The ability to isolate and measure plane-parallel surfaces expands the capabilities of laser interferometry.

Path Matching with the FizCam 2000

Mike Zecchino

Introduction

4D Technology's FizCam 2000 Fizeau interferometer greatly extends the capability of traditional interferometry for measuring planar optics. The FizCam enables measurements that are difficult or impossible with traditional phase-shifting interferometers and provides a simplified, faster and more repeatable technique for many common measurements.

Isolating Surfaces for Measurement

With traditional interferometers, which use long coherence laser sources, interference occurs between reflections from any surfaces in the beam path. When more than two reflective surfaces are in the path the various fringe patterns overlap to create a complex interferogram from which it is difficult or impossible to extract information to measure any one surface.

Figure 1 shows such a case, in which the parallel surfaces of a transparent disk create interference with the reference surface R1, and with each other. To measure S1 the reflection from S2 must to be eliminated. This can be accomplished by temporarily covering the back surface in an anti-reflective coating. However, the coating and cleaning process is time consuming, messy and potentially damaging to the optic. Flaws in the coating, removing and re-aligning the optic, and operator-to-operator variability all add error sources that greatly limit the repeatability of these measurements.

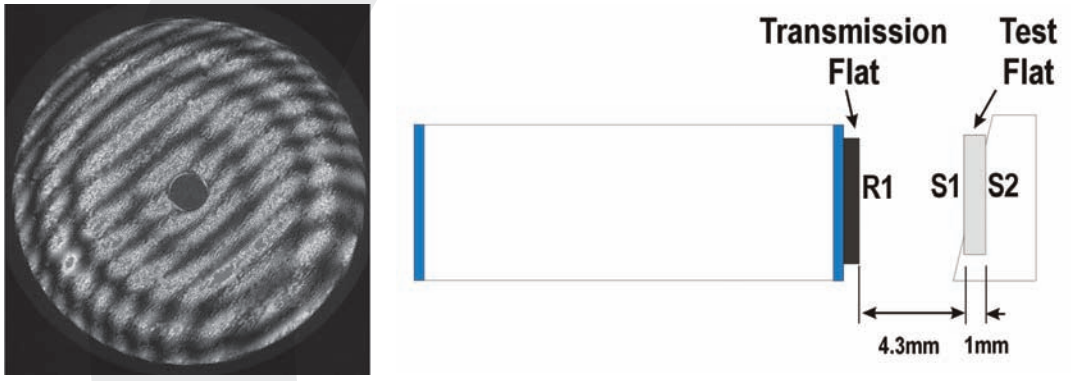

Figure 1. Reflections between a reference and transparent disk create a complex interferogram.

By employing a short coherence (~300 µm) laser source the FizCam 2000 provides a unique method for isolating interference from any pair of reflections. An internal "Path Matching" mechanism (Figure 2) adjusts the reference arm of the interferometer to equal the optical path difference (OPD) between any pair of reflecting surfaces. The OPD can be anywhere from 0.1 - 400 mm (0.1 – 2000 mm for extended path systems).

In the example in Figure 1 interference will occur between three cavities:

- R1 and S1, with a nominal OPD of 4.3mm
- S1 and S2, with a nominal OPD of 1.5mm (1mm thickness multiplied by 1.5, the index of refraction of the optic)
- R1 and S2, with a nominal OPD of 5.8mm.

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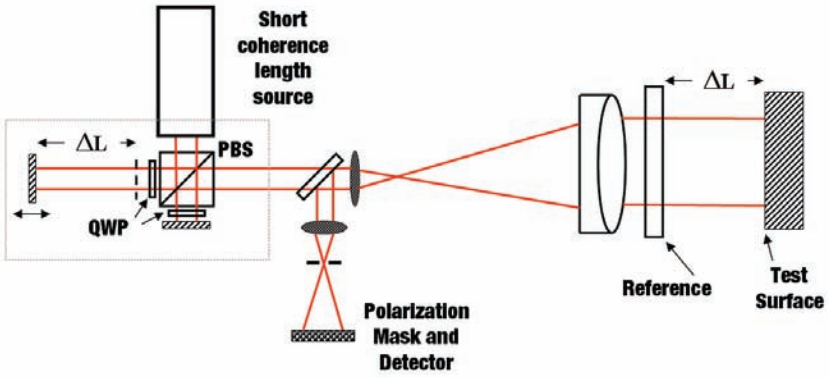

Figure 2. The FizCam 2000 path matching mechanism.

If the path match distance is set to 4.3 mm then interference will occur only between R1 and S1. Setting the path match distance to 1.5mm will generate interference only between S1 and S2. Finally, setting the path match distance to 5.8mm will generate interference only between R1 and S2.

This ability to isolate plane-parallel surfaces enables measurement of windows, prisms, bonded optics and other multi-surface setups, without the need for anti-reflective coatings.

The FizCam 2000 also enables "solid cavity" measurements in which the two sides of a transparent optic are used as the test and reference surfaces. Since the Fizcam uses polarization-based Dynamic Interferometry® to acquire all phase data simultaneously, the reference does not need to be translated relative to the test surface as in a traditional interferometers, making solid cavity measurements possible.

Path Matching Procedure

The measurement procedure for the FizCam 2000 is essentially the same as that for traditional systems, with the addition of the path matching step. 4Sight analysis software, included with all 4D interferometers, includes an automated procedure to help you scan for, and precisely set, the path match distance:

1. Mount and align all optics.
2. Use a ruler or estimate the OPD between the two surfaces you wish to use as the test and reference. Be sure to account for index of refraction as in the S1-S2 cavity described above.

Tip: The more precisely you can estimate the OPD the shorter the range can be, and thus the faster the path match scan can be.

3. In 4Sight choose **Tools** > **Pathmatch Controller**, or press the **F10** key, to open the **Pathmatch Controller** dialog box (Figure 3).
4. The dialog box shows "live video" output from the data camera. In the **Live Video** area click and drag the red box to a representative location on the test optic.
5. Enter the **Step Size**, the distance the path match motor will move between each scan step. A larger step size gives a faster path match scan; a smaller step may help you locate the precise path match distance when fringe modulation is low.
6. Select the **Preferred Units** for the range values.
7. Enter a **Pathmatch Scan Range** centered on the estimated OPD between the two surfaces.

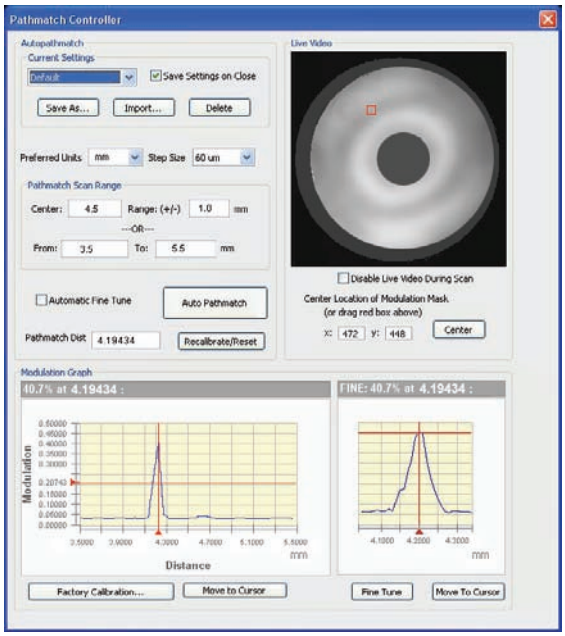

Figure 3. Pathmatch Controller Dialog Box.

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8. You can define the range in one of two ways:

   a. set a **Center** value and a **Range** to scan on either side of it, or

   b. enter the beginning (**From**) and end (**To**) points of the range.

   For example, in Figure 3, if S1 is the test surface and R1 is the reference, you could enter a **Center** value of 4.5 mm and a **Range** of ± 1 mm. Entering a range **From** 3.5 mm **To** 4.5 mm will give equivalent results.

9. Click **Auto Pathmatch**. The system will scan through the selected range, moving by increments of the select Step Size. At each step the system will measure the average fringe modulation of the pixels in the red box. These values will be plotted at the bottom of the Pathmatch Controller dialog box.

   Modulation peaks will occur at distances corresponding to the OPDs between each set of reflections. For example, in Figure 3 a single peak was found at 4.194 mm, the actual OPD between R1 and S1. Note that the value was a little lower than our estimate of 4.3 mm, which is why the automated scan is useful.

10. The system will automatically set the path match distance to the highest modulation peak (in this case, 4.194 mm).

11. If the **Automatic Fine Tune** option is selected then the system will perform a second, high-resolution scan before moving the mechanism.

Tip: You can hit the **Esc** key to end a Pathmatch or Automatic Fine Tune scan once the peak modulation has been found.

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

Locating, and Moving to, Multiple Peaks

A path match scan is not limited to locating a single modulation peak. Again using Figure 1 as an example, if you set the Pathmatch Scan Range to run From 1mm to 6mm, all three modulation peaks would appear, as in Figure 4.

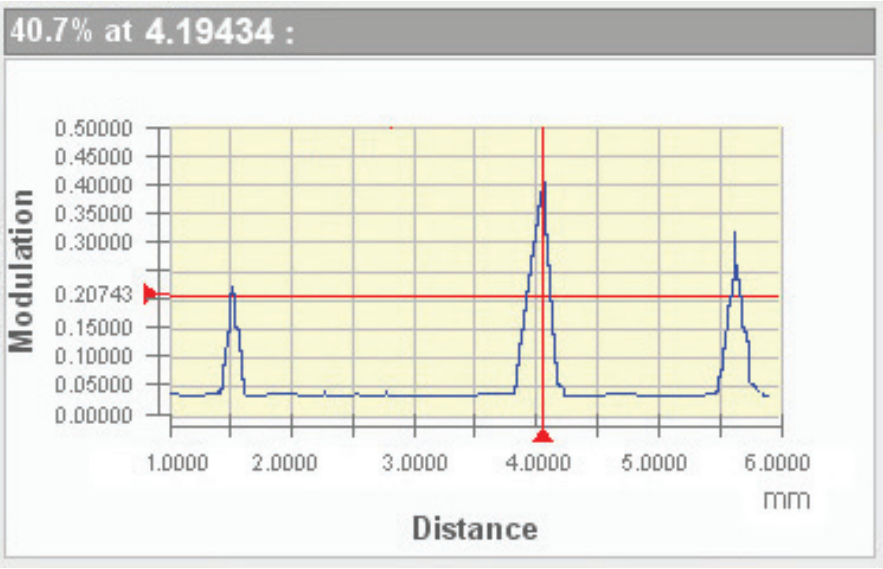

Figure 4. Multiple modulation peaks found in one long path match scan.

When more than one peak is found 4Sight will automatically select the path match distance that produces the highest modulation peak. You can, however, manually select the location of one of the other peaks. Click in the plot at the desired location, then click the **Move to Cursor** button to change the path match distance. If the **Automatic Fine Tune** option is selected then a fine tune scan will take place as well.

Computing Complex Path Match Distances

The path match distance takes into account the beam's travel to and from the test surface. For example, the path match distance between R1 and S1 is 4.194 mm, though the actual round trip path travelled is 8.388 mm (4.194 mm out from R1 to S1, plus 4.194 mm back to R1). This arrangement makes it easy to simply estimate the distance between test and reference and enter that value for the path match.

For some cases the path match distance takes a little more calculation. In Figure 5 a prism is being measured in a double pass configuration. The OPD in this case is the sum of:

- the distance X from the reference to the prism
- the path through the prism (which equals d * the index of refraction n)
- the distance X from the prism back to the reference.

Therefore the Path Match distance is 2X + dn.

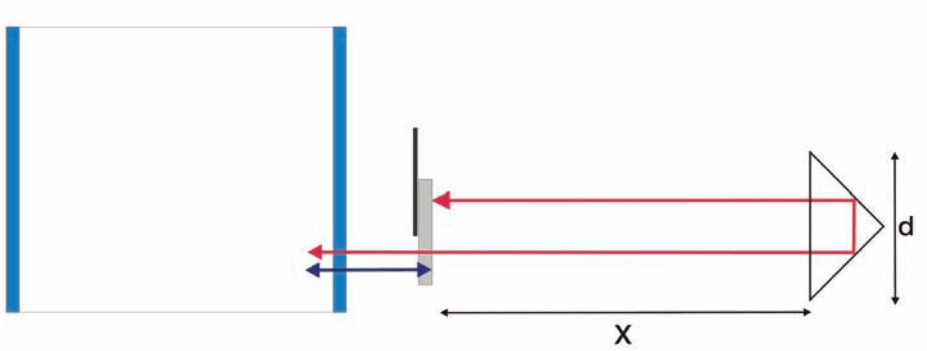

Figure 5. Path match distance for a Double pass prism setup is 2X + dn.

Measuring Multiple-Surface Components

One of the advantages of the FizCam 2000 is its ability to measure optics and systems with multiple surfaces, such as bonded optics or optical stacks. Provided there is sufficient fringe contrast you can set the path match distance and measure each surface sequentially with a single test setup.

In order to measure all surfaces the OPDs between all reflections must be separated by more than 300µm.

Complete Characterization of Planar Optics

The FizCam 2000 makes it possible to measure planar optics more thoroughly than previously possible, typically with a single test setup. Using path matching you can measure multiple cavities to obtain:

- surface shape
- transmitted wavefront error
- homogeneity
- wedge
- and point-by-point optical thickness.

Application notes are available from 4D describing these measurements.

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