The AccuFiz with 4Sight software makes it easy to fully characterize the errors in corner cubes.

Measuring a Corner Cube with the AccuFiz®

Don Roberts, Mike Zecchino

Introduction

The AccuFiz laser interferometer with 4Sight software makes it simple to characterize the errors in corner cubes. Corner cubes can be measured in either single or double pass configurations (Figure 1). In single pass, six interferograms are obtained. The tilt difference between any two interferograms gives the angle error in the corner cube. For double pass, half of the aperture is blocked, as in Figure 1. Three interferograms are obtained with one fringe covering the entire interferogram. The tilt of each interferogram gives one angle error in the corner cube.

Double pass is the preferred method as any errors in the collimated beam will cancel out, leaving only error within the corner cube.
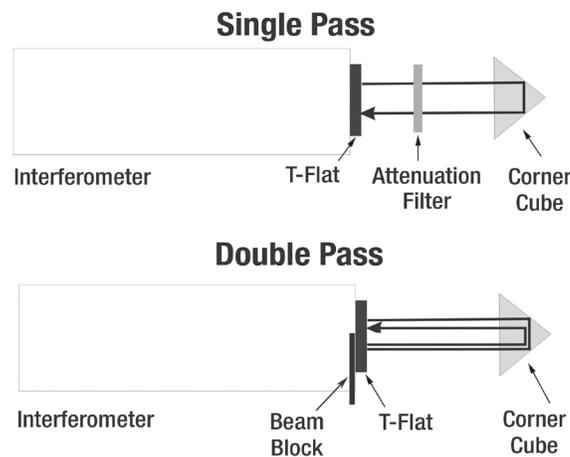

Figure 1. Single and double pass measurements of a corner cube.

4Sight calculates the **Dihedral Angle Error**, the physical deviation of the glass from a perfect angle between faces. It is given by:

$$\varepsilon = \frac{\alpha}{4mn\sin\theta}$$

where:

α = beam deviation

θ = the angle between the roof edge and the incident beam

m = number of passes

n = index of refraction.

For a corner cube, three calculations are reported:

C (1-2)   The angle between faces 1 and 2 across edge C.

B (2-3)   The angle between faces 2 and 3 across edge B.

A (3+1)   The angle between faces 3 and 1 (flipped) across edge A. This is equivalent to the angle between faces 3 and 4; however, since only faces 1, 2 and 3 are available in double-pass mode, 4Sight calculates the angle using the flip of face 1.

4D Technology

Optical Metrology for a Dynamic World

The **Sign** of the dihedral angle will be reported as obtuse if it is larger than the anticipated angle, or acute if it is smaller than the anticipated angle.

The labeling for seams and faces is based upon the corner cube analysis mask applied in 4Sight. As in Figure 2 the seam that is 90 degrees from the mask's rotation handle will be labeled A. The other seams will be labeled clockwise from there. The first face clockwise from Seam A will be labeled 1, and so on.
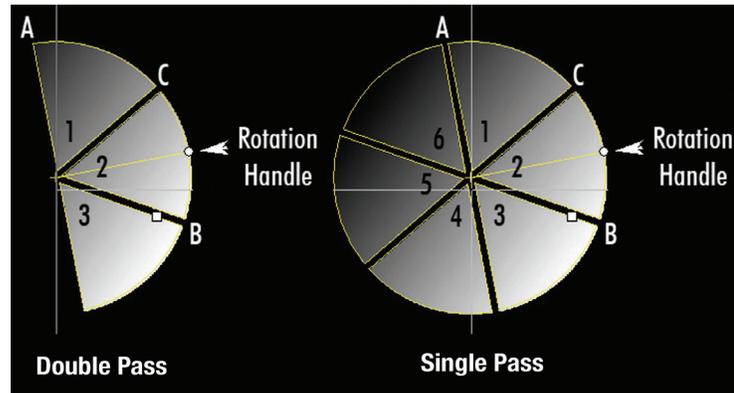

Figure 2. Corner cube face and seam labels are based on position of the mask.

4Sight also calculates the **Retroreflection Errors**, which are the deviation between the outgoing and incident beam for each round-trip pass through a corner cube. The retroreflection error is based on the relative tilt between faces, the Index of Refraction of the corner cube, and the number of passes through the corner cube. It is calculated as the average of beam deviation errors for each set of opposing faces; thus, opposing faces (1 and 4, 2 and 5, 3 and 6) will have the same results.

Retroreflection errors are typically displayed in arc-seconds. You must specify lateral scaling to see real tilt units such as arc-seconds.

Finally, the analysis calculates the peak-to-valley (PV) and root-mean-square (RMS) roughness for each of the surfaces.

Measuring a Corner Cube

These instructions cover measurement in Double Pass mode, with instruction specific to single pass mode included where the procedures differ:

1. First verify that the instrument calibration is up to date. If necessary calibrate the phase-shifter per the instructions in your AccuFiz user manual.

2. Set up the measurement apparatus:

   a. Mount a bayonet-mounted transmission flat on the front of the AccuFiz.

   b. For Single Pass mode place an attenuating filter (pellcle) between the transmission flat and the corner cube, as in Figure 1.

   c. Run 4Sight analysis software.

   d. Click the **Measurement Screen** button to open the **Measurement Screen**.

   e. Click the **Alignment Screen** button.

   f. Tip and tilt the transmission flat to center the alignment spot on the target. Close the Alignment screen.

   g. Mount the corner cube in a 3-jaw chuck and center it in front of the AccuFiz. The cube should be roughly aligned with the instrument; that is, it should appear symmetrical in all axes. For a solid corner cube ensure that the front face of the cube is slightly off axis to avoid generating unwanted fringes.

h. For Double Pass mode, block half of the aperture by placing a piece of paper or card between the Transmission Flat and the AccuFiz, as in Figure 1.

3. Set the parameters in 4Sight:

   a. Choose **Measure > Measurement Mode > Temporal**.

Note: It is not recommended to use spatial carrier dynamic mode for measuring corner cubes.

   b. Choose **Edit > Units** to open the **Units** dialog box.

   c. Set the **Angular** units to **arcsec** then click **OK** to close the dialog box.

   d. Choose **Analysis > Aberration Removal**.

   e. Click **None**, then click **Apply**.

   f. Click **Copy to Future**, then click **Close** to close the Aberration Removal window.

   g. Choose **Analysis > Island > Per Island Aberration Removal**.

   h. On the **Per-Island** tab verify that **None** of the per-island aberrations are removed, then close the dialog box.

   i. Choose **Measure > Measurement Options**.

   j. On the **Averaging** tab uncheck **Smart Averaging** and **Equalize Islands**, then click **OK** to close the dialog box.

   k. Using the "-" **Zoom** button on the Hand Controller, zoom all the way out (1:1).

   l. Using the **Source** adjustment on the Hand Controller, decrease the size of the source spot to maximize the fringe contrast.

   m. Using the **Focus** buttons on the Hand Controller, adjust the focus to achieve sharp edges on the seams.

   n. Click the **Camera Settings** button to open the **Camera Settings** window.

   o. Adjust the **Exposure** and **Gain** to just below the point of saturation (saturation is shown as red pixels). Then close the window.

4. Set the lateral scaling:

   a. Right-click in the Live Video image and choose **Specify Lateral Scale**.

   b. Click and drag the handles on either end of the scaling tool to the edges of the corner cube.

   c. Enter the width of the corner cube in the **Known Distance** field, then click **OK** to close the dialog box.

5. Adjust the phase shift calibration to account for the double-pass setup:

   a. Choose **Measure > Calibration > Phase Shifter Calibration**.

   b. Note the value shown under **Calibrated PZT Slope**.

   c. Enter 1/2 of this value under **New PZT Slope** and click **OK**.

6. Acquire the data:

   a. On the **Measurement Screen**, enter the number of measurements to average in the box to the right of the **Averaged** button.

   b. Click the **Averaged** button to take the averaged measurement.

7. Create an Analysis Mask:

   a. Choose **Edit > Masks**, or click the **Analysis Mask** toolbar button. The **Mask Editor** window will open.

   b. Under **Drawing Tools** select **Corner Cube Mask**.

   c. Click and drag one of the round handles to size and rotate the mask.

d. Click and drag the crosshair to move the mask's center point.

e. Click and drag the square handle to set the width of the areas to mask at each seam.

Note: Remember that the numbering of the faces and seams is based on the location of the round handles.

8. Run the **Corner Cube** analysis:

a. Choose **Analysis > Prism > Corner Cube**. The **Prism Options** dialog box will open.

b. Under Passes, select **Double Pass** or **Single Pass**.

c. Set the **Wedge** value to **0.5** for Double Pass, or **1.0** for Single Pass.

d. Input the corner cube's **Index of Refraction**. For a solid glass cube, enter the index of the glass. For a hollow corner cube enter 1.0.

e. Check the **Mask Editor** box to have 4Sight open the Analysis Mask Editor before each measurement. This will allow you to adjust the mask for each measurement, which is useful if you are measuring a series of corner cubes.

f. Make sure that **Show this dialog before each analysis** is checked.

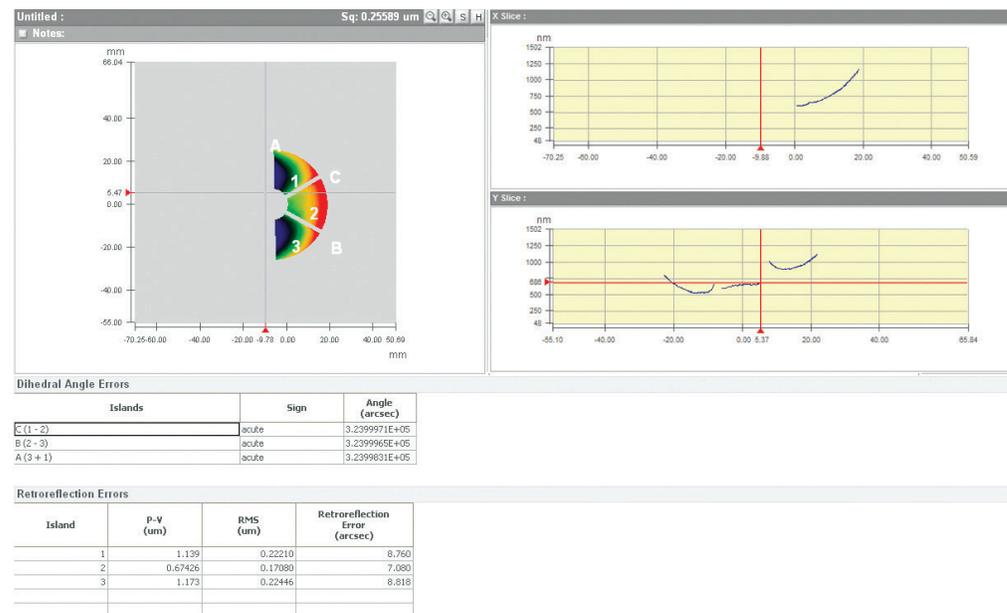g. Click OK to run and display the Corner Cube Analysis (Figure 3).

Figure 3. Corner Cube Analysis for a Double Pass measurement.

The Contour Plot in the upper left shows the seams and faces of the corner cube, numbered sequentially for identification. Click and drag the cursor on the contour plot to view the XY Slice plots through any pixel.

The tables below the contour plot show the **Dihedral Angle Errors** for each pair of faces, the **Retroreflection Error** due to each face, and the **PV** and **RMS** roughness for each face.

Tip: By default, the analysis also displays additional information including Tilt, Tilt Angle and Beam Deviation for each face. These columns can be hidden, as in Figure 3. To hide the data, right-click in either of the tables, select **Column Chooser**, and deselect the parameters to hide.

For more information on corner cube measurement see *Optical Shop Testing* by Daniel Malacara, 1992.

4D Technology
Optical Metrology for a Dynamic World