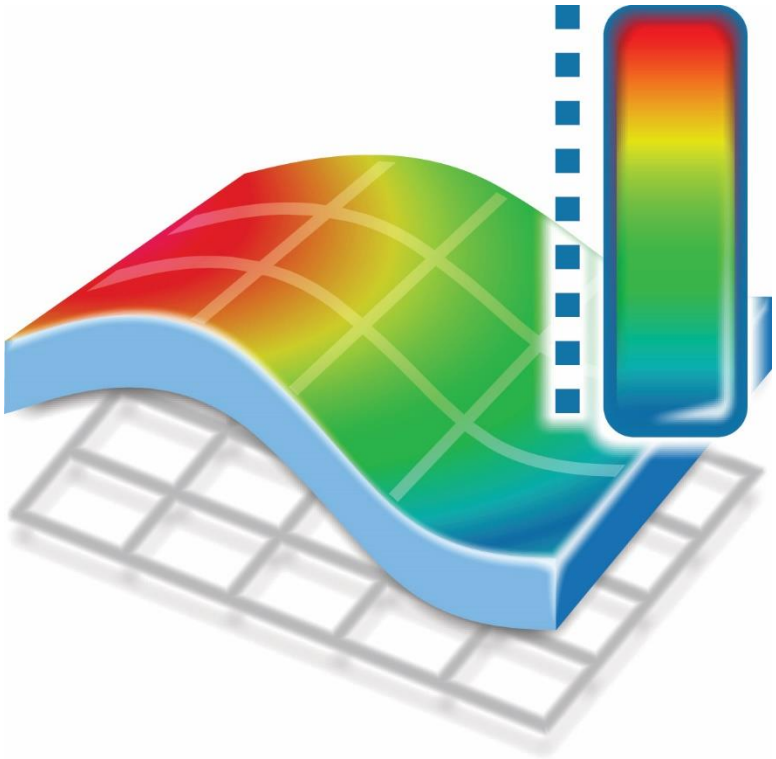
akrometrix

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 8.3.

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, Amplitude Threshold, Unwrapping Parameters,* 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.
- **Batch Convert** allows the user to convert displacement files back into phase images
- **Batch Feature Detection** allows the user to apply a custom mask based on detected features in a phase image

1.2 Warnings and Notes

1.2.1 Warnings and Notes in this Manual

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

Figure 1.1 Warning Icon

Figure 1.2 Note Icon

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

1.3 Technical Support

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

When contacting Akrometrix, please provide the system serial number, the version numbers of the Akrometrix software being used, a description of the problem or question, and contact information for reply. If the question concerns a particular measurement or analysis, please provide electronic copies of the *.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 2.4.7**) 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.

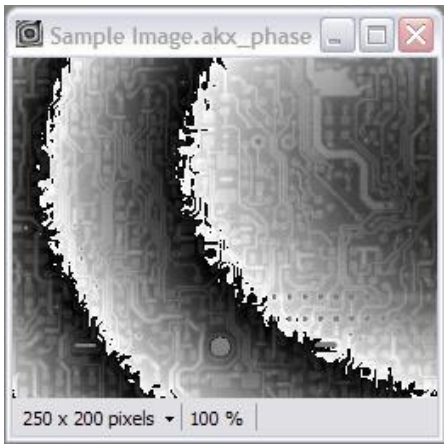

Figure 2.1 Phase Image 100% Magnification

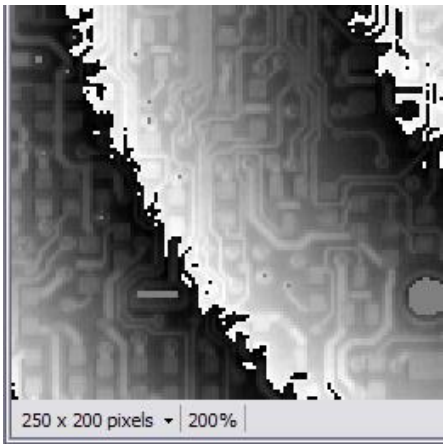

Figure 2.2 Phase Image 200% Magnification

2.3.2 Data Information

When a phase image is displayed in **Surface Analysis**, the image size and magnification ratio information are shown on the status bar located at the bottom of the image (**Figure 2.1**).

2.3.3 Measurement Information

In addition to the information described in **Section 2.3.2**, the measurement metadata can be displayed by right-clicking on the image and choosing **Properties…** (**Figure 2.3**). 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.

2.3.4 Edit Metadata

Metadata for an individual phase image can be changed by right clicking on a phase image and going to **Edit Metadata**. For further information on metadata see **Section A.1.1**

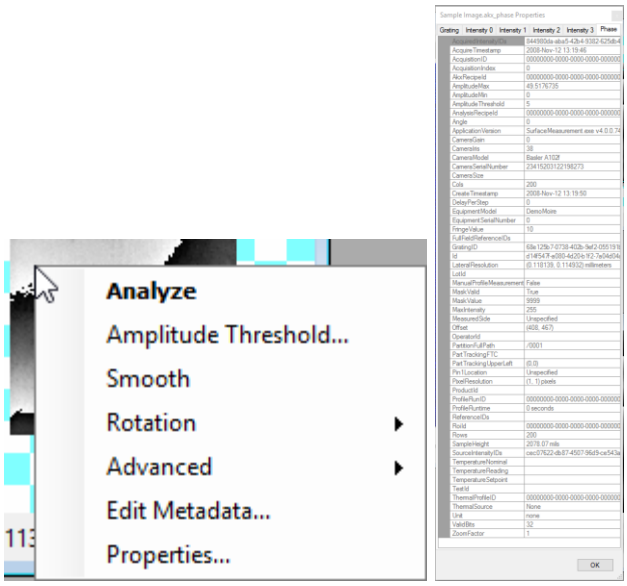

Figure 2.3 Displaying Measurement Metadata

2.3.5 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 2.4**). 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.

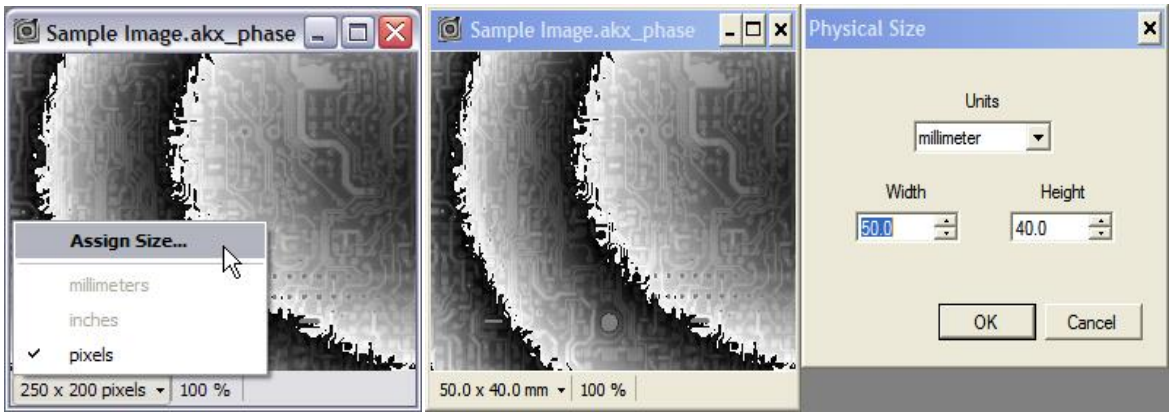

Figure 2.4 Assigning Physical Size for a Phase Image

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

2.3.6 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**, **U**, **S**, and the numbers **1-4**. The currently viewed image can be saved to disk in by selecting **File→Save Image…** or **Ctrl+I**.

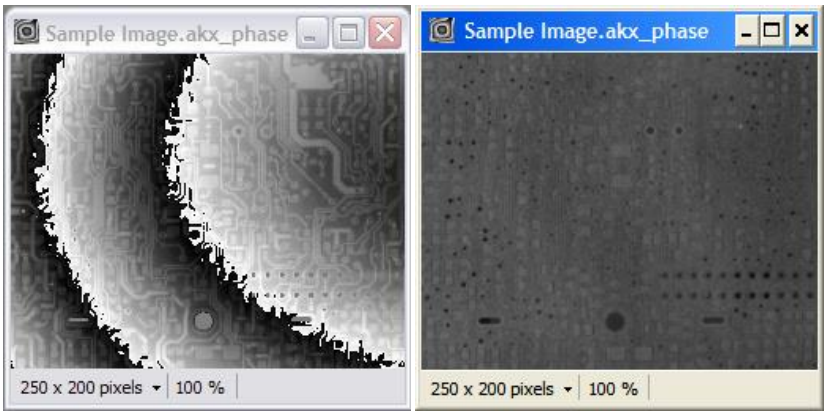

Figure 2.5 Phase and Surface Image Views

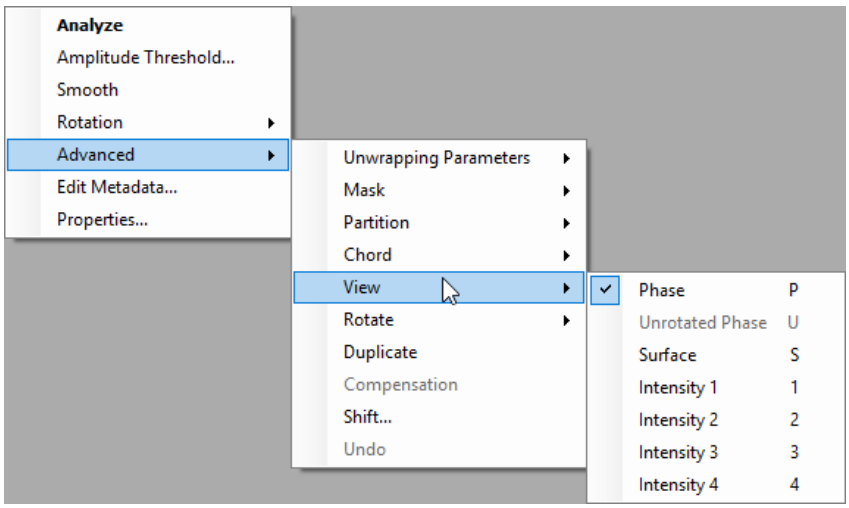

Figure 2.6 Menu Command for Showing Surface or Intensity Images

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 2.7**.

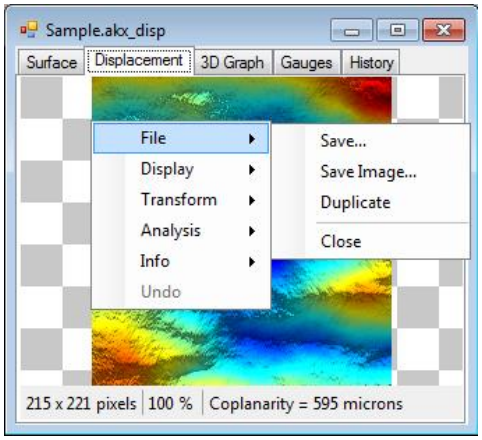

Figure 2.7 Loaded Displacement Window

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.

This window can be resized using a normal click and drag function. The data can be resized using **Ctrl+** or **Ctrl-** or by scrolling the mouse wheel. Either option increases or decreases the size of the displayed data by 25%.

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

Detect Features	Allows the user to filter data based on pattern recognition for specific features. See **Section 2.4.7**.
Mask	Allows the data to be masked. All functions are the same as described for phase images in **Section 3.2**, with the exception of “Z-Range…”, which is unique to displacement data. See **Section 2.4.8**.
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 2.4.9**.
Partition	Shows the same commands as under the **Advanced→Partition** menu for phase images, except for Array. See **Section 3.4**.
Chord	Shows the same commands under the **Advanced→Chord** menu for phase images. See **Section 5.4**.

2.4.5 Info

Allows the user to access the properties window and edit metadata associated with the displacement image.

2.4.6 Undo

Allows the user to undo the most recent change.

2.4.7 Feature Detection

Feature Detection allows the user to create a custom mask by searching for certain regions in the displacement data. This function is modal. Selecting it from the Transform context menu brings up a feature ROI whose default shape is an ellipse (**Figure 2.8**) and the Feature Detection window (**Figure 2.9**). While Feature Detection mode is active, the user cannot change tabs in the displacement image window. This mode can be turned off by pressing **Esc** or selecting Cancel from the context menu.

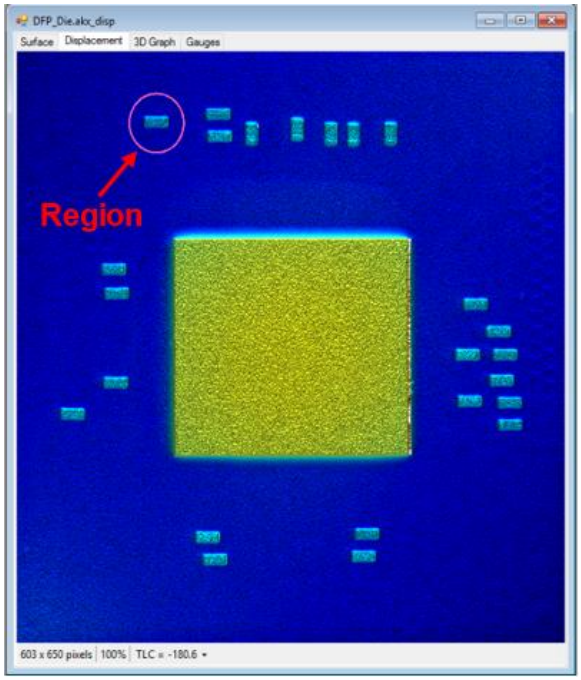

Figure 2.8 Feature Detection Region

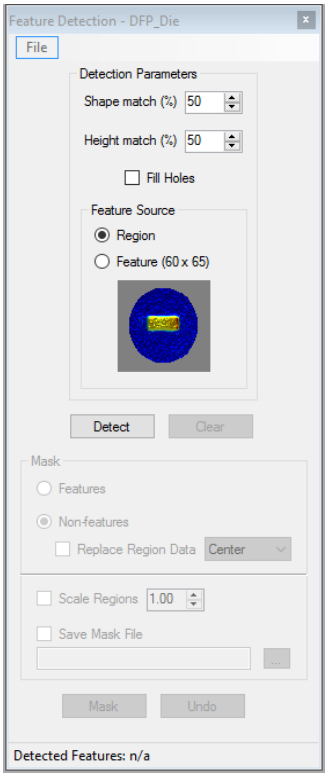

Figure 2.9 Feature Detection Parameter Window

The Feature Detection process consists of two steps: detection and masking. The parameter window and context menu are divided accordingly. During detection, the user sets up a single ROI with matching parameters and finds all features that fit that shape. During masking, the detected ROIs can be edited to create a final mask, which may then be burned or saved. The user always has access to certain options, including saving or loading Feature Detection settings files.

Switching between the Feature Detection steps is accomplished using the **Detect** and **Clear** buttons in the middle of the Parameter Window. **Detect** scans the image for instances of the feature in question, creating an ROI around each one that can be edited in Masking mode. **Clear** deletes all ROIs but the original one, returning to the detection step.

The two versions of the Feature Detection context menu are shown in **Figure 2.10** and **Figure 2.11**. They are mostly the same, but since the mask step can have multiple ROIs, there are more editing options.

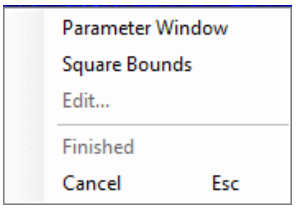

Figure 2.10 Feature Detection Context Menu - Detection

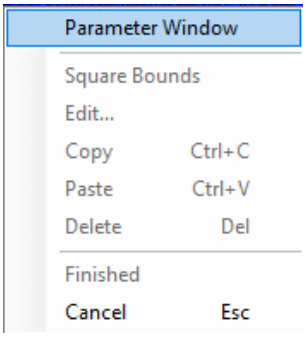

Figure 2.11 Feature Detection Context Menu - Masking

- **Parameter Window** opens the window or brings it to the front, depending on whether it is already open
- **Square Bounds** equalizes the horizontal and vertical dimensions of the ROI as the shorter value of the two
- **Edit** brings up the ROI Editing window described in **Section 3.1**.
- **Copy** (**Ctrl+C**) copies the selected ROI into memory.
- **Paste** (**Ctrl+V**) places an instance of the copied ROI at the cursor location.
- **Delete** (**Del**) deletes a single ROI.
- **Cancel** (**Esc**) exits out of Feature Detection without making any changes to the displacement image, although the Feature Detection settings will be remembered as long as the same instance of the *.akx_disp file is open.
- **Finished** exits Feature Detection when the user is done, leaving applied masks in place. This menu item is always visible but only active at the end of the Feature Detection process.

Note: Mask ROIs start out as copies of the Detection ROI, but can be independently edited. Everything in **Section 3.1** applies to Feature Detection ROIs.

In the first half of the Feature Detection Parameter Window (**Figure 2.9**), the user can set detection parameters based on their detection ROI. This is the initial ROI which appears when Feature Detection is opened, and which the user should edit to cover the feature to be found. **Shape Match** and **Height Match** control the degree of accuracy in exact shape and size required to find matches. Higher numbers here will typically result in more features found. **Fill Holes** fills all mask regions with fabricated data based on the neighboring edges. Note that this option does not affect the final output, only the input dataset for the detection process, so there will be no visual indication on the 3D data that anything has changed. For a typical solder ball detection application, having this checked will improve the number and accuracy of features found.

If previous detection has been performed the user may use **Feature Source** to search with the Feature image shown in the center of the parameter window instead of using the detection ROI. When the user is satisfied with their detection settings, they may press **Detect** to detect similar regions.

In the mask step, the user edits the ROIs on the displacement image and sets mask parameters in the Parameter Window. These include the choice of whether Feature or non-Feature data is masked. If Non-feature data is masked, then the user also has the option to replace data in the remaining regions with a single value, which can be the maximum, the minimum, or the value of the center pixel in each region. Scale regions increases or decreases their size when masking, and **Save Mask File** converts the results into a mask file that can be applied to other files without going through the full feature detection process. Once the user is satisfied with their settings, they can select **Mask** to apply the mask or **Undo** to remove it, and then exit Feature Detection by selecting Finished from the context menu.

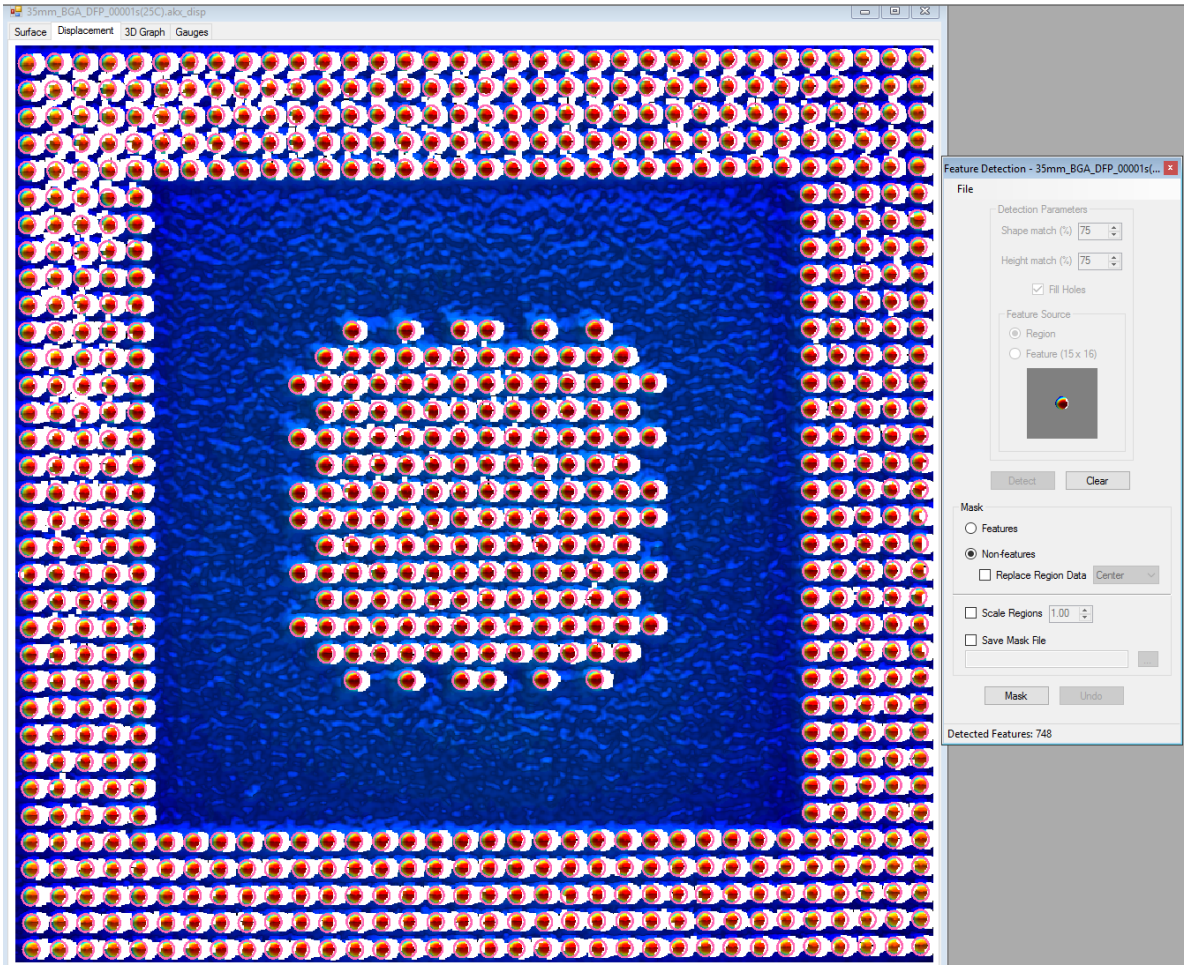

Figure 2.12 Feature Detection with Fill Holes – Solder Ball Peaks on BGA

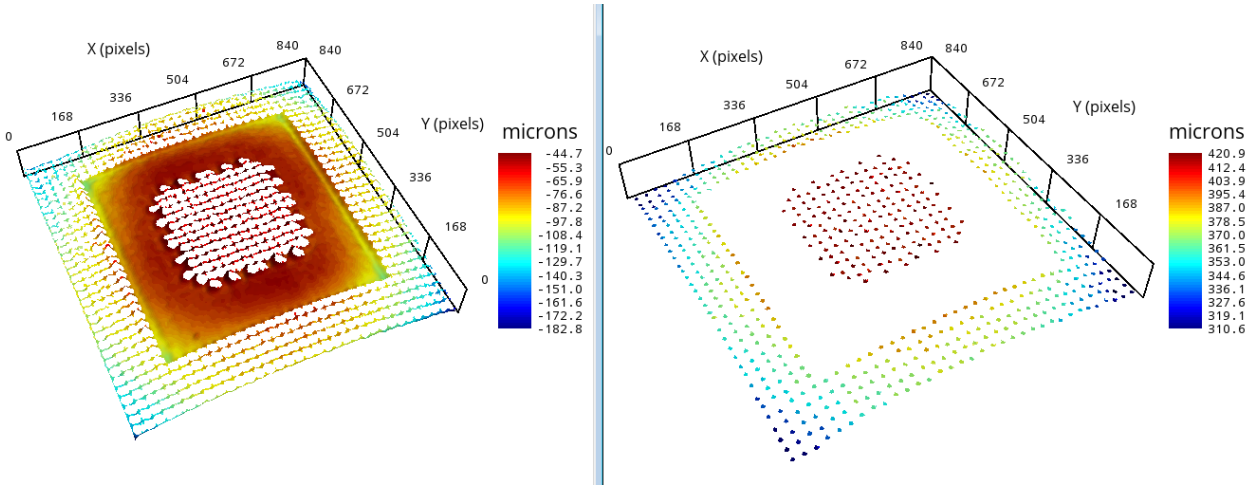

Figure 2.13 Analyzed Data with Feature Detection: Mask Feature and Mask Non-Feature

2.4.8 Z-Range Mask

Z-Range Mask functionality serves as a high and low pass filter for displacement data by filtering based on Z-axis displacement values. Like Feature Detection, this is a modal function that deactivates tab changing. Once Z-Range… is selected from the Mask menu, the Z-range Mask Parameters window will appear (**Figure 2.15**) and the context menu will change to that for Z-Range Mask (**Figure 2.14**). This mode can be turned off by pressing **Esc** or selecting Cancel from the context menu.

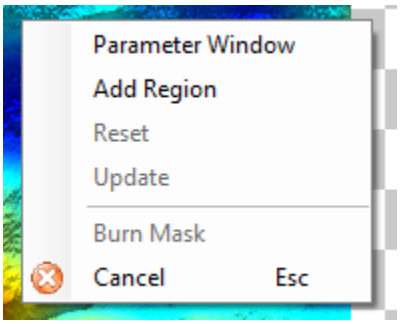

Figure 2.14 Z-Range Mask Context Menu

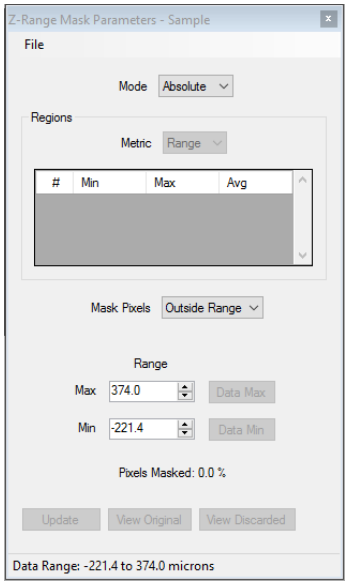

Figure 2.15 Z-Range Mask Parameters Window - Absolute

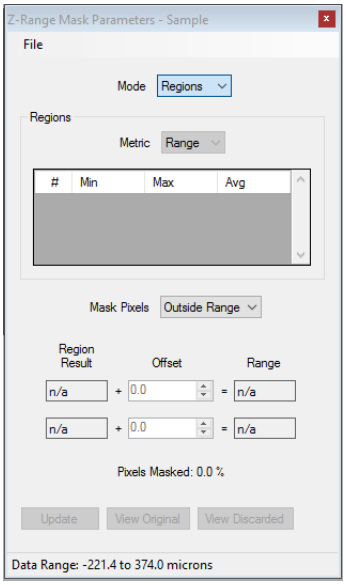

Figure 2.16 Z-Range Mask Parameters Window - Regions

The Z-Range Context Menu has 6 options, listed below.

Parameter Window	Opens the Parameter window if it is closed and brings it to the front if it is opened.
Add Region	While Regions mode is active, allows the user to add a region.

Reset	Removes any regions and masks and returns the data to its unfiltered state.
Update	Applies any parameter changes to the data.
Burn Mask	Applies current filtering settings to the displacement image and closes Z-Range Mask Mode.
Cancel	Closes Z-Range Mask mode without applying a mask.

Note: Right-clicking on a single Region brings up a context menu dedicated to ROI editing. Regions are subject to the same ROI editing options described in **Section 3.1**.

The Z-Range Mask Parameters Window has a variety of filtering options. At the very top is a File menu with three options. Load allows the user to save the current parameters as a Z-Range Mask File (*akx_zRangeMask). Save creates a new Z Range Mask file from the current settings. Finally, Save Map, which activates once a mask has been updated on the file, creates a *.akx_mask file out of the current Z-Range Mask. This turns the masked data based on Z-Range into a normal, location based mask.

Next, the user can choose between Absolute Mode (**Figure 2.15**), in which data is filtered based on absolute Z-values, and Regions Mode (**Figure 2.16**), in which data is filtered based on the data values in selected regions. Most of the menu is the same between these modes.

The regions section is next. This is inactive in Absolute mode. It lists all currently-active regions, complete with data. The Metric drop-down allows the user to decide whether to filter based on the average or range of the regions.

Note: When there are multiple regions, an overall average of all of the pixels that they contain will be used as the result data for Average, and the overall largest and smallest Max and Min values will be used for Range.

Mask Pixels allows the user to choose how the masked data should relate to the range values. The options are Above Max, Above Min, Outside Range, Inside Range, Below Max, and Below Min. Data within the selected range will be masked out.

The next section varies slightly between Region and Absolute modes, but both display what values are being used to filter data. In Absolute mode, these values are set directly, and may be quickly reset to the max or min of the data. In Regions mode, these values are set mathematically based on the regions, but may be adjusted by changing the Offset values of the maximum or minimum of the data.

Note: In both Regions and Absolute mode, the maximum is the top number and the minimum the bottom.

The final portion of the Z-Range Parameters Window displays data relevant to the filtering process and allows the user to view the results. There is a display of the percentage of currently-masked pixels, and a data range at the bottom with the Min and Max of the original image. The user can hold down the View Original or View Discarded buttons to see what the original data looked like and what portions of it are currently masked out. Finally, the Update button allows the user to propagate any settings changes and see them on the displacement image. No parameter changes have any effect until either Update or Burn Mask has been selected. Example data filtered by two different Z-Range Masks is shown in **Figure 2.17**.

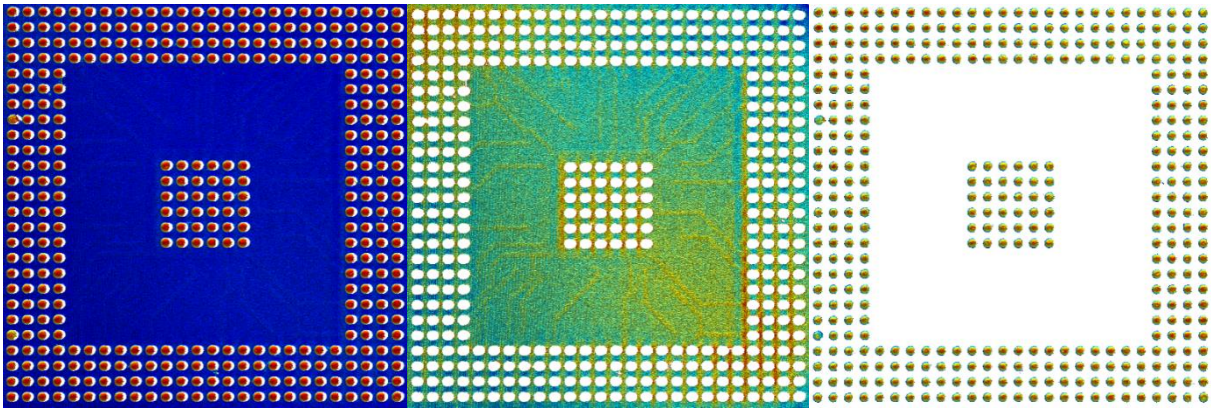

Figure 2.17 Data with High and Low Z-Range Masks

2.4.9 Step Height Calculation

Clicking on **Step Height→Add Step** (**Figure 2.18**) 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 2.19** and **Figure 2.20**). 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.

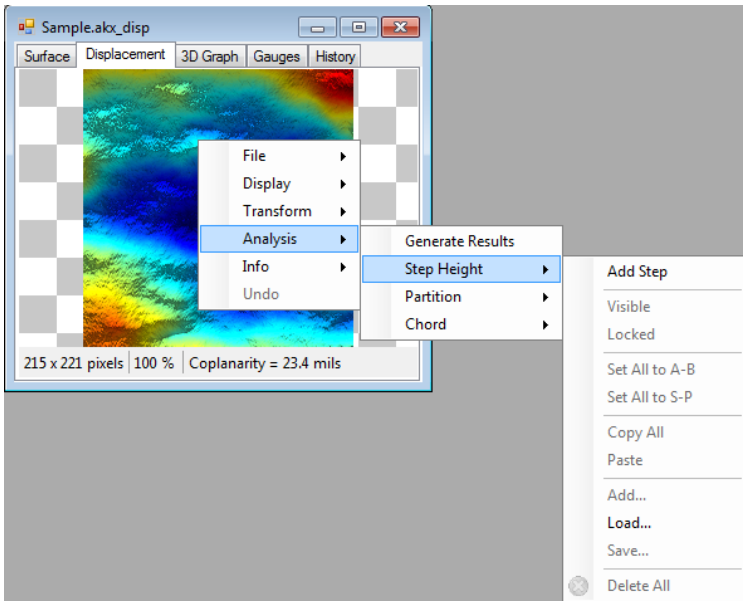

Figure 2.18 Step Height Menu

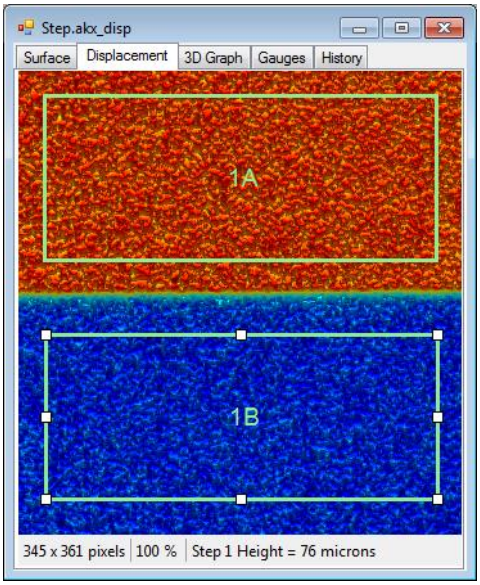

Figure 2.19 Step Height Calculation A>B

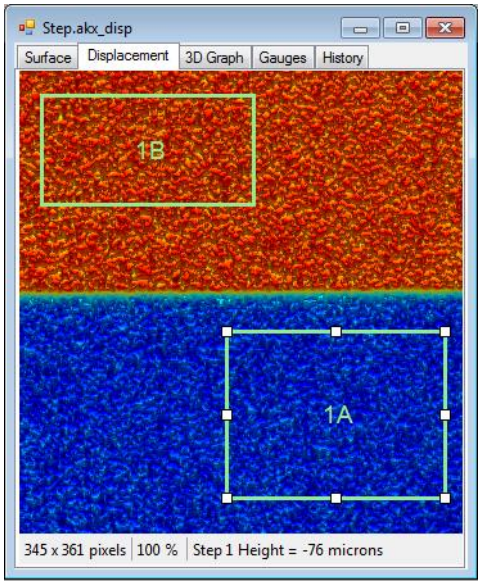

Figure 2.20 Step Height Calculation A<B

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 2.21** and **Figure 2.22** for an example.

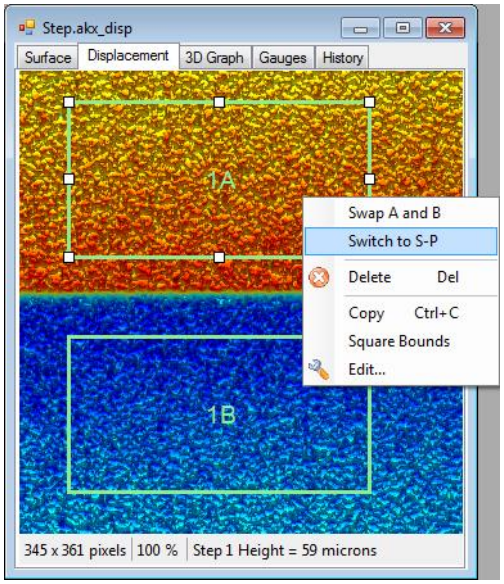

Figure 2.21 A-B Mode

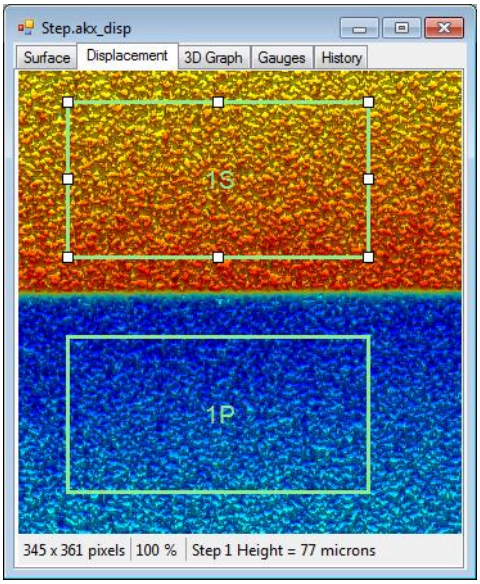

Figure 2.22 S-P Mode

2.5 Saving Displacement Images

A modified displacement 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 displacement image window is closed or the program is shut down.

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

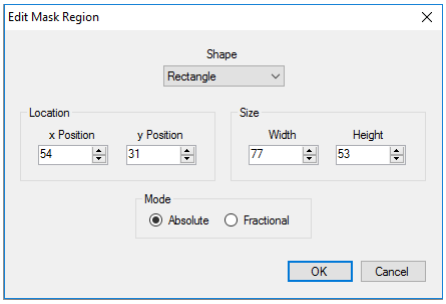

Figure 3.2 Edit ROI Region Size and Position

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: Other functions in Surface Analysis, such as Feature Detection and Z-Range Mask, also use ROIs in their interfaces. These ROIs can be edited using the functionality described above.

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.

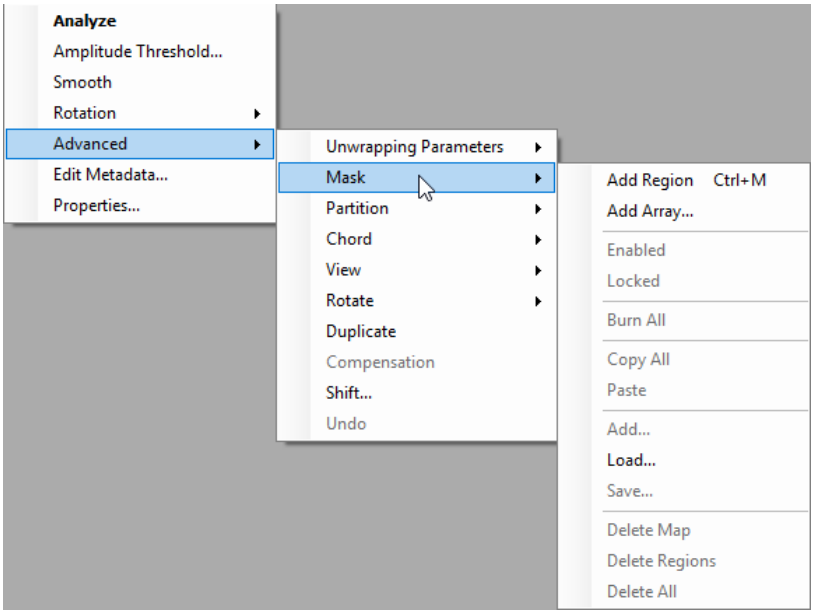

Figure 3.3 Mask Menu

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.

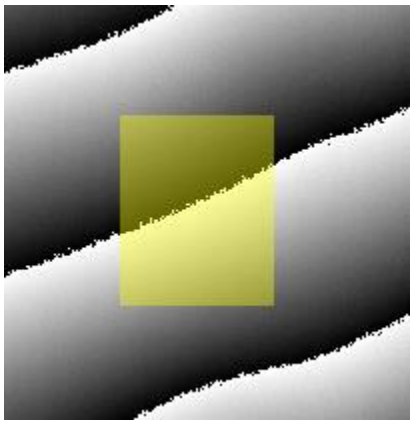

Figure 3.4 Loaded Image Mask in Yellow

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.

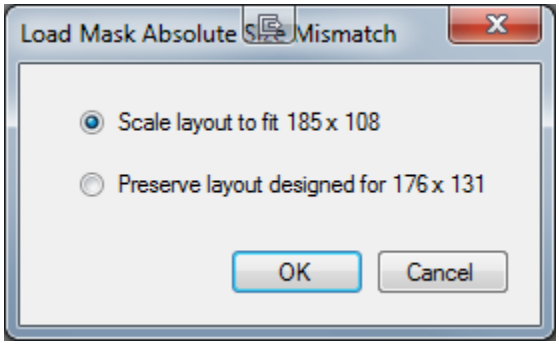

Figure 3.5 Abolute Size Mismatch Dialog

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.

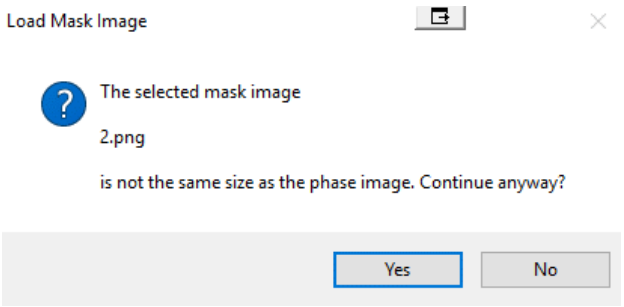

Figure 3.6 Load Image Mask Mismatched Size Dialog

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

All masks on a phase image 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.

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.

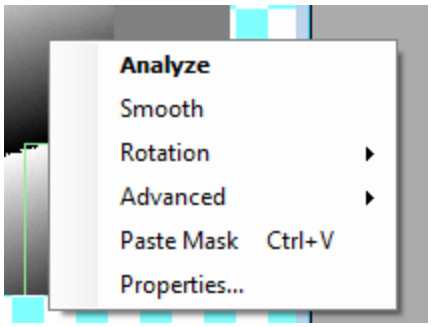

Figure 3.7 Paste Mask Option in Phase Image Context Menu

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

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

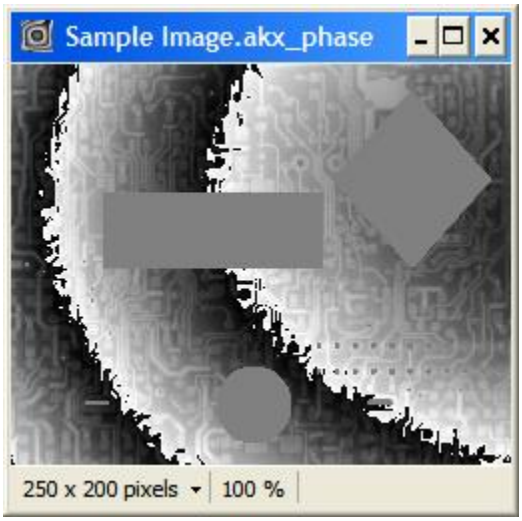

Figure 3.8 Burned Mask Areas

3.2.5 Adding a Mask Array

An array is a grid of mask ROIs. This function is useful for automatically creating a large quantity of mask regions on a phase image. Common use cases include repetitive regions on a PCB or BGA.

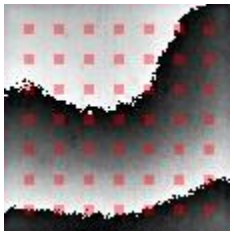

Figure 3.9 Example of a Mask Array

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

   Advanced→Mask→Array…

2. By default, a grid of mask regions appear on the phase image. Also, a box with various array parameter options appear (**Figure 3.10**). The **height** and **width** refer to the individual dimensions of a single mask region. The **center offset** is the distance of the center of the full array from the center of the image. The **spacing** controls how much space exists between each mask region. The **inset** refers to how much of the image is covered by the array (a larger inset reduces the total array size). Each option affects all ROIs in the same way.

   Note: There is no way to independently edit one mask 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.

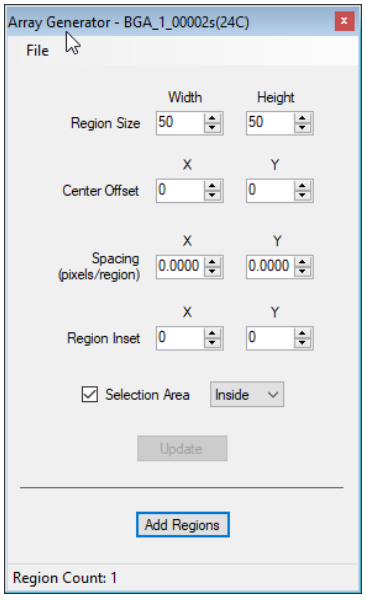

Figure 3.10 Mask Array Parameters

4. To save the mask regions, use the green array bounds box to select the specific regions to be saved. Note that only regions whose whole areas are enclosed by the green rectangle will be saved, as seen in the figure below. Click on **Add Regions** to add the selected regions. The program will lock these regions so that they cannot be edited. Interaction with the created array can occur just as with a normal mask (see **Section 3.2.1**).

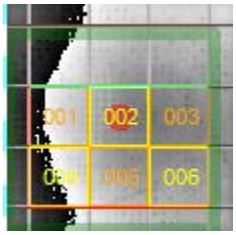

Figure 3.11 Green Array Bounds Box

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.

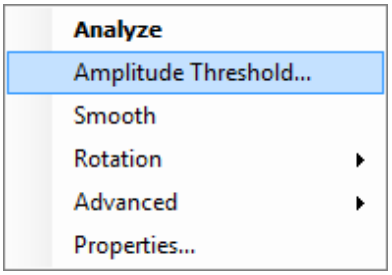

Figure 3.12 Amplitude Threshold Menu Option

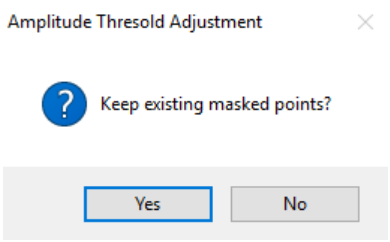

Figure 3.13 PAT Keep Existing Masked Points?

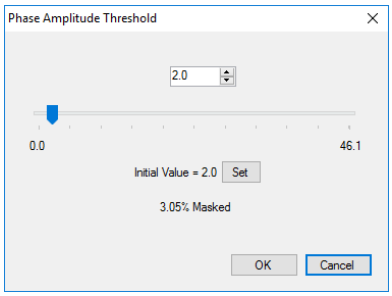

Figure 3.14 Phase Amplitude Thresholding Adjustment Window

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.

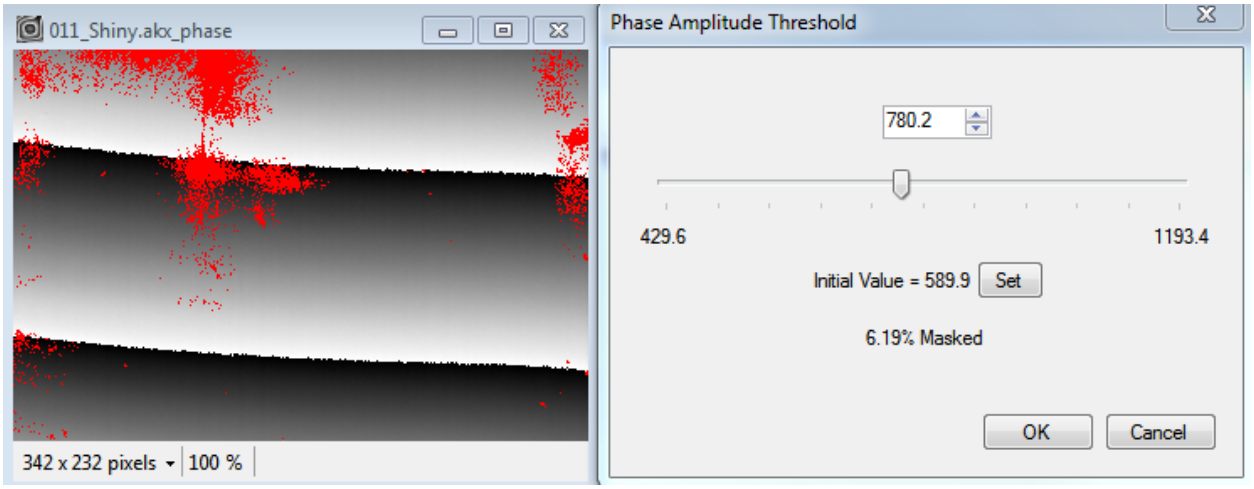

Figure 3.15 Phase Amplitude Thresholding

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.

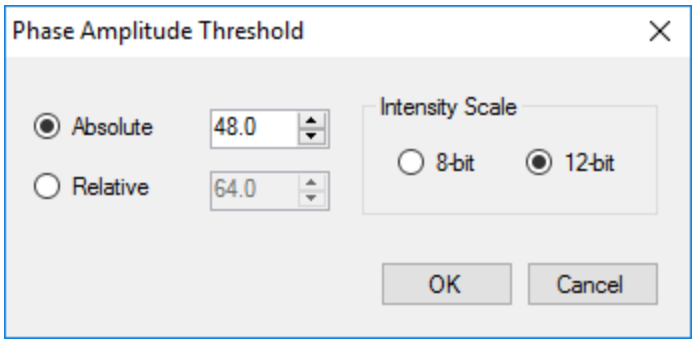

Figure 3.16 Phase Amplitude Threshold Batch Dialog

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**.

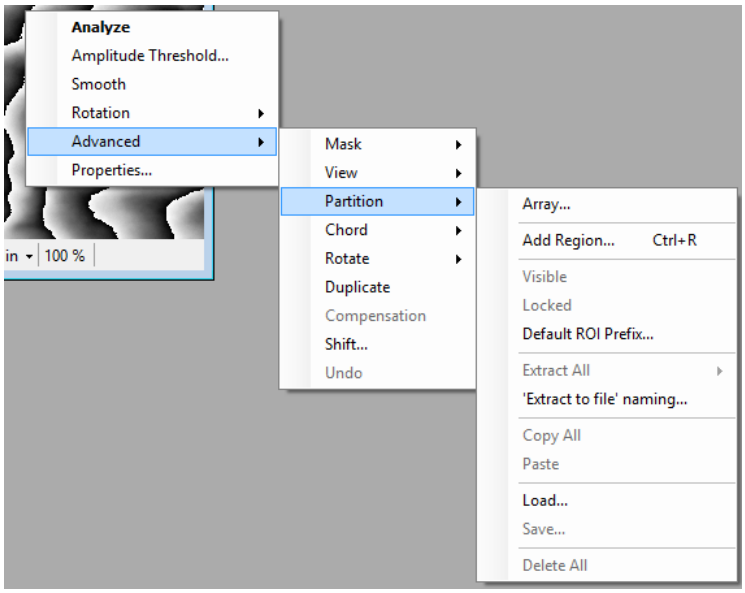

Figure 3.17 Partition Menu

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.

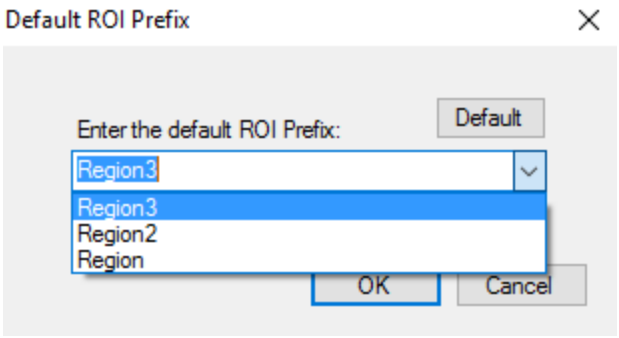

Figure 3.18 Default ROI Prefix Dialog

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 3.19**). 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.

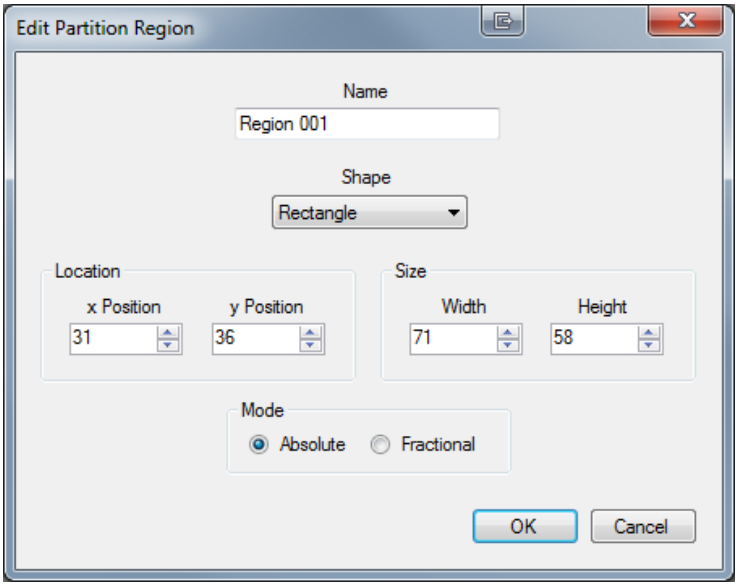

Figure 3.19 A Partition ROI Properties Window

5. Additional domains can be added to the partition (**Figure 3.20**) by repeating steps 1 through 3. Domains may overlap.

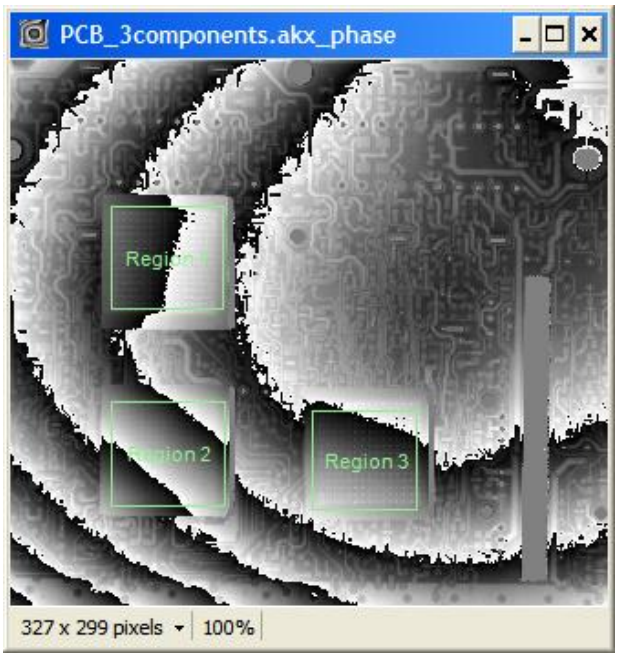

Figure 3.20 Multiple Domains on One Phase Image

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.

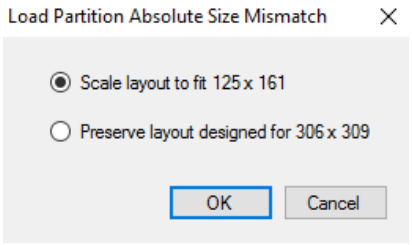

Figure 3.21 Load Partition Absolute Size Mismatch

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.

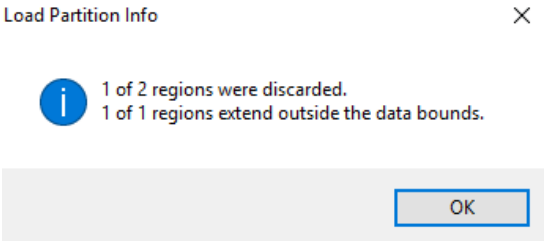

Figure 3.22 Load Partition Preserve Layout Info

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.

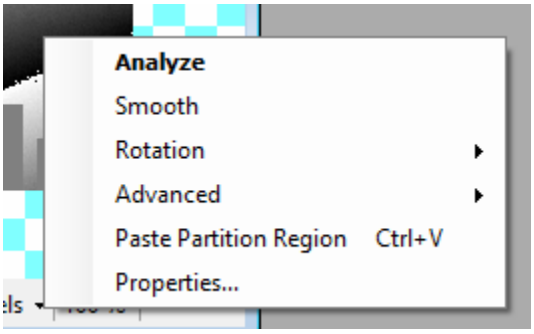

Figure 3.23 Paste Partition Region Option in Phase Image Context Menu

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

Partitions can be extracted from the original phase image, either to new windows (**Figure 3.24**) or to independent *.akx_phase files. To extract a domain as an independent phase image in its own window, right-click inside the domain and choose **Extract**, then choose between '**to window'** and **'to file…'** (**Figure 3.25**). To extract all domains when multiple exist, right-click inside any ROI and choose **Extract All**, and again choose to extract to windows or files. If **'to windows'** is chosen, a new window will pop up for each ROI.

When partitions are extracted to files, the default file name is the ROI name appended to the name of the parent file (Example: Sample_0001.akx_phase). This default can be changed in **Advanced→Partition→'Extract to File' Naming**. The default file names can be edited when extracting individual partitions to files, but are used automatically when **Extract All→'to files…'** is chosen.

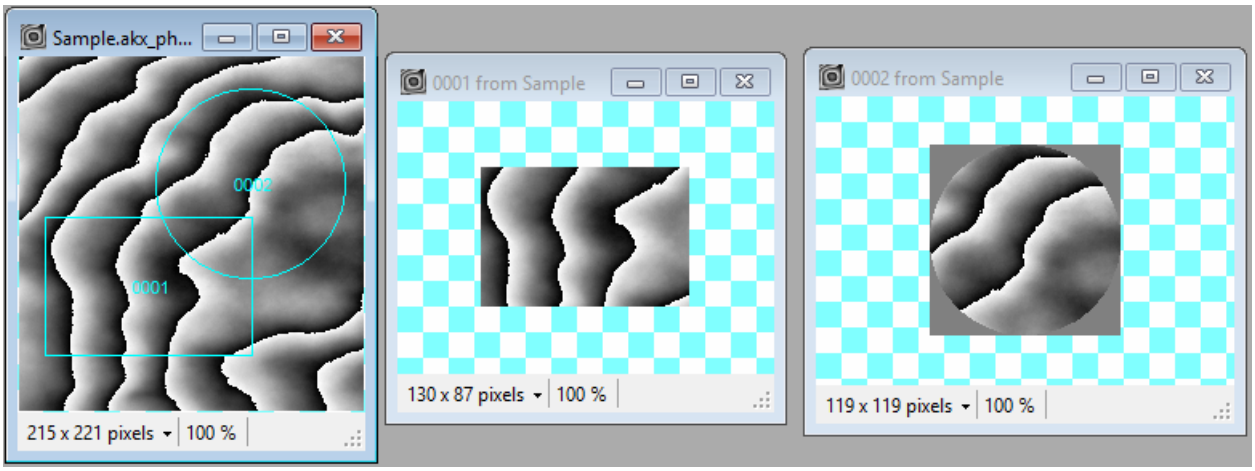

Figure 3.24 Extracted Domains from a Phase Image

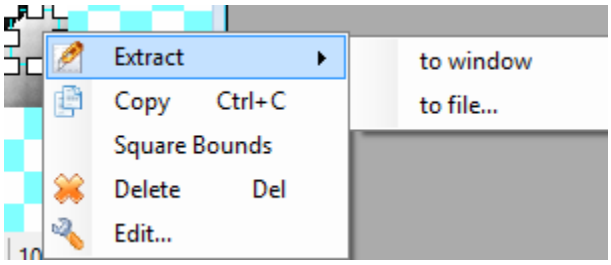

Figure 3.25 Partition Context Menu - Extract

3.5.5 Adding a Partition 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 3.26 Example of a Partition 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 3.27**). 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 **spacing** controls how much space exists between each partition region. The **inset** refers to how much of the image is covered by the array (a larger inset reduces the total array size). 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.

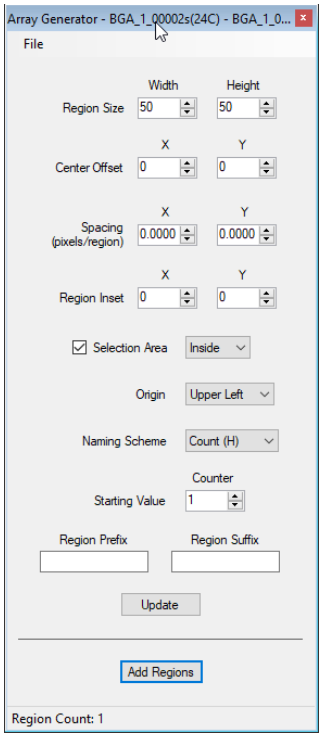

Figure 3.27 Partition Array Parameters

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 **Add Regions** to add the selected regions. The program will lock these regions so that they cannot be edited. Interaction with the created array can occur just as with a normal partition (see **Section 3.5.1**).

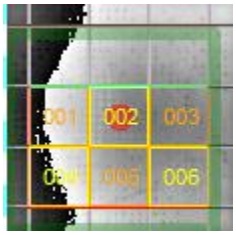

Figure 3.28 Green Array Bounds Box

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 3.30**).

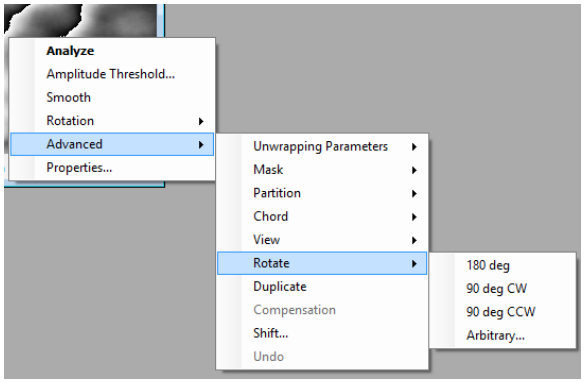

Figure 3.29 Phase Image Rotation

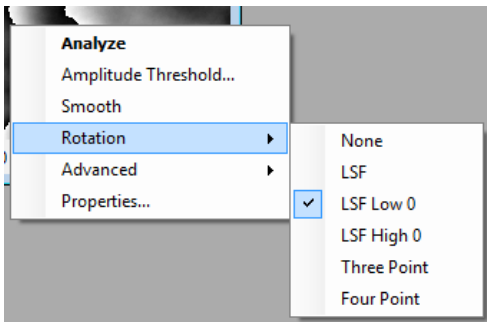

Figure 3.30 Reference Plane Rotation

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 3.31**).

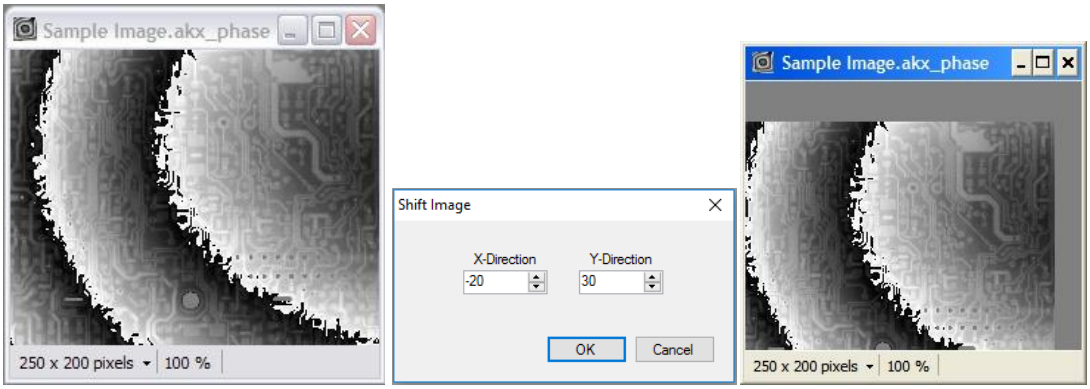

Figure 3.31 Shifting a Phase Image

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 4.6**. 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**.

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. Activating a gauge means that it will be calculated and displayed in both the Displacement Window Gauges tab and at the bottom of any 3D graphs. 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.

Note: The second check box currently has no effect, and its value is not retained. It will have a use in future updates.

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 **Sections 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. Also allows the default file format to be selected as well as whether the file full path is included in the batch results.

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

Cancel The window will close without changes to the settings.

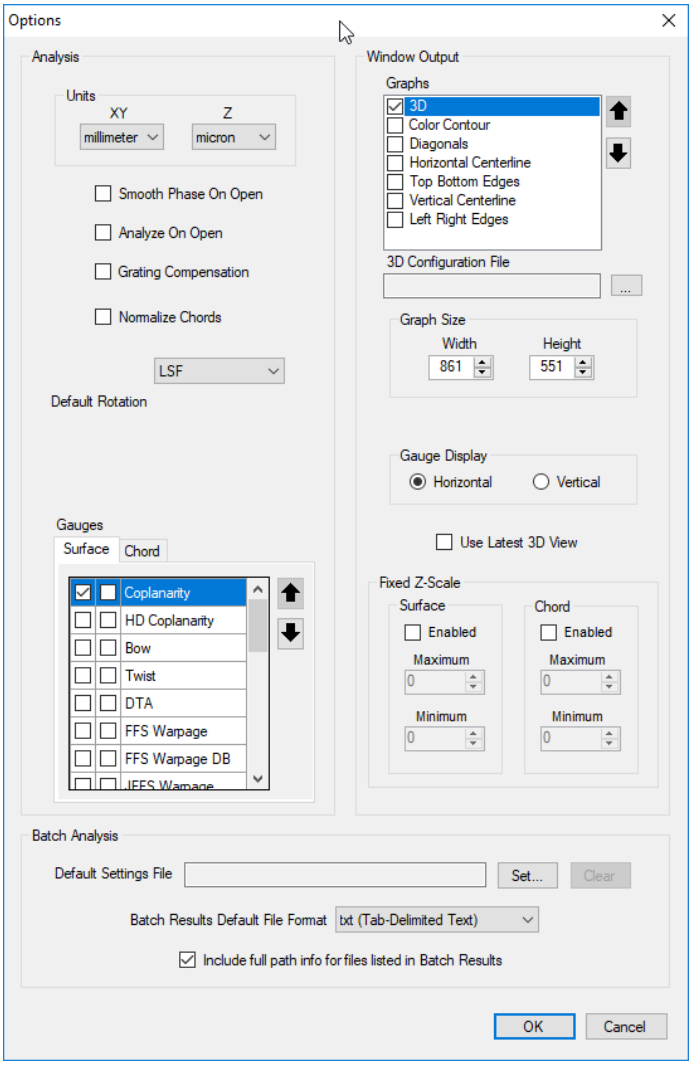

Figure 4.1 Options Window

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 used to rotate the entire surface.

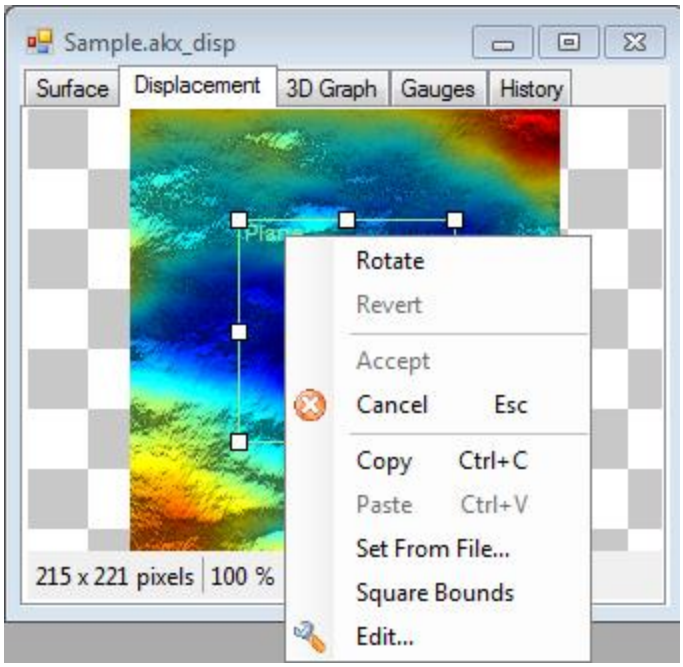

Figure 4.2 User Defined Plane Rotation

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 2.3.5**). 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.

4.6 Unwrapping Parameters

A procedure called “unwrapping” is a key part of the analysis of measured phase data (See **Akrometrix Optical Techniques and Analyses 101**). The unwrapping process starts in the geometric center of the image and converts phase data to displacement values. Because the flood-fill algorithm used is inherently sequential, it simply stops any time a mask value is reached. As a result, it was impossible in previous versions of Surface Analysis to see data that was entirely separated by mask from the center of the surface being analyzed. An example of such data is shown in **Figure 4.3**. Only the center is analyzed because of the mask, which stops the unwrapping process from continuing to the valid surrounding data.

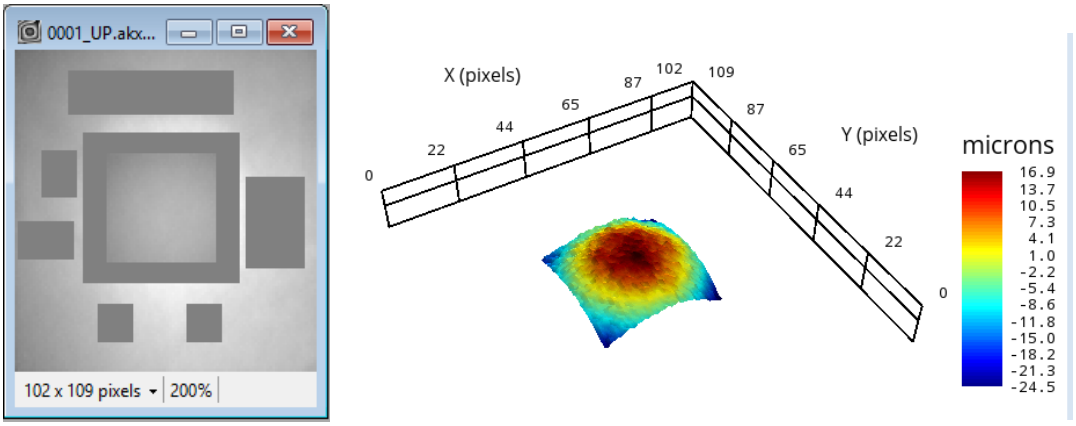

Figure 4.3 Isolated data

As of Studio 8.2, Unwrapping Parameters functionality allows the user to control aspects of the otherwise automated unwrapping process, thereby mitigating these data isolation issues. Unwrapping Parameters as a category covers two specific, mutually exclusive functions, Start Point and Phase Bridging, which solve the issue of isolated data in different ways.

4.6.1 Start Point

Start Point allows the user to manually change the start location of the unwrapping process, which, by default, starts in the center of the image. If only one isolated island of data is of interest, changing the start point allows the user to start the analysis in that island. **Figure 4.4** shows an example. Instead of starting in the center as in **Figure 4.3**, the same image is analyzed with the start point moved to a corner, and the previously-inaccessible edges are now visible at the expense of the center.

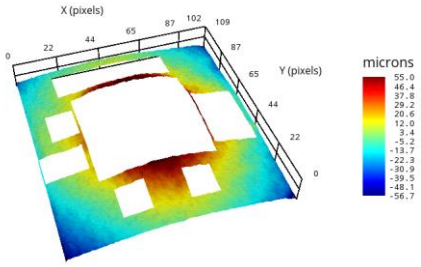

Figure 4.4 Analyzed Data with Altered Start Point

The key steps in editing a Start Point are:

1. Right click on the phase image and go to **Advanced→Unwrapping Parameters→Edit**.
2. In the resulting menu, change the X and Y location of the start point and select OK.
3. An orange dot will appear on the phase image, representing the new start point location. This can be toggled on and off using **Advanced→Unwrapping Parameters→Start Point**.
4. Analyze the file using the new Start Point.

4.6.2 Phase Bridging

Phase Bridging is a more complex solution to the issue of isolated data. With phase bridging, the user draws a bridge from one data "island" to another, so that the analysis software can bridge the gap. Unlike Start Point, Phase Bridging can be used to show all of the data at once. Examples of phase bridging are shown in **Figure 4.5** and **Figure 4.6**. Note that in **Figure 4.5** the data is all at a similar height, while **Figure 4.6** contains a discontinuous step whose height causes much of the actual warpage to be masked. Phase data is still used to calculate exact height from areas, although the height difference itself is entered manually for each bridge.

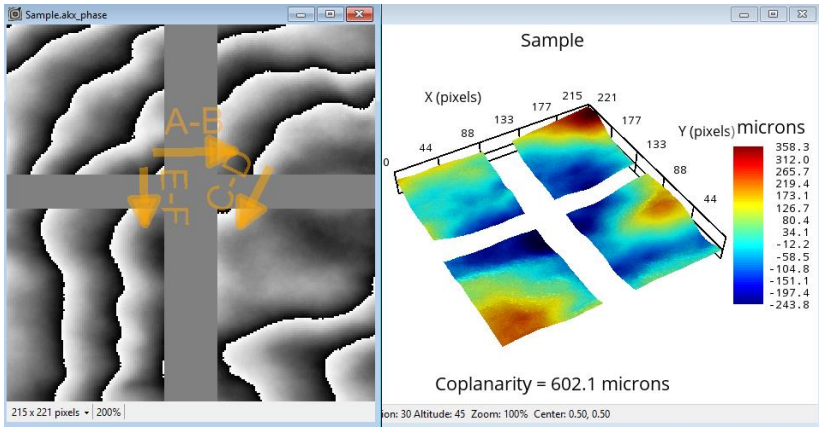

Figure 4.5 Phase-bridged Data at Similar Heights

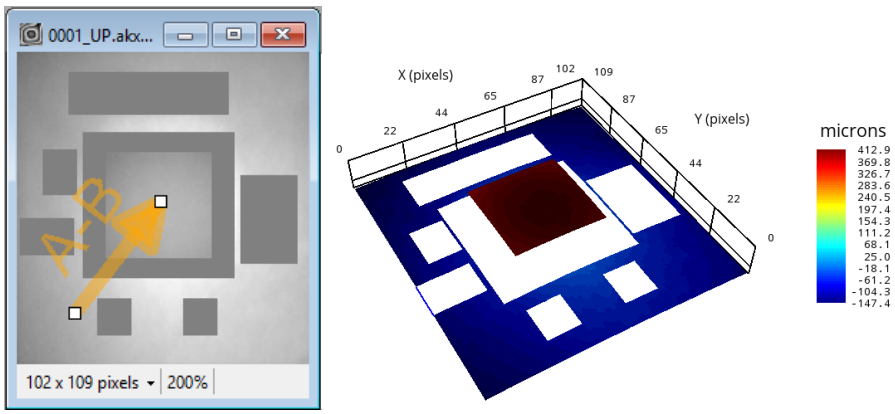

Figure 4.6 Phase-bridged Data with a Step

The key steps in creating a Phase Bridge are:

1. Right click on the phase image and go to **Advanced→Unwrapping Parameters→Add Bridge**, or press **Ctrl+B**.
2. Click on a start and end point in the phase image. Make sure to start in one data "island," and end in another.
3. As of Studio 8.3, Surface Analysis will then show a "Rotated" phase image where the data is shown relative to an LSF plane of the "A" phase region. This helps in determining where to place bridges and what height estimates to apply. Note that this is not the final data rotation as that is performed on the whole data set after unwrapping is complete.
4. An orange arrow will appear on the phase image, representing the new phase bridge. This can be toggled on and off using **Advanced→Unwrapping Parameters→Phase Bridging**
5. The user can add as many phase bridges as are necessary to connect all of the isolated data.
6. Analyze the file using the new Phase Bridge(s).

Note: Once a phase bridge has been added, unwrapping will begin from the beginning of the first phase bridge, and then start at the end of the bridge when that is complete, and so on across all phase bridges. This is why Start Point and Phase Bridging are mutually exclusive, and also why it is not possible to have multiple bridges leaving the same section of data. Bridges must move sequentially from section to section.

The user has a variety of options when it comes to editing and adjusting phase bridges. The start and end points of an existing phase bridge may be altered at any time by clicking and dragging the white handles at either end. In addition, right-clicking on an existing phase bridge brings up a unique context menu whose options are explained below.

Reverse Direction	Switches the start and end points of the phase bridge
Align	Aligns the phase bridge horizontally or vertically
Delete (Del)	Deletes the phase bridge
Edit	Brings up the Phase Bridge Edit Window shown in **Figure 4.7.**

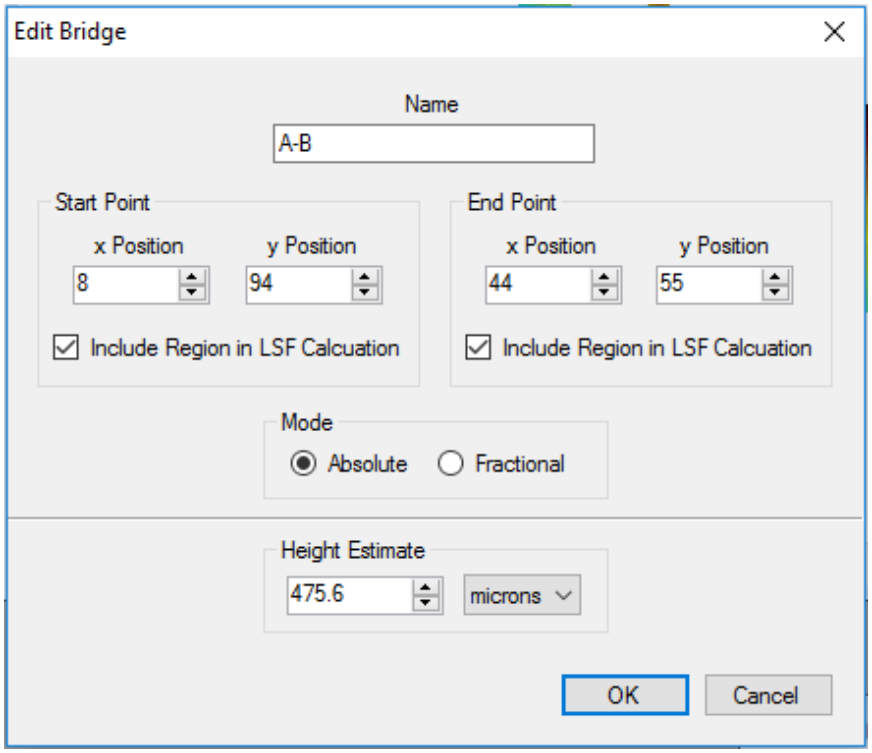

Figure 4.7 Phase Bridge Edit Window

The Edit Bridge window gives the user access to several powerful options for controlling phase bridges. These include:

Name	Change the name of the phase bridge. The default naming scheme for phase bridges is A-B, B-C, C-D, etc.
Start Point	Determines the coordinates of the start point of the phase bridge.
End Point	Determines the coordinates of the end point of the phase bridge.
Include Region in LSF Calculation	Selecting this option includes a given region when an LSF plane calculation is performed on the data (see **Section 4.3**).
Mode	Determines whether the coordinates of the start and end points are expressed in absolute or fractional mode.
Height Estimate	The user-entered height estimate is used by the program to determine the relative height of bridged sections. Since phase data is relative, the program doesn't treat a connected section a different fringe order unless the user tells it to. The user height estimate determines the fringe order of the isolated section while the actual phase data is used for fine scale height within that fringe order.

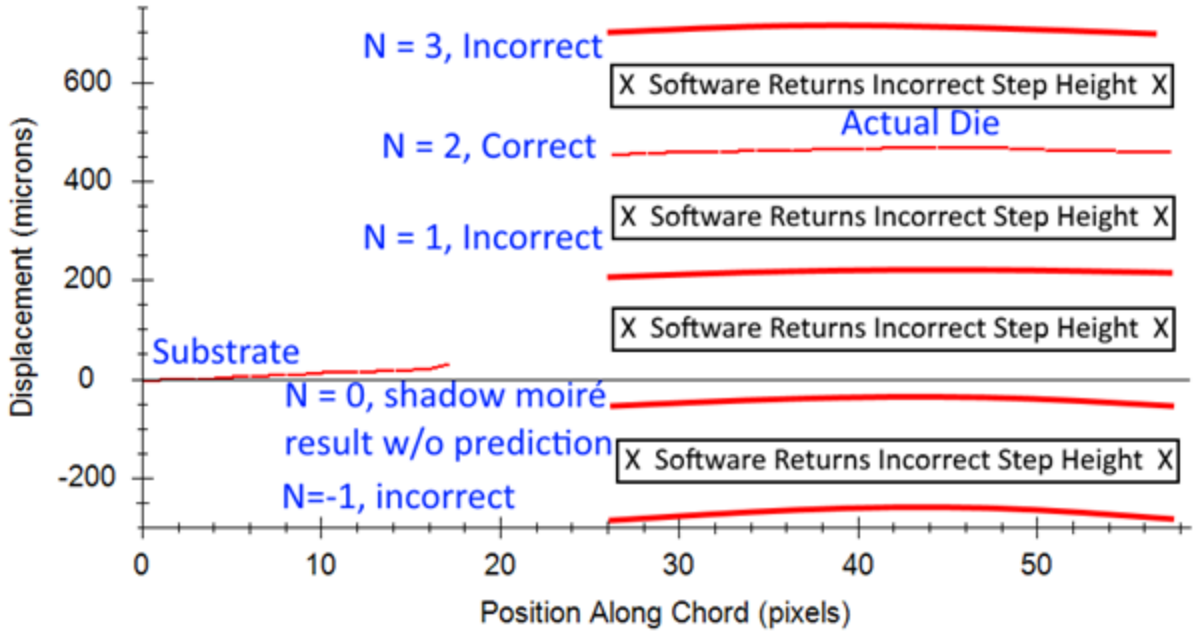

Figure 4.8 Phase Bridge Step Height Example

Note: Height estimates must fall within +/- 0.25 Fringe Values of the measurement (+/-64 microns with the 100 LPI). Height Estimates incorrect by +/- 0.25 to 0.75 Fringe Values will generate an error from the software stating an incorrect height estimate. Height approximations incorrect beyond this threshold would lead to incorrect data. This is illustrated in **Figure 4.8** using the same data set from **Figure 4.6**.

4.6.3 Unwrapping Parameter Files

Once unwrapping parameters have been set, the user can copy or save them to use them in other files. From the Advanced>Unwrapping Parameters context menu, the user can:

- Load existing *.akx_unwrap files.
- Save any active unwrapping parameters as *.akx_unwrap files.
- Copy any active unwrapping parameters.
- Paste copied unwrapping parameters onto phase images.

Note: In this context, “active unwrapping parameters” are those that are toggled on in the context menu and visible in orange on the phase image.

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.

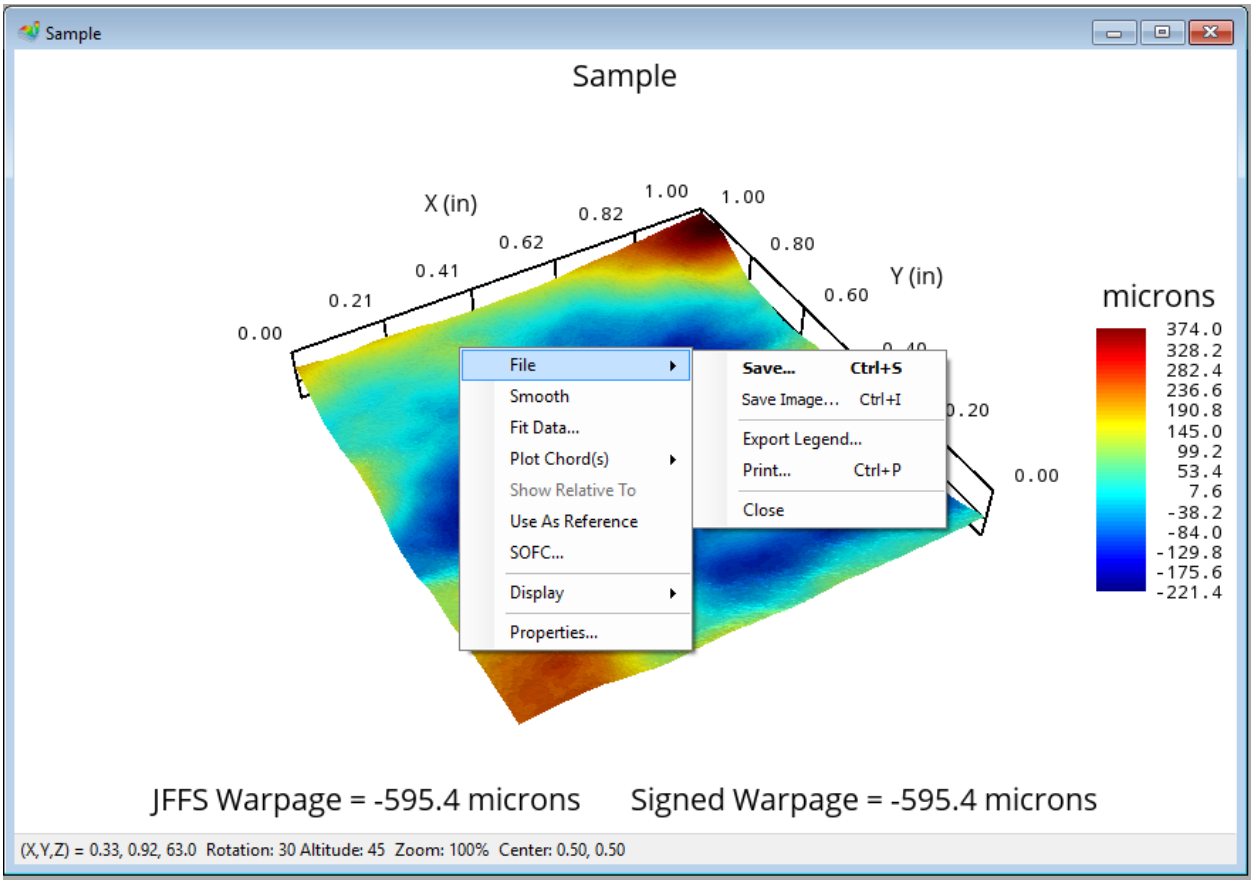

Figure 5.1 3D Surface Plot

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 multi-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
SOFC	Displays a window containing all Second Order Fit Coefficients used to calculate a 2nd order polynomial fit for the 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, scale options, and a switch to show Pin 1 Location on plots. Lastly, graph configuration parameters are accessed here. See **Section 5.1.5**
Properties…	Opens a displacement object properties window with all saved parameters relating to the displacement object.

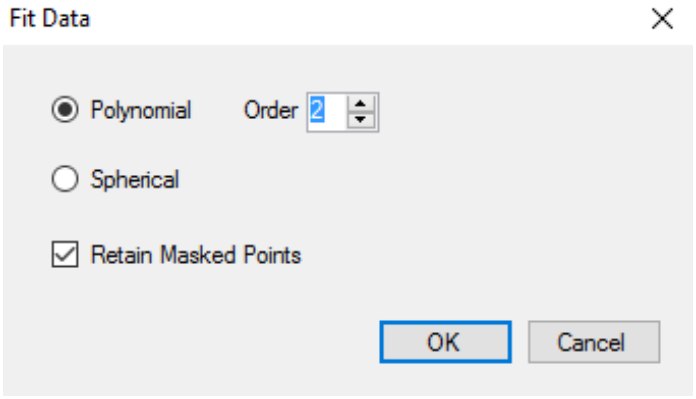

Figure 5.2 Fit Data Dialog

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.

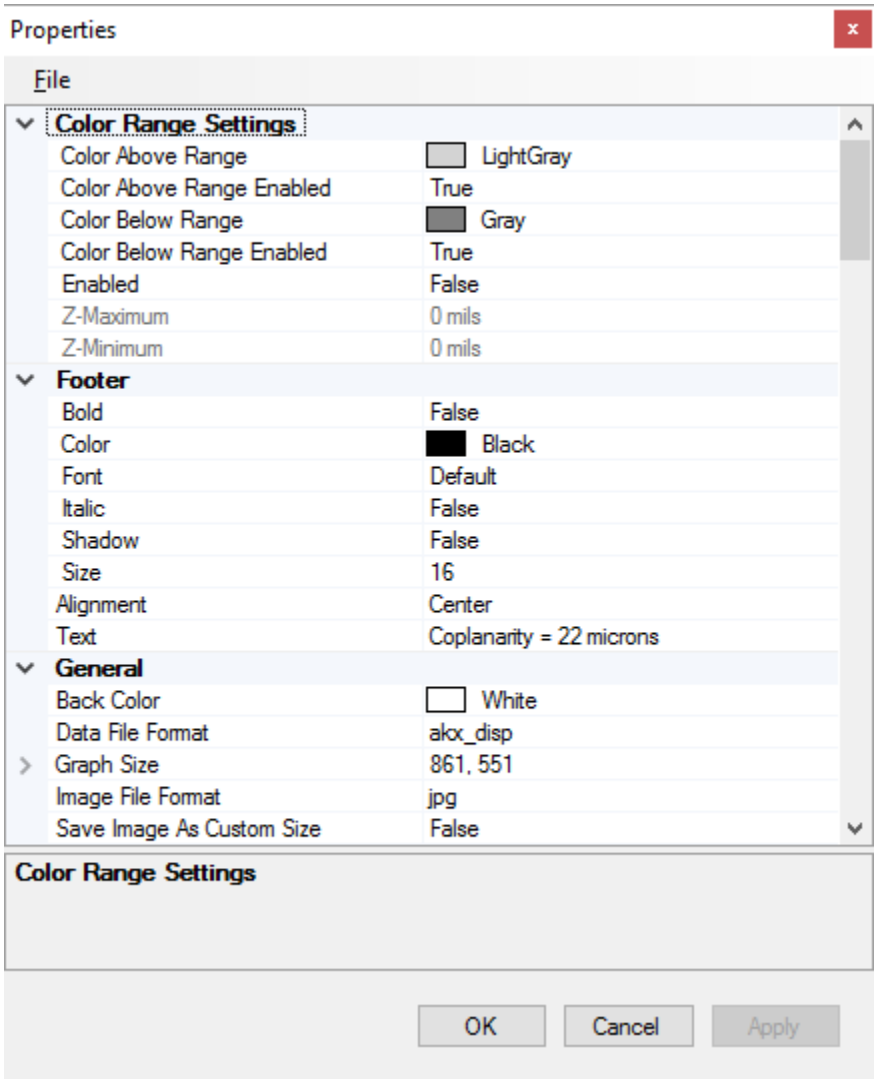

Figure 5.3 Display Configuration Window

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**).

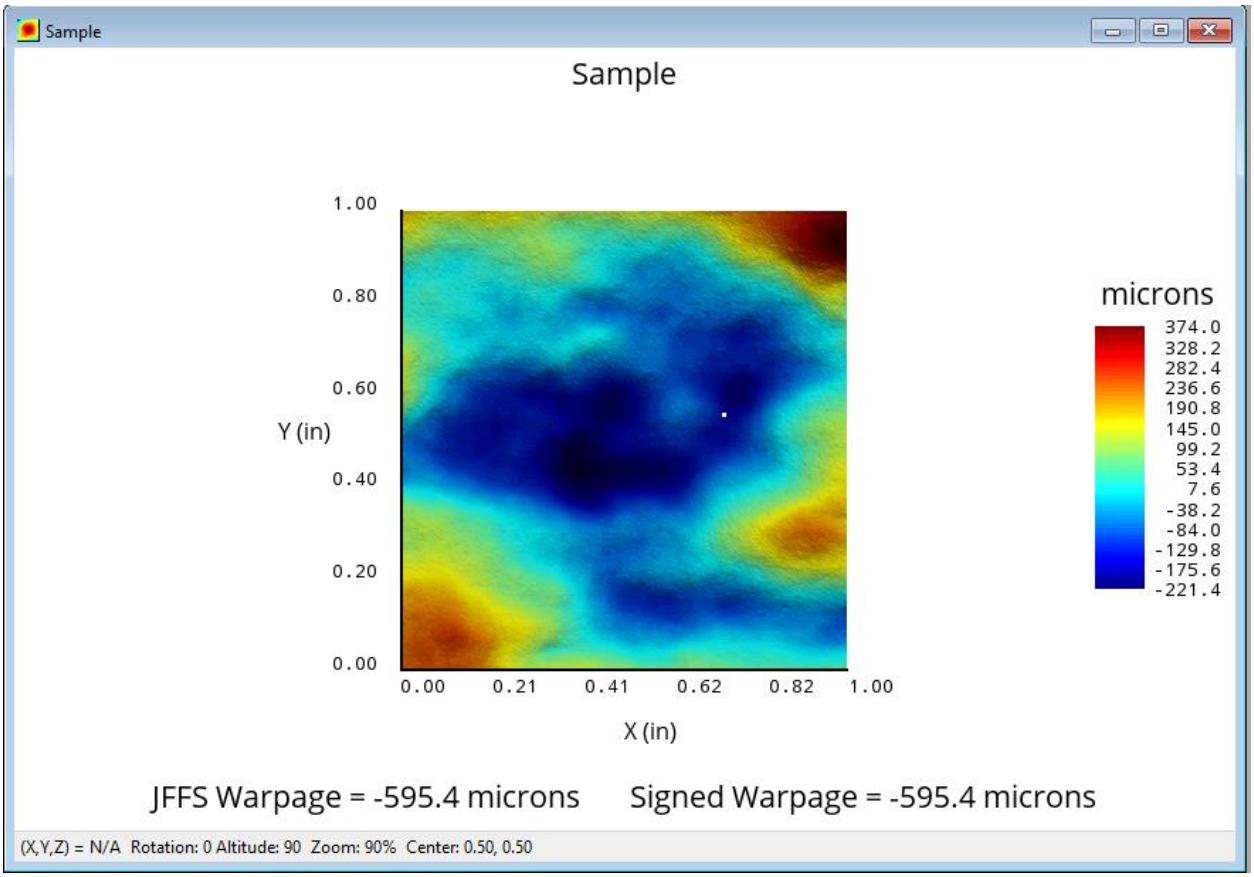

Figure 5.4 Contour Plot

5.3 Graphical Output – Default Chord Plots

A chord is a 2D line across the surface of a part. A chord plot graphs the z-values along these lines. Surface Analysis can display a wide variety of plots for both default and custom chords. The most common default chords are Diagonals, Horizontal Centerline, Vertical Centerline, Top Bottom Edges, and Left Right Edges. These common chords are all available on the **Graphs** list in Tools>Options, and checking them there causes these chord plots to come up automatically when analyzing a phase image.

Note: The diagonal plot (**Figure 5.5**) represents two cross-sections of the surface along diagonal lines connecting the corners.

The plot window for any of these common chord plots, along with some other default chords, can also be opened by right-clicking on the 3D display window and selecting **Plot Chord(s)→Chord Name**. A full list of available default chords is below.

- Diagonals
- Centerlines
- Top Bottom Edges
- Left Right Edges
- All Edges

- All Edges Centers Diags
- Five Vertical
- Five Horizontal
- Horizontal Centerline
- Vertical Centerline

Note: All of the chords oriented horizontally are plotted from left to right and all vertical chords are plotted from top to bottom.

Note: The caption of the 2D display window can be renamed by right-clicking on its title bar and selecting **Rename Window…**.

Note: On the 3D Graph tab of a displacement file, **Analysis→Plot Chord(s)→Chord Name** will bring up a chord plot.

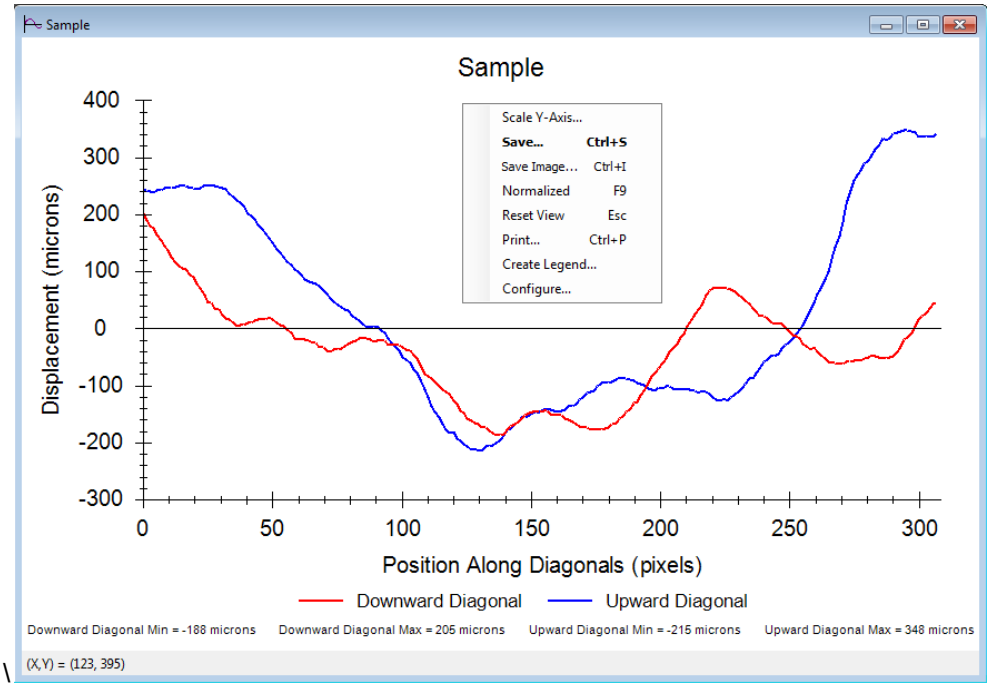

Figure 5.5 Diagonal Plot

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.png).
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 – Custom Chord Plots

In addition to the default chords described in **Section 5.3**, arbitrary chords or chord sets can be defined, where out-of-plane displacement data along any line(s) can be displayed. The following subsections 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)**. Using the mouse, draw a line across the image, holding down the left mouse button at the start point and releasing it at the end point.

Note: Chords can also be plotted on 2D displacement images (*.akx_disp files). The menus and functionality are the same, but the Chord Menu is found under **Analysis→Chord** for displacement images, rather than **Advanced→Chord** in phase images. The rest of this section will use the terminology for phase images.

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. They cannot be edited.

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.

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 (Del)	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 5.3.1**.

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. These files can be loaded in batch analysis and report creation as well as on individual phase or displacement images.

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)**. 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 in PNG 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 from the context menu. For any 2D plot, this is done by right-clicking on the display window and selecting **Save…**. A standard **Save** window appears with multiple choices for the save format in the **Save as type** pull-down list at the bottom. 3D plots – Color Contour and 3D graph – have slightly different context menus and save options, as described in **Section 5.1.4**.

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

Dat and text files containing chord data will use the same prefixes as chord image files, as described in **Section 5.4.5**.

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 seven batch functions available:

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

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 seven 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.

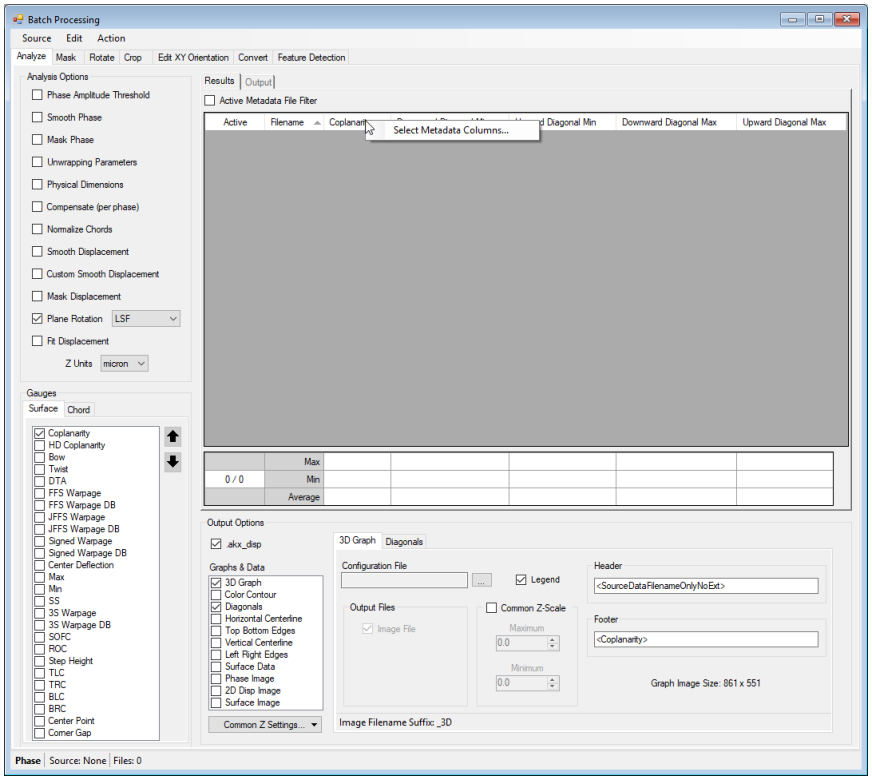

Figure 6.1 Batch Processing Screen

6.2 Batch Analysis

The batch analysis function opens the image or displacement files in the selected folder(s), 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 → Settings → Duplicate Window	Opens a duplicate of the current batch processing window, including all loaded data and current settings.
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 must be done before analysis. See **Section 7.1** for details.
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, as well as displaying images in the Output tab. See **Section 6.2.5**.

Action → Lock Results	Locks the results of analysis to a particular window. This option is not active unless Generate Output has been performed. While it is active, the output images will be held in temporary memory and will not be affected by any other analysis of the same files, allowing the user to compare different analysis settings on the same files. Unlocking the results will clear them from memory, requiring the files to be reanalyzed.
Action → Create Report…	Opens the report creation window with analysis 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.

Note: The List Files option in the context menu in **Figure 6.4** gives a list of all filenames of currently-active files in the folder. This can be used with Filename Filter to more precisely filter out any unwanted files.

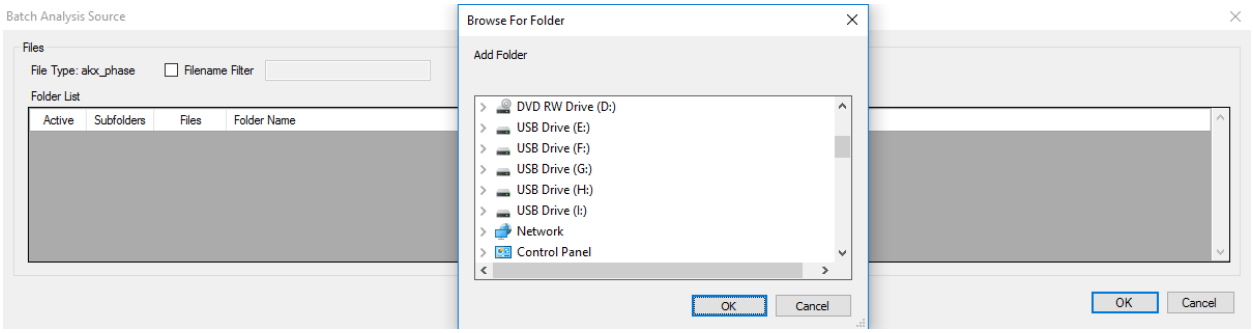

Figure 6.2 Batch Analysis Source Selection Browse for Folder

Figure 6.3 Batch Analysis Source Selection Add Folders

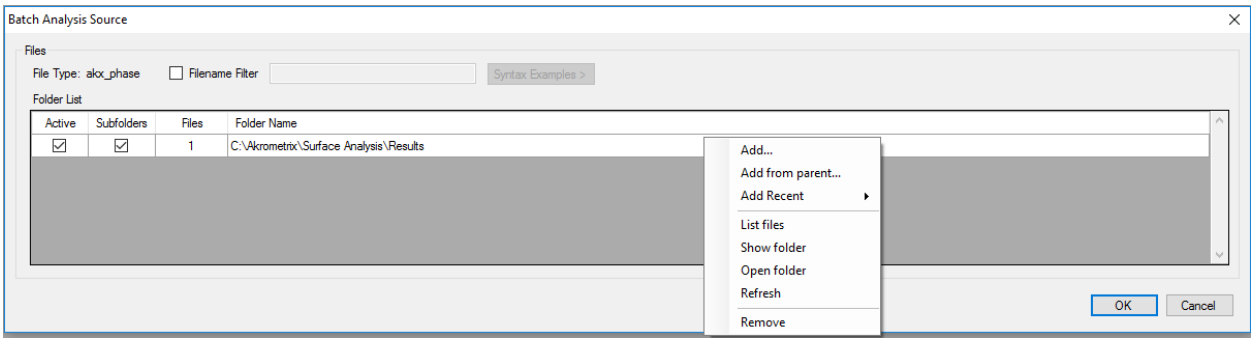

Figure 6.4 Batch Analysis Source Selection Add from parent...

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. In addition, several options allow the user to set the active files en masse.

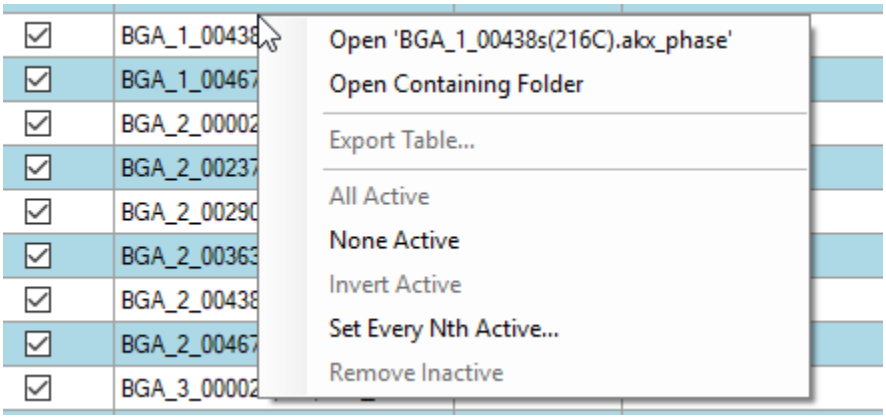

Figure 6.5 Analysis Results Table with Context Menu

3. Select analysis options (**Section 6.2.3**) and any additional columns of metadata required (right click on column headers in Results tab).
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.

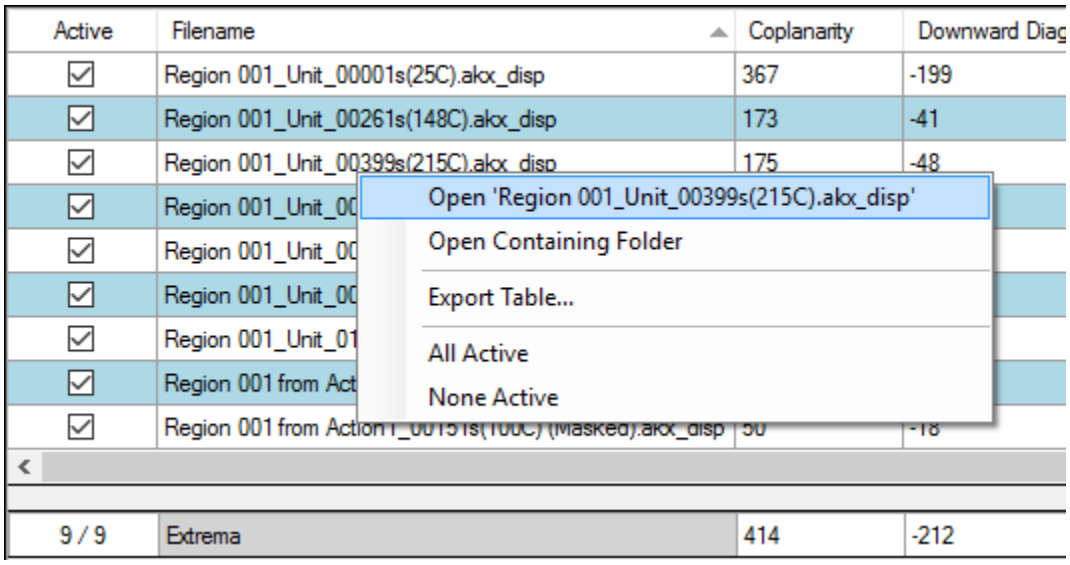

Figure 6.6 Batch Results Table after Analysis

5. Filter out any data not desired using the Active Metadata File Filter option. Files can be unchecked from being Active by setting up filter/logic conditions in the Metadata File Filter Query Builder (**Figure 6.7**). File filter queries can be saved and loaded as *.akx_query files in the Query Builder interface for future use.

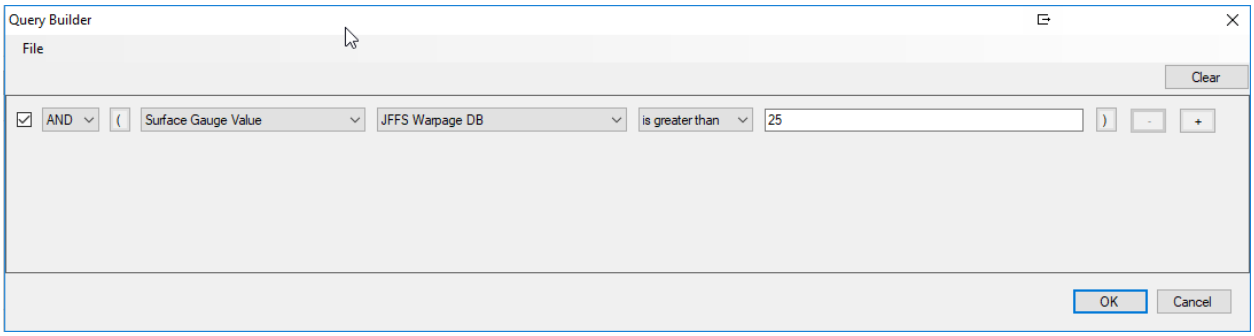

Figure 6.7 Metadata File Filter Query Builder

Note: In Studio 8.3, all numerical queries occur in microns. The word “null” can be substituted for a numerical query to find results for gauges that have failed to calculate.

6. Select desired output and create results. The user may now either go to the automated report generator by selecting **Action→Create Report** (see **Section 7**) to create a formatted pdf report, or create and save images of the results using the **Action→Generate Output** functionality (see **Section 6.2.5**). Settings for the latter are found under Output Options (see **Section 6.2.4**).

6.2.2 Using Batch Analysis to Create Relative Plots

In order to set one of the images in the selected folder as a 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.

6.2.3 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.
Unwrapping Parameters	Allows adjustment of the unwrapping parameters of each phase image for more accurate analysis. See **Section 4.6**.
Physical Dimensions	Assigns a specific physical size to each data file (see **Section 2.3.5**).
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, DTA, 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, as can custom chordsets (*.akx_chordset).

Note: Many of the gauges on the list are abbreviated. Hovering the mouse cursor over an abbreviated gauge will bring up a tooltip containing its full name.

6.2.4 Output Options

These options affect the results of the **Action→Generate Output** command (See **Section 6.2.5**).

.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.

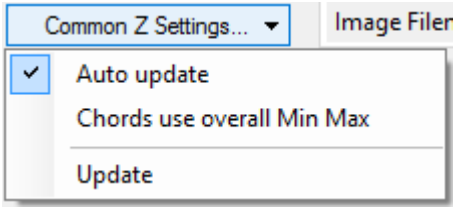

Figure 6.8 Common Z Settings

Output Files This section is only active 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).

After output is generated, image and data 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.

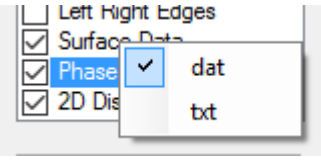

Figure 6.9 Surface Data Options

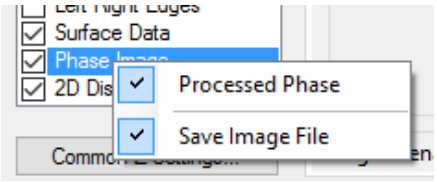

Figure 6.10 Phase Image Options

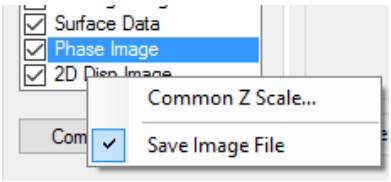

Figure 6.11 2D Disp Image Options

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.

6.2.5 Output Tab

After analyzing the data, the user may save images and directly view their results by selecting **Action→Generate Output**. This brings up an Output tab in which all plots selected under Output Options are visible. The user can use the arrows and tabs here to switch between files and graph types. If the results are locked using **Action→Lock Results**, then the images will remain visible even if the underlying *.akx_disp files are altered or overwritten.

If the user has opened multiple batch processing windows, then it is possible to sync the visible image between them, allowing for side-by-side comparison of different analysis options. This is done using the context menu shown in **Figure 6.12**. The sync option is not available in a given batch processing tab unless its results are locked. When selected, the result plot is changed on all batch processing windows currently open when it is changed on one. This allows for quick comparison of results between different batch processing windows.

Note: All batch processing results windows must be locked in order for the Sync option to be available.

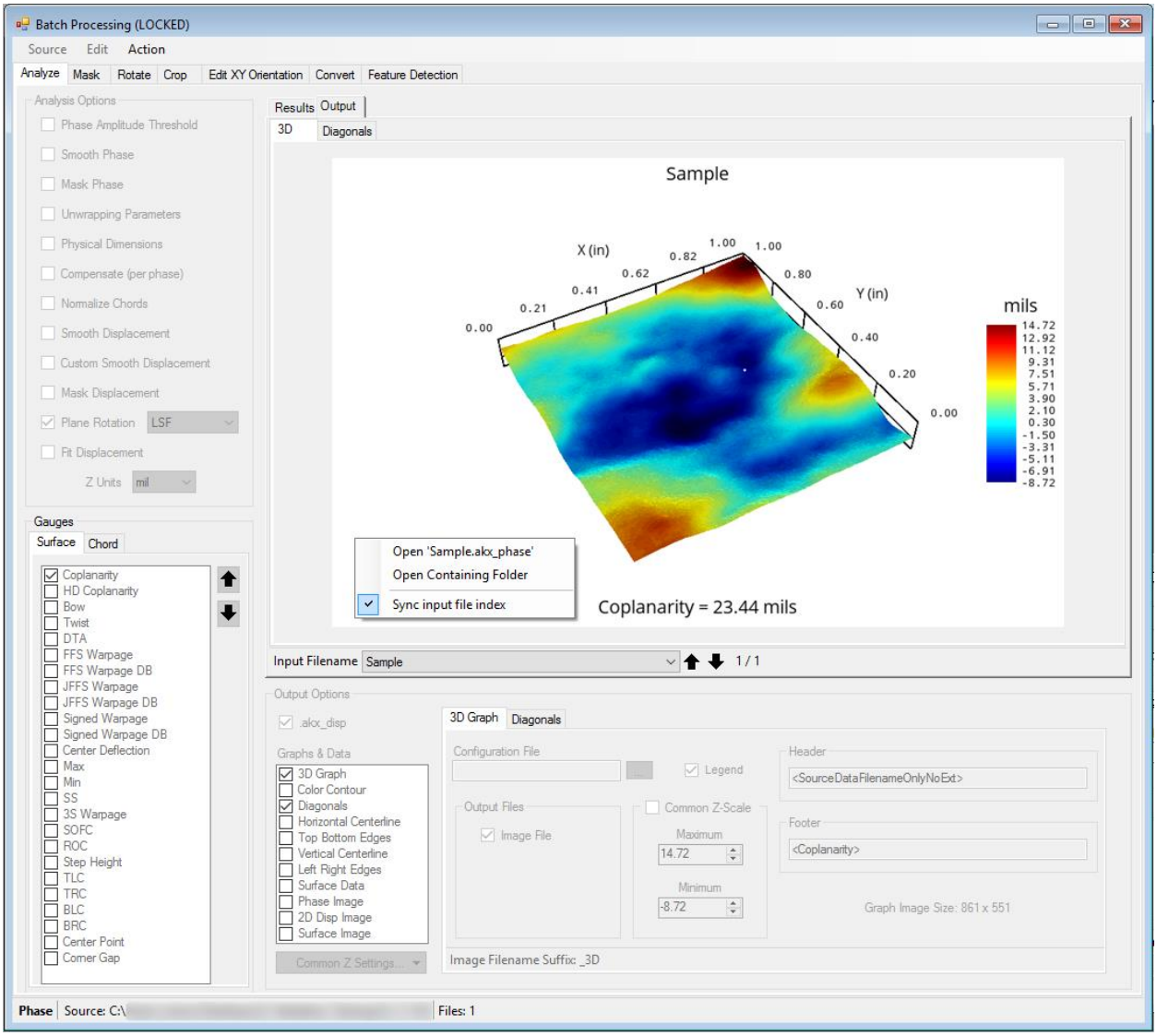

Figure 6.12 Output Tab

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 6.13**).

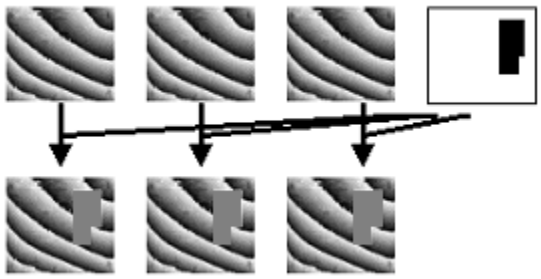

Figure 6.13 Batch Burn

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 6.14.

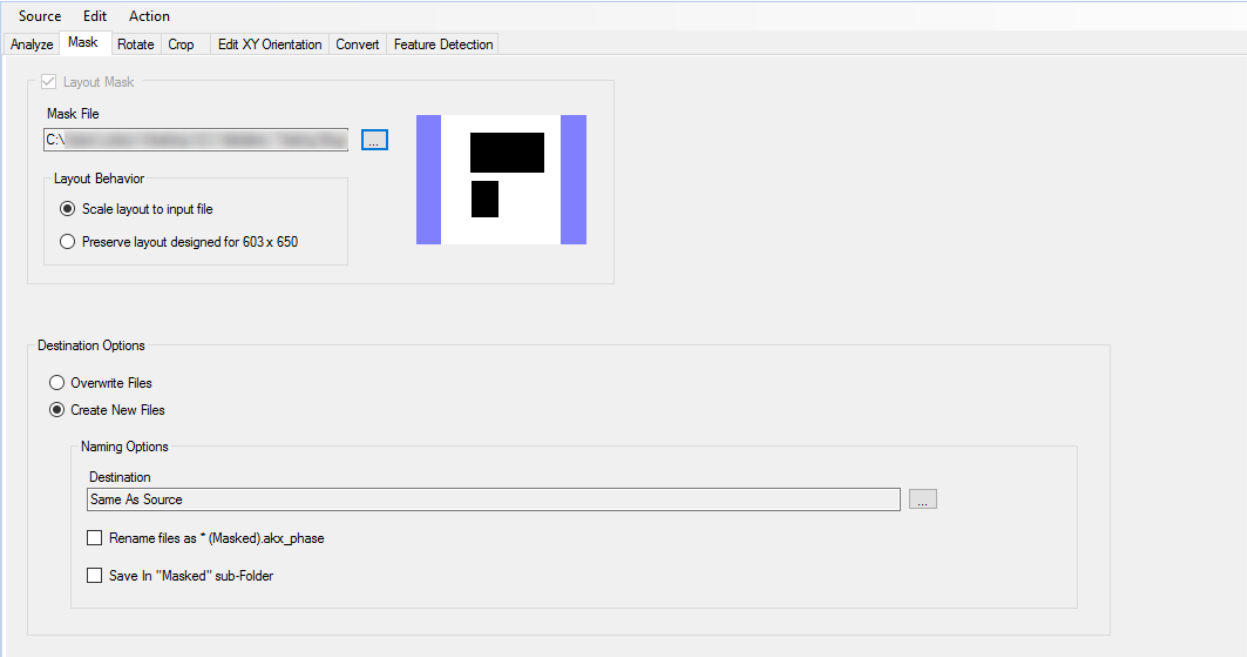

Figure 6.14 Batch Masking Screen

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). When masking *.akx_disp files, new options become available (see **Section 6.3.6**).
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.
Rename 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.

6.3.6 Masking Displacement Files

When masking *.akx_disp files in Batch Mask, several new options appear in the Batch Processing Window, as shown in **Figure 6.15**. These options are Z-Range Masking, Plane Rotation, and a Results Table.

Displacement files can be masked with the standard masks described earlier, Z-Range Masks, or both. Z-Range Mask functionality is described in **Section 2.4.8**, and works in essentially the same modal fashion with the same options in batch mode as in one-off mode. In Absolute Mode, the user may set a range and mask logic to mask the source files, or load in a *.akx_zRangeMask file containing these settings. To enter Region mode, the user must load a *.akx_zRangeMask file containing at least one region. They may then adjust metric, logic, and offset as they would in one-off mode before masking.

Plane Rotation gives the user an option to adjust the rotation of masked data. The rotation options are those described in **Section 4.3**. If this option is checked, then after

masking the rotation plane of the data will be changed to the selected one. This is useful for masking out noisy data that might have adversely affected initial rotation.

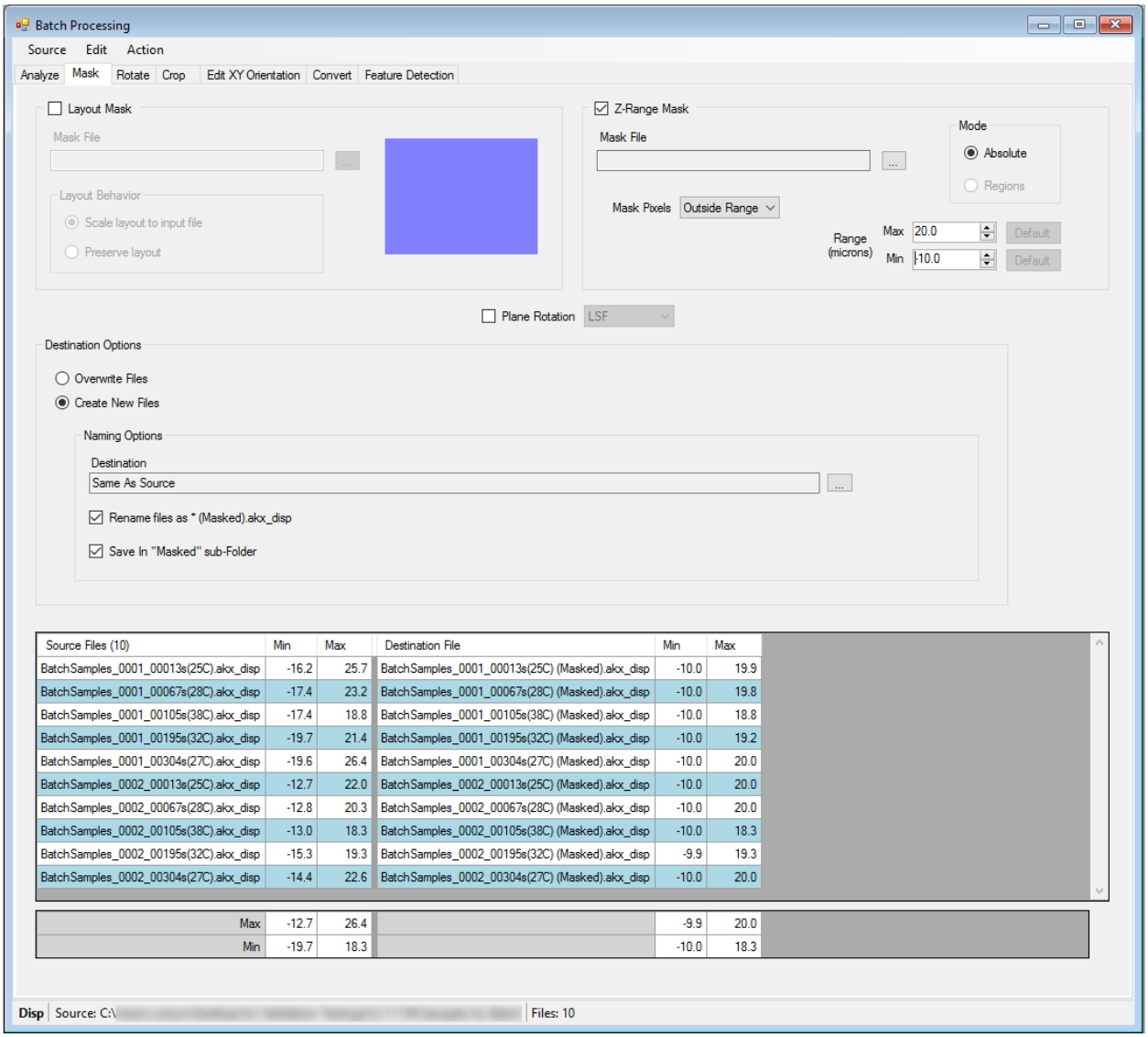

Figure 6.15 Batch Mask Results for Displacement Files

Finally, when File Type is set to *.akx_disp, the Results section appears at the bottom of the Batch Mask window. This populates itself with a list of the source filenames when files are loaded. The rest of the table does not populate until masking has been performed. Once it has, the table fills with the minima and maxima of each original and destination file, plus overall minima and maxima. This allows the user to see whether anomalous maxima or minima were actually filtered out, as is often the intent of masking operations, and to assess the quality of the masking operation.

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 6.16**.

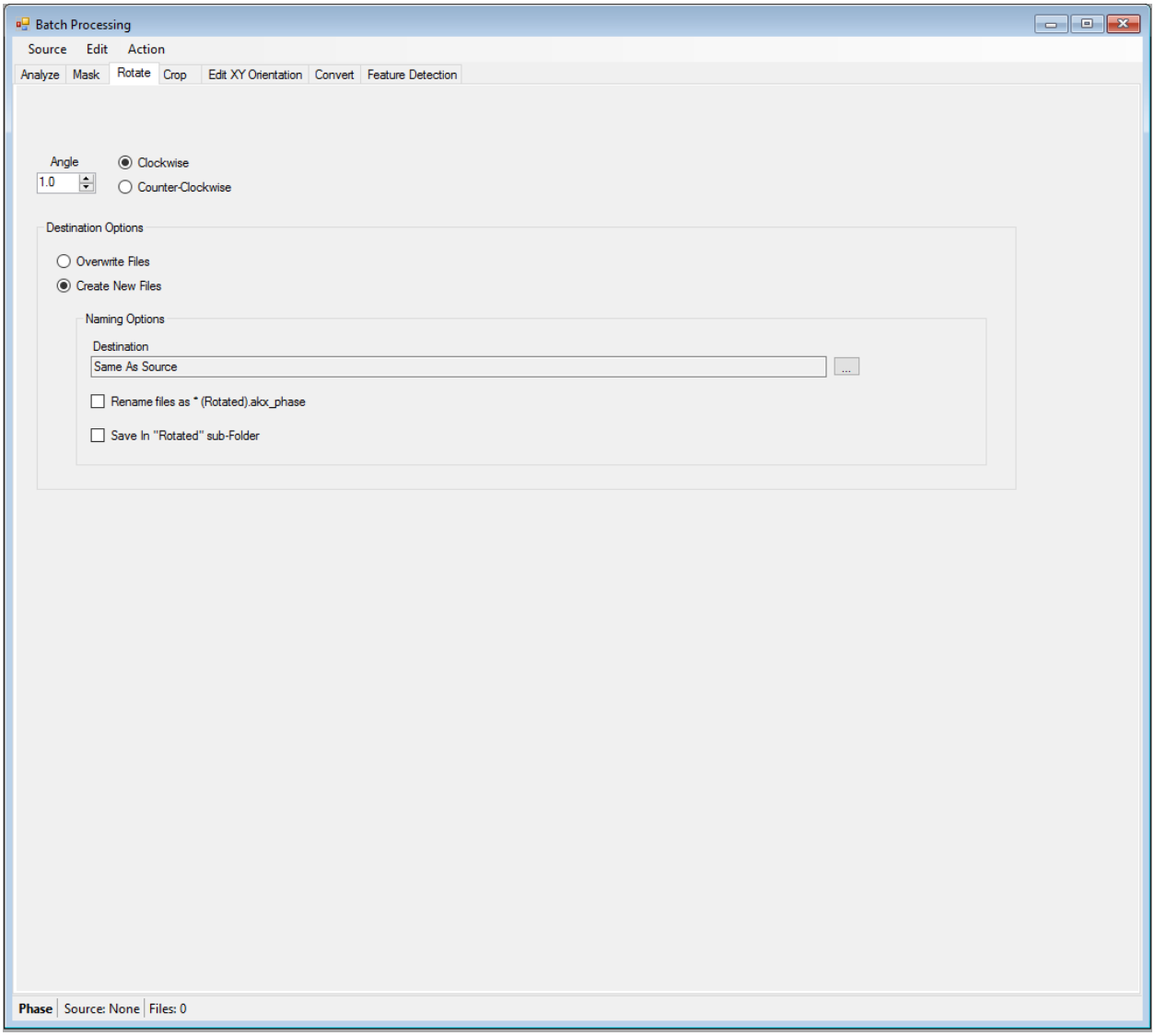

Figure 6.16 Batch Rotation Screen

The key steps in using batch rotation are:

1. Select a folder containing images to be rotated (**Source→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.
Rename 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 6.17**).

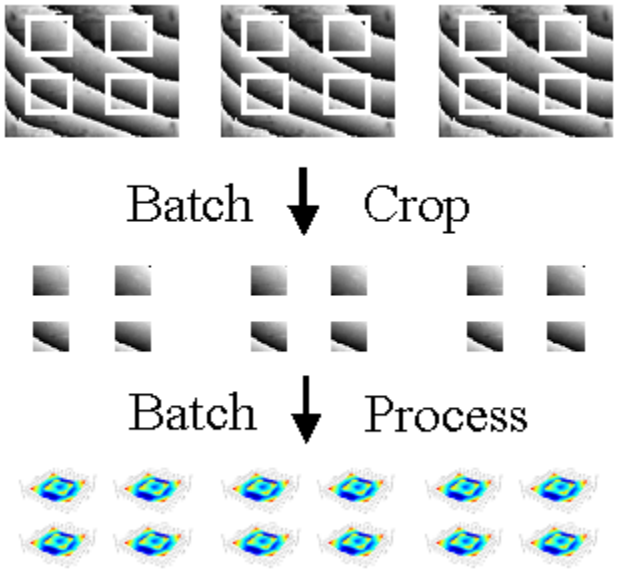

Figure 6.17 Batch Cropping and Analysis

6.5.1 Using Batch Cropping

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, DTA, 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.

6.6 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.

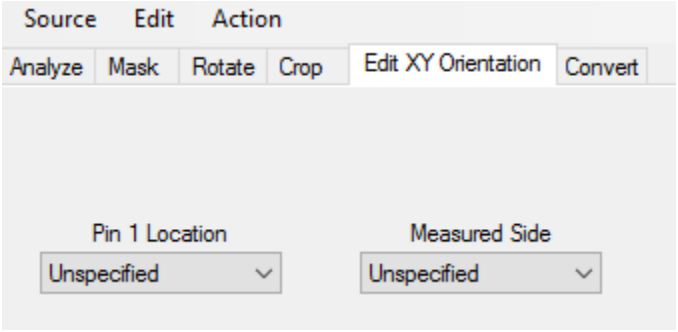

Figure 6.18 Edit XY Orientation Screen

The key steps in using Edit XY Orientation are:

1. Select a folder containing data to be edited **Source→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 (**Source→Select…** menu item)
2. Perform the Batch Convert operation (**Action→Convert** menu item)

6.8 Batch Feature Detection

6.8.1 Using Batch Feature Detection

Batch Feature Detection allows the user to apply the Feature Detection function described in **Section 2.4.7** to a specified folder of displacement files. This batch function detects features according to options loaded in a settings file and edited in the batch feature detection tab window, then applies a customized mask based on the detected features. The batch Feature Detection screen is shown in **Figure 6.19**.

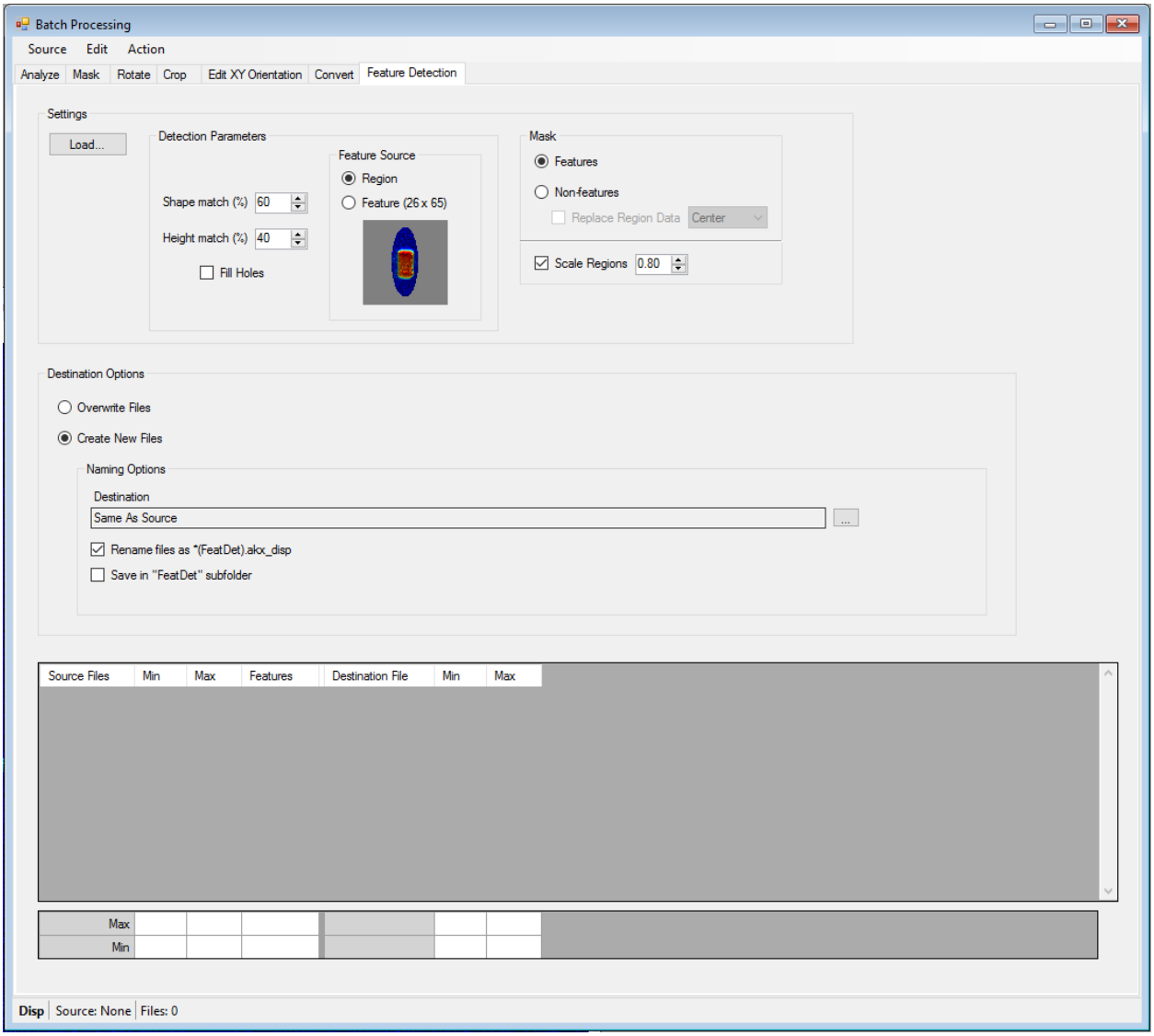

Figure 6.19 Batch Feature Detection Screen

The key steps in using Feature Detection are:

1. Select a folder containing *.akx_disp images to be masked (**Source→Select…** menu item)
2. Load in a Feature Detection Settings file and edit the settings if desired (see **Section 6.8.2**).

3. Select destination options (see **Section 6.8.3**)
4. Create and save results (**Action→Detect Features** menu item)
5. View results in Results table (see **Section 6.8.4**).

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

6.8.2 Feature Detection Settings

These Settings are all identical to those in the Feature Detection Parameter Window, which is described in **Section 2.4.7**. They are set by loading the Feature Detection Settings file, but can be edited by the user before batch detection.

The user cannot, however, edit the detection ROI as is possible in one-off Feature Detection. The region or detected feature present in the loaded settings file is used.

6.8.3 Destination and New Naming Options

Overwrite Files	Resulting data overwrites original data files.
Create New Files	Saves resulting data to a new destination and/or with a new name. The original data files are unchanged.
Destination	Selects the output folder where resulting data is saved. Click on the ... button to the right to browse for the destination folder.
Rename files as *(FeatDet).akx_disp	Appends the string “(FeatDet)” to the end of the original filename for the resulting data.
Save In “FeatDet” sub-Folder	A single new folder named “FeatDet” will be created in the destination folder and all resulting data will be saved in this subfolder. This is only available when the destination folder is the same as the source folder.

6.8.4 Results Table

The last section of the Batch Feature Detection Tab is the results table. This table is similar in functionality to the results table for Batch Mask, which is described in **Section 6.3.6**. This table populates itself with a list of the source filenames when files are loaded, but does not fully populate until Feature Detection has been performed. Once populated, the table contains not only data about minima and maxima in the source and destination files, but also the number of features that were detected in each source file. All of this lets the user assess the quality of the feature detection operation.

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.

Note: Automated report generation does not currently work for room temperature measurements, because temperature and profile metadata are used to organize the data. The **Add file to profile…** function described in **Section 7.1.3** can be used to apply profile metadata to an orphaned measurement (typically a room temperature acquisition taken manually at the end of a profile).

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, 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.

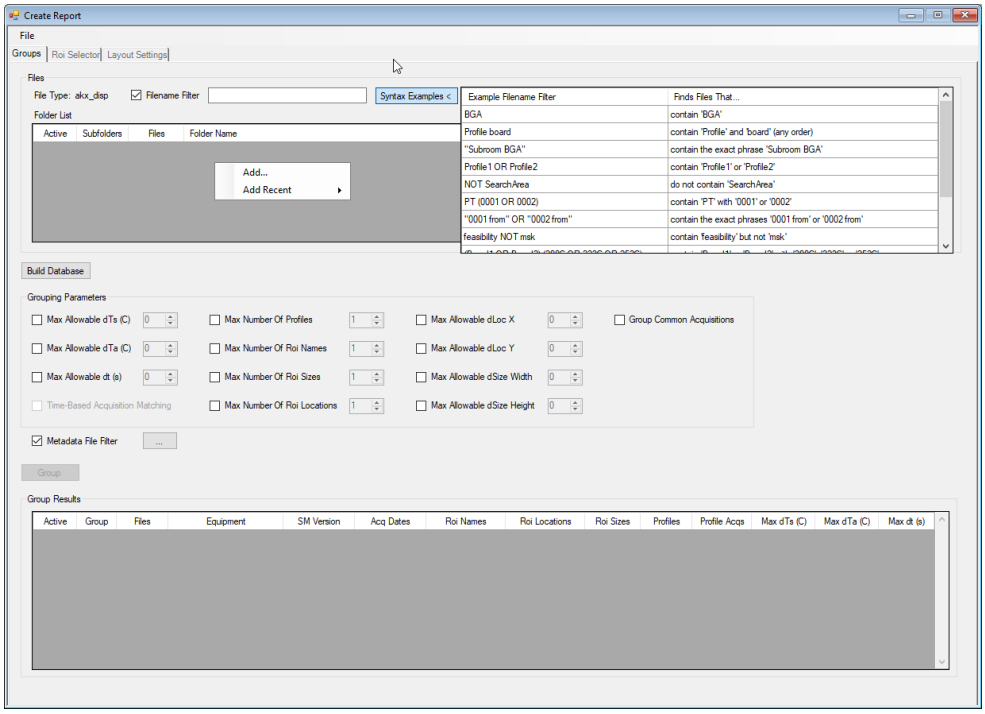

Figure 7.1 Grouping Window

7.1.1 Files

Once the appropriate folders have been added to the Folder List, files can be filtered out by entering in search 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. Other search query syntax examples can be found in the table below.

Example Filename Filter	Finds Files That...
BGA	contain 'BGA'
Profile board	contain 'Profile' and 'board' (any order)
Subroom BGA	contain the exact phrase 'Subroom BGA'
Profile1 OR Profile2	contain 'Profile1' or 'Profile2'
NOT SearchArea	do not contain 'SearchArea'
PT (0001 OR 0002)	contain 'PT' with '0001' or '0002'
0001 from OR "0002 from"	contain the exact phrases '0001 from' or '0002 from'
feasibility NOT msk	contain 'feasibility' but not 'msk'
(Board1 OR Board2) (200C OR 223C OR 252C)	contain 'Board1' or 'Board2' with '200C', '223C' or '252C'
Roi0003 NOT ("Component Side" OR Demo)	contain 'Roi0003' but not with 'Component Side' or 'Demo'
Tray 1 OR NOT Cropped	contain 'Tray 1' or do not contain 'Cropped'
Profile (BGA OR ("Substrate Test"))	contain 'Profile' with 'BGA' Or 'Substrate Test'

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. Time-Based Acquisition Matching: Only available if both ‘Max Allowable dt (s)’ and ‘Group Common Acquisitions’ are selected. This parameter ignores acquisition index for grouping and instead groups based on time, referencing max allowable dt (s). This option could be used if comparing two similar profiles where one profile had an extra acquisition inserted within the profile.

5. Max Number Of Profiles: Sets the max number of profiles in a group.
6. Max Number Of Roi Names: Sets the max number of Roi names in a group.
7. Max Number Of Roi Sizes: Sets the max number of ROI sizes in a group.
8. Max Number Of Roi Locations: Sets the max number of ROI locations in a group.
9. Max Allowable dLoc X: Sets the max difference in X axis location of the region of interest.
10. Max Allowable dLoc Y: Sets the max difference in Y axis location of the region of interest.
11. Max Allowable dSize Width: Sets the max size difference along the X axis of the region of interest.
12. Max Allowable dSize Height: Sets the max size difference along the Y axis of the region of interest.
13. 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

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 Metadata File Filter

Files can be filtered out of the resulting groups by setting up filter/logic conditions in the Metadata File Filter. File filter queries can be saved and loaded as *.akx_query files in the Query Builder interface for future use.

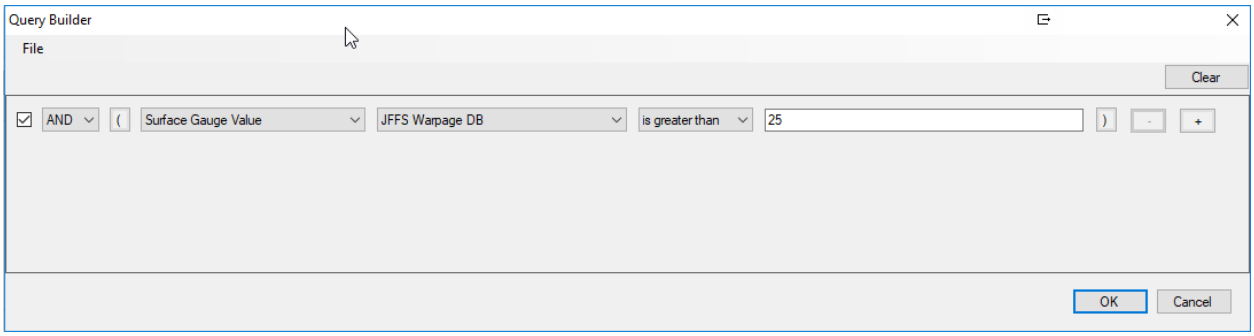

Figure 7.3 Metadata File Filter Query Builder

7.1.4 Group Results

Once the files are indexed, all groups are shown in the Group Results section (**Figure 7.4**). 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.

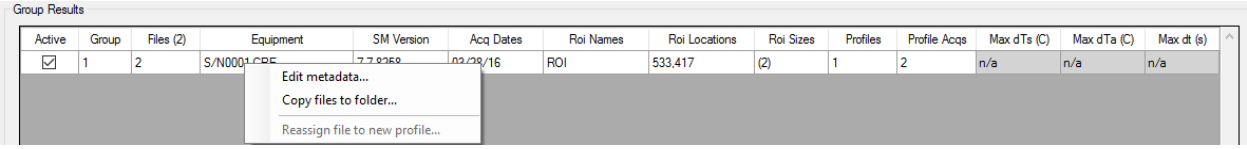

Figure 7.4 Group Results

The Edit Group Metadata window can be loaded from the context menu, or by double-clicking on any group. It allows the user to change ROI names and other metadata to better organize and label the report (**Figure 7.4**).

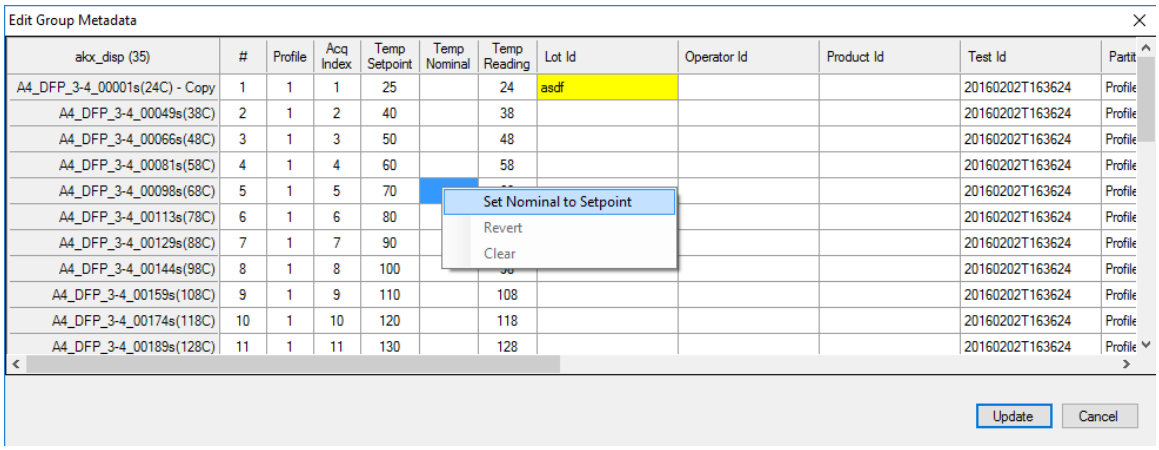

Figure 7.5 Edit Group Metadata

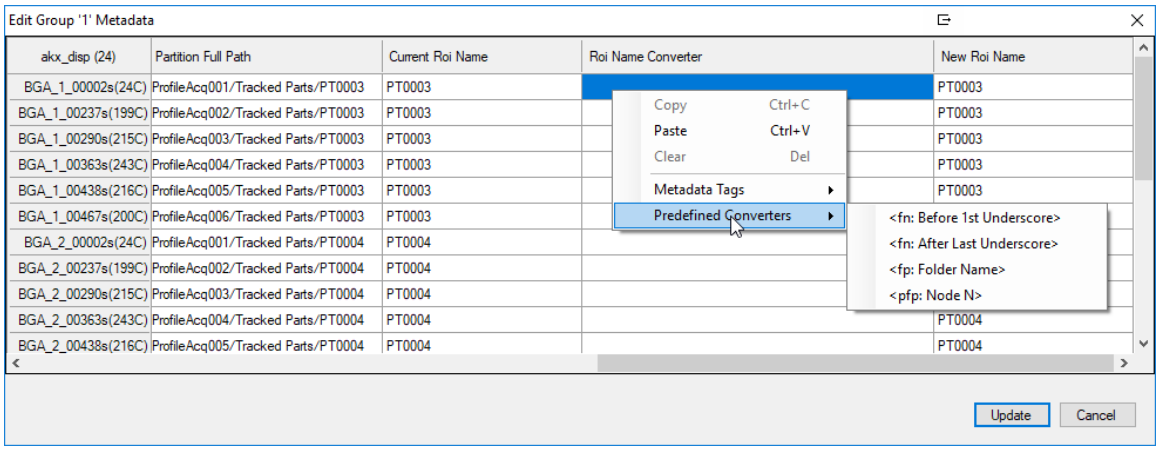

Figure 7.6 Edit Group Metadata - Roi Name Converter

In the Edit Group Metadata window that pops up (**Figure 7.5**), multiple metadata fields can be edited, including **Temp Nominal**, **Lot Id**, **Operator Id**, **Product Id**, and **Test Id**. If a new value is entered into a field, it will be highlighted in yellow until the user clicks the **Update** button. The Temp Nominal context menu will allow the user to set its value to the Setpoint.

The user can also choose what each file's **New Roi Name** will be via the **Roi Name 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 7.6**). The user can also filter ROI names using custom regex converters, which are described in **Section 7.1.5**.

For any field except Temp Nominal, 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 **Update** button is pressed. To change ROI names based on a metadata update, it is necessary to update the metadata first and then reopen the Edit Group Metadata window.

If a file with no profile information is found from the input data, it is possible to add this orphaned file (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 7.7**). 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 7.8**). Likewise, once the file to be added is selected, the profile to which they will be added must be chosen (**Figure 7.9**). 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. In addition, the modified file can be renamed. Once the profile data for a file has been changed, it will automatically be moved to the correct group (**Figure 7.10**).

For files that are already assigned to a profile, these can be reassigned to other profiles if somehow their metadata is incorrect. The process for doing this is identical to adding a file to a profile.

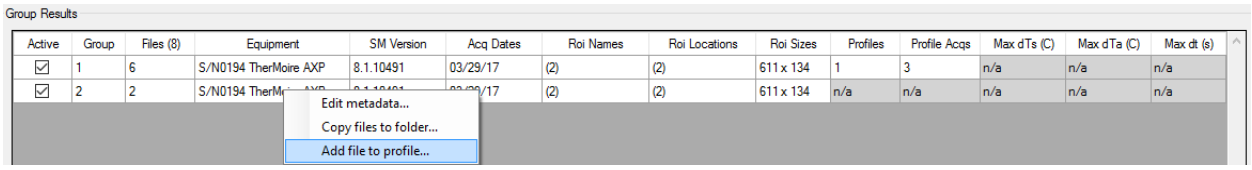

Figure 7.7 Group Results - Context Menu for Orphaned Files

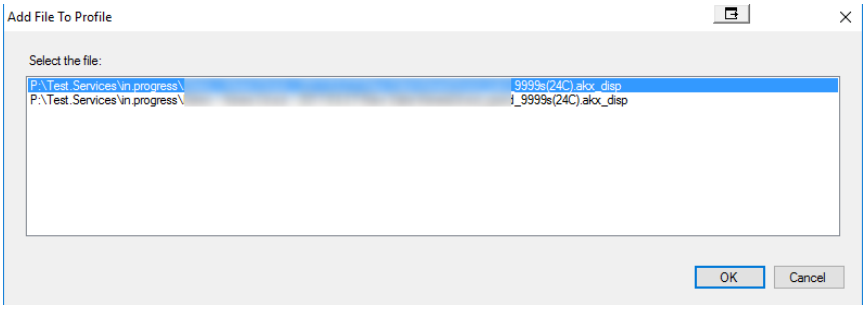

Figure 7.8 Add File to Profile - File Selector

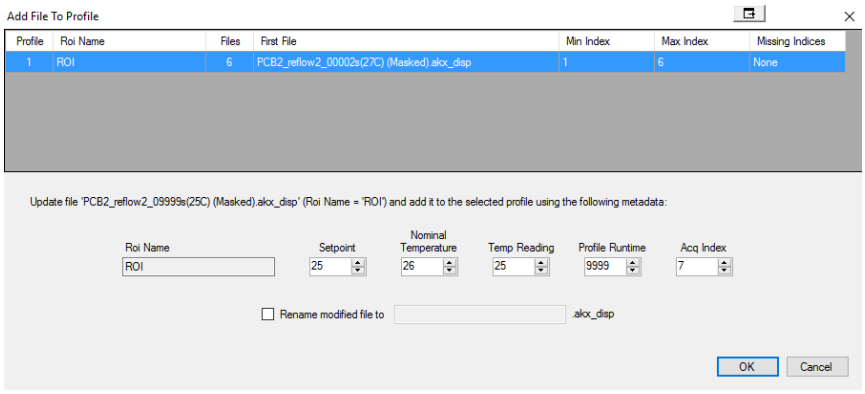

Figure 7.9 Add File to Profile - Profile Selector

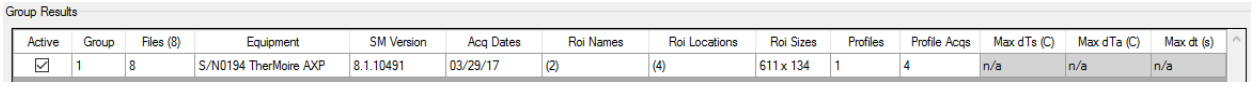

Figure 7.10 Group Results after Adding Files to Profile

7.1.5 Custom Converters

Figure 7.11 displays several custom regex converters, which allow easy extraction of specific character series from a filename and thereby easy ROI naming in the Edit Metadata window. The specific rules followed by custom converters are shown below.

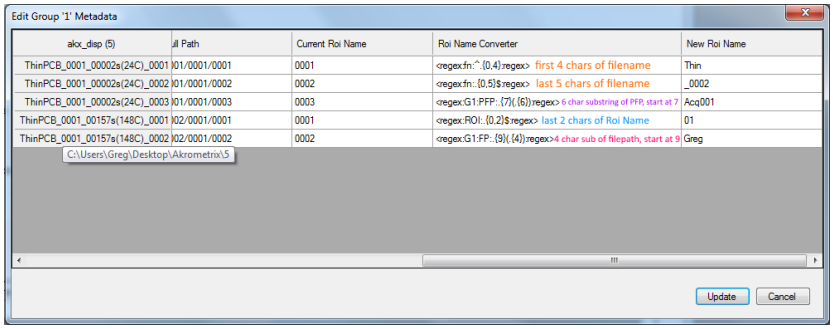

Figure 7.11 Custom Regex Converters

1. Custom converters begin with **<regex**: and end with **:regex>**
2. Custom converters can optionally include a 'Group Index' specifier, which may be required to get the desired regex match
   a. If no Group Index is specified, group index is 0 (default).
   b. Group Index is the first item included inside the regex syntax, and ends with a colon, specified as **G#:** or **G##:**
3. Custom converters can operate on 1 of 4 sources (specifiers are NOT case-sensitive): a colon is required after the source
   a. Filename, specified as **FN**
   b. Filepath (entire path, not including the filename), specified as **FP**
   c. Partition Full Path, specified as **PFP**
   d. Roi Name, specified as **ROI**
4. The regex expression is supplied AFTER the source colon.
5. Examples:
   a. **<regex:fn:^.{0,4}:regex>** the first 4 characters of the filename
   b. **<regex:fn:.{0,5}$:regex>** the last 5 characters of the filename
   c. **<regex:G1:PFP:.{7}(.{6}):regex>** a 6 character long substring of the partition full path, starting at index 7
   d. **<regex:ROI:.{0,2}$:regex>** the last two characters of the Roi Name
   e. **<regex:G1:FP:.{9}(.{4}):regex>** a 4 character long substring of the filepath, starting at index 9

Note: Strings start at index 0. This is important for any search involving a numbered index.

7.2 Selecting ROI's

In the Roi Selector tab (**Figure 7.12**), 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. From this tab, the user can also open any individual *akx_disp file in the report, or the folder that contains said file. This is done using right-click context menus on each thumbnail image. In addition, files can be included or removed en masse with **Include All**, **Include None**, **Invert Included**, and **Include via metadata query…** commands.

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.

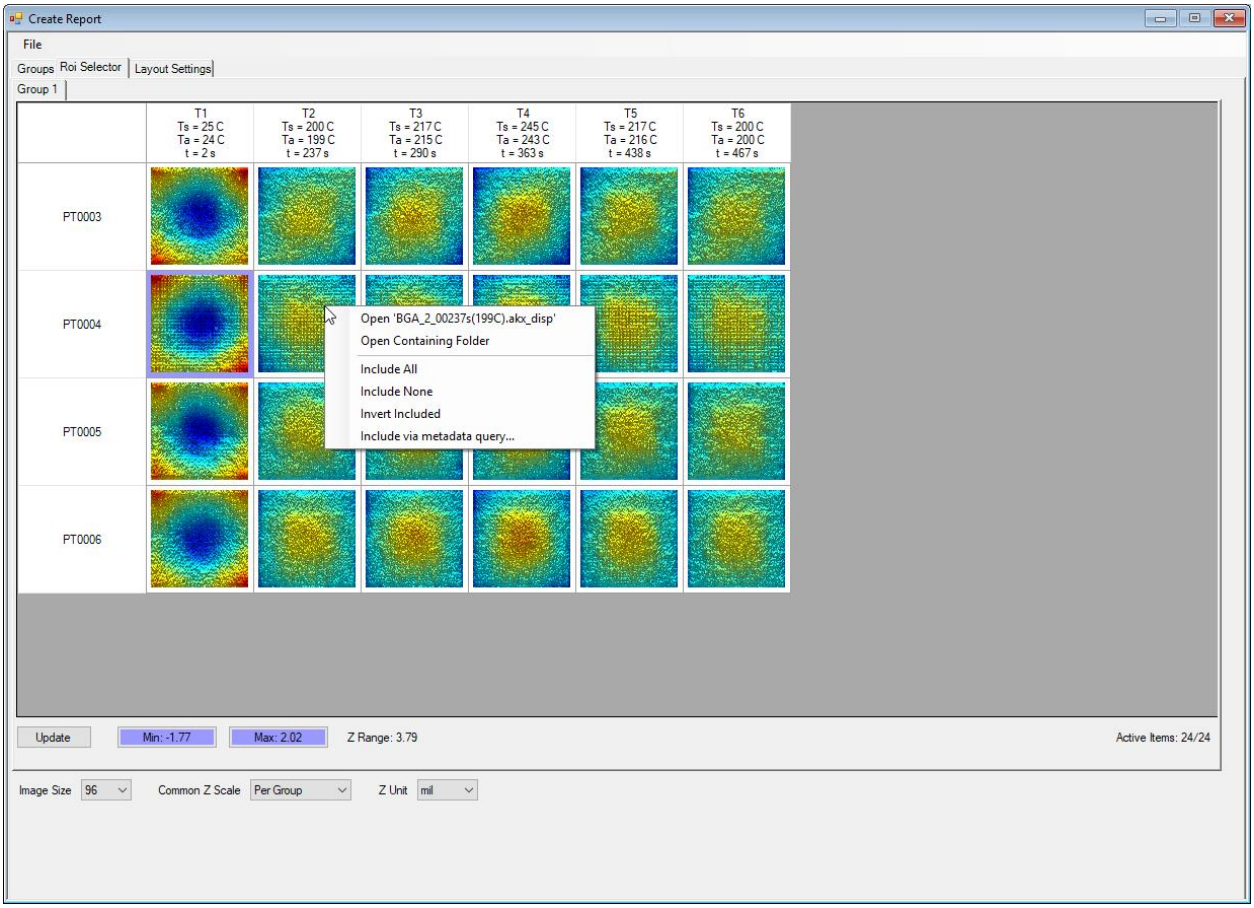

Figure 7.12 Roi Selector

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 checkboxes. 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, such as a list of all the ROI names, or currently selected Gauge Plots.

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.

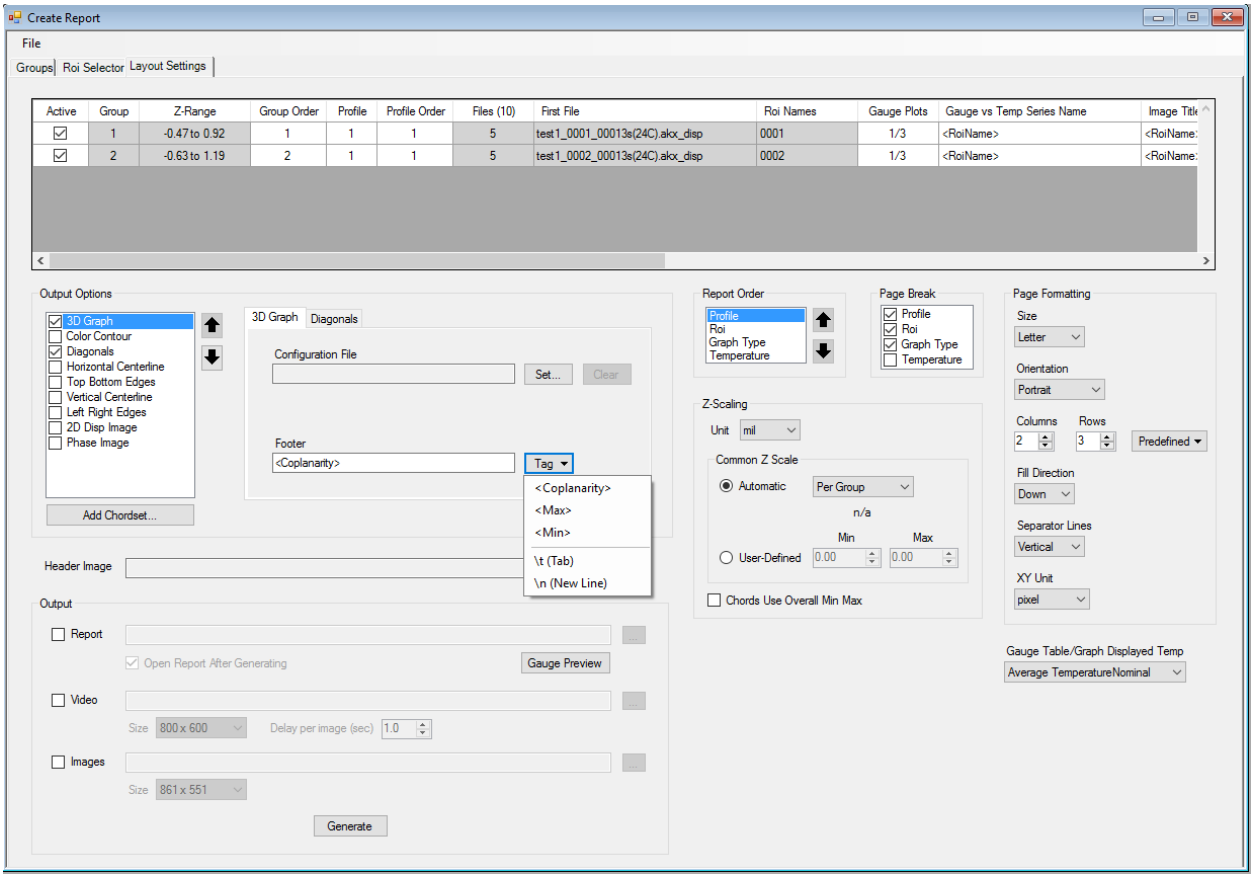

Figure 7.13 Layout Settings Tab

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 7.14**. From this window, the user can choose which of the calculated gauges to display in the report, and which statistical values should be displayed for those gauges. These values can be calculated for each ROI, for each temperature point, or globally throughout a group. Selecting an option by clicking on it 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.

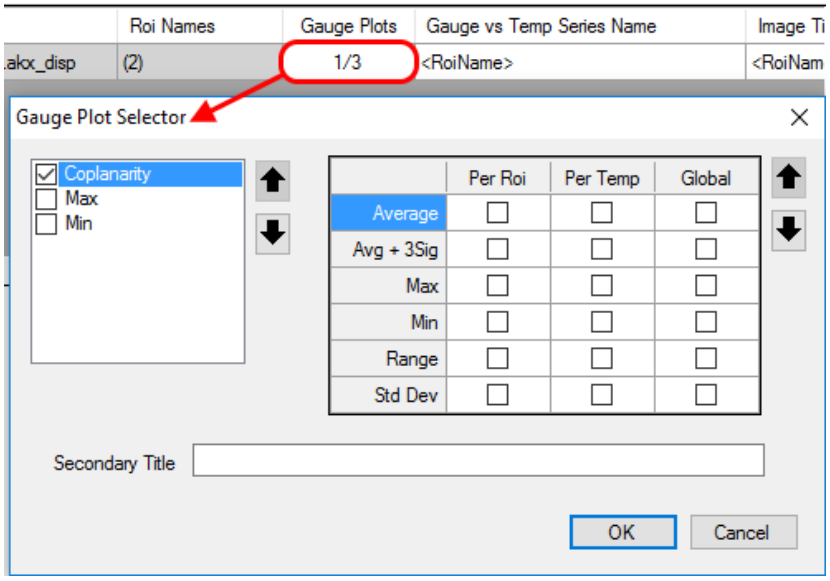

Figure 7.14 Gauge Plot Selector

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.

Note: In addition to the default output plots, custom chord plots can be loaded in using *.akx_chordset files and plotted like any other 2D graph.

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.

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 'Chords Use Overall Min Max' option 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 Gauge Table/Graph Displayed Temp

This allows the user to choose from three temperatures for gauge tables and graphing gauges: Average reading temperature at that time, nominal temperature chosen in Profile Generator, or the Setpoint temperature of the profile.

7.3.10 Header Image File

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

7.3.11 Output

Once all settings have been selected, the user can use the Output section to determine what results will be generated. There are three possible types of output – Report, Video, and Images – and any or all of them may be generated at one time by selecting their check boxes and pressing **Generate**.

Generating any output requires appropriate save data, which the user is automatically prompted to enter if none has yet been added. Report and Video need both filename and destination folder, while Images only needs a destination folder. The first time that a filename or destination folder is entered, it will be shared to the other outputs. The **…** buttons after each option can be used to independently edit destinations and filenames for each output.

1. **Report –** This is a pdf report containing all selected images and gauges. It is the most common option, and the one to which many of the customization options in the Layout Settings tab are dedicated. **Figure 7.15** shows an example. Checking **Open Report After Generating** allows the user to immediately see the results when the report has been created.
2. **Gauge Preview** – This button generates a pdf containing gauge results based on current settings but no images. Since no images are saved, this allows the user to

more quickly see how the groups are organized and what the overall numerical results look like. This button works regardless of whether Report has been selected as an active output.

3. **Video –** This is a video file which strings together all gauge plots and all selected images. The user can choose image size and the delay between images in the video.
4. **Images –** This option saves all images selected in Output Options to a user selected folder. The user may select the image size.

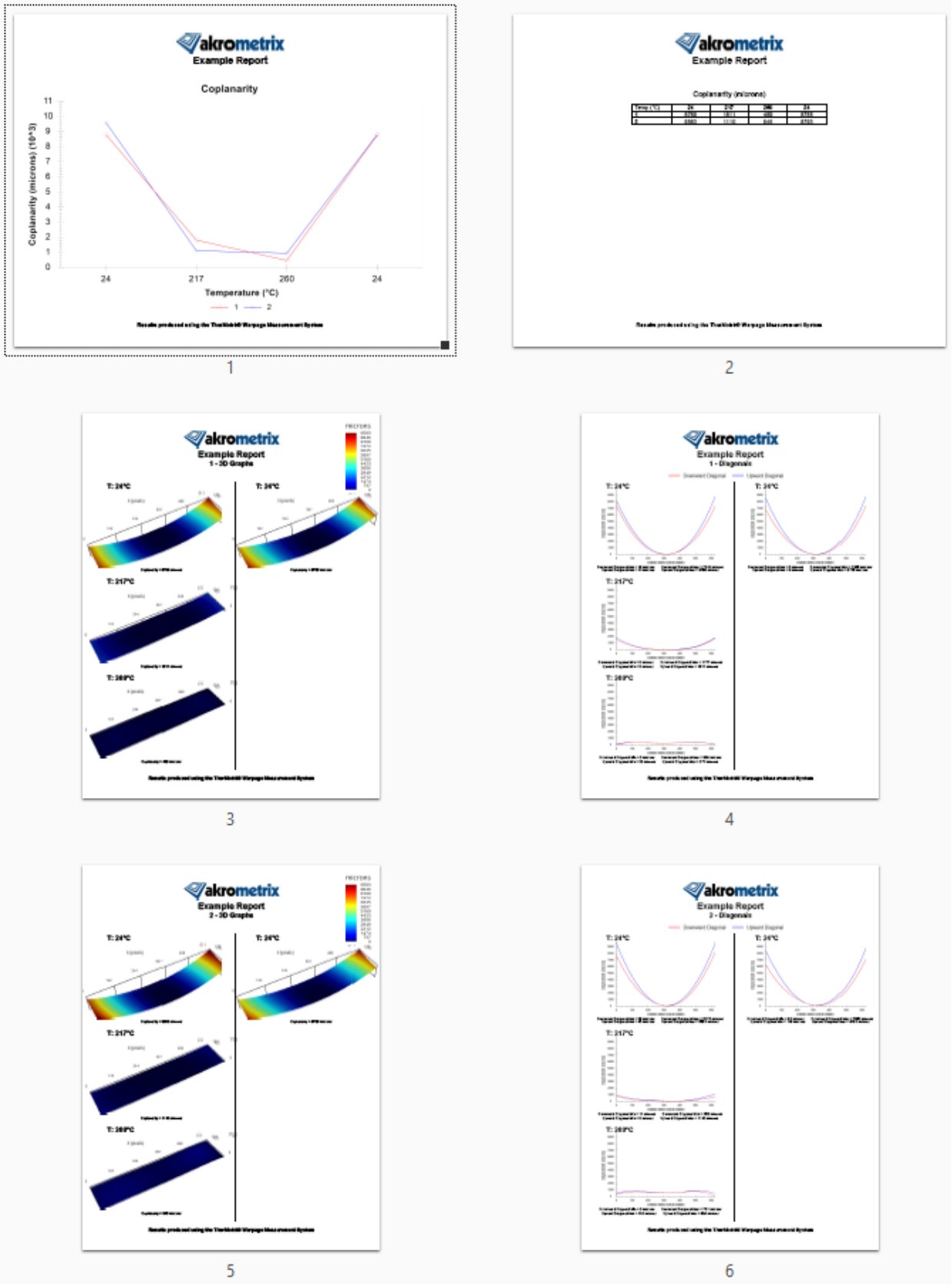

Figure 7.15 Example Report with 6 images per page

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 sequentially 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**.

Note: Aggressive masking may create isolated data "islands" that cannot be crossed by the normal unwrapping algorithms. In this case, the user can alter the Unwrapping Parameters to properly display isolated data. See **Section 4.6**.

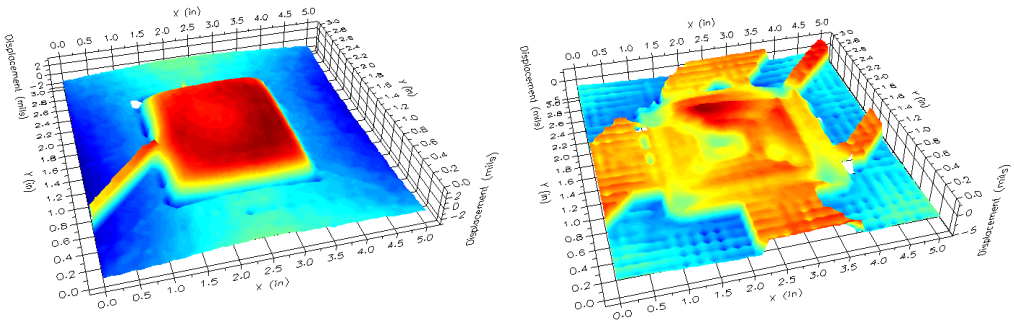

Figure 8.1 Surface Plots with Unwrapping Errors

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 2.3**). 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 (ROI)**	Copy ROI
Ctrl+V	**Paste (ROI)**	Paste ROI
Ctrl plus arrow key increases the ROI size by one pixel in the indicated direction.		
Alt plus arrow key decreases the ROI size by one pixel in the indicated direction.		
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+B	**Advanced→Unwrapping Parameters→Add Bridge**	Create a new phase bridge
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