A new technique provides a faster, more repeatable method for vibration-insensitive measurement of wedge.

Measuring Wedge with the FizCam 2000

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Introduction

Laser interferometry is a standard method for measuring the wedge between the two surfaces of a nominally planar optic. 4D Technology's FizCam 2000 laser interferometer, which employs Dynamic Interferometry® and a short coherence laser source, provides a faster and more repeatable method for vibration-insensitive measurement of wedge, without the need for a transmission or return flat.

Conventional Wedge Measurement

With a standard laser interferometer wedge is measured using the setup shown in Figure 1. The test optic partially fills the aperture, and the tilt through the optic is compared to the empty cavity.

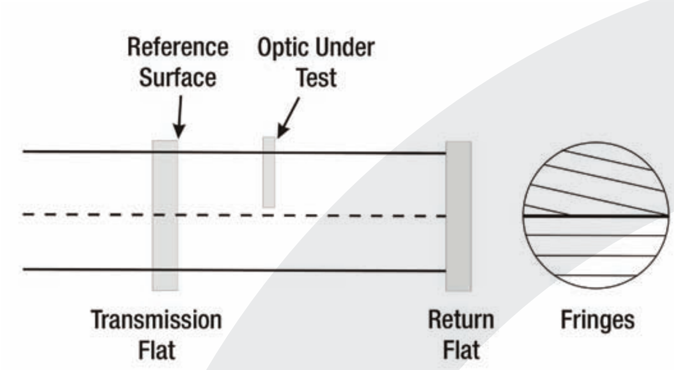

FIGURE 1. Traditional Wedge Measurement Setup

The Wedge is then calculated as $$\text{wedge} = \frac{tilt\_magnitude}{2(n-1)}$$

where n is the index of refraction of the optic.

Since this procedure is completed using a temporal phase shifting interferometer, vibration, air turbulence and thermal stability will all adversely affect the accuracy and repeatability of the measurement. The method also requires two high quality reference optics and mounting hardware, which are additional sources of measurement error as well as representing a significant expense.

Improved Method for Measuring Wedge

4D Technology's FizCam 2000 Fizeau interferometer enables an improved method for measuring wedge. The method takes advantage of the FizCam's unique ability to measure a "solid cavity," using the two sides of a transparent optic as the test and reference surfaces (Figure 2). With a traditional laser interferometer the test or reference must be shifted to acquire multiple frames of phase data, which is impossible with a solid part. The FizCam 2000, however, uses polarization-based Dynamic Interferometry to acquire all phase data simultaneously, without the need to translate the surfaces, making the solid cavity wedge measurements possible.

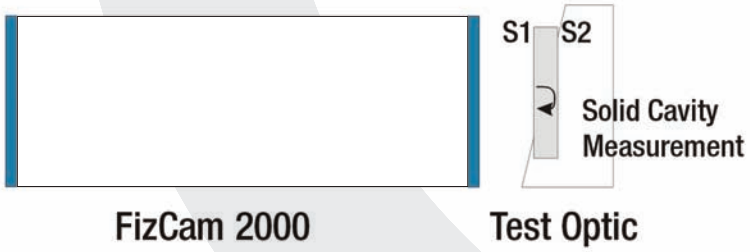

FIGURE 2. A solid cavity measurement is used to calculate wedge with the FizCam 2000.

The wedge value is calculated as: $$\text{wedge} = \frac{tilt\_magnitude}{2n}$$

With n as the index of refraction of the optic.

The improved method offers several important advantages. For one, measurements with the FizCam are nearly instantaneous, making the instrument virtually insensitive to vibration and turbulence. Secondly, only the surfaces of the optic itself are measured, improving accuracy and repeatability by eliminating error sources from the transmission and return flats. Thirdly, since no additional optics are required the procedure is very fast and simple to perform. 4Sight wavefront analysis software, included with all FizCam interferometers, further simplifies the procedure.

Isolating Reflections

Virtually all Fizeau interferometers utilize long coherence laser sources. With these systems interference occurs between reflections from all pairs of surfaces in the beam path. When more than two reflective surfaces are in the beam path, interference occurs between all pairs of reflections, resulting in a complex interferogram from which it is difficult or impossible to separate the fringes to measure any particular surface.

To overcome this difficulty, the FizCam 2000 uses a short coherence (~300 µm) laser source that isolates the interference from any particular pair of reflections in the beam path. An internal “Path Matching” mechanism lets you equate the reference arm of the interferometer to the Optical Path Difference (OPD) of any particular pair of surfaces. Once the path is matched all other cavities fall outside of the 300 µm coherence length and do not contribute fringes.

Wedge Measurement Procedure

The complete measurement procedure is as follows:

1. Position and align the test optic such that the reflected beam from the front face passes through the cross-hairs on the Alignment Monitor.
2. Set the path match distance:
   a. In 4Sight open the **Pathmatch Controller** dialog box (Figure 3).
   b. Click and drag the red box in the live video area to a location on the test optic.
   c. Enter a scan range that includes the expected optical path difference (OPD) between the front and back surfaces. For example, if the optic is approx. 3 mm thick with an index of refraction of 1.5 you could enter a **Center** value of 4.5 mm and a **Range** of ±1 mm.
   d. Click **Auto Pathmatch**. The system will set the path match location to the distance at which peak modulation occurred. In the example in Figure 3, this peak occurs at 4.194 mm.

      You should now see a single set of interference fringes in 4Sight’s Live Video area.

Note: More information is available in the 4D Application Note, “Path Matching with the FizCam 2000.”

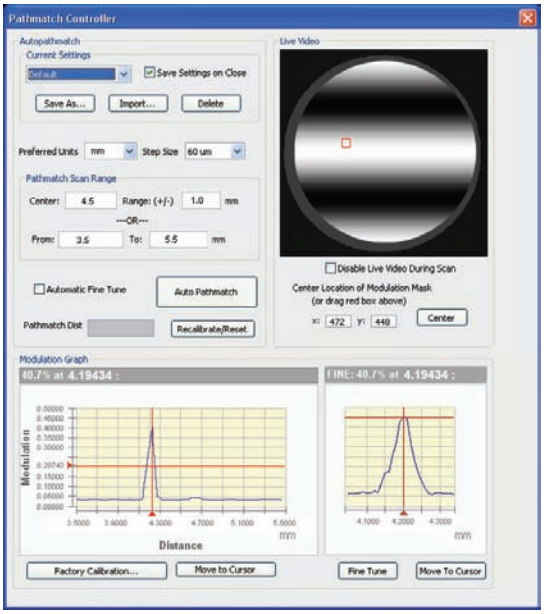

FIGURE 3. Pathmatch Controller dialog box.

3. Use the **Zoom** switch on the FizCam's hand held controller to adjust the magnification until the test optic is entirely within the aperture.
4. Adjust the **Focus** switch on the hand held controller to minimize diffraction rings on a surface feature, or near the edge of the test optic.
5. Choose **Analysis > Aberration Removal.** Click **None** and **Apply** so that no aberrations will be removed (which would result in a tilt angle of zero).
6. Make the measurement. You can make a **Single** measurement, but an **Average** of 16 or more measurements is suggested for improved accuracy.

   A contour plot will be displayed showing the pixel-by-pixel thickness of the sample optic. Red on the plot indicates the area of longer OPD, which in a direct cavity measurement means the thickest area of the optic. Note that the plot displays the data as if you were looking into the interferometer.
7. Adjust the lateral scaling. Several methods are available and described in the 4Sight User Manual. One method is:
   a. Right-click in the contour plot and choose **Specify Lateral Scaling**. The Lateral Spacing dialog box will open, showing a line with targets at either end.
   b. Click and drag each end of the line to the edges of a feature of known size (such as the diameter of the sample).
   c. Enter the **Known Distance** between the points and click OK.
8. Choose **Analysis > Direct Cavity > Direct Cavity Analysis**. The **Direct Cavity Options** dialog box will open.
9. Enter the **Index of Refraction** and click **OK**.

   4Sight will now display the **Tilt Magnitude**, **Window Wedge** and the **Tilt Angle** (Figure 4). A tilt angle of "0 degrees" indicates that the sample is thickest at the right side of the display; "90 degrees" indicates that it is thickest at the top, and "-90" that it is thickest at the bottom (Figure 5).

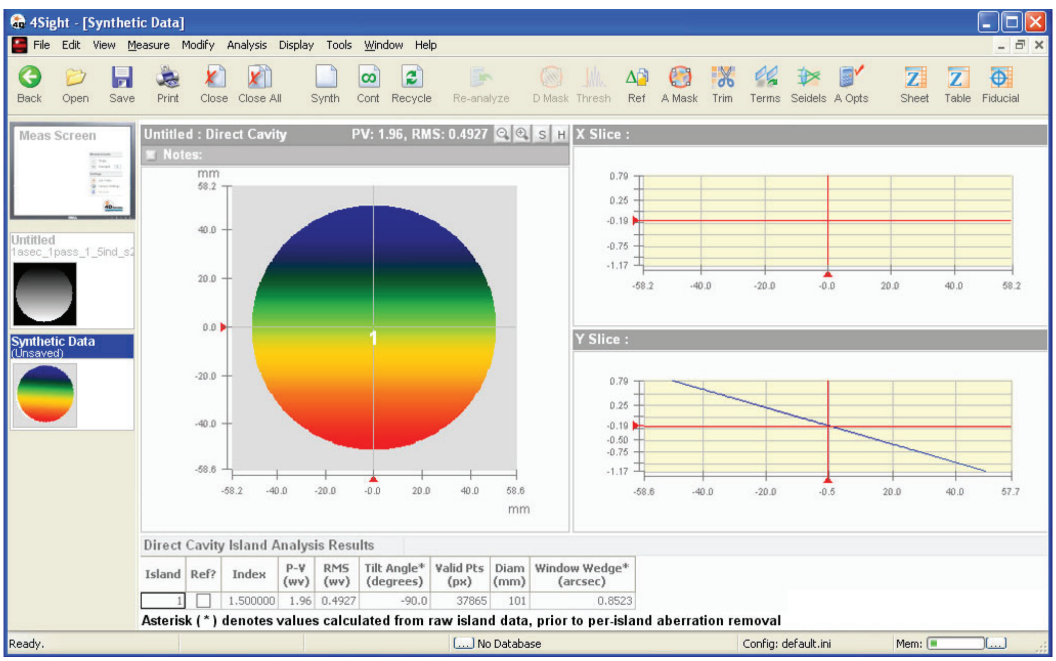

FIGURE 4. Wedge of a transparent optic measured using the FizCam 2000.

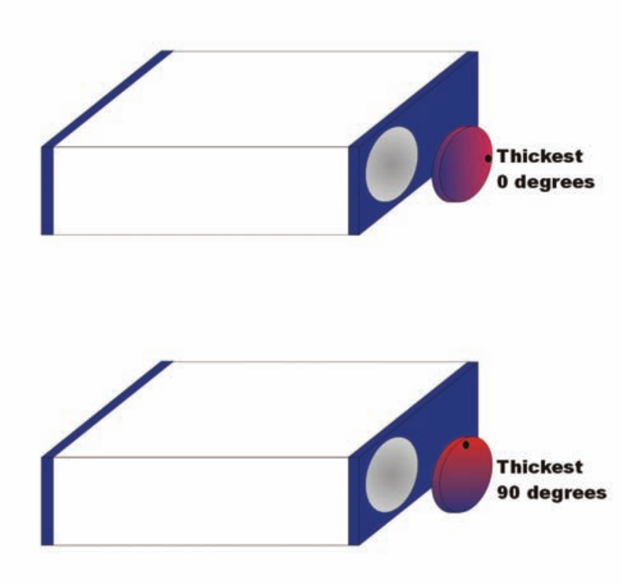

FIGURE 5. Definition of Tilt Angle.

Measuring a Highly Wedged Sample

The method described above works well for samples with wedge up to approx. 100 fringes across the aperture. For a more highly wedged sample the fringes become so dense that the phase unwrapping algorithms have difficulty resolving the heights, resulting in unwrapping errors that manifest as discontinuities.

Several adjustments can increase the measurable tilt range to approx. 200 fringes across the aperture:

- When aligning the part set the reflections from the front and back surface equidistant from the crosshairs on the Alignment Monitor.
- Zoom in on the required portion of the optic to decrease the fringe density
- Adjust the Modulation Threshold to retain only highly reliable pixels.

Complete Characterization of Planar Optics

The FizCam 2000 makes it possible to measure planar optics more thoroughly than previously possible. Using procedures based on the solid cavity measurement described above you can obtain:

- transmitted wavefront error
- the shape of both surfaces
- homogeneity
- wedge
- and point-by-point optical thickness.

Application notes are available from 4D describing all of these measurements.