

TESTING MATRIX PERFORMANCE

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OVERVIEW

If you wish to skip the introduction and start with step by step instructions, go to the *Simulating the Incoming Wavefront* section, on page 5

This document describes the third part of A++, matrix testing or evaluating wavefronts reconstructed by matrices. Matrices tested fall into two categories: 1) *geometry* matrices which produce slopes when multiplied by a wavefront, and 2) *reconstructor* matrices which produce wavefronts when multiplied by slopes. *Filter* matrices are classified as reconstructors.

A++ has reserved four sets of windows for matrix evaluation purposes. A particular window set consists of a *Flying Carpet* and a *Slopes* window – both will display their respective data either graphically or numerically. One of these sets is dedicated to simulating the *incoming* wavefront, three others are used to *reconstruct* it, thus, making it possible to simultaneously test three different matrices using the same incoming wavefront.

Before a reconstruction can take place, you must designate the matrix to be tested by assigning it to a window. When assigned, the matrix name will appear in the bottom margin of the window. *Flying Carpet* windows are associated with *reconstructor* matrices because wavefronts are produced by them, whereas *Slopes* windows are associated with *geometry* matrices because they produce slopes.

The three window sets used for reconstruction, require only a designated *reconstructor* matrix before any one of them can be used to test a matrix – assigning a *geometry* matrix to the window pair is optional. If assigning, it will be used to generate slopes from the *reconstructed* wavefront as the final step of a reconstruction cycle, if not, the cycle stops without warning messages.

The matrix requirement for the *Incoming Wavefront* window pair differs. Because the wavefront is never reconstructed – it is always simulated – the *Flying Carpet* window will ignore any attempt to designate a matrix for it. On the other hand, the *Incoming Slopes* window, may or may not have a *geometry* matrix associated with it. If the reconstruction cycle starts with the simulated wavefront (usually the case), the geometry matrix will be required, but it is also possible to bypass the incoming wavefront and reconstruct directly from edited slopes, in which case the matrix is unnecessary, see *BYPASSING THE INCOMING WAVEFRONT* on page 23.

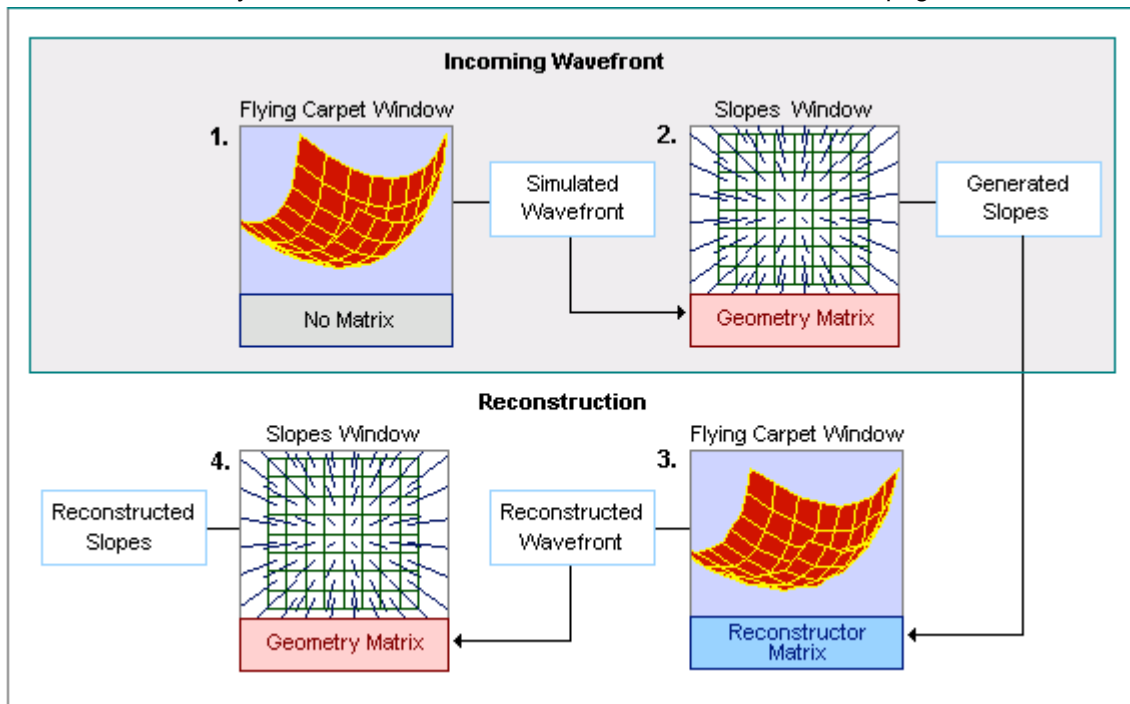


Figure 1.

Figure 1, depicts two sets of windows, each consists of a *Flying Carpet / Slopes* window pair. The first is reserved for simulating the incoming wavefront, the other for reconstruction. There are three such window sets reserved for reconstruction and they all function alike.

- 1) In figure 1, a wavefront is simulated in window 1. In this case it has been produced by a making a *zernike* wavefront, but it could have been edited directly. Note that no matrix is assigned to this window, the wavefront is always simulated, never reconstructed.
- 2) The geometry matrix assigned to window 2 is then multiplied by the simulated wavefront to produce simulated slopes as shown in window 2.
- 3) Next, the reconstructor matrix assigned to window 3 is multiplied by the simulated slopes vector to reconstruct the wavefront as shown in window 3.
- 4) The final step produces slopes from the reconstructed wavefront by using the geometry matrix assigned to window 4. If no geometry matrix had been assigned to the reconstruction *Slopes* window, this step would have been eliminated.
- 5) When the incoming wavefront is bypassed, reconstruction starts with window 2, using the slopes vector as it is. This type of reconstruction is meaningful only if the slopes vector is directly edited, see *BYPASSING THE INCOMING WAVEFRONT* on page 23

NOTE: It is possible to assign different geometry matrices to each of the Slope windows making it feasible to evaluate different geometry matrices in future versions of A++. Currently, only the Southwell configuration will produce more than one type of geometry matrix.

SIMULATING THE INCOMING WAVEFRONT

Reconstruction cycles, as described above, start with the incoming wavefront which is always simulated. (Reconstructing directly from slopes will be treated in subsequent sections.) Simulation can be accomplished in two different ways 1) making zernike wavefronts and 2) directly editing it. Step by step instructions start on page 5

SELECTING ZERNIKES

In order to make a zernike wavefront, zernikes must first be selected. This is accomplished with the *Zernike* window which has already been introduced in the *MAKING AND MANAGING MATRICES* document when the manufacture of zernike projection matrices was covered. For simulating wavefronts, zernikes must likewise be selected, but not just selected, gains must be set to non-zero values. When the simulation is made, selected zernikes with intensities determined by their individual gains will form the wavefront. This is always triggered by the *Incoming Wavefront* window - the *Zernike* window itself is used exclusively for selecting and setting zernikes gains, nothing else. Once zernikes and gains have been determined, the *Zernike* window can even be closed.

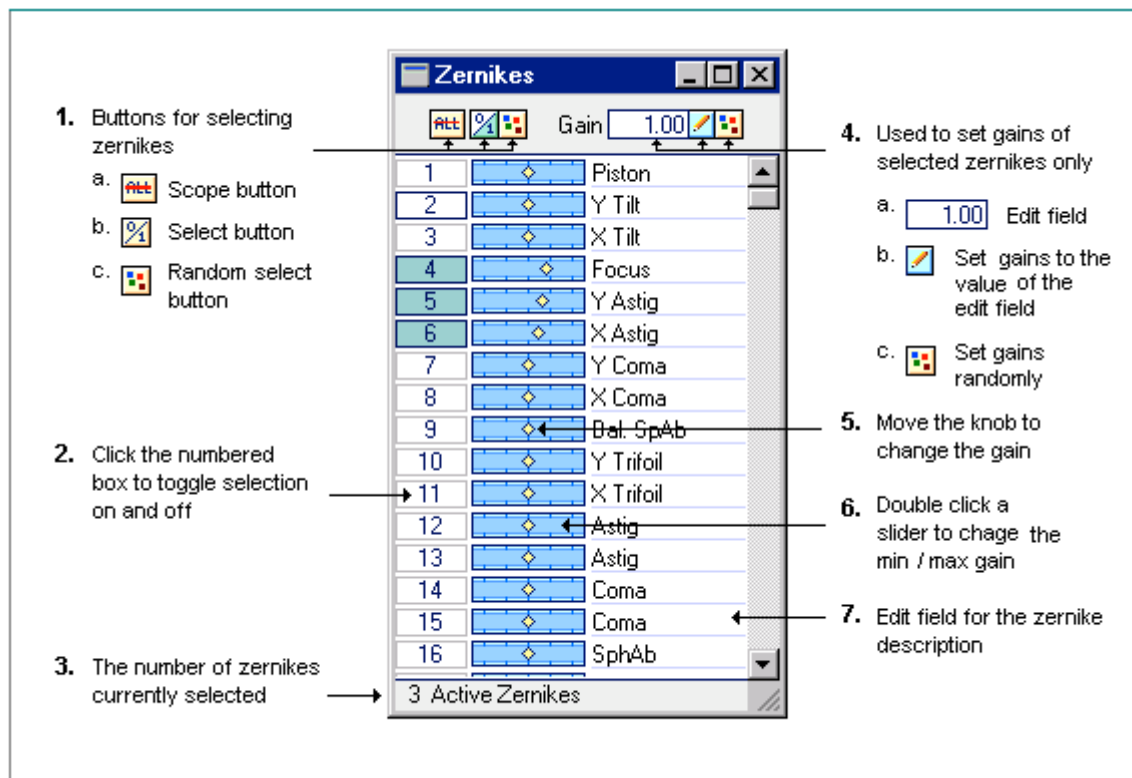


Figure 2.

Description of Window

A total of 400 zernikes are available in this window. Settings remain fixed until they are manually changed – even after the window is closed.

- 1) These three buttons select/deselect zernikes collectively:
 - a) The *Scope* button toggles between *affecting all 400 zernikes* or only those *visible in the window*. This button neither selects nor deselects, but it affects the reach of the next two buttons: b) and c).
 - b) The *Select* button toggles zernikes between selected and deselected, depending on the *Scope* setting. If scope is set to *ALL*, all 400 zernikes will be selected/deselected, otherwise only those visible in the window will be affected.

- c) The *Random Select* button selects zernikes depending on the setting of the *Scope* button. If scope is set to *All*, the random selection will be applied to all 400 zernikes, otherwise, the selection will be applied only to those currently visible in the window. In both cases, a random number of zernikes will be selected randomly.
- 2) Select/deselect zernikes individually by clicking the *numbered box* next to a zernike. The zernike will toggle between selected (aqua in color) and deselected status (white).
- 3) Displays the number of zernikes selected.
- 4) Use these two buttons and the edit field to change the gains of *selected* zernikes only:
 - a) The edit field contains a value which will be applied to selected zernikes when the adjacent button is pressed. To change the number, click it and key in a new value. Use the left and right arrow keys to move the cursor within the edit field. To stop editing, click anywhere in the window except on buttons, edit fields or zernike number boxes.
 - b) The *pencil* button applies the value in the edit field to selected zernikes only.
 - c) The *random* button will randomize gain values of selected zernikes only.
- 5) To set gains individually, move the slider knob to the left or right.
- 6) Double click a slider anywhere in the blue area to change the *min / max* gain. The *min / max* change to one slider will affect all 400 zernike sliders.
- 7) The zernike name is an edit field. Click it and enter a new name. Use the left and right arrow keys to move the cursor. The first 20 zernikes have default names, but these too may be changed.

NOTE: Because gain values are taken into account, it becomes possible to form wavefronts with varied zernike intensities. As a consequence, a gain value of zero will have no effect on the wavefront even if the zernike has been selected. However, if the gain is non-zero, a non-selected zernike is ignored.

Instructions

- 1) Open the *Zernike* window from the *Evaluation* option in the main menu bar. If the screen is cluttered, optionally close all windows first, by clicking *Windows* in the main menu bar, then click *Close Windows* and select *All*.
- 2) Optionally, clear all zernikes and their gains.
 - a) Activate all zernikes first. If the *All* button (item 1a, fig. 2) is crossed out by a red line, click the button to set the scope to all 400 zernikes, then click the *Select* button (item 1, fig. 2b). If the number boxes are white, click the *Select* button again – they must be aqua in color and the message “400 Active Zernikes” should appear in the bottom margin of the window.
 - b) Clear all gains. Make sure the edit field (item 4a, fig. 2) contains zeros. If it does not, click it and enter zero. To stop keyboard entry, click anywhere in the window except on buttons and the edit field. *NOTE: If you have set the min / max range of zernike sliders to excludes zero, you will not be able to enter a zero into this field. Either change the min/max gain (see item 6, fig. 2) or use another value.*
 - c) Click the *pencil* button (item 4b, fig. 2). This will apply the zero value to gains of selected zernikes, in this case to all 400 of them.
 - d) Now deselect the zernikes. Click the *Select* button (item 1b, fig. 2) so that all number boxes turn white and the message “No Active Zernikes” appears in the bottom margin.
- 3) Select – *Focus*, *X & Y Astigmatism*, and *X & Y Trifoil*. by clicking their boxes: 4, 5, 6, 10 and 11 or select zernikes of your choice. Selected number boxes will turn aqua.

- 4) Give the selected zernikes some gain by moving the slider to a value of your choice or clicking the *random* button (item 4c, fig. 2).

This step is completed.

Options

- 1) Double click any slider anywhere in the blue area to open a popup window. Enter -10 for the minimum gain and 10 for the maximum gain. Click *Ok* to close the popup window.
- 2) Double click another slider anywhere in the blue area. Note that the min / max gain matches the one you changed. Enter -1 and 1 for min / max gains, then click *Ok* to close the popup window.
- 3) Now double click the slider you changed in step 1. Notice how the min and max gains have changed to -1 and +1. Click *Reset* or *Ok* to keep these values.

SIMULATING A ZERNIKE WAVEFRONT

Once zernikes have been selected and gains set, a wavefront can be made by clicking a button in the *Incoming Wavefront* window. Figure 3, shows an 8 by 8 *Fried* configuration, depicting a wavefront made from zernikes selected in the *Zernike* window as in the instructions above – *Focus*, *X & Y Astigmatism*, and *X & Y Trifol*. Gains were set randomly. Step by step instructions are on page 8.

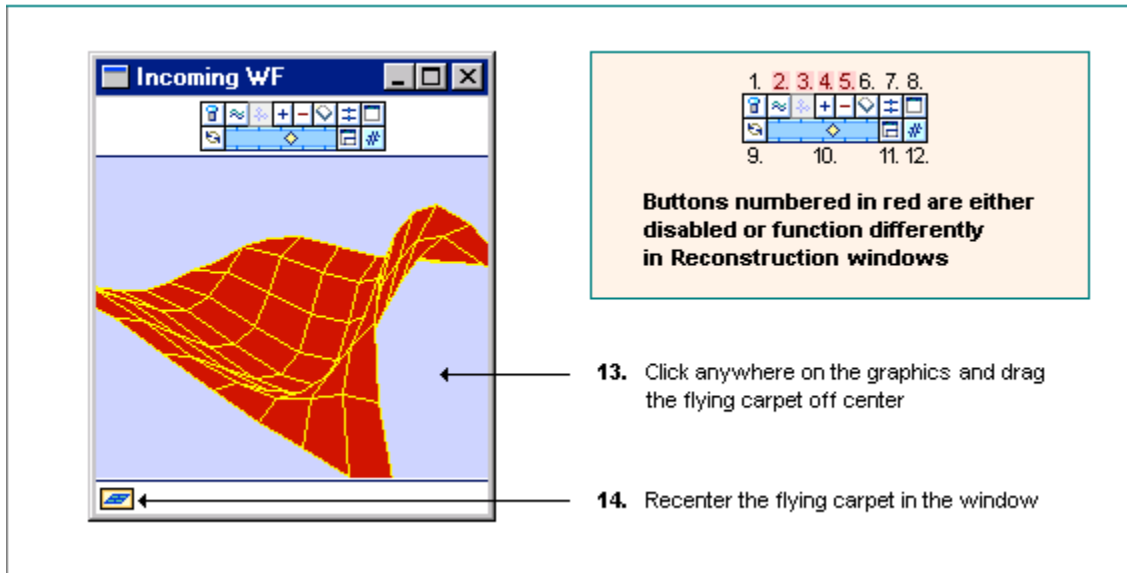


Figure 3.

Description of Window

There are four *Flying Carpet* window which are essentially the same. One is used to simulate the incoming wavefront and three are used for reconstructing it. Differences in operation between the two types are indicated by buttons highlighted in red. Please note that a matrix is not required for this window, therefore, no matrix has been assigned.

- 1) This button toggles the display of virtual actuators on or off. Virtuals are shown only in graphics, they are ignored otherwise.
- 2) This button makes a wavefront using the current settings in the *Zernike* window. Selected zernikes with intensities determined by their individual gain values will form the wavefront.
- 3) This button is always disabled for the *Incoming Wavefront* window. It reconstructs a wavefront directly from slopes and has no meaning in the *Incoming Wavefront* window.
- 4) This button adds the wavefront vector found in the *Edit Wavefront* window to the vector in this window. Editing the wavefront will be covered in the next topic.
- 5) This button subtracts the wavefront vector found in the *Edit Wavefront* window from the vector in this window. Editing the wavefront will be covered in the next topic.
- 6) This button clears the wavefront vector. All phases will be set to zero and the flying carpet will become flat.
- 7) This button sets slider values of all *Flying Carpet* windows to the gain of this slider. Min / max gain will also be set accordingly. Unlike the min/max gain of the 400 zernike sliders, the sliders of these windows are independent of each other and can have their own min / max range.
- 8) This button opens its own window pair, in this case the *Incoming Slopes* window. Matrix evaluation windows come in sets or pairs, a flying carpet and a slopes window.
- 9) This button opens the *Rotation* window which permits rotating flying carpets. *All* flying carpet windows will be affected.
- 10) Moving the slider will increase / decrease the gain of the flying carpet as a whole, maintaining proportionate differences of individual phases. To change the min / max gain of a slider,

double click it anywhere in the blue area. A change here will affect only the slider clicked, in contrast to the 400 zernike sliders which must retain the same min / max gain at any one time.

- 11) This button "synchronizes" the sizes of all *Flying Carpet* windows. The window in which it is clicked, becomes the measure of all the other windows of its kind.
- 12) This button toggles the display between graphical and numerical mode, affecting only the window in which it was clicked.
- 13) The graphics area of the window can be clicked and dragged off center.
- 14) This icon Indicates the direction in which the flying carpet was dragged. It will re-center the flying carpet when pressed.

Instructions

- 2) Select zernikes as in instructions on page 5.
- 3) Open the *Incoming Wavefront* window from the *Flying Carpet* submenu under the *Evaluation* option of the main menu bar.
- 4) Click the *make zernike wavefront button* (item 2, fig. 3).

This step is completed.

Options

Please refer to *DISPLAY OPTIONS AND PREFERENCES* on page 32.

RECONSTRUCTING THE INCOMING WAVEFRONT

Before any reconstruction can take place, matrices used for reconstruction must be selected – geometry matrices for building slope vectors and reconstructor matrices for forming wavefronts. To specify a matrix for an operation, attach it to a window designated for a specific purpose. Attaching them to windows has already been covered in the *MAKING AND MANAGING MATRICES* document when foundation matrices were assigned to the *Make Matrix* window and when they were selected for viewing. Step by step instructions start on page 10.

Assigning Matrices Via the *Source Matrices* Window

The *Source Matrices* window displays matrix assignments used for all operations other than viewing. It can also be used to attach a matrix to the target window – moving a matrix unto an area in the *Source Matrices* window is equivalent to moving it to the window reserved for that area.

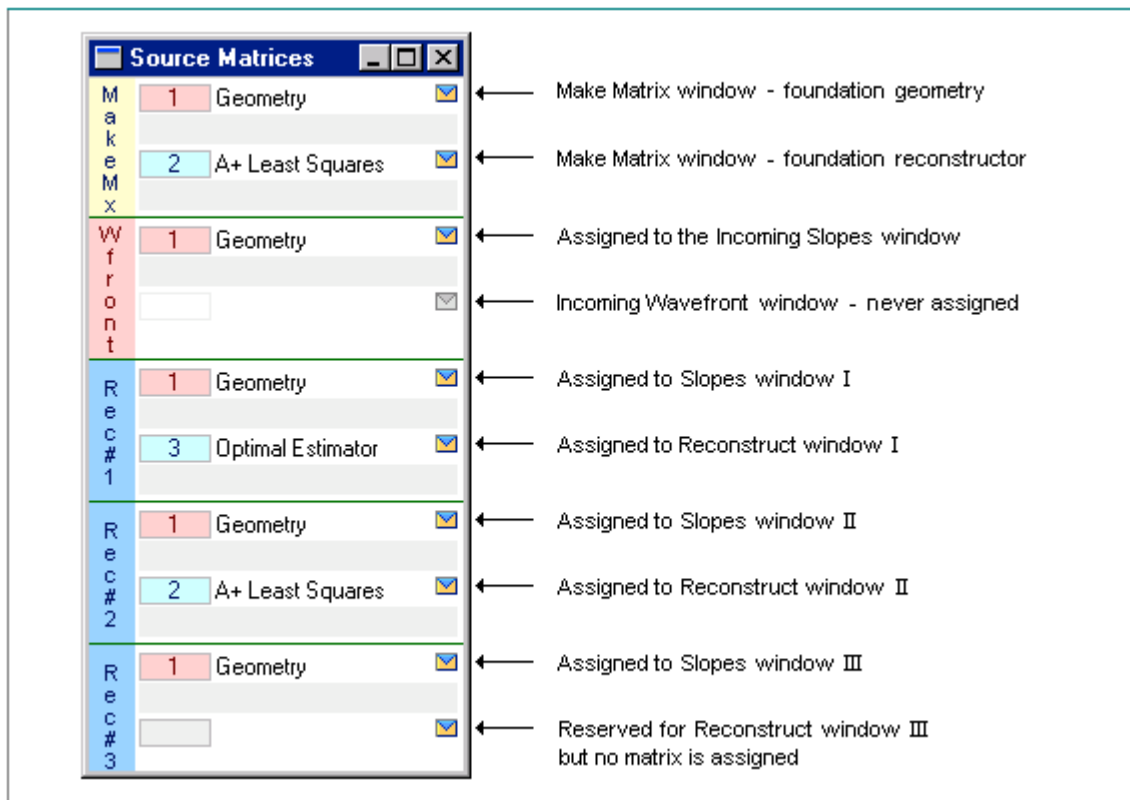


Figure 6.

Description of Window

The five divisions of the *Source Matrices* window are divided into two parts, the top is reserved for the geometry matrix and the bottom for the reconstructor. In the *Make Matrix* window, both the geometry and the reconstruction foundation matrices are assigned to the same window, but because evaluation windows come in pairs, the reconstructor matrix will be assigned to the *Flying Carpet* window and the geometry to the *Slopes* window. The following points should be kept in mind when assigning matrices:

- Because the incoming wavefront is always simulated never reconstructed, the place reserved for the reconstruction matrix is not used. Any attempt to attach a matrix to the *Incoming Wavefront* window will be ignored.

- Matrices can be moved to windows in one of two ways: 1) using *the popup menu button* which limits the selection to matrices listed in the *Catalog* window or 2) dragging a matrix across the screen which is not limited to any window – all drag boxes are operational where ever they appear.
- When assigning matrices through the *Source Matrices* window, A++ will perform an error check – the matrix must match the location. For example, if a geometry matrix is selected for a place reserved for a reconstructor, (or the matrix type cannot be determined), a warning will be sent to the screen with the option to continue or cancel the matrix designation.

Assigning Matrices Directly to Target Windows

The *Source Matrices* window is a convenience, but it is not essential. Matrices can be assigned directly to the windows that use them. The following points should be kept in mind when attaching matrices to target windows:

1. When popup menus are used, the selection is not only limited to matrices listed in the *Catalog* window, but the matrix type must fit the window. If it does not, a warning will be displayed. The warning messages will provide the option to continue or cancel the designation.
2. When dragging matrices unto windows, A++ will automatically assign the proper matrix to the proper location.
 - a) The *Make Matrix* window uses two foundation matrices. When a matrix is dragged unto the window, a geometry matrix will be automatically assigned as the geometry foundation matrix and a reconstructor or filter as the reconstructor foundation matrix.
 - b) Evaluation windows come in pairs - a *Flying Carpet* window requires a reconstructor matrix and a *Slopes* window requires a geometry matrix. Dragging a matrix unto any one of the window pair will result in a correct designation – a geometry matrix will be attached to a *Slopes* window, even if it was dragged unto the *Flying Carpet* window of its pair, and vice versa.
 - c) If the matrix has a classification other than *geometry, reconstructor or filter*, an error message will be sent and the matrix will be rejected. To attach it anyway, use the *Source Matrices* window (drag it unto the location designated for the target window and override the warning message).
- 3) The *first* time a *geometry* matrix is assigned to any one of the *Slopes* windows, either by dragging or by using the popup menu, the same geometry matrix will be assigned to all *Slopes* windows. Subsequent assignments of matrices will affect only the location designated. This is true for the *geometry* matrix only, reconstructor types must always be individually assigned.

Instructions

The following is a simple exercise to demonstrate the different ways of assigning matrices to windows.

- 1) Make two matrices: a geometry and a reconstructor. For detailed instruction on how to make matrices, please refer to the *MAKING AND MANAGING MATRICES* document.
 - a) Open the *Make Matrix* window from the *Matrices* option in the main menu bar.
 - b) If the diamond next to *Geometry* is not red, click it to select it, then click the *Ok* button.
 - c) Select the matrix you just made as the *geometry* foundation matrix by using the *top* popup menu button in *the Make Matrix* window.
 - d) Click the diamond next to *A+ Least Squares* to select it, then click the *Ok* button.
- 2) Open the *Matrix Catalog* window by clicking the *Windows* option in the main menu bar, then click *Catalog* and select *Matrix*.

- 3) Drag the *A+ Least Squares* from the *Matrix Catalog* window anywhere onto the *Make Matrix* window. It is now designated as the foundation matrix to be used for making filter matrices – we will omit making filters in this exercise and continue with assigning matrices.
- 4) Open the *Source Matrices* window from the *Matrices* option in the main menu bar, and notice that the two foundation matrices are assigned to the *Make Matrix* window.
- 5) Open the *Incoming Wavefront* window (click *Evaluation* in the main menu bar, then click *Flying Carpets* and select *Incoming Wavefront*). Use the numbered drag box and drag the *geometry* matrix from any window which displays its name unto the *Incoming Wavefront* window. The *Source Matrices* window will now show the *geometry* matrix assigned to all *Slopes* windows. This was the first *Slopes* window matrix assignment, subsequent ones will be limited to the window for which it was intended.
- 6) Open the *Incoming Slopes* window (click *Evaluation* in the main menu bar, click *Slope Vectors* and select *Incoming Slopes*). Note that the *geometry* matrix appears in the bottom margin of the window (as it will appear in all *Slopes* windows).
- 7) Open the *I Reconstruct* window. Click the *Evaluation* option in the main menu bar, click *Flying Carpets* and select *Reconstruct I*.
- 8) Use the popup menu button in the lower right corner of the *I Reconstruct WF* window and select *Geometry*. A warning message is displayed. Enter *no*.
- 9) Drag the *Geometry* matrix from the *Matrix Catalog* window to the *Sources Matrices* window, unto the area designated for the *reconstruction* matrix (blue label *Rec#2*). This time enter *yes* to the warning. It is possible to override the warning. In some cases, this may be useful.
- 10) Open the *I Slopes* window, by clicking the *Evaluation* option of the main menu bar, then click *Slope Vectors* and select *Slopes I*.
- 11) Now drag the *A+ Least Squares* matrix from the *Make Matrix* window, or the *Matrix Catalog* window unto either the *I Reconstruct* window or the *I Slopes* window. *A++* will assign the matrix correctly.
- 12) Assign the *A+ Least Squares* matrix from within the *Source Matrices* window by dragging it from partition *Rec#1* to partition *Rec#2* to the area designated for reconstructors. If you dragged it to the place reserved for *geometry* matrices a warning will be sent.
- 13) Open the *II Reconstruct* window and drag unto it the *A+ Least Squares* matrix from the *I Reconstruct WF* window.

NOTE: All popup menu buttons for selecting matrices and all matrix drag boxes function in the same way where ever they appear.

RECONSTRUCTING WAVEFRONTS

Once the incoming wavefront has been simulated and matrices have been assigned, reconstruction occurs at the click of a button. Step by step instructions start on page 14.

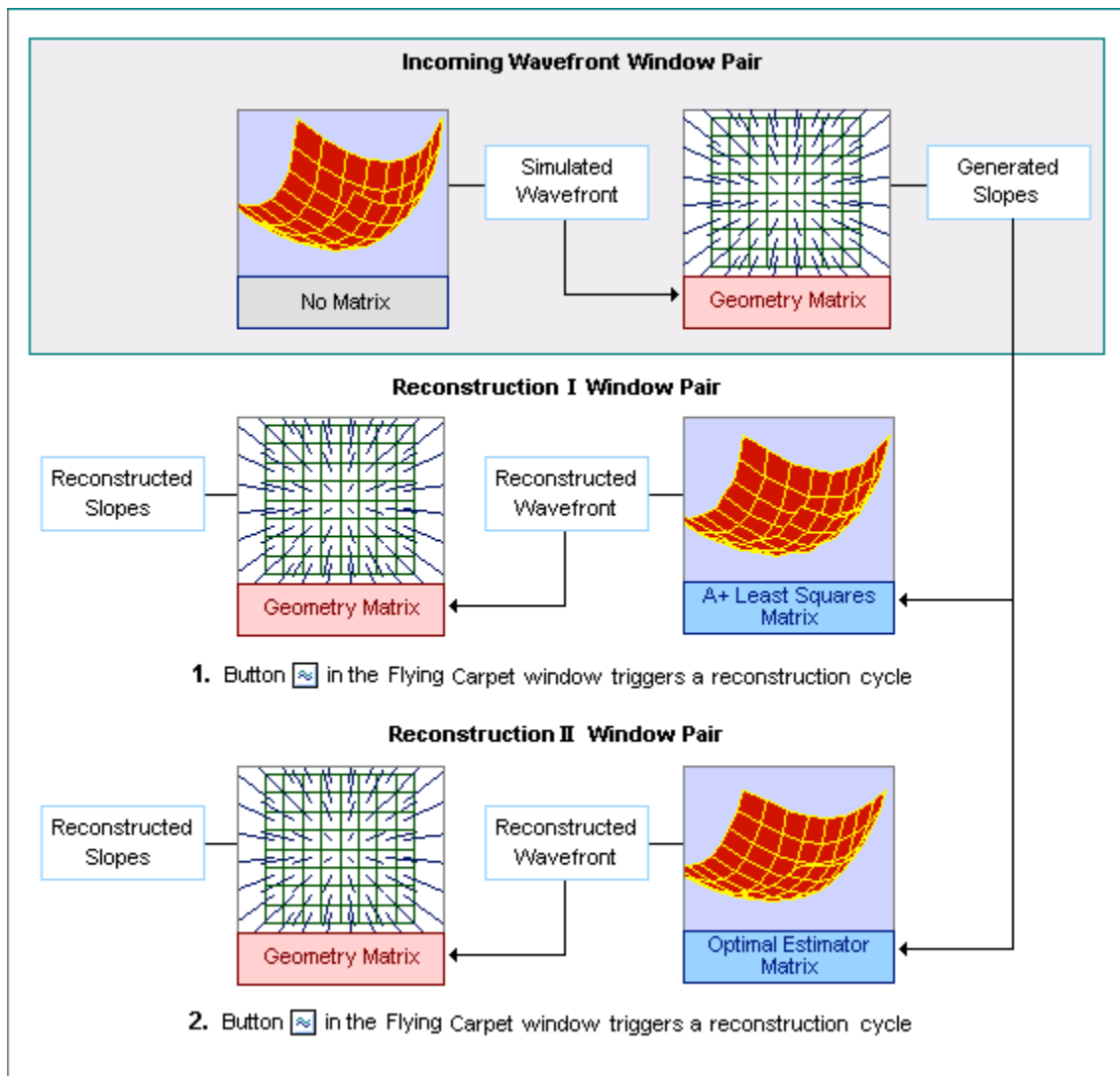


Figure 7.

Description of Window

Figure 7 shows a simulated zernike wavefront (focus) in the *Incoming Wavefront* window. All *Slope* windows have been assigned the same geometry matrix. A *Least Squares* matrix has been assigned to *I Reconstruction WF* window and an *Optimal Estimator* to the *II Reconstruction WF* window. To trigger a reconstruction cycle, always use one of the three *Flying Carpet* windows reserved for reconstruction. Reconstruction cycles are *never* triggered from any other window.

- 1) When the indicated button in the *Reconstruction I Window Pair* (in fig. 7) is pressed, the following occurs:
 - a) The simulated wavefront displayed in the *Incoming Wavefront* window is used to multiply the *geometry* matrix assigned to the *Incoming Slopes* window, resulting in a slopes vector.
 - b) The slopes vector is then used to multiply the *A+ Least Squares* matrix assigned to the flying carpet window of the *Reconstruction I Window Pair* and is displayed in it.

- c) As a final step, the geometry matrix assigned to the *Slopes* window in the *Reconstruction I Window Pair* (which may differ from those assigned to other *Slopes* windows) is multiplied by the reconstructed wavefront and the resulting slope vector is displayed in the window.
- 2) The same process occurs for the *Reconstruction II Window Pair*, including generating *incoming slopes anew*.

The Reconstruction Flying Carpet Window

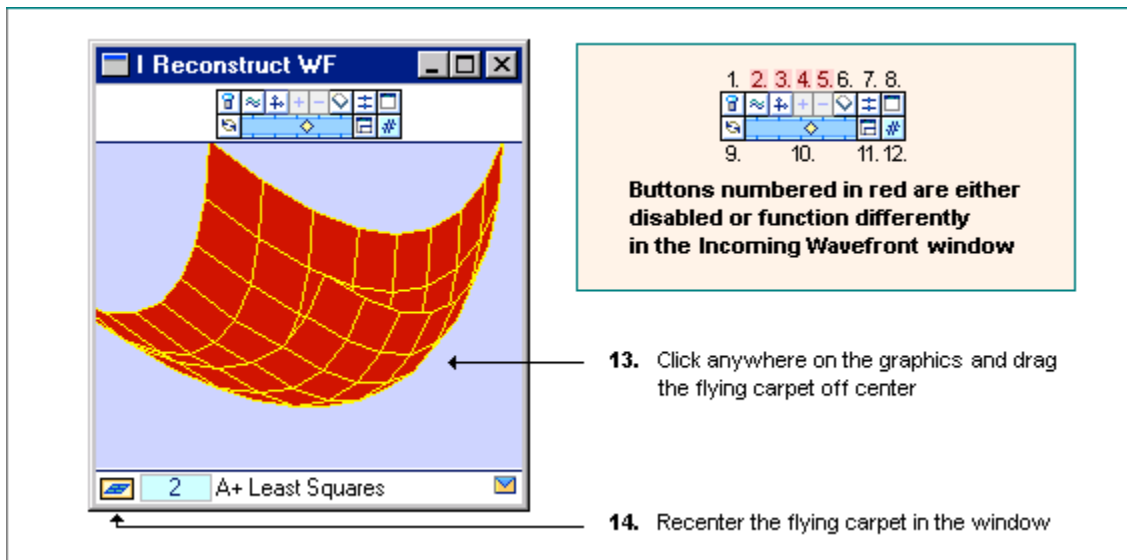


Figure 8.

Description of Window

Flying Carpet windows dedicated for reconstructing wavefronts differ very little from the *Incoming Wavefront* window (fig.3 page 7) – the buttons highlighted in red indicate a difference in operation or a disabled function. A matrix must be assigned before a reconstruction can take place as shown in fig. 8, where an *A+ Least Squares* matrix has been attached to the window.

- 1) This button toggles the display of virtual actuators on or off. Virtuals are shown only in graphics, they are otherwise ignored.
- 2) This button triggers a reconstruction cycle starting with the wavefront displayed in the *Incoming Wavefront* window. This button has a different function in the *Incoming Wavefront* window, there it produces a zernike wavefront.
- 3) This button is used to bypass the incoming wavefront and start a reconstruction cycle directly from the slopes displayed in the *Incoming Slopes* window. Because all reconstruction cycles are triggered from *Flying Carpet* windows designated for *reconstruction*, this button is disabled in the *Incoming Wavefront* window.
- 4) This button is used only in the *Incoming Wavefront* window and is disabled in all other *Flying Carpet* windows. It adds the vector found in the *Edit Wavefront* window to its own vector.
- 5) This button is used only by the *Incoming Wavefront* window and is disabled in all other *Flying Carpet* windows. It subtracts the vector found in the *Edit Wavefront* window from its own vector.
- 6) Clears the wavefront of the window in which it is pressed. As a result, the flying carpet will become flat. This button is available in all *Flying Carpet* windows.
- 7) This button sets slider values of all *Flying Carpet* windows to the gain of this slider. The min / max gain of the slider will also be set accordingly. Please note that the min / max gain of sliders in all four *Flying Carpet* windows need not be identical.

- 8) This button opens the associated window of its pair. In figure 8, depicting *the I Reconstruct WF*, this button would open the *I Slopes Reconstruct* window.
- 9) This button opens the *Rotation* window which permits rotating the flying carpet. Rotation affects all *Flying Carpet* windows, see *DISPLAY OPTIONS AND PREFERENCES* on page 32.
- 10) Moving the slider will increase / decrease the gain of the flying carpet as a whole, maintaining the proportional differences of phases. To change the min / max gain of a slider, double click it anywhere in the blue area. A change here will affect only the slider clicked.
- 11) This button “synchronizes” the sizes of all *Flying Carpet* windows. The window in which it is clicked, becomes the measure of the other windows of its kind.
- 12) This button toggles the display between graphical and numerical mode, affecting only the window in which it was clicked.
- 13) The graphics area of the window can be dragged anywhere off center.
- 14) This icon indicates the direction in which the flying carpet was dragged. Used as a button, it will re-center the flying carpet when pressed.

Instructions

Make Matrices. Make a geometry, a reconstructor and two zernike filter matrices. For detailed instructions on making matrices, please refer to the *MAKING AND MANAGING MATRICES* document.

- 1) Open the *Make Matrix* window from the *Matrices* option in the main menu bar.
- 2) If the diamond icon for *Geometry* is not red, click it, then press *Ok*.
- 3) Click the top *popup menu* button in the *Make Matrix* window and select the matrix you just made as the geometry foundation matrix.
- 4) Select the *A+ Least Squares* matrix: click the diamond icon next to it, then click *Ok*.
- 5) Use the lower *popup menu* button and select the *A+ Least Squares* matrix you just made as the foundation reconstructor.
- 6) Open the *Zernike* window from the *Evaluation* option of the main menu bar.
- 7) Clear all zernikes first: if the *All* button is crossed out, click it, then click the button next to it. ‘No Active Zernikes’ must appear in the bottom margin of the window and zernike number boxes are in white. Click the button again if that is not the case.
- 8) Click the 5th and 6th zernike, Y and X Astigmatism. The numbered boxes will turn aqua in color. Do not worry about the gain.
- 9) Click the diamond icon for *In Slopes Zernike Project* in the *Make Matrix* window, then click *Ok*.
- 10) Click the diamond icon for *Out Slopes Zernike Project* in the *Make Matrix* window, then click *Ok*.

Assign Matrices.

- 11) Open the *Matrix Catalog* window from the *Windows* option in the main menu bar by clicking the *Catalog* submenu under it and select *Matrix*.
- 12) Open all 4 *Flying Carpet* windows. Click the *Evaluation* option in the main menu bar, then click *Flying Carpets* and select all 4 windows in turn.
- 13) Drag the *Geometry* matrix from the *Matrix Catalog* window onto one of the *Flying Carpet* windows – any one of them will do. This matrix will be assigned to all four *Slopes* windows.
- 14) Assign the reconstructor matrices: the *A+ Least Squares*, *In Slopes Zernike Project* and the *Out Slopes Zernike Project* to the three *Reconstruct Wavefront* windows, it’s not important which *reconstruction* window contains which matrix. Drag them or use the popup menu buttons.

You are now ready to test matrix performance.

TESTING MATRICES

The *Incoming Wavefront* (or the *Incoming Slopes* window described in subsequent topics) is always the starting point of reconstruction – always. Once the wavefront has been formed, and matrices assigned, reconstruction is triggered from one of the *Flying Carpet* windows designated for *reconstruction* purposes – *never* any other window. Step by step instructions are on page 16.

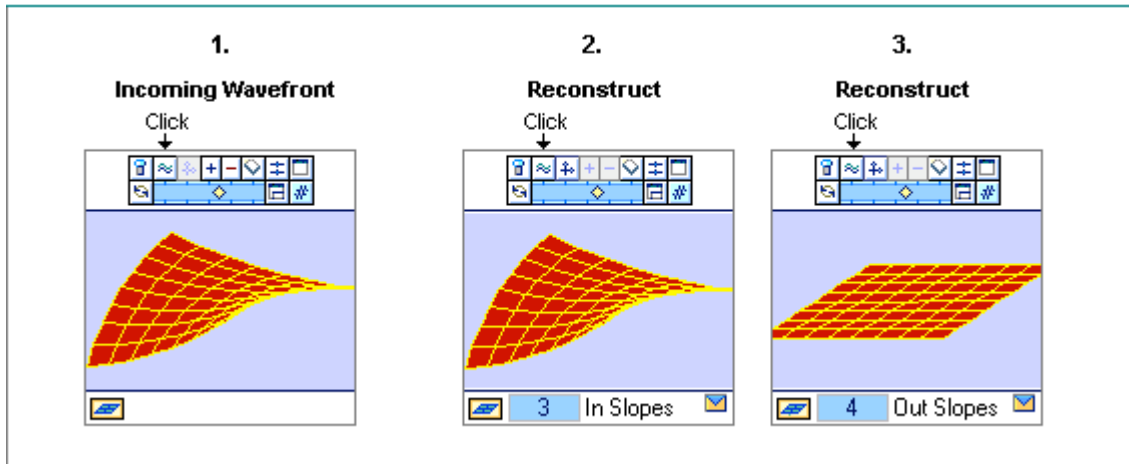


Figure 9.

Description of Windows

- 1) In figure 9, the wavefront in the *Incoming Wavefront* window has been formed from two zernikes: Y and X astigmatism.
- 2) The *In Slopes Projection* matrix is attached to the first *Reconstruction Flying Carpet* window. The matrix was built from the same zernikes as the simulated wavefront, namely the Y & X astigmatism. *In projection* matrices extract the zernikes used to built it from the wavefront. This is evident In fig. 9, the reconstruction of window 2 is almost identical to the incoming wavefront.
- 3) The *Out Slopes Projection* matrix is attached to the second *Reconstruction Flying Carpet* window, also built from the same zernikes as the simulated wavefront, namely the Y & X astigmatism. But because it filters out the zernikes from which it was built, the flying carpet is flat.

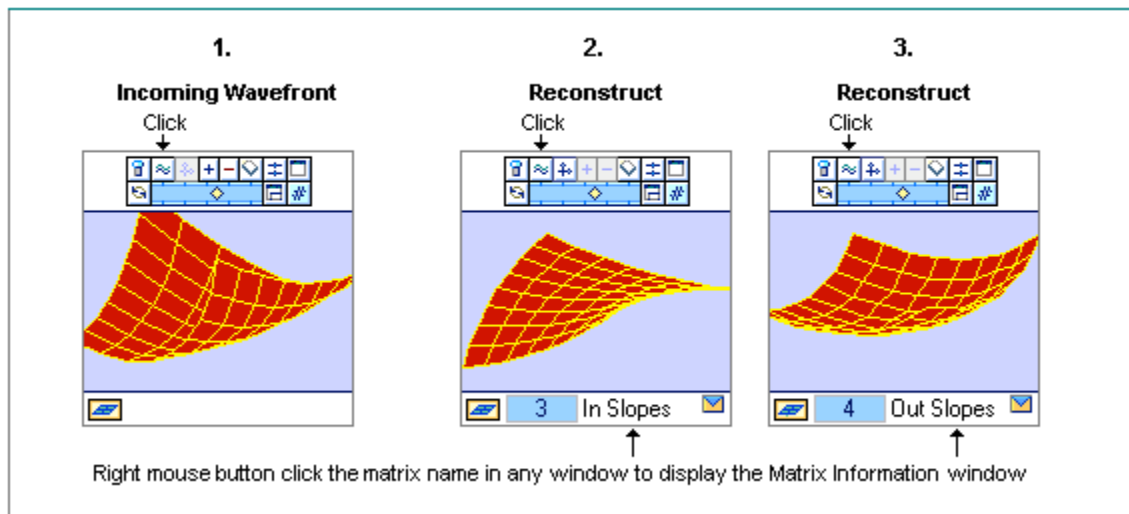


Figure 10.

Description of Windows

Nothing has been changed between Figure 9 and 10 except the incoming wavefront.

- 1) Zernike 4 (focus) has been added to the *Incoming Wavefront*.
- 2) The *In Slopes Projection* matrix extracts the zernikes it was built from and as a result, only X and Y astigmatism are apparent, focus has been filtered out in the second window of fig. 10.
- 3) The *Out Slopes Projection* matrix filters out the zernikes it was built from, leaving only the remaining focus zernike, in window 3 of fig. 10.

Instructions

This exercise is a continuation of the previous instructions on page 14, assuming that matrices have been made and assigned to windows as per instructions.

- 1) Open the *Zernike* window if it is not on the screen. Use the *Evaluation* option in the main menu bar. *Zernikes* 5 and 6 should be still active from the previous exercise. Give them some gain by moving their sliders.
- 2) If not already on the screen, open the *Incoming Wavefront* window and the two *Reconstruction Flying Carpet* windows that have the zernike projection matrices attached to them as in the previous instructions. Open them from the *Evaluation* option of the main menu bar and the *Flying Carpets* submenu.
- 3) First, simulate the incoming wavefront from selected zernikes: click the second button (top row) in the *Incoming Wavefront* window, then click the same button in each of the other *Flying Carpet* windows. It is irrelevant which *Reconstruction* window is clicked next.
- 4) Now click the 4th zernike for focus and give it some gain. Simulate the incoming wavefront again, and reconstruct it in both windows. Compare your results to the fig 9 and fig.10. Try changing slider gains in the *Zernike* and *Flying Carpet* windows.

Options.

- 1) Right mouse button click the name of one of the zernike projection matrices. An information window will be displayed. Note that the remark lists the zernikes used in making the matrix. It is an edit field which is disabled in all but the *Catalog* and the *View Matrix List* windows.
- 2) Right button mouse click the information window or double click it anywhere except on buttons or edit fields to remove it from the screen. The right mouse button on a matrix name in any window will access the information window.

EDITING THE INCOMING WAVEFRONT

In addition to building wavefronts from zernikes, it is also possible to edit individual phases in one of two ways: 1) within the *Incoming Wavefront* window or 2) using the *Edit Wavefront* window. The first method is very simple but limited. [Instructions follow on this page.](#)

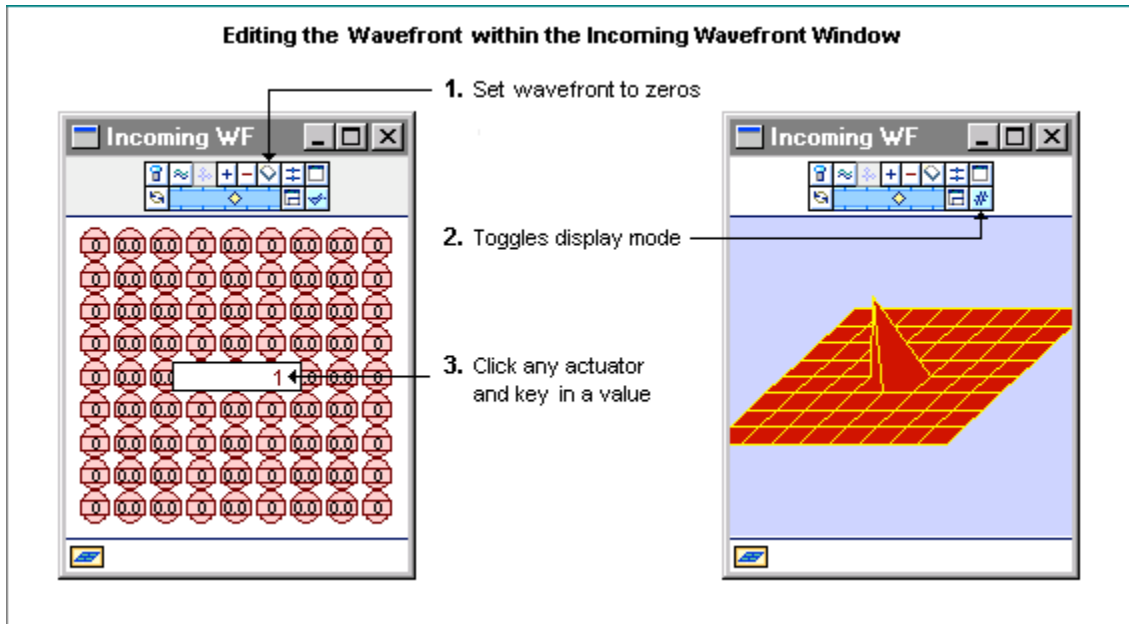


Figure 11.

Description of Window

The two images in Figure 11 are of the same window displaying the same wavefront vector, only the display mode differs. On the left is a numerical presentation of the wavefront and on the right one in graphics.

- 1) This button clears the wavefront vector of the window – sets it to zeroes.
- 2) This button toggles the display between graphics and numerical mode.
- 3) When in numerical mode, a click on an actuator will open an edit field. Use the left and right arrow keys to move the cursor. To stop editing, click anywhere in the window except on buttons and actuators. To copy/paste, click an actuator to highlight it and press *Control/C* then click another actuator to highlight it and press *Control/V*. To tab over to the next actuator, click an actuator and enter a value, then before clicking anywhere else, tab over to the next one. Shift/tab works in reverse.

Instructions

- 1) If not already on the screen, open the *Incoming Wavefront* window by clicking the *Evaluation* option of the main menu bar, then click *Flying Carpets* and select *Incoming Wavefront*.
- 2) If the window is not in numerical mode, click the button indicated by item 2, fig. 11.
- 3) Optionally, set all phases to zeros by clicking item 1 in fig. 11.
- 4) Click any actuator and enter a value. To stop editing, click anywhere in the window except on buttons and actuators.
- 5) Click item 2, fig. 11 to change the display to graphics mode. If you do not see a peak, move the slider in the *Incoming Wavefront* window.

Options

Please refer to *DISPLAY OPTIONS AND PREFERENCES*, page 32

THE EDIT WAVEFRONT WINDOW

A more flexible way of changing the incoming wavefront is to use the *Edit Wavefront* window which allows vector retrieval. Step by step instructions are on the next page.

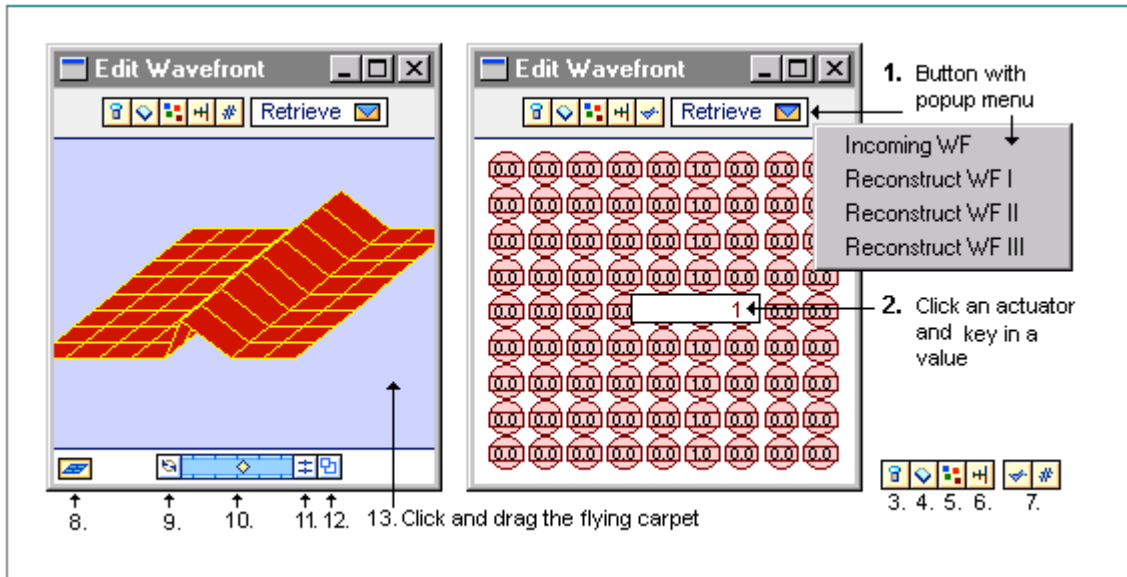


Figure 12.

Description of Window

- 1) The popup menu lists the four *Flying Carpet* windows from which the wavefront can be retrieved. For example, if the 3rd *reconstruction* window contains a wavefront which you wish to change and reconstruct again in another window, the *Edit Wavefront* window can retrieve it.
- 2) Click any actuator and key in a value. Use the left and right arrow keys to move the cursor. To copy / paste, click an actuator to highlight it and press *Control/C* then click another to highlight it and press *Control/V*. To stop editing a field, click the window anywhere except on buttons or actuators. To tab over to the next actuator, you must be in edit mode. Click an actuator and change its value, then before clicking anywhere else, tab over to the next actuator. Shift/Tab works in reverse.
- 3) This button toggles virtual actuator display on or off.
- 4) This button clears the wavefront in the *Edit Wavefront* window.
- 5) This button randomizes the phase values of the *Edit Wavefront* window.
- 6) This buttons opens a window which permits changing *the minimum / maximum* range for random numbers. It affects the randomize button of this window only.
- 7) This button has two faces, one for numerical and the other for graphical display. Click it to toggle display mode.
- 8) This button and the following are available while the *Edit Wavefront* window is in graphics display mode. If the flying carpet has been dragged off center, this button will indicate the direction. Clicking it re-centers the flying carpet.
- 9) This button opens the *Rotate* window which permits rotating the flying carpet. All flying carpets will be affected.
- 10) Move the slider left or right to decrease or increase the gain. Double click it anywhere in the blue area to change the min / max gain of this slider only.
- 11) This button sets the slider gain and the min / max range of all flying carpet windows to the values of this slider.
- 12) This button re-sizes all *Flying Carpet* windows to the size of this window.

- 13) Click anywhere within in the graphics display area and drag the flying carpet off center. Item 8 indicates the direction in which it was dragged.

Instructions

- 1) Open the *Edit Wavefront* from the *Evaluation* option of the main menu bar.
- 2) If the window is in graphics mode, change the display to numeric by clicking button 7 in fig. 12.
- 3) Clear the wavefront in the *Edit Wavefront* window by clicking the erase button (item 4, fig.12).
- 4) Set all actuators in any one column to the value of 1. Click an actuator and enter '1'. To stop editing, click anywhere in the window except on buttons or actuators. Now copy / paste phase values, click the actuator you just changed to highlight it and press *Control/C* to copy the value. Then change the rest of the actuators in the same column, click each one in turn to highlight it and press *Control/V*. It's possible to tab over to the next actuator in the row, but not to the same column in the next row. In this example, tabbing will be of little use.
- 5) Set graphics mode to view the results, click button 7 in fig.12. Move the slider in the *Edit Wavefront* window if the flying carpet is flat.

Options

- 1) Clear the wavefront and use the random button (item 5, fig. 12) in the *Edit Wavefront* window. Click the display mode button to view it in numeric mode.
- 2) Change the *min / max* number range by clicking item 6 in fig. 12, and move the slider knob. Then randomize the wavefront again.

Using the Edit Wavefront Window

The above exercise used the *Edit Wavefront* window to demonstrate editing features. To put the window to use, the edited wavefront must be moved to the *Incoming Wavefront* window. In *A++*, vectors are always retrieved, never sent. Therefore, the *Incoming Wavefront* window must retrieve the vector from the *Edit Wavefront* window, it is the only window which can do so – other *Flying Carpet* windows reconstruct, never simulate. On the other hand, even though only one window can retrieve the vector from the *Edit Wavefront* window, the *Edit Wavefront* window can retrieve the vector from any *Flying Carpet* window. Step by step instructions start on the next page.

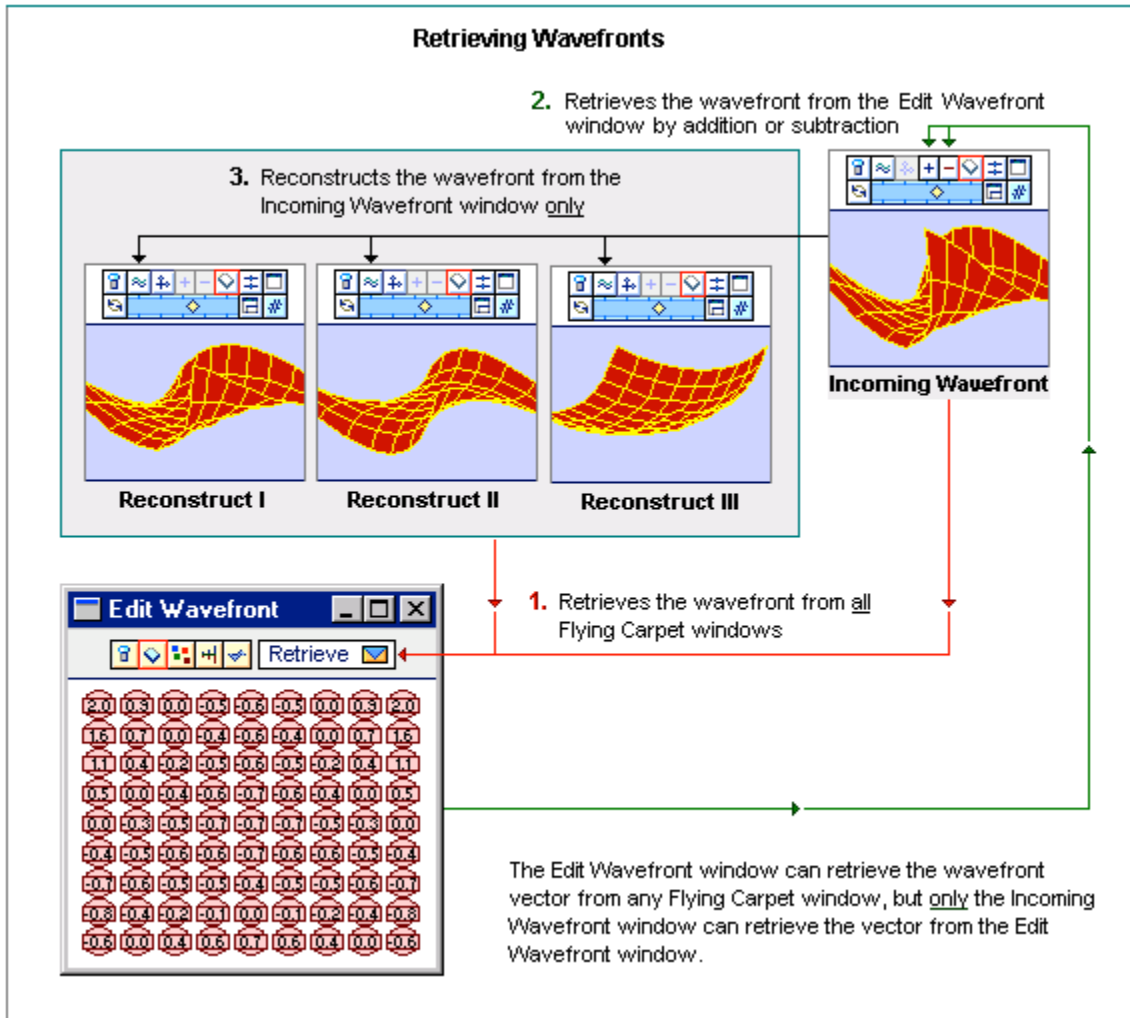


Figure 13.

Description of Windows

Figure 13, depicts the relationship between the *Edit Wavefront* window to other *Flying Carpet* windows.

- 1) The *Edit Wavefront* window can retrieve the wavefront from any *Flying Carpet* window.
- 2) Only the *Incoming Wavefront* window can retrieve the vector from the *Edit Wavefront* window by using the *plus* or *minus* buttons to add/subtract it to/from it's own vector. To attain a copy of the wavefront, first clear the vector in the *Incoming Wavefront* window then use the *plus* button to retrieve it from the *Edit Wavefront* window.

- 3) The three *Flying Carpet* windows reserved for reconstruction retrieve no vectors. They are used exclusively for reconstructing, never simulating.
- 4) The erase button (outlined in red in fig. 13) will clear the vector in its own window only and is operational in all windows.

Instructions

- 1) Make a geometry and three reconstructors matrices: *A+ Least Squares*, *In Slopes Zernike Project* and *Out Slopes Zernike Project* from zernike 9, Bal. SpAb. For detailed instructions on making matrices please refer to the *MAKING AND MANAGING MATRICES* document.
 - a) Open the *Make Matrix* window from the *Matrices* option in the menu bar.
 - b) If the diamond next to *Geometry* is not red, click it, then click the *Ok* button.
 - c) Use the top *popup menu* button to select the matrix you just made as the foundation geometry matrix, then click the diamond next to the *A+ Least Squares* matrix and click the *Ok* button. Use the lower *popup menu* button to select the matrix you just made as the foundation reconstructor.
 - d) Open the *Zernike* window from the *Evaluation* option of the main menu bar.
 - e) Clear all zernikes: if the "All" in the *All* button is crossed out, click it, then click the adjacent button until all zernike number boxes are white and "No Active Zernikes" appears in the bottom margin of the window.
 - f) Click Zernike 9, Bal. SpAb, the bottom margin of the window should read '1 Active Zernikes'.
- 2) Assign matrices to windows. For detailed information on assigning matrices, please refer to page 10.
 - a) Open all flying carpet windows. Click the *Evaluation* option in the main menu bar, then click *Flying Carpets* and select each of the windows in turn.
 - b) Assign the geometry matrix to all *Slopes* windows: drag the *Geometry* matrix from the *Make Matrix* window to any of the flying carpet windows, it will be assigned to all *Slopes* windows. Open a *Slopes* window to verify this. To do so, click the right-most button (top row) in any of the flying carpet windows. The button will open the window if it's pair (evaluation windows come in pairs – flying carpet / slopes vector). Or use the *Slope Vectors* submenu under the *Evaluation* option of the main menu bar.
 - c) Use *popup menu* buttons to select reconstructors: attach the *A+ Least Squares* matrix to *I Reconstruct WF* window, the *In Slopes Zernike Projection* to *II Reconstruct WF*, and the *Out Slopes Zernike Projection* to *III Reconstruct WF*. Window assignments are only a suggestion, assign matrices to windows as you wish.

NOTE: The slider in Flying Carpet windows must be non-zero, otherwise the flying carpet will remain flat. Move the slider knob to the left or right. To coordinate all sliders, click the second from the right button (top row). To coordinate sliders from the Edit Wavefront window, put it into graphics display mode first, then click the second button from the right in the bottom margin of the window.

- 3) Make a Bal. SpAb. incoming wavefront. The *Zernike* window should show it as the only active zernike (from step 1f). Give it some gain by moving its slider to the left or right (in figure 13 it was given a positive gain value), then click the second button (top row) in the *Incoming Wavefront* window to make the wavefront.
- 4) Move the Bal. SpAb. wavefront to the *Edit Wavefront* window. Open the *Edit Wavefront* window from the *Evaluation* option of the main menu bar. Click the *popup menu* button at the top of the *Edit Wavefront* window and select *Incoming Wavefront* to retrieve the Bal. SpAb. wavefront from the window.
- 5) Make a focus incoming wavefront. Use the *Zernike* window. Click zernike 4 (focus) to select it and zernike 9 (Bal. SpAb.) to deselect it. The number box for focus should be aqua in color and all others white. Click the second button (top row) in the *Incoming Wavefront* window to make the focus wavefront.

- 6) Add the Bal. SpAb. wavefront from the *Edit Wavefront* to the focus wavefront: Click the *plus* button in the *Incoming Wavefront* window. Add it again. Note how the Bal. SpAb. zernike becomes more pronounced.
- 7) Click the *minus* button in the *Incoming Wavefront* window to subtract the extra Bal. SpAb. wavefront and return it to its former proportion.
- 8) Click the second button (top row) in all *Flying Carpet* windows reserved for reconstruction and notice how the *A+ Least Squares* matrix reconstructed the wavefront as it is, the *In Slopes Zernike* matrix extracted the Bal. SpAb. from the wavefront and the *Out Slopes Zernike* matrix filtered out the Bal. SpAb zernike leaving only focus.
- 9) Now subtract the Bal. SpAb from the incoming slopes window. Click the *minus* button in the *Incoming Wavefront* window - only focus remains.
- 10) Use the display mode button (rightmost, second row) periodically to view flying carpets in numeric and graphics mode.

Options

- 1) Clear the wavefront in the *Edit Wavefront* window and set one column of actuators to the phase value of 1 as in the instructions are on page 19 (shown in figure 12 on page 18).
- 2) Clear the wavefront in the *Incoming Slopes* window and use the *plus* button to retrieve the edited wavefront.
- 3) Use the *plus* button a number of times. The effect will cause the gain to increase.
- 4) Use the *minus* button until the flying carpet first becomes flat then peaks in the opposite direction.
- 5) Use the display mode button periodically to view the flying carpet in numeric and graphics mode.

BYPASSING THE INCOMING WAVEFRONT

All A++ requires for reconstruction to take place is a reconstruction matrix and a slopes vector. Normally, the slopes vector is extracted from the incoming wavefront by multiplying it with a geometry matrix, but if slopes are already formed, it is possible to bypass the incoming wavefront and reconstruct directly from slopes. The next instructions start on page 26.

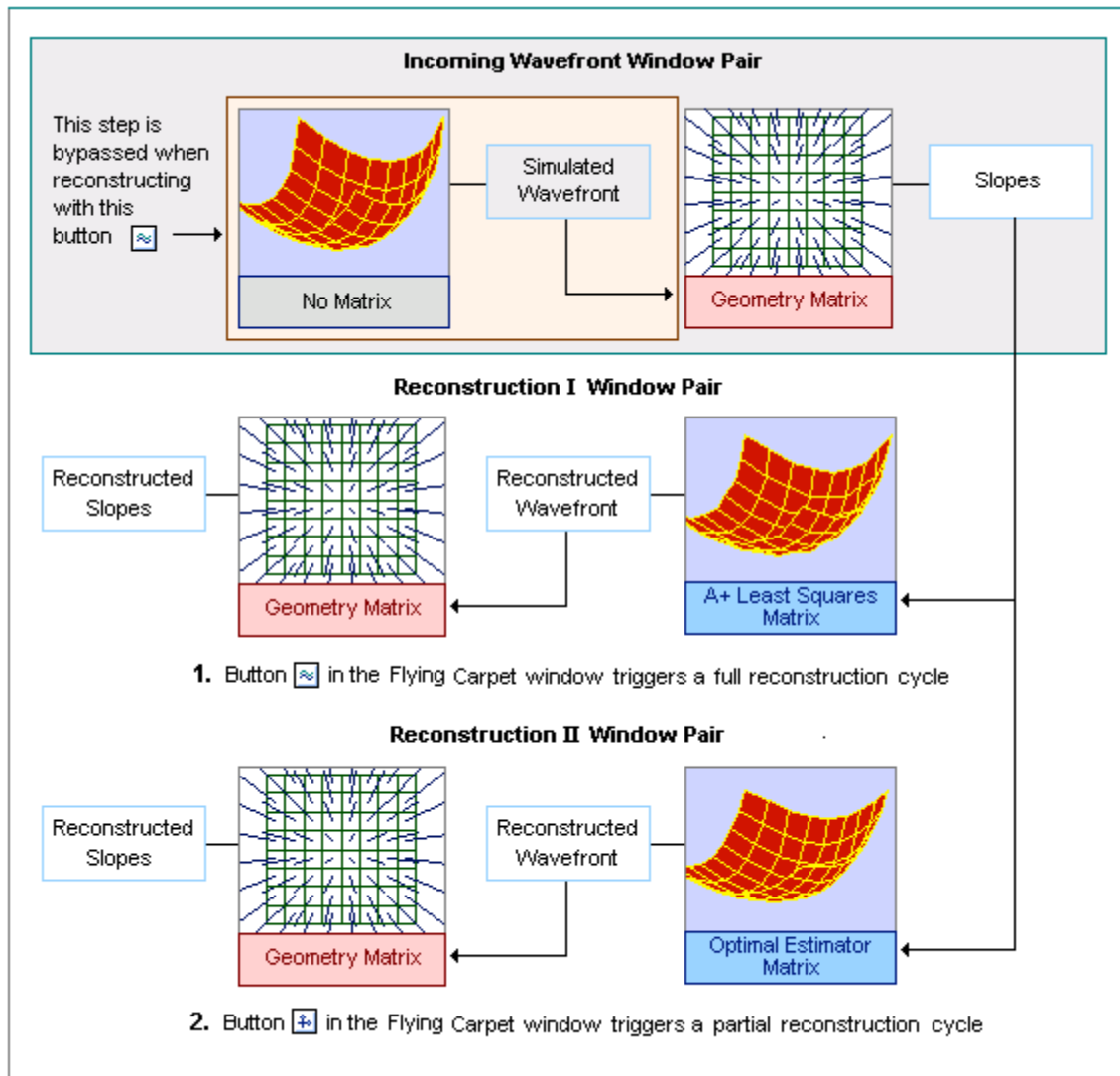


Figure 14.

Description of Windows

Figure 14 differs very little from fig. 7 on page 12. The difference lies in the manner the second reconstruction was achieved, but the end result is exactly the same.

- 1) The first reconstruction was triggered when the indicated button was pressed:
 - a) The incoming wavefront vector was used to multiply the geometry matrix assigned to the *Incoming Slopes* window to produce slopes.
 - b) Next, the newly generated slopes vector was used to multiply the *A+ Least Squares* matrix attached to flying carpet window of the *Reconstruct I Window Pair* to render the reconstructed wavefront.
 - c) The final step used the *reconstructed wavefront* to generate slopes by multiplying it with the matrix attached to the *Slopes* window of the *Reconstruct I Window Pair*.

- 2) The second cycle was a partial reconstruction. It was triggered by the button indicated in the *Reconstruct II Window Pair*, bypassing the first step (1a). Assuming incoming slopes In fig. 14, have not been changed since the reconstruction (step 1) occurred, the two methods are equivalent.

NOTE: All Slopes windows are passive, reconstruction cycles whether they are full or partial are never triggered by them, but only by Flying Carpet windows reserved for reconstruction.

THE SLOPES WINDOW

The *reconstruct from slopes button* is used primary to reconstruct from *edited* slopes, the time saved by bypassing the extraction of slopes from the incoming wavefront anew is insignificant. But before delving into editing them, it would be expedient to describe the *Slopes* window in some detail.

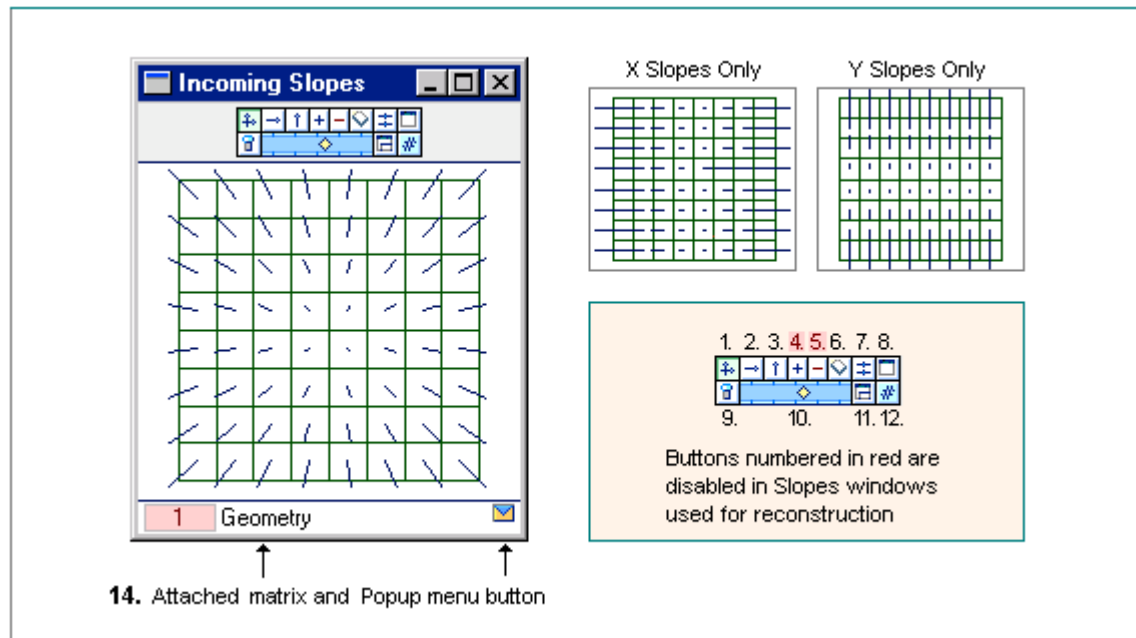


Figure 15.

Description of Window

Figure 15 shows the *Incoming Slopes* window with a vector generated by multiplying the geometry matrix assigned to the window with the wavefront from the *Incoming Wavefront* window. It was a focus zernike, as seen by the pin cushion effect.

- 1) This button displays both the *x* and *y* slope in graphics and numerical mode.
- 2) This button displays the *x* slope only in graphics and numerical mode.
- 3) This button displays the *y* slope only in graphics and numerical mode.
- 4) This button adds the slopes vector found in the *Edit Slopes* window to the *Incoming Slopes* window, it is disabled in all other *Slopes* windows.
- 5) This button subtracts the slopes vector found in the *Edit Slopes* window from the *Incoming Slopes* window, it is disabled in all other *Slopes* windows.
- 6) This button erases (or sets to zeroes) the slope vector of it's own window – according to the current display option. If both *x* and *y* slopes are displayed, both will be set to zeroes, otherwise only the shown slope will be cleared, whether in graphic or numerical mode. This button is operational in all *Slopes* windows.
- 7) This button sets the values of all *Slopes* window sliders to the slider value of the window in which it is clicked. The min / max gain of sliders are also set accordingly.

- 8) This button opens the *flying carpet* window associated with the *Slopes* window in which the button was clicked.
- 9) This button toggles the display of virtual subapertures on or off. Virtual subapertures are indicated only, they take part in no operation.
- 10) The slider knob will increase / decrease slope vector gains. To change the min / max gain of the slider, double click it anywhere in the blue area. Sliders in *Slopes* windows are independent of any other slider. Collective changes are achieved only with button 7, in fig. 15 on page 24.
- 11) This button “synchronizes” the sizes of *Slopes* windows. The window in which it is clicked becomes the measure of all other *Slopes* windows.
- 12) This button toggles the display mode between graphic and numeric.

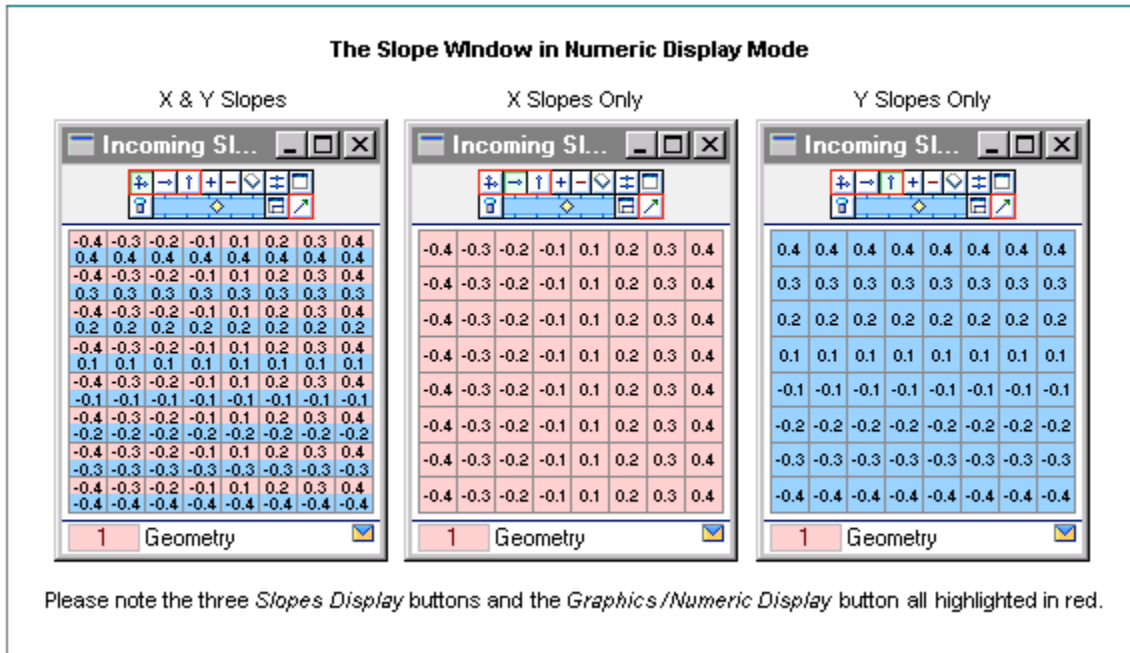


Figure 16.

Figure 16, is another version of figure 15. It is the same window with the same vector, but in numeric mode.

EDITING SLOPES

As with editing the wavefront, there are two ways slopes can be directly edited, 1) changing them in the *Incoming Slopes* window or 2) using the *Edit Slopes* window. *Slopes* windows paired with *Flying Carpet* windows reserved for reconstruction cannot be edited.

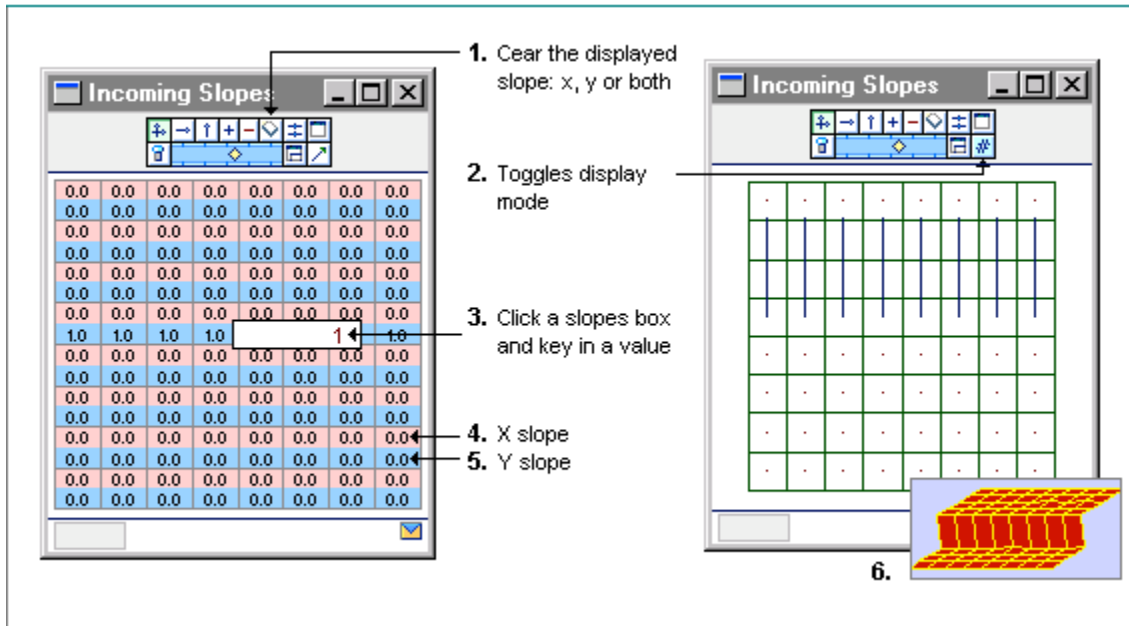


Figure 17.

Description of Window

Fig. 17 shows two views of the same *Incoming Slopes* window. The image on the left is in numeric mode and the one on the right in graphics mode.

- 1) This button clears the slopes vector depending on the setting of the display option (first three buttons, top row). If both x and y slopes are displayed, both will be cleared otherwise only the slope displayed will be cleared. It is operational in all *Slopes* windows.
- 2) This button has two faces, it toggles display mode between numeric and graphic.
- 3) Click a slope value box and enter a value. If both slopes are displayed, click the rose colored box for the x slope and the blue for the y slope. Use the left and right arrow keys to move the cursor. To stop editing, click anywhere in the window except on slope values or buttons. To copy a slope value: click it to highlight, then press *Control/C*; to paste: click another slope value to highlight it and press *Control/V*. To tab over to the next slope, you must be in edit mode: click a slope and enter a value, then before clicking anywhere else, tab over to the next slope. *NOTE: You may tab over only to the slope vector you are currently editing, either x or y but not both.*
- 4) X slopes are rose in color.
- 5) Y slopes are blue in color.
- 6) This inset depicts a flying carpet reconstructed from the edited slopes as shown in fig. 17. Note that no geometry matrix has been assigned to the *Incoming Slopes* window, it is not needed when the incoming wavefront is by-passed. However, a reconstructor matrix was used by the *Reconstructor* window that generated the flying carpet. (The slider gain of the *Flying Carpet* window was set to a negative value in Fig. 17, item 6)

Instructions

If matrix assignments exist before starting these step by step instructions, you must first clear them: select *Clear Matrix Attachments* from the *Matrices* option in the main menu bar.

- 1) Make a geometry and a reconstructor matrix, but assign only the reconstructor matrix to one of the *Flying Carpet* windows reserved for reconstruction. (A geometry matrix may be

assigned at any time, it will not hinder any reconstruction, but for demonstration purposes, refrain from doing so.)

- a) Open the *Make Matrix* window from the *Evaluation* option in the main menu bar.
 - b) Click the diamond next to *Geometry* if it is not red, then click the *Ok* button.
 - c) Click the top popup menu button and select the matrix you just made as the geometry foundation matrix.
 - d) Click the diamond next to *A+ Least Squares* and click the *Ok* button.
 - e) Open the *I Reconstruct WF* window. Click the *Evaluation* option in the main menu bar, then click *Flying Carpets* and select *Reconstruct I*, or select a *Flying Carpet* window of your choice, as long as it is not the *Incoming Wavefront* window.
 - f) Click the popup menu button at the lower right of the *Flying Carpet* window and attach to it the *A+ Least Squares* matrix.
 - g) Verify that no other matrix except the *A+ Least Squares* reconstructor has been assigned to evaluation windows. Open the *Source Matrices* window from the *Matrices* option in the main menu bar. It will display only two assigned matrices, a geometry as the foundation matrix for the *Make Matrix* window and the *A+ Least Squares* matrix you just attached to the *I Reconstruct WF* window.
- 2) Open the *Incoming Slopes* window. Click the *Evaluation* option in the main menu bar, then click *Slope Vectors* and select *Incoming Slopes*.
 - 3) If the window is not in numeric mode, click the display mode button (item 2, fig. 17 on page 26).
 - 4) Clear x and y slopes. Click the *erase* button (item 1, fig. 17 on page 26). If both slopes are showing, both x and y will be set to zeros. If only one is showing, display the other slope (use one of the three left-most buttons, top row) before clearing – or – select both slopes at the outset and use the *erase* button.
 - 5) Edit slope values as you wish, or set up the slope vector as shown in figure 17 on page 26 by setting one row of y slopes to 1. Click a blue colored slope value, the second one in the row of your choice. Enter '1', then tab over to the next slope and enter '1'. Next *Shift/Tab* over the next two slopes and enter '1'. Or copy/paste them, click a slope with a value of 1 to highlight it, and press *Control/C* then click the rest in turn to highlight them and press *Control/V*.
 - 6) Click the 3rd button (top row) in the *I Reconstruct WF* window to reconstruct from edited slopes. Move the slider knob to the left or right for different views.

Options

Click the *display mode* button, (right-most, second row) in the *Incoming Slopes* window from time to time. If slopes in graphics mode are not being drawn, move the slider. Click the first three buttons (top row) to see x and y slopes separately and together.

THE EDIT SLOPES WINDOW

The *Edit Slopes* window is the counterpart of the *Edit Wavefront* window and works analogously. [Step by step instructions are on page 30.](#)

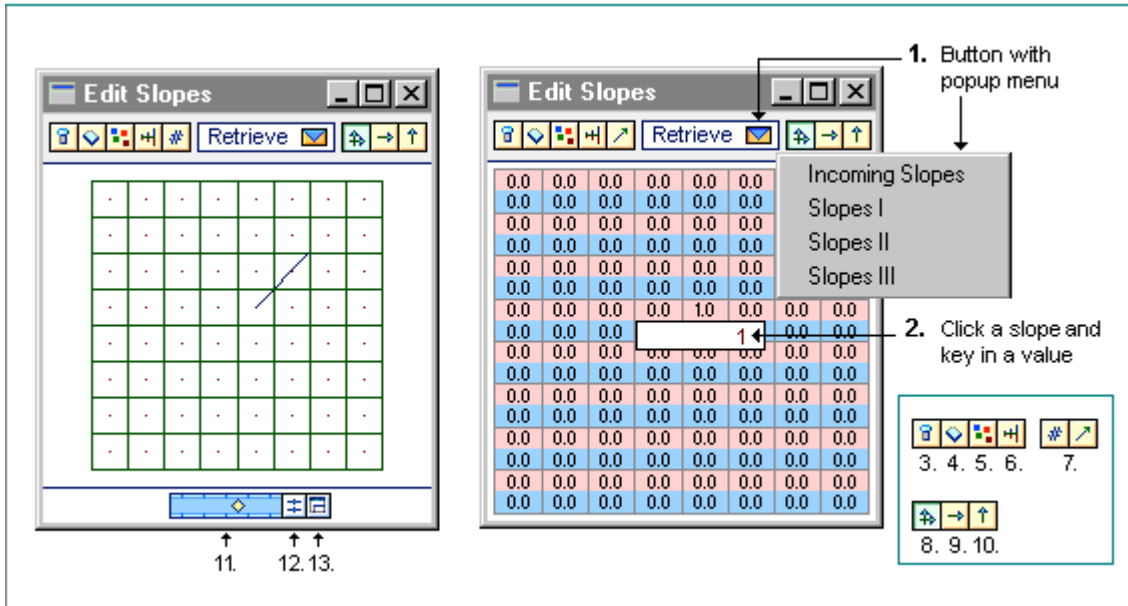


Figure 18.

Description of Window

- 1) This button will retrieve the slopes vector (always both x and y) from the selected *Slopes* window.
- 2) Click a slope to change it. Copy / paste with *Control/C* and *Control/V* while the box is highlighted. To move the cursor, use the left and right arrow keys. To stop editing, click anywhere in the window except on buttons and slopes. To tab over to the next slope, you must be in edit mode: change a slope and before clicking anywhere else, tab over to the next slope. To tab back, press *Shift/Tab*. When both slopes are displayed, a tab will always go to the next slope of its kind.
- 3) This button toggles the display of virtual subapertures on or off.
- 4) This button clears the visible slope only. If both slopes are displayed, both will be cleared.
- 5) This button randomizes the values of the visible slope only. If both slopes are displayed, the values of both slopes will be randomized.
- 6) This button will open a window in which the *min / max* range for random values can be changed. The random number range affects only this window.
- 7) This button has two faces, it toggles the display mode between graphic or numeric.
- 8) When enabled, this button will display both x and y slopes.
- 9) When enabled, this button will display x slopes only.
- 10) When enabled, this button will display y slopes only.
- 11) When in graphics mode, move the slider left or right to change the gain of the slope vector. Double click it anywhere in the blue area of the slider to change the *min / max* gain of this slider only.
- 12) Click this button to apply the *min / max* range and gain setting of this slider to all *Slopes* windows.
- 13) Click this button to resize all *Slopes* windows to the size of this window.

RECONSTRUCTING FROM SLOPES

The *Edit Slopes* window permits not only direct editing but also vector retrieval. Like *Flying Carpet* windows, the *Edit Slopes* window can retrieve the vector from any *Slopes* window, but only the *Incoming Slopes* window can retrieve it from the *Edit Slopes* window. Step by step instructions are on page 30.

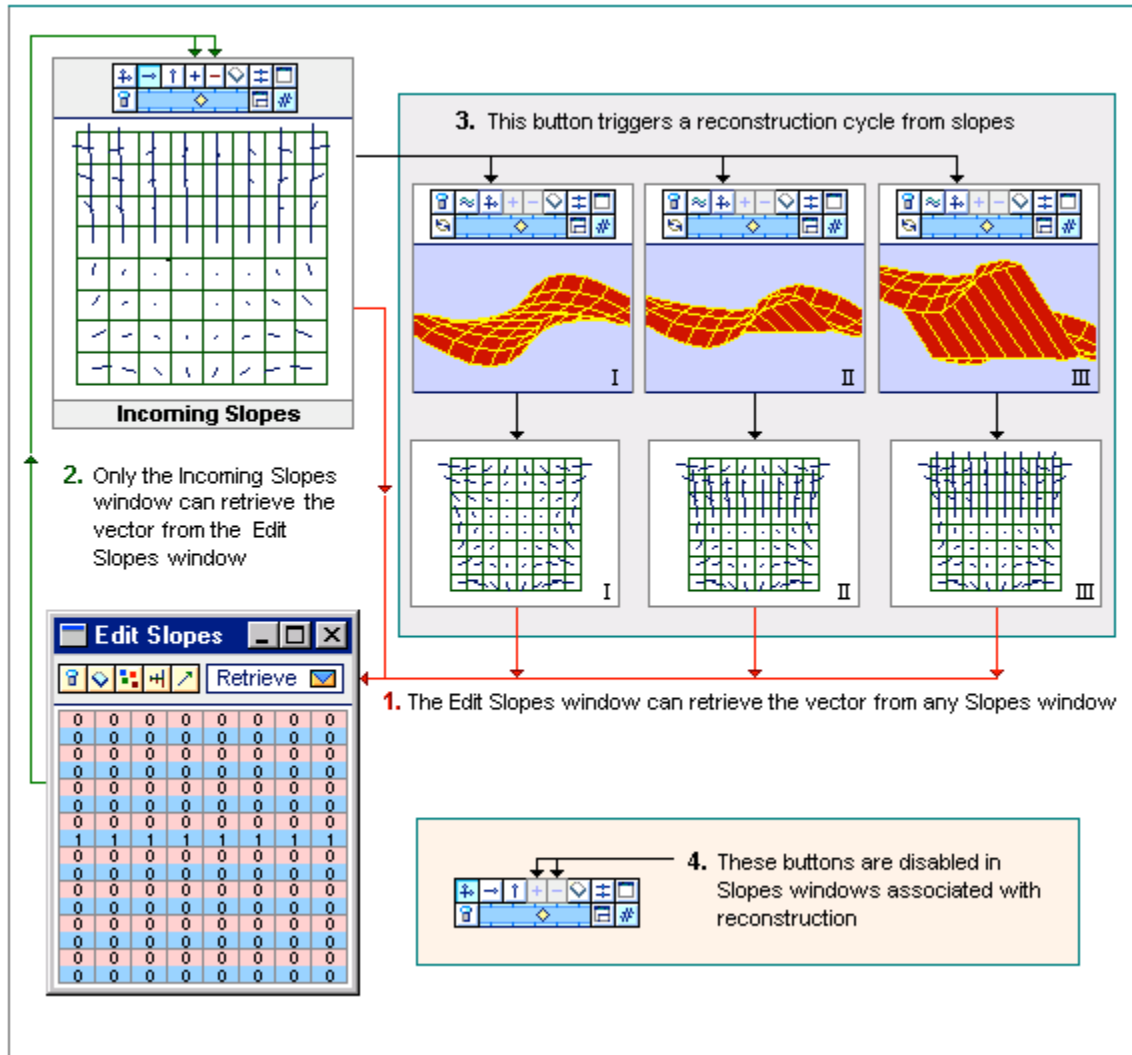


Figure 18.

Description of Windows

- 1) The *Edit Slopes* window can retrieve the vector from any *Slopes* window.
- 2) The *Incoming Slopes* window is the only one that can retrieve the vector from the *Edit Slopes* window. Use the *plus* or *minus* button to either add or subtract the vector. Both slopes, x and y are retrieved each time. To copy the vector, clear it in the *Incoming Slopes* window first, then press the *plus* button.
- 3) To trigger a partial reconstruction cycle, that is, to by-pass the incoming wavefront, click the 3rd button from the left (top row) in any *Flying Carpet* window reserved for *reconstruction*. The reconstruction cycle ends with slopes generated from the *reconstructed* wavefront, as seen in *Slopes* windows *I*, *II* and *III*, fig.18. It is important to note that reconstruction cycles are always triggered from *Flying Carpet* windows, never *Slopes* windows.

- 4) These buttons are disabled in the *Slopes* windows associated with *Flying Carpet* windows used for reconstruction. All other buttons operate alike in all *Slopes* windows.

Instructions

Make a geometry and a reconstructor matrix. Assign the geometry matrix to all *Slopes* windows and the same reconstructor matrix to all *Flying Carpet* windows reserved for reconstruction.

- 1) Open the *Make Matrix* window from the *Evaluation* option in the main menu bar.
- 2) Click the diamond next to *Geometry* if it is not red, then click the *Ok* button.
- 3) Click the top popup menu button and select the matrix you just made as the geometry foundation matrix.
- 4) Click the diamond next to *A+ Least Squares* and click the *Ok* button.
- 5) Open all the *Reconstruct WF* window. Click the *Evaluation* option in the main menu bar, then click *Flying Carpets* and select *Incoming Wavefront*. Do the same for the rest of the flying carpet windows.
- 6) Drag the *Geometry* matrix from the *Make Matrix* window to one of the *Flying Carpet* windows. This matrix will now be assigned to all *Slopes* windows.
- 7) Assign the same *A+ Least Squares* matrix to all *Flying Carpet* windows reserved for reconstruction: use the popup menu button in the lower right corner to select the matrix (or drag it from the *Matrix Catalog* window).

Edit slopes.

- 8) Open the *Edit Slopes* window from the *Evaluation* option of the main menu bar.
- 9) If the window is not in numeric display mode, click the 5th button from the left (top row).
- 10) Clear x and y slopes. Make sure the window is wide enough to show all buttons. Click the third button from the right, at the top (with two arrows) to select both slopes for display.. Then click the *erase* button (second from the left at the top of the window).
- 11) Set one row of y slopes to 1's. Click the first y slope in the row of your choice (fig. 18 selected the 4th row), and enter the value 1. Tab over to the next slope y and enter the value 1, until all y slopes in the 4th row are set to 1's. You may also click to highlight a slope with a value of '1' and copy it by pressing *Control/C* then click the rest of the slopes in turn to highlight them and paste with *Control/V*.

Select a zernike and give it some gain.

- 12) Open the *Zernike* Window.
- 13) Clear all zernikes if necessary. Click the *All* button if the 'All' is crossed out. Then click the adjacent button until all zernike selection boxes are white and "No Active Zernikes" appears in the bottom margin of the window.
- 14) Click the 9th zernike (Bal. SpAb) to select it, and give it some gain by moving the slider.

Reconstruct from slopes.

- 15) Open all *Slopes* windows. Either use the right-most top button in flying carpet windows (which displays its window pair) or open them from the *Evaluation* option in the main menu bar, found under the *Slope Vectors* submenu, or open several windows at a time, please refer to *OPENING SEVERAL WINDOWS AT A TIME*, on page 33.
- 16) Clear the vector in all *Slopes* windows. Set the display to show both x and y slopes (click the top-most first button (it shows two arrows), then click the *erase* button (3rd top-most button from the right).
- 17) Move the slider in one of the *Slopes* windows so that it is not set on zero. Then click the synchronize sliders button (second button from the right, top row). This will set all *Slopes* windows to the same slider value.
- 18) Make the Bal. SpAb wavefront. Click the second button from the left (top row) in the *Incoming Wavefront* window. Notice that the vector in the *Incoming Slopes* is still zero, slopes are not generated when incoming wavefronts are simulated.
- 19) Reconstruct the incoming wavefront in the *I Reconstruct WF* window, by clicking the second button from the left (top row). Note that the vectors in both the *Incoming Slopes* window and

the *I Slopes Reconstruct* window fit the wavefront pattern. If they do not, the sliders are still set on zero, refer to step 17.

- 20) Add the slopes vector from the *Edit Slopes* window to the *Incoming Slopes* window by clicking the *plus* button once.
- 21) Reconstruct the incoming slopes, by clicking the 3rd button from the left (top row) in the *II Reconstruct WF* window for the sake of comparison.
- 22) Add the slopes vector from the *Edit Slopes* window to the *Incoming Slopes* window again (click the *plus* button). Add it twice.
- 23) Reconstruct from incoming slopes by clicking the 3rd button from the left (top row in the *III Reconstruct WF* window).

ROTATING THE FLYING CARPET

The Flying Carpet can be rotated in any direction using the *Rotate* window. Figure 19 shows an expanded *Rotation* window. A change in rotation will automatically be applied to all flying carpets.

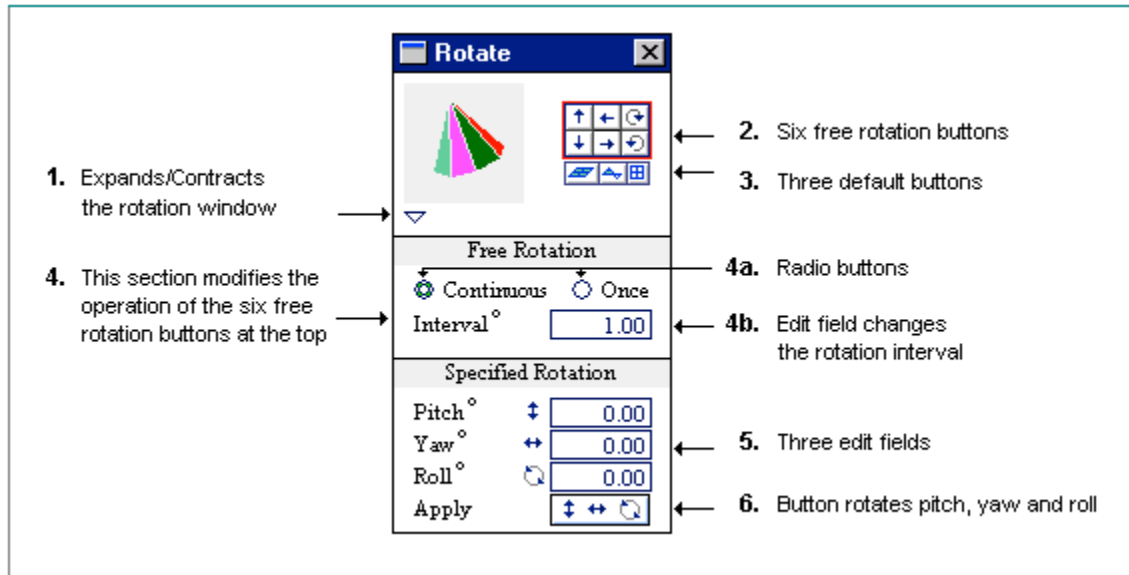


Figure 19.

Description of Window

- 1) Click this button to expand or contract the window.
- 2) These six buttons (highlighted in red) will rotate the flying carpet in the direction of the arrow. The amount of rotation depends on parameters set in the second section of the window under the heading *Free Rotation*.
- 3) These three buttons rotate the flying carpet to a predefined view. The first button rotates it to an *oblique* view, the second to an *edge on* view and the third to a view with zero rotation.
- 4) This section affects the free rotation buttons outlined in red.
 - a) If the *Once* radio button is active, the flying carpet is rotated once with every mouse click. The amount rotated is in degrees, as shown by the edit field labeled *interval*. If the *Continuous* radio button is active, rotation continues as long as the mouse button remains down, also by the degrees as shown in the edit field. Only the cone image in the *Rotate* window will whirl about during a continuous rotation, flying carpets are positioned after rotation stops.
 - b) This edit field determines the amount in degrees rotated by the six free rotation buttons in the direction of the arrow.
- 5) These three edit fields are used with the button at the bottom of this section of the window, under the heading *Specified Rotation*. They are values in degrees for pitch, yaw and roll.
- 6) This button applies rotation degrees as shown in the three edit fields for pitch, yaw and roll.

Instructions

Change the speed of a continuous rotation.

- 1) Open the *Rotate* window from the Evaluation option of the main menu bar.
- 2) Expand the window if it is contracted.

- 3) Click the *Continuous* radio button if it is not active.
- 4) Enter '10' into the edit field labeled *interval*. Click it and key in the value. To stop editing, click anywhere inside the window except on buttons or edit fields.
- 5) Click and hold down any one of the six free rotation buttons (item 2, fig. 19 on page 32. The cone will whirl too fast – unless your computer is very slow.
- 6) Now enter '.05' into the edit field labeled *interval* and rotate again. If it's still too fast, enter .001. If it's too slow enter a higher value.

OPENING SEVERAL WINDOWS AT A TIME

Because A++ contains many windows, the screen can sometimes become very cluttered. To remove clutter, use the *Windows* option in the main menu bar to remove and/or open an assortment of windows at a time.

Instructions

- 1) Click the *Windows* option of the main menu bar, then click *Close Windows* and select *All*.
- 2) Click the *Windows* option of the main menu bar. Click *Show Windows* and select *Matrix Generation*. This option opens a number of windows useful when making matrices.
- 3) Click *Windows* option of the main menu bar. Click *Show Windows*, click *Matrix Evaluation*, and select any one of the available window combinations.

