs into independent ROI's whose size and position can be edited.
6. Loading an array is the same process as loading a partition. Right click on the phase image and choose **Advanced→Partition→Load** to choose the pertinent partition.

3.6 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.

3.7 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 3.26**).

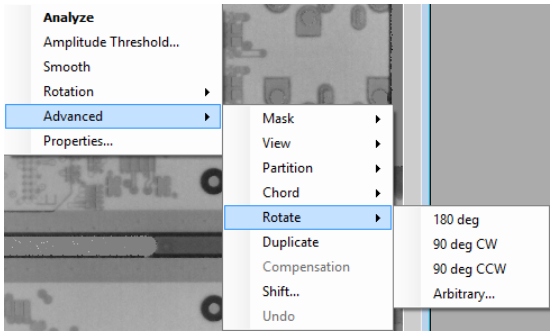

Figure 3.25 Phase Image Rotation

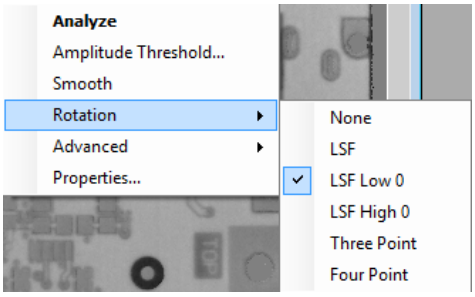

Figure 3.26 Reference Plane Rotation

3.8 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 3.27**).

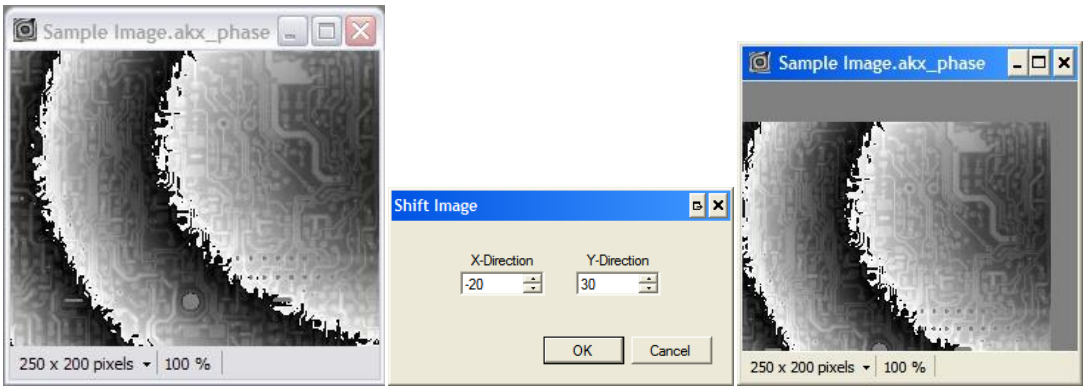

Figure 3.27 Shifting a Phase Image

3.9 Undoing a Phase Image Modification

To undo phase image modification from masking, partitioning, 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.

3.10 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).
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.
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.
Normalize Chords	Checking this box causes all 2D chord plots to be displayed with the endpoints referenced to zero.
Default Rotation	Pull-down list sets the reference plane rotation to be applied during the analysis. See **Section 4.3**.
Gauges – Surface	Select which gauges (numerical values quantifying flatness) are Active and/or Show in 3D Footer. Checking the first box (Active) means that gauge will be displayed in the Displacement Window Gauges tab. Checking the second box (Show in 3D Footer) means the gauge will be displayed at the bottom of a 3D graph. A gauge on the list may be highlighted by clicking on it once. The up and down arrows move the highlighted gauge up and down the list, changing the order in which gauges are displayed.
Gauges – Chord	Select which gauges show up at the bottom of a Chord Graph. Order By also determines the order in which the selected 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**).

Batch Analysis Allows the user to load a *.akx_recipe file to change the default Batch Analysis settings

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

Cancel The window will close without changes to the settings.

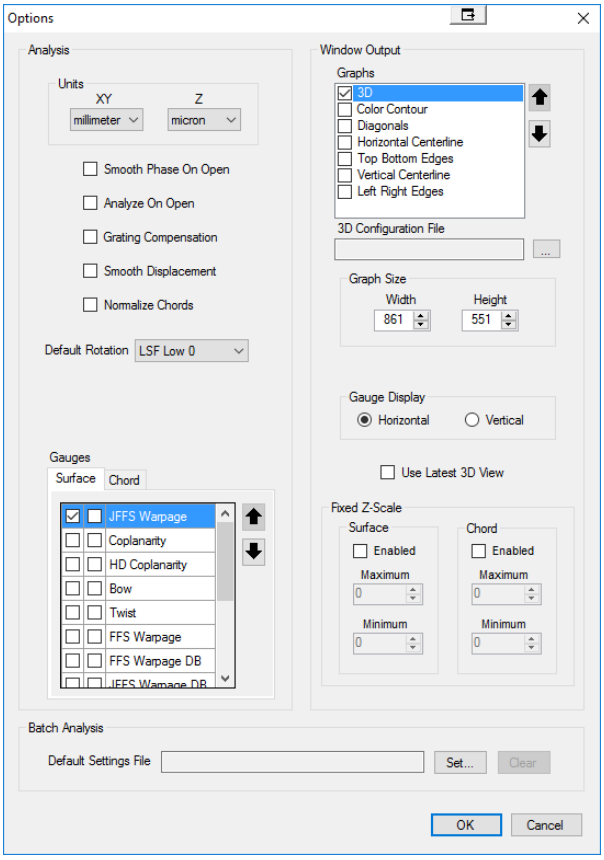

Figure 4.1 Options Window

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.

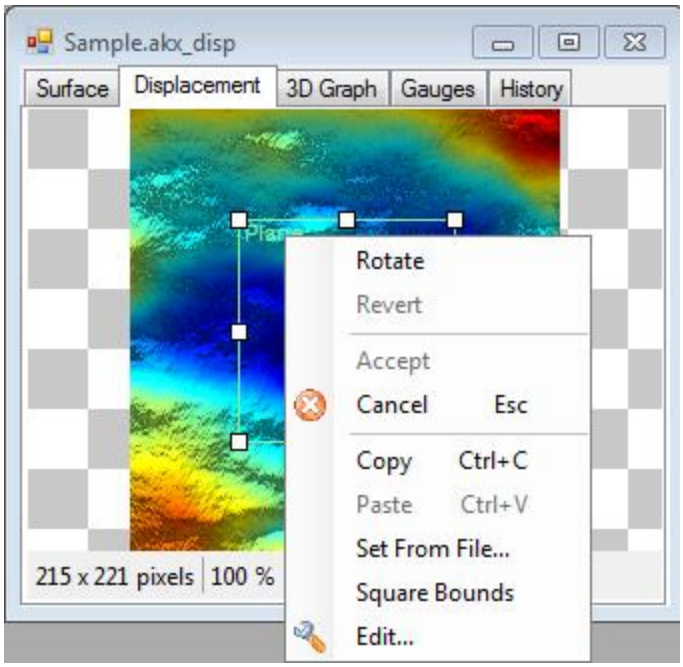

Figure 4.2 User Defined Plane Rotation

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 **Use as Reference**. 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 5.1.4**. 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.

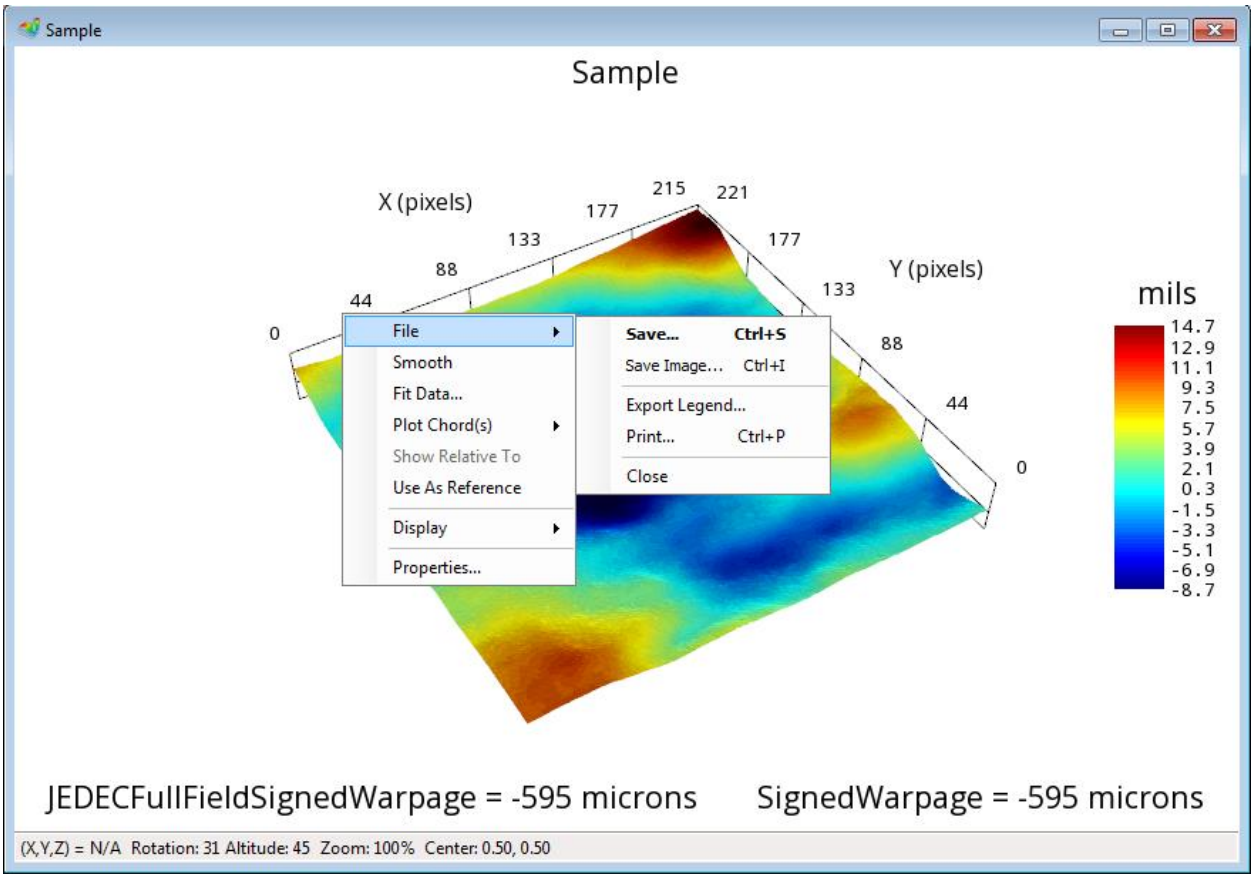

Figure 5.1 3D Surface Plot

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 a different context menu depending on whether it came from a phase image or a displacement file. The context menu for a 3D graph created from a phase image is described below. For 3D graphs originating from a displacement window, the context menu command list is the same as that on the 3D Graph tab in the mutli-tabbed *.akx_disp window. See **Section 2.4**.

File — Allows saving of the current displacement data either numerically or as a picture. Also contains commands for exporting a legend, printing the picture and closing the window.

Smooth	Applies a smoothing function to the 3D data and shows the smoothed surface in a new window. This command can be repeated multiple times. See **AOTA101** for more information.
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.
Plot Chord(s)	Plots pre-defined chords in a new window.
Show Relative To	Displays the relative displacement data calculated by subtracting a selected 3D data from the current 3D data in a new window.
Use as Reference	Sets the current 3D data to serve as the reference surface
Display	Contains the copy, paste, and reset view commands for applying one 3D graph orientation and zoom to another. Also contains Z-Axis units and scale options. Lastly, graph configuration parameters are access here. See **Section 5.1.5**
Properties…	Opens a displacement object properties window with all saved parameters relating to the displacement object.

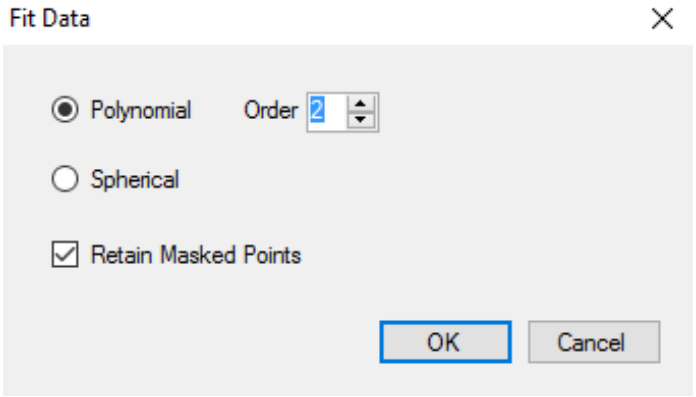

Figure 5.2 Fit Data Dialog

5.1.5 Display Configuration Window

The display configuration window (**Figure 5.3**) gives the user the ability to customize 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.

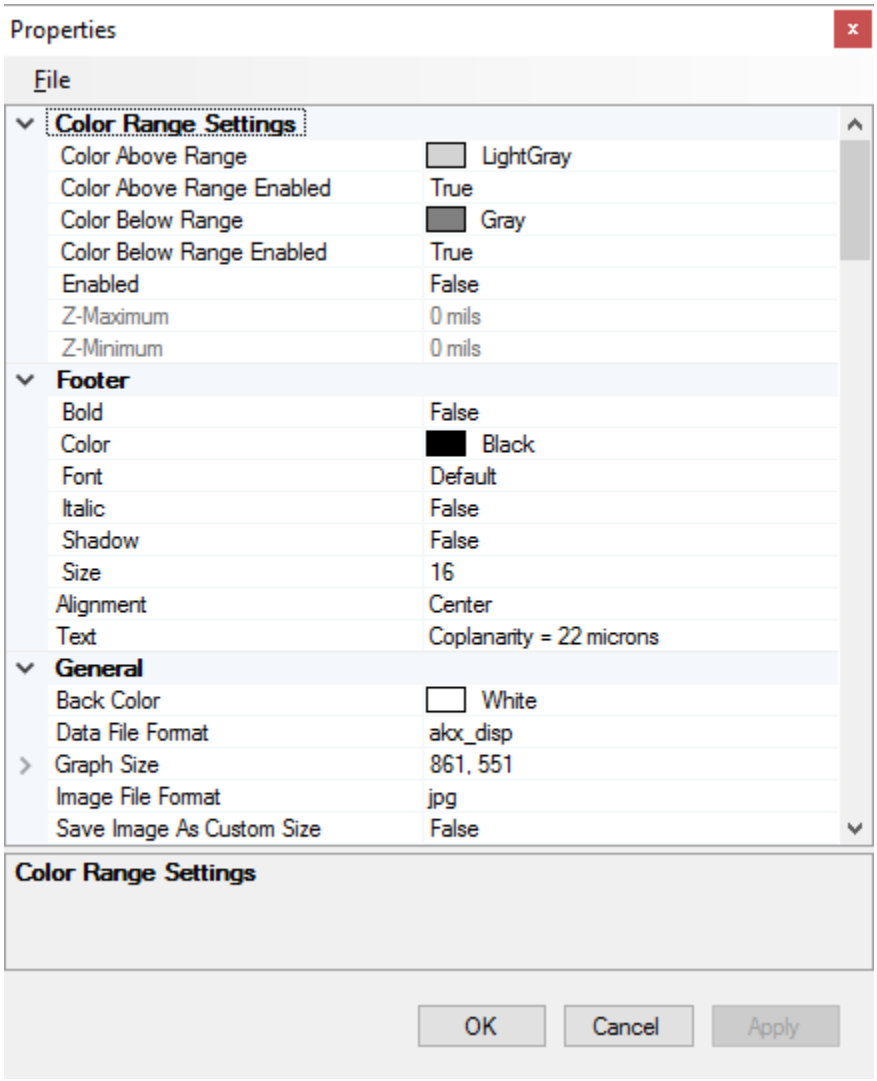

Figure 5.3 Display Configuration Window

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**).

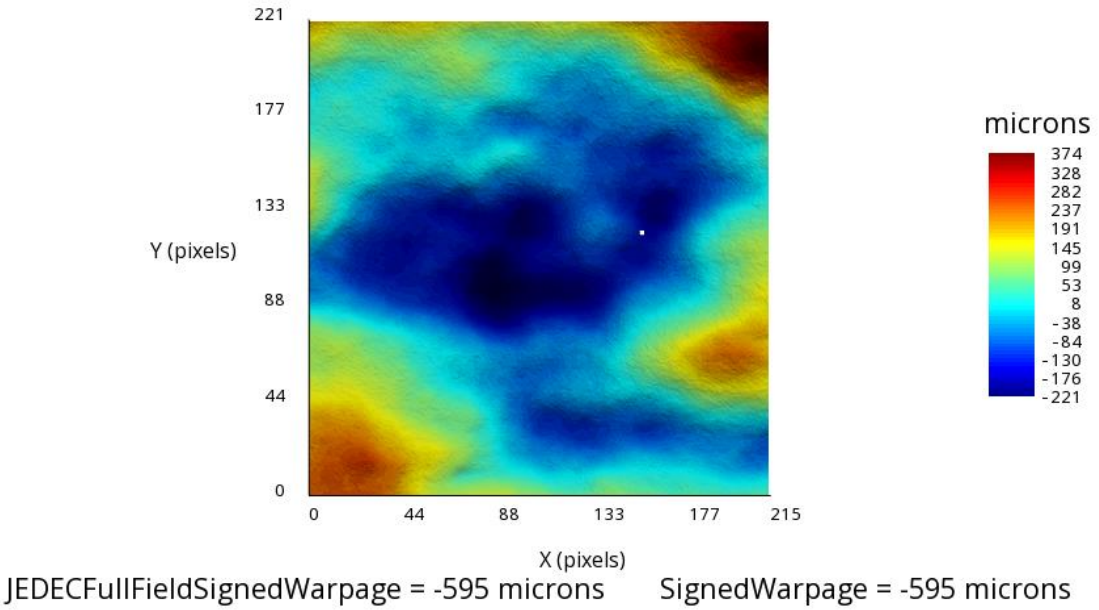

Figure 5.4 Contour Plot

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…**.

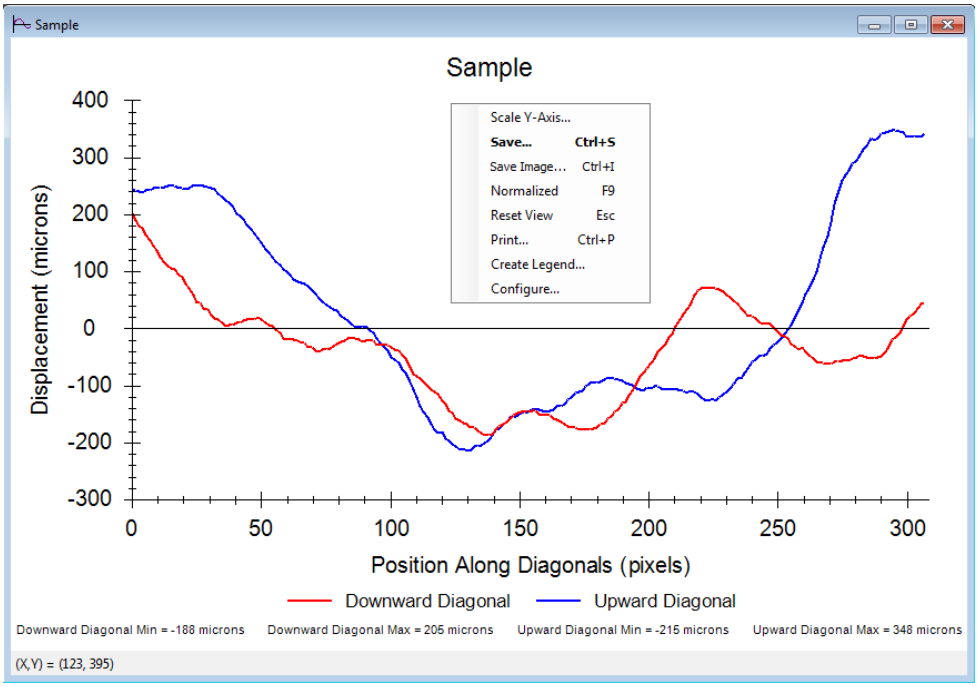

Figure 5.5 Diagonal Plot

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, other special chord options are defined as follows

- Centerlines
- Top Bottom Edges
- Left Right Edges
- All Edges
- All Edges Centers Diags
- Five Vertical
- Five Horizontal
- Horizontal Centerline
- Vertical Centerline

They can be accessed by right-clicking on the 3D display window and selecting **Plot Chord(s)**. All of these chords oriented horizontally are plotted from left to right and all vertical chords are plotted from top to bottom. 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 Extension
Diagonal	_dia	.png
Horizontal Centerline	_hzc	.png
Horizontal Edges	_hze	.png
Vertical Centerline	_vtc	.png
Vertical Edges	_vte	.png
Arbitrary	_crd	.png

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 (not available for chords)

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 six batch functions available:

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

To access the batch processing functions, select the **Tools→Batch Processing…** menu item. This will open a batch processing window (**Figure 6.1**). Tabbed screens appear for the six 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.

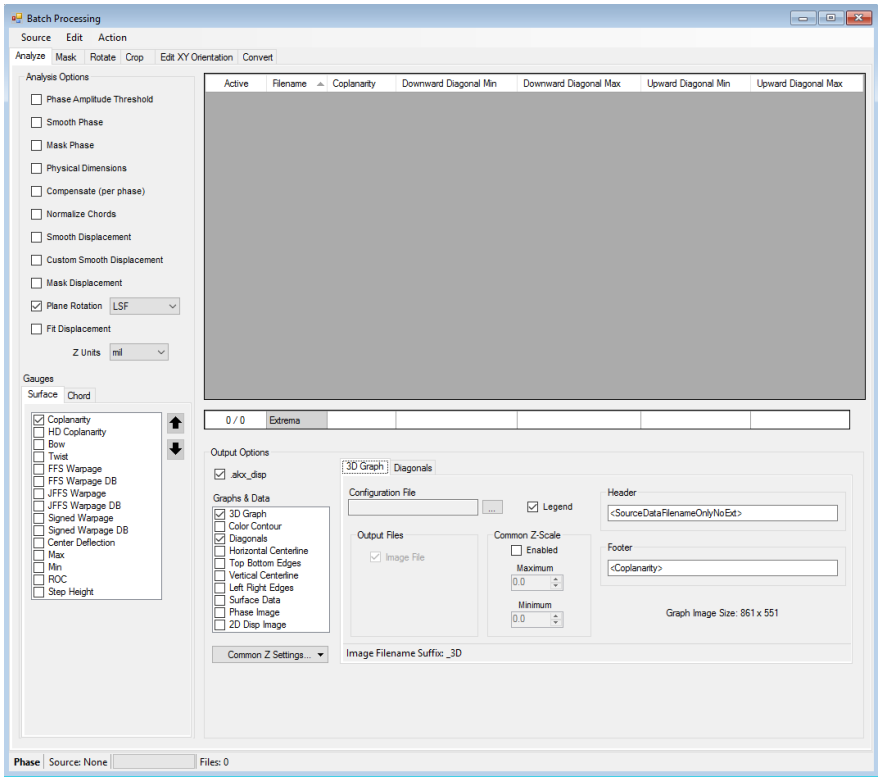

Figure 6.1 Batch Processing Screen

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.

Source → Select…	Identifies the folder of *.akx_phase or *.akx_disp files on which the batch processing functions will be applied. As of Studio 8.0, multiple folders can now be analyzed via a pop-up folder selector. See **Section 6.2.1**.
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 → Settings → Load…	Loads settings for Batch Processing from a *.akx_recipe file
Edit → Settings → Save…	Saves settings for Batch Processing to a *.akx_recipe file
Edit → Settings → Load Defaults…	Loads program defaults
Edit → Settings → Set From Preferences	Loads settings from the Options window.
Edit → Output Performance →	Sequential or Parallel: for large batch operations parallel will speed up analysis at the expense of populating the table in non-sequential order.
Action → Group…	Initiates the grouping function in order to organize files for reporting purposes. This can be done after analysis as well.
Action → Analyze	Analyzes the phase or displacement files loaded into the file list.
Action → Generate Output	Produces output files (pictures and/or data) of various kinds and writes them to disk.
Action → Create Report…	Opens the report creation window with data from the Current Batch pre-loaded in memory.

6.2.1 Using Batch Analysis

The key steps in using batch analysis are:

1. Select a folder to be analyzed (**Source→Select…** menu item). Multiple folders can be added and filenames filtered out. Files can be added from a parent folder by

right clicking on an already added folder row. Subfolders can be added via a checkbox in this form. If multiple rows are added, certain rows can be “deactivated” for quick comparison between multiple data sets without having to remove or add folders.

Note: A common filename filter that many users might find useful is to enclose some part of the filename in asterisks. For example, *PT* will only include files that include the string “PT” somewhere in the filename. This is particularly useful when filtering out part tracked search area files from the individual ROIs. PT can be substituted for any other string that’s included in all the files needed.

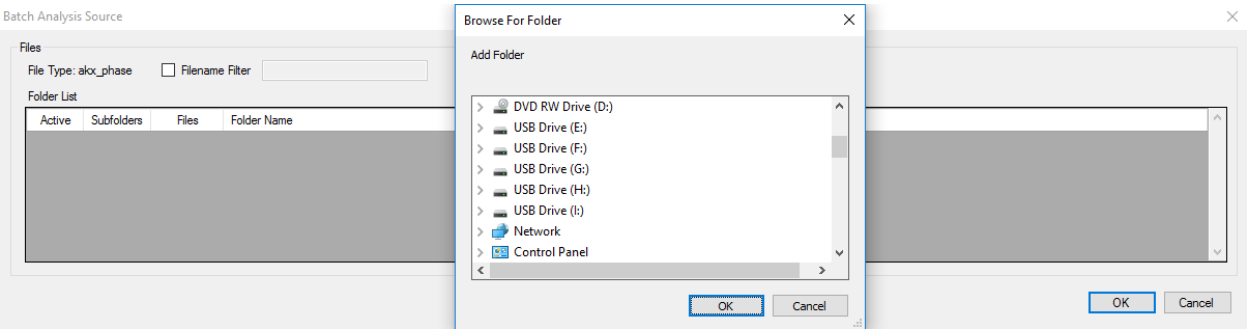

Figure 6.2 Batch Analysis Source Selection Browse for Folder

Figure 6.3 Batch Analysis Source Selection Add Folders

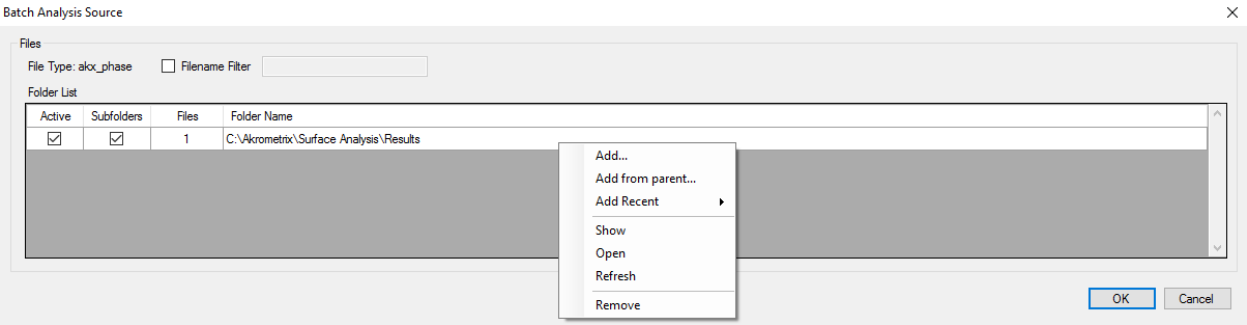

Figure 6.4 Batch Analysis Source Selection Add from parent...

2. Once all folders have been added to the Batch Analysis Source dialog, click OK. The files from this dialog will be populated into the Batch Analysis Results table

sans any displacement gauge information. Right-clicking on a row brings up a context menu where individual files or folders can be opened.

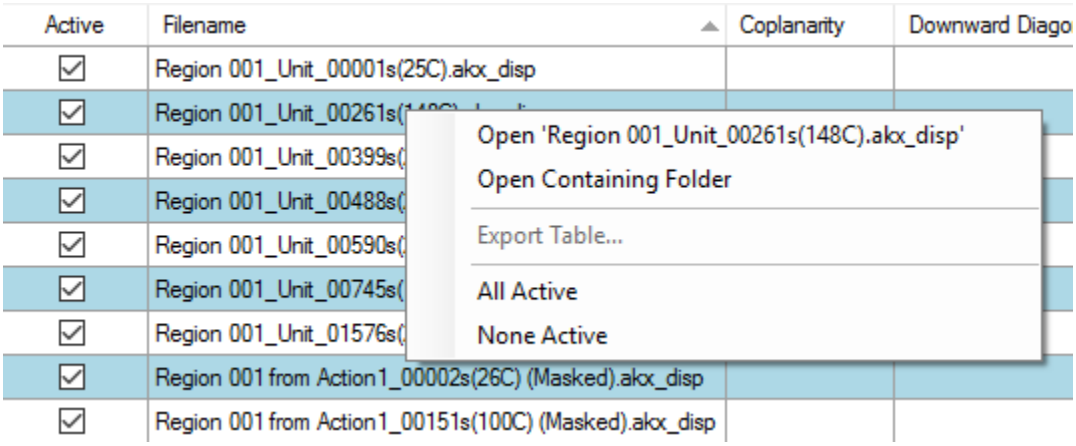

Figure 6.5 Analysis Results Table with Context Menu

3. Select analysis options (**Section 6.2.2**)
4. Analyze the measurement data (**Action→Analyze** menu item). The measurement gauge results will be populated into the table. The extreme values of each parameter are shown below, which can provide the default scale for generating plots. The table is exported to each top level directory of the folders being analyzed.

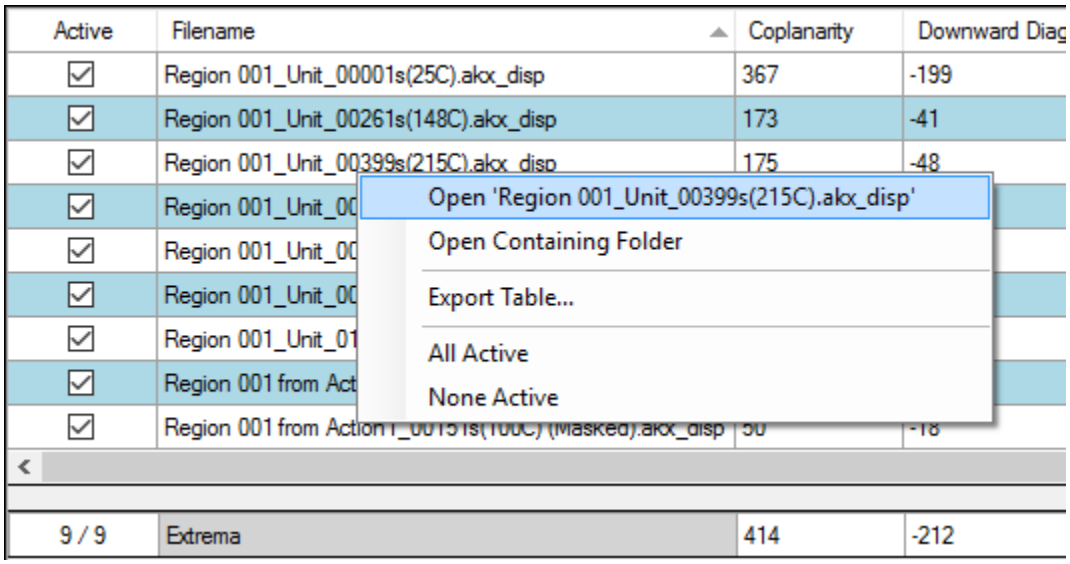

Figure 6.6 Batch Results Table after Analysis

5. Select output options (**Section 6.2.3**)
6. Create and save results (**Action→Generate Output** menu item)

6.2.1 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

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.

6.2.2 Analysis Options

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

Batch analysis options are described below:

Phase Amplitude Threshold	Allows adjustment of the phase amplitude threshold on either an absolute or relative basis (see **Section 3.4**). A dialog appears with these options when checked.
Smooth Phase	Applies a smoothing function once to phase images before analysis (see **Section 3.6**)
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 (per phase)	Enables a compensation for the non-planar surface of the grating. Physical dimensions are required to perform this calculation
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.
Custom Smooth Displacement	Applies a custom smoothing function to the surface data. See **Optical Techniques and Analyses 101**.
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.
Fit Displacement	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.
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. Gauges are defined in the **Optical Techniques and Analyses 101** manual. The ROC, Bow, and Twist gauges all require physical dimensions to be applied to the phase image. Step height definition files (*.akx_StepDef) can also be loaded and calculated alongside normal gauges.

6.2.3 Output Options

.akx_disp	Saves *.akx_disp files to disk during analysis. These files are produced in memory during analysis anyways, so this saves time and an extra step if the user knows that they want them anyways. When displacement files are the input, *_mod.akx_disp files are saved to denote the modified displacement files.
Graphs & Data	Selects which graph/data/image formats (see **Sections 5.1** through **5.4**) are saved during **Generate Output**.
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**.
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.

Common Z Settings… The Auto update switch chooses whether to change the Common Z-Scale after each analysis. The Chords use overall Min Max switch puts the same Z-Scale into the chord plots as the 3D's. If the user has analyzed something but changed the default Z-Scale value based upon the current file list, the Update button will restore the default Z-Scale.

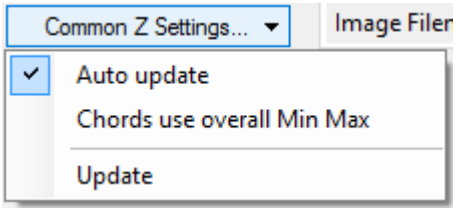

Figure 6.7 Common Z Settings

Output Files This section is only visible on chord plot tabs. Chord tabs allow the user to select whether images, data, or both are output.

Header The header for each image file can be created using tags from the metadata stored in each input phase or displacement file. Available tags can be found in the properties of a phase or displacement image. Tags will reference the original file metadata such that the entry is a variable changing on input file. The default <SourceDataFilenameOnlyNoExt> tag puts the file name minus its extension into the header. The user can also enter any normal text as a constant header.

Footer Allows the user to choose the footer from the available gauges chosen during analysis. Each gauge is input using brackets and the name as spelled in the Analysis Options Gauges section. For example, <Coplanarity> will add the Coplanarity gauge to the bottom of the graph. "\t" inserts a tab character and "\n" inserts a return character to start a new line.

Graph Image Size Displays the image size to be output (will vary if config file is loaded with different image size).

Image files are saved to the folder in which the original phase or displacement file is located.

Note: PNG files are the only option for output graphs as of Studio 8.0.

Options for the Surface Data, Phase Image, and 2D Disp Image can be selected by right-clicking on the respective data type. These options are explained below.

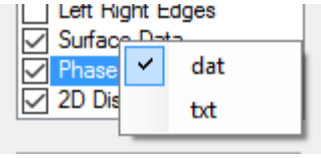

Figure 6.8 Surface Data Options

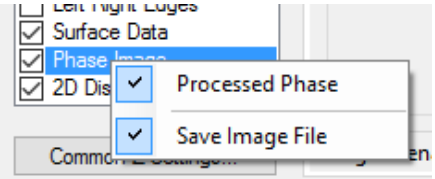

Figure 6.9 Phase Image Options

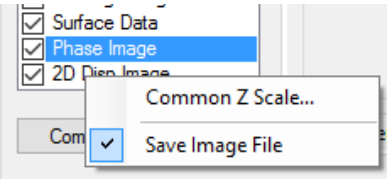

Figure 6.10 2D Disp Image Options

Surface data files can be exported as either *.dat, or *.txt, for importing into other numerical analysis programs. Phase Image files can be saved to disk or not in either the processed form (phase smooth is the only option that would change the phase image look) or raw form. Lastly, 2D Disp Images can be saved to disk or not with either a common Z-scale across all pictures or individual Z-scales on each picture.

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 6.11**).

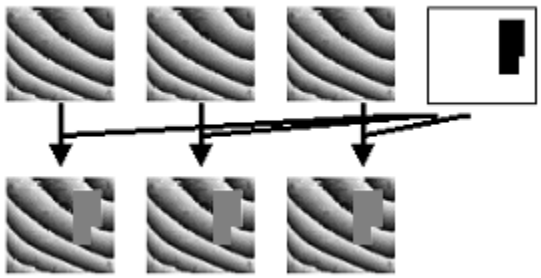

Figure 6.11 Batch Burn

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 6.12**.

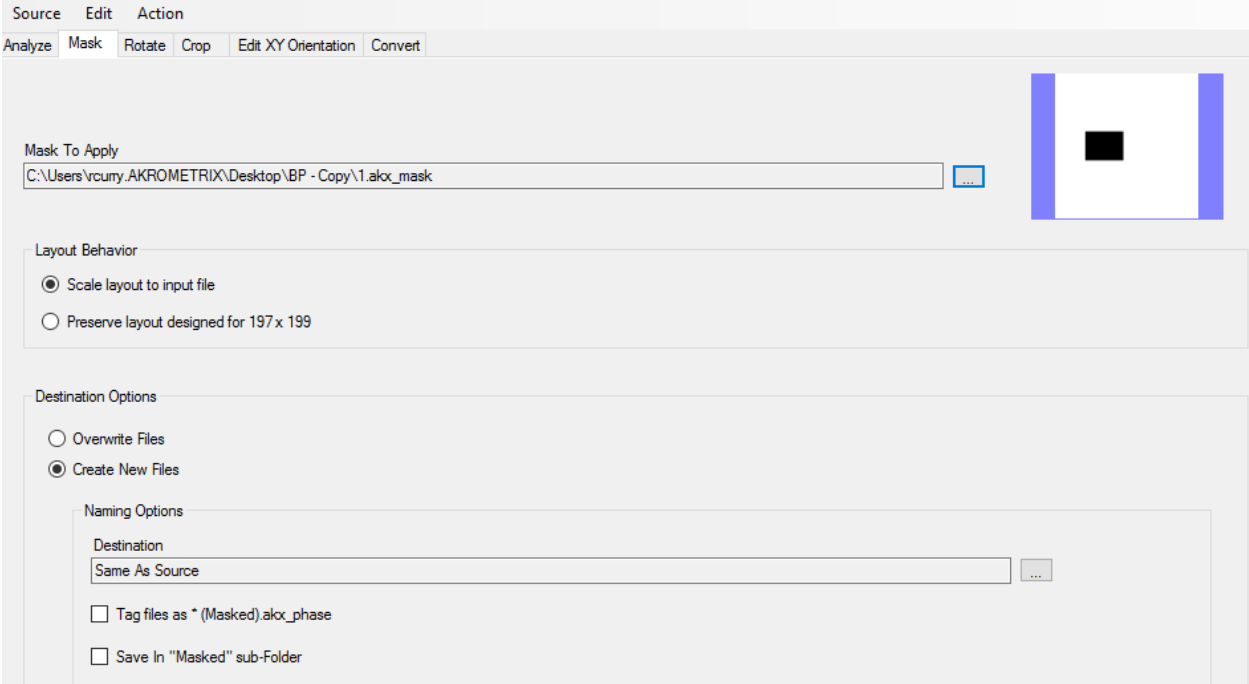

Figure 6.12 Batch Masking Screen

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 the Layout Behavior
4. Select destination options (**Section 6.3.4**)
5. Create and save results (**Action→Mask** menu item)

6.3.2 Source, Edit, and Action Menus

Source → Select…	Identifies the folder of *.akx_phase or *.akx_disp files on which the mask will be applied.
Source → Recent	Shows the 4 most recent folders that were used.
Edit → File Type	Switches between masking phase images (*.akx_phase) and displacement data (*.akx_disp).
Edit → Include Subfolders	Applies the batch processing function to subfolders within the selected folder in addition to the original folder.
Edit → Refresh Source Folder (F5)	Allows the user to update the file count since the folder was originally selected.
Action → Mask	Performs the mask operation

6.3.3 Loading a Mask File

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

6.3.4 Layout Behavior

Choose whether to scale the input mask file if any difference in dimension exists or to preserve the layout. If preserve is chosen and the array dimensions do not match, the mask array will be anchored to the top left of each image and any mask regions which lie outside the image dimensions will be truncated.

6.3.5 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 3.7** 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 6.13**.

Figure 6.13 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)

The Source, Edit, and Action menus for Rotation are all virtually identical to the Mask operation.

6.4.2 Rotation Options

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 displacement 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 6.14**).

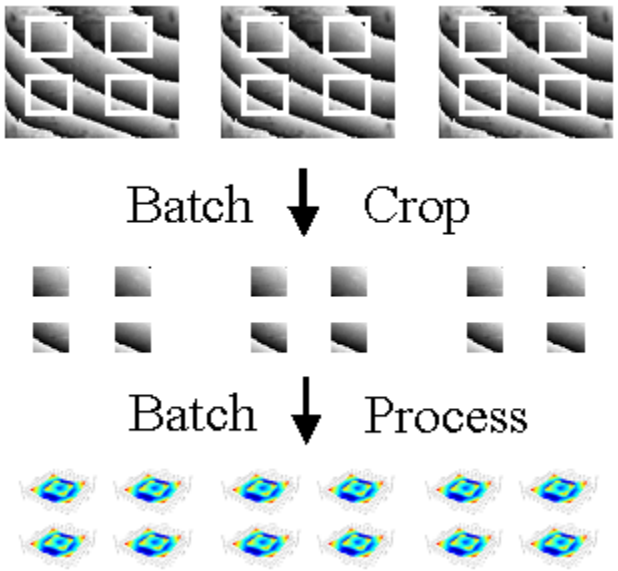

Figure 6.14 Batch Cropping and Analysis

6.5.1 Using Batch Cropping

Batch cropping requires that the user has created a partition file as described in **Section 3.5**. 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 6.15**.

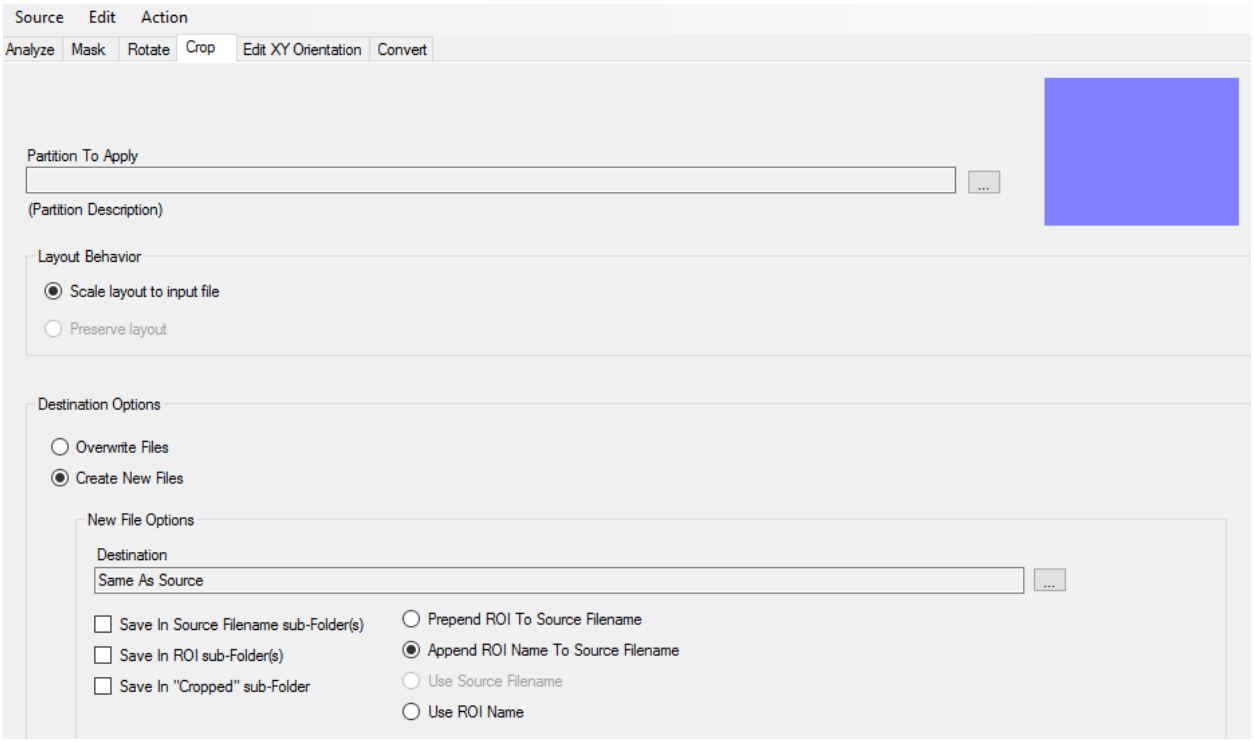

Figure 6.15 Batch Cropping Screen

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 3.5** 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)

The Source, Edit, and Action menus for Crop are all virtually identical to the Mask operation.

6.5.2 Source Directory

Partition to Apply Click on the ... button to browse for a partition file. A preview of the partition file will show on the right

6.5.3 Layout Behavior

Choose whether to scale the input partition file if any difference in dimension exists or to preserve the layout. If preserve is chosen and the array dimensions do not match, the partition array will be anchored to the top left of each image and any regions which lie outside the image dimensions will be truncated.

6.5.4 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.

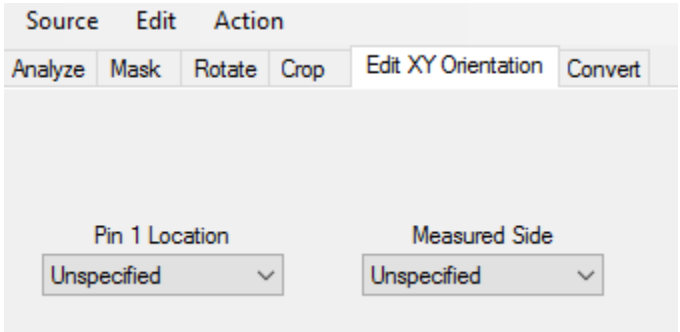

Figure 6.16 Edit XY Orientation Screen

The key steps in using Edit XY Orientation 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)

6.7 Batch Convert

Converts *.akx_disp files containing phase data back to the *.akx_phase format. The key steps in using batch converting are:

1. Select a folder containing displacement files to be converted (**Folder→Select…** menu item)
2. Perform the Batch Convert operation (**Action→Convert** menu item)

7 Batch Reporting

As of Studio 8.0, Surface Analysis now incorporates the ability to batch create reports based on the metadata from each displacement file being analyzed. The Create Report window has three subsections: Groups, Roi Selector, and Layout Settings.

7.1 Grouping by Metadata fields

Grouping can either happen before or after analysis. For purposes of analysis, multiple folders can be selected. See **Section 6.2.1** for details on how to add folders. The context menus are identical in the Group interface Folder List section as they are to the folder selection interface in Batch Analysis.

Note: If the Create Report function was opened from Batch Processing, the Folder List context menus will initially be the same as if there was no data loaded, despite the analyzed data being present. New folders can still be added and removed, but the analyzed data cannot be removed or made inactive from the folder list.

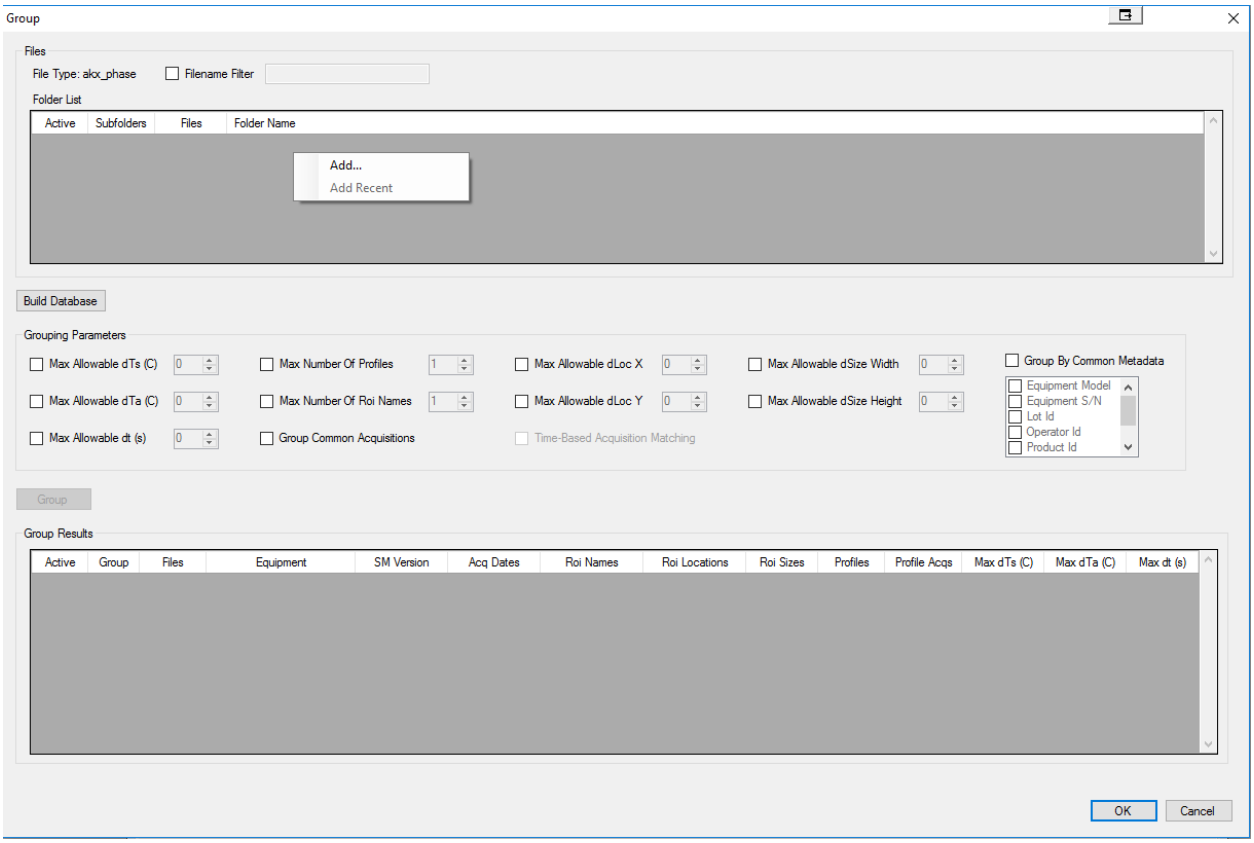

Figure 7.1 Grouping Window

7.1.1 Files

Once the appropriate folders have been added to the Folder List, files can be filtered out inclusively by entering in strings that the user desires. The "*" character can be added before, after, or in the middle of a string to denote parts of the filename that aren't important to match.

Examples: *PT will find all files that end in the string "PT"

a*b will find all files that begin with the string "a" and end in "b"

Once the appropriate files are loaded into the folder list, the files must be indexed by clicking Build Database. After a database has been built, the files will be grouped together by acquisition index. If the user wishes to break the files into different groups for reporting purposes, one or more of the Grouping Parameters must be selected.

7.1.2 Grouping Parameters

1. Max Allowable dTs (C): Sets the max allowable difference for setpoint temperature. This will allow setpoint temperatures that are off by a user specified amount to be grouped together despite the difference. Common acquisition indices are compared and the greatest differential is referenced for grouping.
2. Max Allowable dTa (C): Sets the max allowable difference for acquisition temperature. This will allow acquisition temperatures that are off by a user specified amount to be grouped together despite the difference. Common acquisition indices are compared and the greatest differential is referenced for grouping.
3. Max Allowable dt (s): Sets the max allowable difference in acquisition time. This will allow acquisition times that are off by a user specified amount to be grouped together despite the difference. Common acquisition indices are compared and the greatest differential is referenced for grouping.
4. Max Number Of Profiles: Sets the max number of profiles in a group.
5. Max Number Of Roi Names: Sets the max number of ROI names in a group.
6. Group Common Acquisitions: If multiple profiles are being reported on and the acquisition indexes aren't all coincident this option will filter out orphaned acquisitions. In **Figure 7.2**, the profiles being reported on have varying numbers of acquisitions and in Profile 2, the first acquisition has been removed. By checking this option, only the acquisitions highlighted in yellow will be added to the report.

	Acquisition Index				
Profile 1	1	2	3	4	5
Profile 2		2	3		
Profile 3	1	2	3		

Figure 7.2 Group Common Acquisitions Example

7. Max Allowable dLoc X: Sets the max difference in X axis location of the region of interest.

8. Max Allowable dLoc Y: Sets the max difference in Y axis location of the region of interest.
9. Max Allowable dSize Width: Sets the max size difference along the X axis of the region of interest.
10. Max Allowable dSize Height: Sets the max size difference along the Y axis of the region of interest.
11. Group by Common Metadata: Allows grouping of data by other common metadata fields including Equipment Model, S/N, Lot Id, Operator Id, etc.

Note: When in doubt about a grouping parameter's effect on the output groups, it can be quite useful to simply trial and error the setting in question to see the effect on the data.

7.1.3 Group Results

Once the files are indexed, all groups are shown in the Group Results section (**Figure 7.3**). This section lists pertinent information about each group, such as number of files, number of ROI names and locations, and number of temperature profiles. Individual groups can be activated or deactivated in this section, making it trivial to choose which ROIs go in the final report.

Note: An asterisk next to the number of files indicates that some files were excluded.

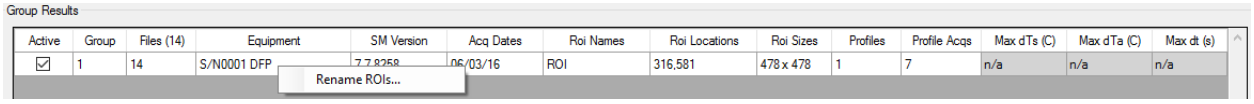

Figure 7.3 Group Results

Right-clicking on any loaded group allows the user to Rename ROIs to better organize and label the report (**Figure 7.3**).

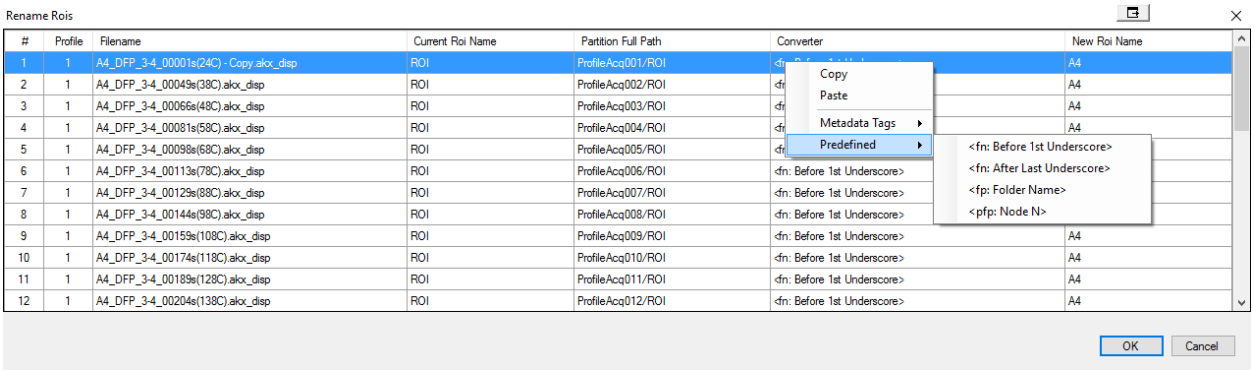

Figure 7.4 Rename ROIs

In the Rename Rois window that pops up (**Figure 7.4**), the user can choose what each file's **New Roi Name** will be via the **Converter** column. The resulting ROI name, including the current values of entered tags, will be shown in the **New ROI Name** column.

By default, the **<fn: Before 1st Underscore>** function provided will create a New Roi Name by parsing the input filename and using the string before the first underscore. Usually this corresponds to the Test ID based on how Surface Measurement creates filenames by default. In cases where this does not make sense, however, the user can enter a static string, or any of the metadata fields surrounded by Less Than or Greater Than signs. For instance, **<LotId>** would enter the Lot Id metadata information. A list of available Metadata tags is accessible by right-clicking on the Converter field. A few other predefined functions are also available via this same context menu (**Figure 7.4**). Strings can be copied and pasted into new rows. Also, multiple rows can be selected at once by shift-clicking, allowing values to be pasted onto multiple rows at once.

Note: Any changes to file metadata will not be made until the OK button is pressed. To change ROI name based on a metadata update, it is necessary to update the metadata first and then reopen the Rename Rois window.

If multiple groups are found from the input data, it is possible to add orphaned files (a typical example would be data taken manually after a profile is complete) to an existing profile. In the Group Results section of Create Report, right-clicking on a group will bring up a context menu (**Figure 7.5**). If multiple files are orphaned, when Add file to profile… is selected, the user will have to choose which file to add to a profile (**Figure 7.6**). Likewise, once the file to be added is selected, the profile to which they will be added must be chosen (**Figure 7.7**). With the profile selected, the user can choose the **Setpoint**, **Temp Reading**, **Profile Runtime**, and **Acquisition Index** to add to the metadata for that file. Once the profile data for a file has been changed, it will automatically be moved to the correct group (**Figure 7.8**).

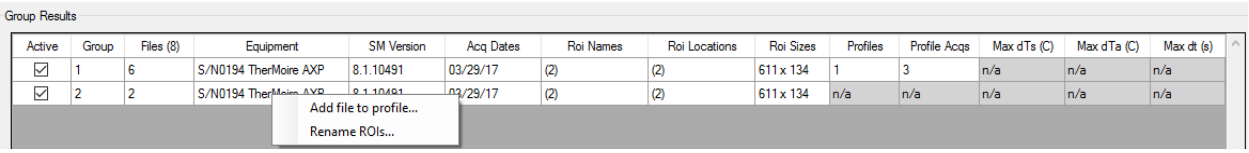

Figure 7.5 Group Results - Context Menu for Orphaned Files

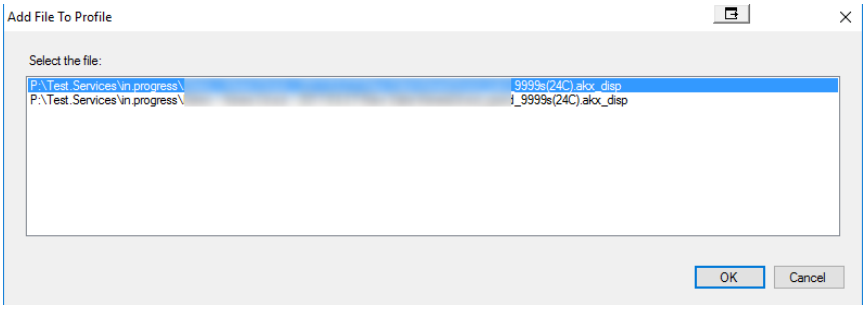

Figure 7.6 Add File to Profile - File Selector

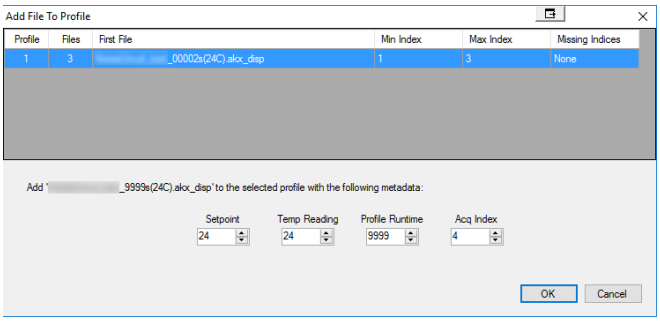

Figure 7.7 Add File to Profile - Profile Selector

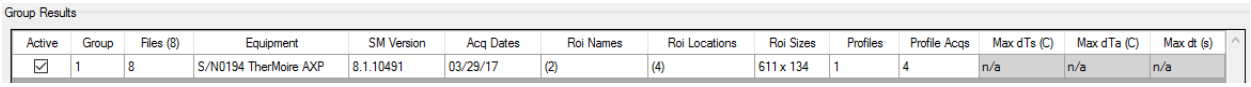

Figure 7.8 Group Results after Adding Files to Profile

7.2 Selecting ROI's

In the Roi Selector tab (**Figure 7.9**), the user can view 3D graphs of all active files, sorted into tabs by group. This tab allows the user can see a thumbnail view of a 3D graph for each active file, sorted into tabs by group. The user can then quickly find the minima and maxima, both overall and in each group, and discard any bad data before generating a report.

The user can activate or deactivate individual ROIs in each group by clicking on them. In addition, entire rows or columns can be removed from the report entirely. These operations are the only things in this tab that affect the resulting report – the other options at the bottom of this window affect only the data displayed in the Roi Selector tab. These options include changing the size of the thumbnail images and editing the units of the Z-scale. Any changes made by the user will be applied when the Update button is pressed. The values of the minima and maxima for each group are displayed automatically, with the figures that have those values being highlighted in shades of purple – dark for Min, and light for Max.

Using the common Z-Scale menu, the user can decide whether Z-scales for the 3D graphs are shared within individual groups, within all files, or not at all. When Across Groups is selected as the common Z-Scale, the minimum and maximum overall Z-values will be displayed, as well as the range, and clicking on the Min and Max buttons will change the selected group to the one with the lowest or highest Z-value, respectively.

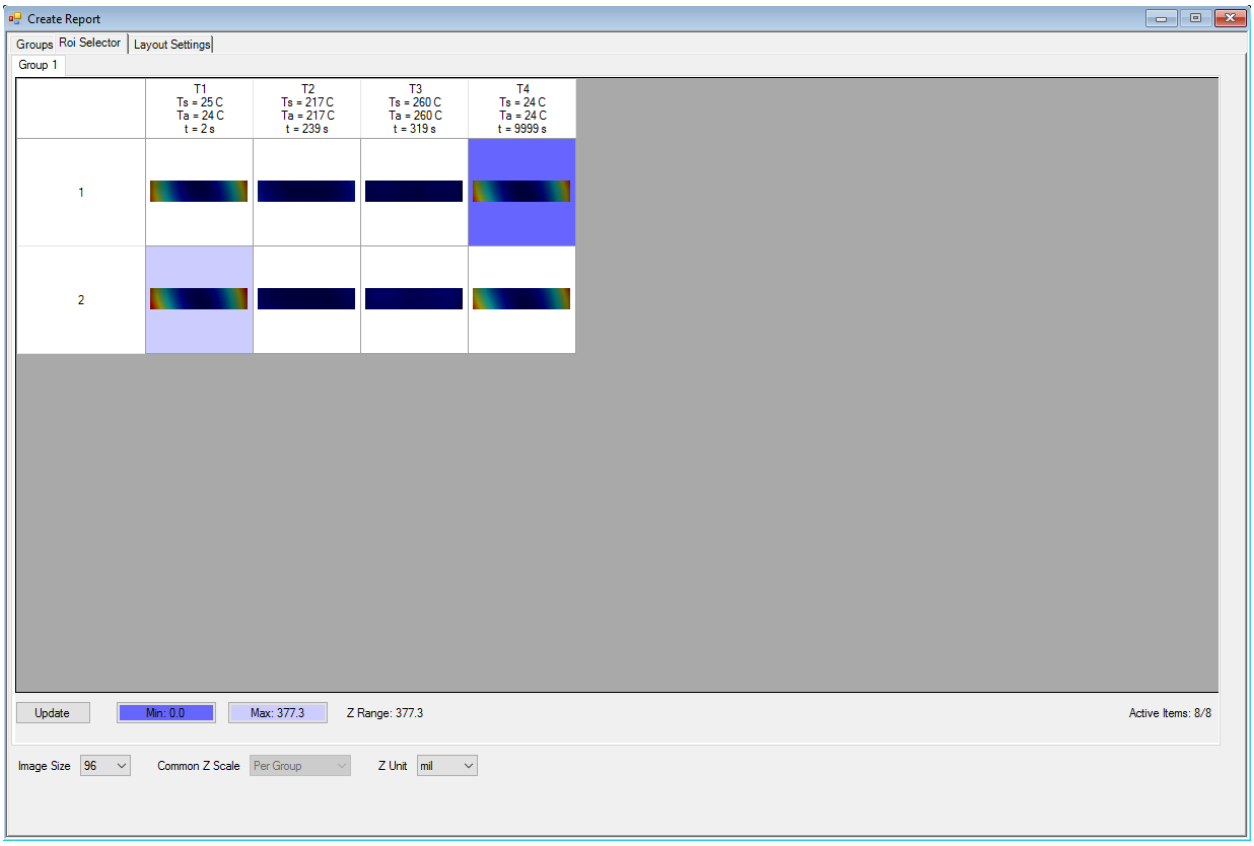

Figure 7.9 Roi Selector

7.3 Choosing Report Layout Settings

Once appropriate ROIs for the report have been organized into groups with any bad data discarded, the user can use the Layout Settings tab to determine the formatting and displayed data of the final report. The user also has the option to deactivate groups without changing other settings, making it simple to create both overall reports and individual reports for different groups. The user has a variety of options in this tab, separated into several subsections.

7.3.1 Group and Plot Selection

The uppermost section of the Layout Settings tab offers several useful options. The user can choose which groups to include in a report using the Active tabs. They can see a variety of information about the group, including Z-Range, group number, number of ROI names, and the name of the first file in the group. Mousing over some of these cells will show a tooltip with further information, like a list of all the ROI names, and selected Gauge Plots, for instance.

Further to the right, this section also contains a number of editable labels that can appear in the report. These can be used to create titles for individual images, series labels in the legends of Gauge vs temperature plots, page titles and subtitles, and footers. Any of these options can use metadata tags like <RoiName> and <PageGraphType>. The labels will appear only on pages with data for the selected group, and the report will automatically separate groups into different sections.

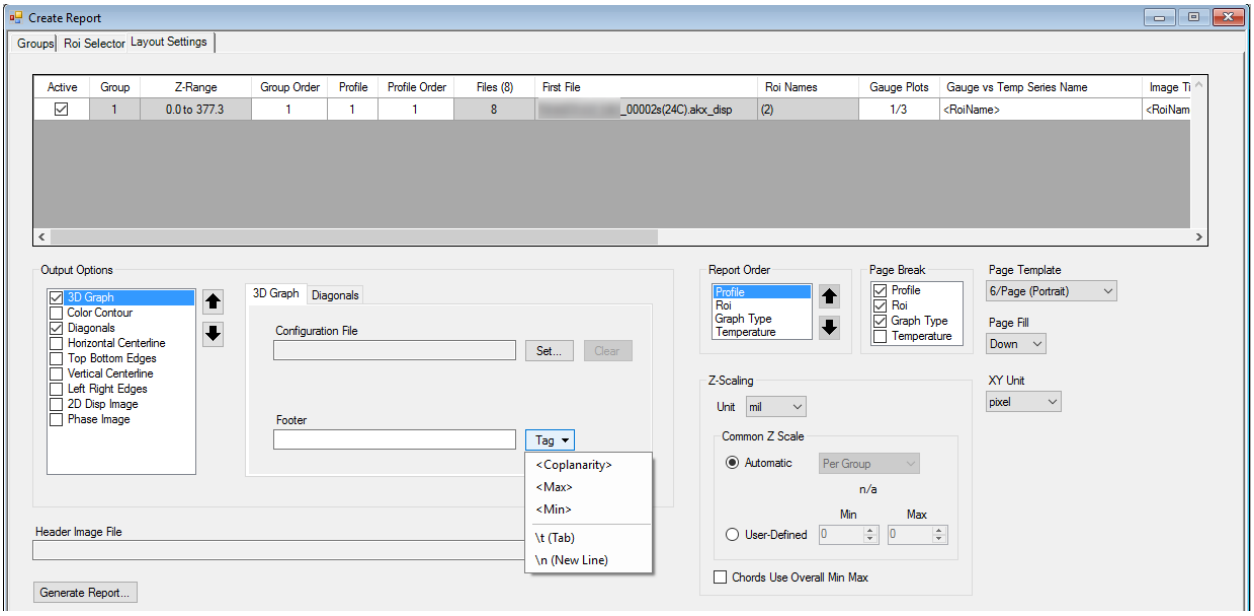

Figure 7.10 Layout Settings Tab

The user can also click on the Gauge Plots cell for any group in this section. This will open the Gauge Plot Selector window shown in **Figure 7.11**. From this window, the user can choose which of the calculated gauges to display in the report. Selecting an option and moving it up and down in the list with the arrows will reorder the gauge plots in the report.

Note: If a desired gauge is not in this list, then it was not calculated during analysis. In Batch Processing, the user must select whichever gauges are desired in the final report, so that they are present in the *.akx_disp files that are used to build the report.

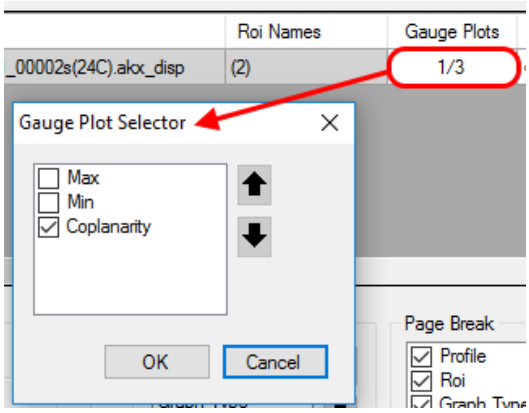

Figure 7.11 Gauge Plot Selector

7.3.2 Output Options

This section allows the user to decide what graphs will be shown in the report, how they are configured, and what footer information the graphs have. Editing the configuration of graphs requires loading a previously created *.akx_2dConfig or

*.akx_3dConfig file (depending on graph type) for each graph that is changed from its default layout. To add footers to the graph, the user can choose from a list of tags that changes with the selected graph. The user may also use tab (/t) and new line (/n) tags to format the footers in the final report. Finally, the Normalize checkbox causes all 2D chord plots to be displayed with the endpoints referenced to zero.

7.3.3 Report Order

This option determines what data ordering takes precedence within a group. The default is Profile > ROI > Graph Type > Temperature.

7.3.4 Page Break

This determines after what data page breaks occur. The default is Profile, ROI, and Graph Type, but not temperature. This allows the user to separate graphs by file metadata and organize the final report.

7.3.5 Z-Scaling

This section allows the user to choose the Z-scale for displacement graphs. They can choose the units of Z, and either enter a custom Z-scale or choose an automatic Z-scale. The automatic options are None, Per Group, and Across Groups. The toggle “Chords Use Overall Min Max” determines whether 2D chord plots use individual minima and maxima in their z-scales, or the overall minima and maxima across all groups.

7.3.6 Page Template

This option determines whether data layout is portrait (6 graphs/page) or landscape (24 graphs/page).

7.3.7 Page Fill

This option lets the user decide whether initial population of figures and graphs is top-bottom and then left-right, or vice versa.

7.3.8 XY Unit

This lets the user determine the XY units on each graph if a lateral resolution is specified in each file. This would allow the graph XY axes to be shown in physical units instead of pixels.

7.3.9 Header Image File

This allows the user to choose a header image to go at the top of each page.

7.3.10 Generate Report…

Once all settings have been selected, the user can select generate report, which brings up a dialog in which to name and save the new report in *.pdf format. An example report is shown in **Figure 7.12**.

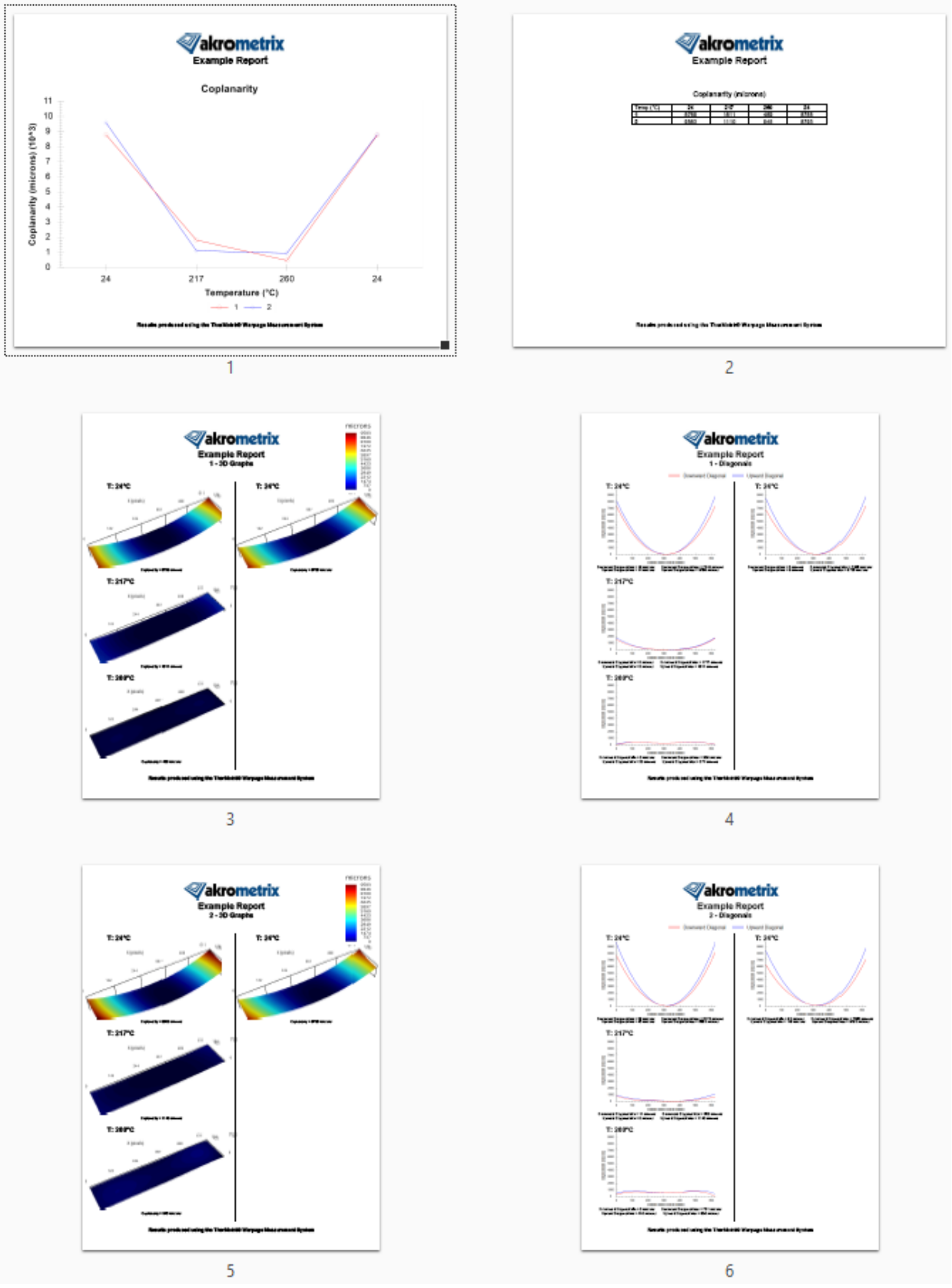

Figure 7.12 Example Report with 6 images per page

8 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.

8.1 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.

8.1.1 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 8.1**, where the error originates from a step condition on the sample surface.

8.1.2 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.

8.1.3 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**.

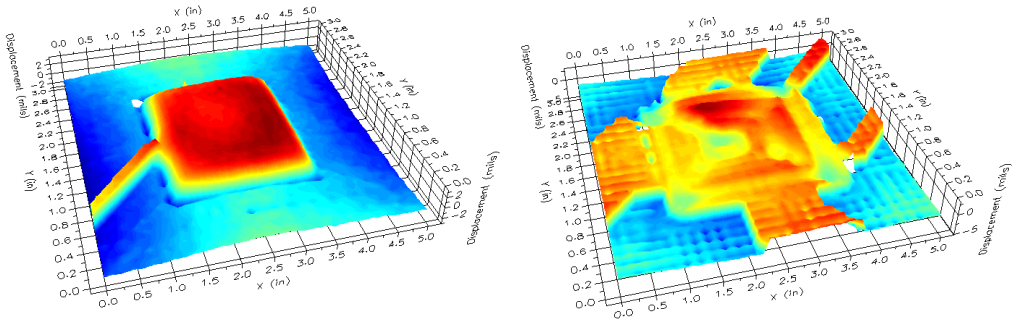

Figure 8.1 Surface Plots with Unwrapping Errors

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 are exclusively *.png 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)
*.akx_recipe	Stores batch processing settings for recall later.

A.1.1 Metadata Fields

Metadata fields embedded in *.akx_phase or *.akx_disp objects can be used in building filenames, output paths, and report labels in various places in Akrometrix Studio applications. Some of the more commonly used metadata fields are described below.

<RoiName>	User defined when adding ROIs to the Camera Window in Surface Measurement. Also defined when partitioning in Surface Analysis.
<LotId>	User defined in the Metadata settings dialog in Surface Measurement or Thermal Profiler
<TestId>	User defined in the Metadata settings dialog in Surface Measurement or Thermal Profiler
<OperatorId>	User defined in the Metadata settings dialog in Surface Measurement or Thermal Profiler
<ProductId>	User defined in the Metadata settings dialog in Surface Measurement or Thermal Profiler
<TemperatureNominal>	User defined when creating a profile in **Profiler Generator**
<TemperatureReading>	Any thermocouple data for the acquisition (can include up to 16 temperatures in the case of a CRE measurement). With no suffix, this metadata tag will provide TC1 data, but a two digit numerical suffix, such as “02” will provide the data for the corresponding thermocouple.
<TemperatureSetpoint>	User defined when creating a profile in **Profile Generator**
<ProfileSecondsAndTemp>	Time/temperature when a phase/disp file was acquired.

Other metadata fields such as Pin 1 Location, Equipment Model, etc. are available in the Properties window of any phase or displacement image (**Figure 2.4**). Any entry in this list can be surrounded by "<" ">" symbols to indicate to the application to use that metadata field in populating the corresponding text entry area. In addition, any gauge value can be added in the same way.

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 downward diagonal chord (upper left to lower right corner) on the image
Shift+U		Create upward diagonal chord (lower left to upper right corner) on 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