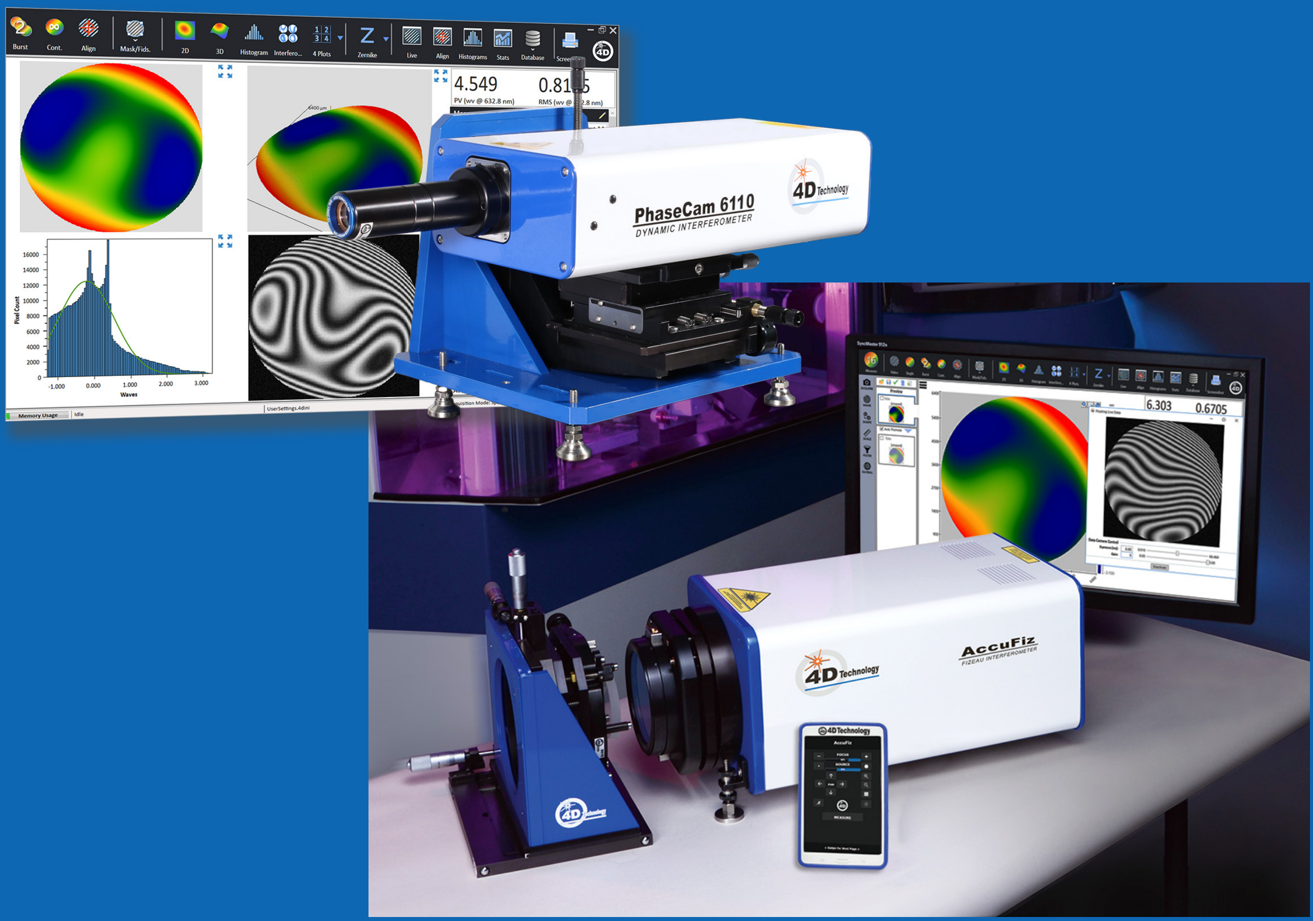


# Twyman-Green vs Fizeau Interferometer: Which Type is Best for Your Application

Two powerful technologies for measuring optics and optical-grade surfaces

4D Technology
An Onto Innovation Subsidiary

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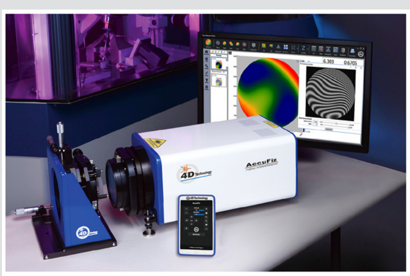
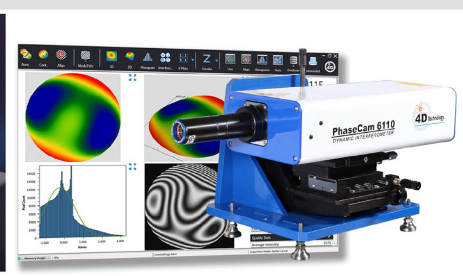
### Interferometers for a Wide Range of Applications

Laser interferometers are the de facto standard for measuring the surface shape and transmitted wavefront quality of small, large, and very large optics, as well as optical systems and optical-grade surfaces.

Fizeau interferometers were among the first widely used commercial systems. Fizeaus are available in a range of wavelengths and aperture sizes and are robust and durable.

Twyman-Green interferometers offer distinct advantages for measuring flat and concave optics, particularly in challenging environments. Compact and lightweight, with an inherently on-axis design, Twyman-Green systems excel in applications that would incapacitate most measurement systems, including vibration-heavy shop floors and cleanrooms, remote measurement towers, and long-path measurements where vibration isolation would be prohibitively expensive.



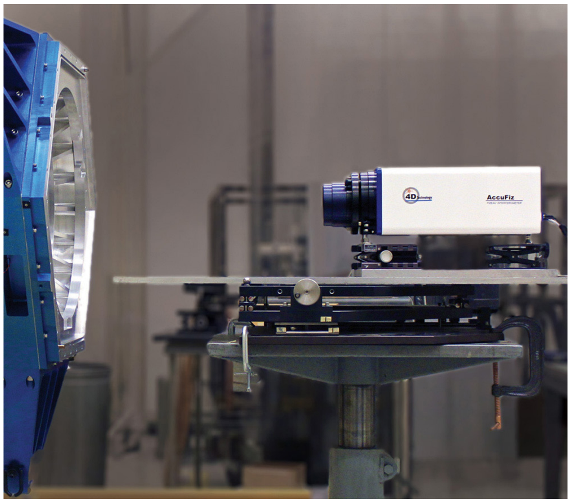




## Learn more and download datasheets:

4D AccuFiz Fizeau Interferometers

4D PhaseCam Twyman-Green Interferometers

*While Fizeau Interferometers are the most widely used, Twyman-Green systems offer distinct advantages.*



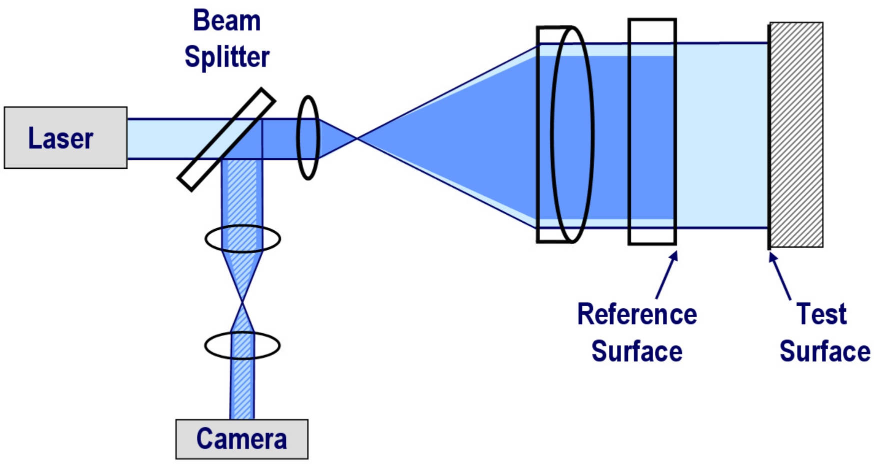
# Which is the Best Interferometer for Your Application?

By Mike Zecchino

Laser interferometry is a primary technique for measuring the surface quality and transmitted wavefront error of precision optics. While Fizeau laser interferometers are the most widely used commercially, Twyman-Green interferometers have distinct advantages for a variety of applications. In this article we introduce the two configurations and discuss the applications served by each systems' particular strengths.

## Fizeau Interferometers

In a Fizeau laser interferometer, the beam from a laser source is divided by a beam splitter. The "reference beam" is reflected from a high-quality surface. Typically, the reference is an external transmission flat or transmission sphere matched to the shape of the test optic. The "test beam" passes through the reference optic to the test surface, or it continues through the test optic to a high-quality return mirror for transmission measurements. In either case the reflecting beam passes back through the reference surface.




*Fizeau interferometer schematic for measuring surface quality.*

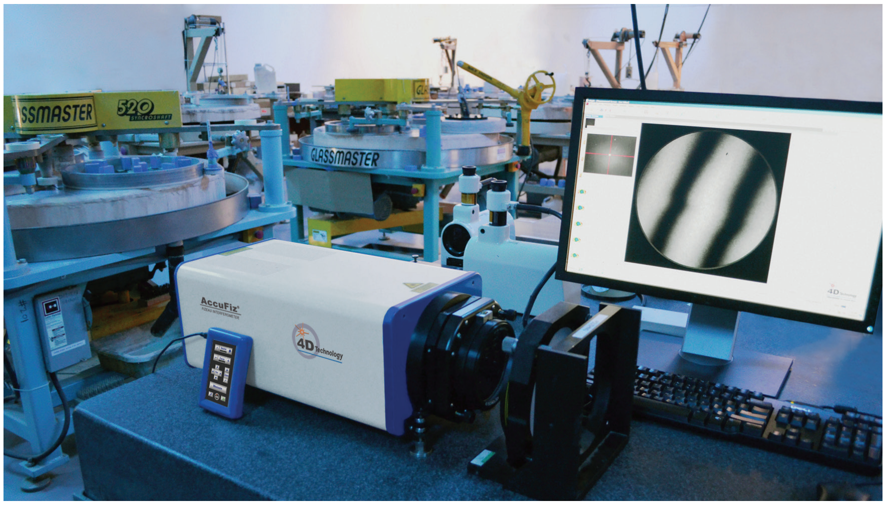
*Fizeau interferometers are well suited for general purpose measurement of small to very large concave, convex, and flat optics.*

When the two reflected beams pass back through the beam splitter, they recombine at the sensor (camera), forming an interference pattern. The pattern is due to changes in phase caused by the differences between the test and "perfect" reference wavefronts. The camera records this interference pattern as a single measurement frame. The reference surface is moved in several small steps (less than the wavelength of the test beam), and several more frames are acquired, from which the heights of all points on the test surface can be measured, or the error in the wavefront due to the beam passing through the optic can be determined.

### Fizeau Advantages and Applications

The Fizeau interferometer's large aperture (typically 100mm up to 800mm) makes it well suited for general purpose measurement of small to very large concave, convex, and flat optics, as well as corner cubes and prisms. Widespread availability and acceptance throughout industry and research institutions mean that most people working with optics have at least some experience with a Fizeau.

The optical design of a Fizeau involves a relatively small number of optics, with the quality of the measurement cavity determined largely by the external reference optic. The result is a cost-effective, reliable system that can support production throughout an optical shop.




*Fizeau interfermeters are widely used for general shop floor measurement (Courtesy Precision Optical)*

### Fizeau Disadvantages

One challenge with Fizeau interferometers is that the optical configuration is inherently lossy. Typically, less than 10% of the light from the system's laser makes it back to the camera. This results in longer acquisition times that can lead to low-quality interference fringes in the presence of vibration.

A second issue is that there is no means to balance the power of the returning reference and test beams to maximize the fringe contrast. When measuring a highly reflective test optic, a pellicle must be inserted into the test path to reduce its power to match that of the return beam (and thus to obtain sufficient fringe contrast).

The third, and perhaps most challenging aspect of a Fizeau is that it is very sensitive to vibration and air turbulence. The instrument and test piece must be mechanically coupled, with the entire setup isolated from vibration using large, expensive air tables. For measuring very large optics, the cost of isolating the system can be prohibitive.

## Dynamic Fizeau Interferometers

Dynamic Interferometry® was pioneered by 4D Technology to measure despite vibration and turbulence. In a dynamic Fizeau interferometer all phase data is acquired simultaneously, rather than over several frames. This extremely short acquisition time means that vibration and turbulence are effectively frozen, producing excellent measurements, even without isolation.

A Dynamic Fizeau interferometer can measure effectively in production floor environments and cleanrooms despite vibration from pumps and machinery.

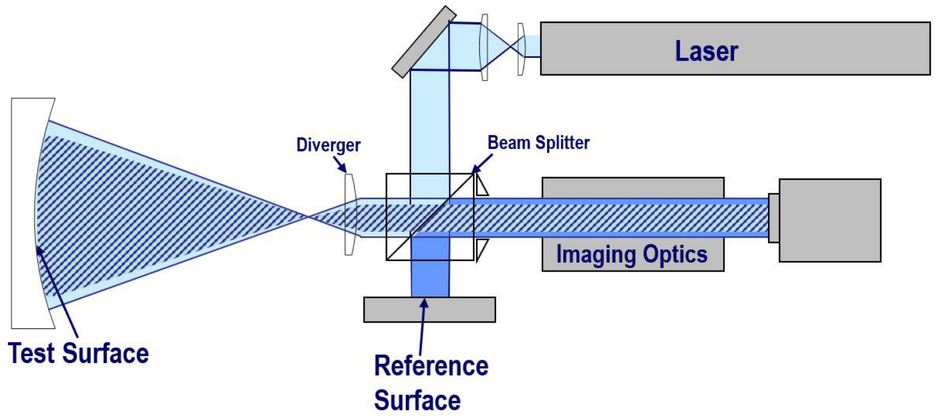
There are challenges with creating a dynamic Fizeau, however, primarily in how the test beam is spatially separated from the reference beam. One method is to to tilt the reference beam off-axis to create a "carrier fringe pattern." This method results in a base measurement error that must be subtracted from each measurement to achieve high accuracy. The higher the camera's pixel count, the larger the error that needs to be subtracted.

A second method is to use a measurement system with a short coherence source and a second "path matching" interferometer. This approach requires an extra path-matching operation for each new test setup and sometimes with each new optic that is measured.

*Twyman-Green Interferometers are excellent for measuring concave or flat optics up to many meters in diameter, over long paths and in challenging environments.*

## Twyman-Green Interferometers

A Twyman-Green laser interferometer operates by the same principals as a Fizeau but with a different optical configuration. In a Twyman-Green, the source beam is collimated before it is divided by the beam splitter. The reference beam is directed to a small, high-quality, internal reference mirror, while the test beam exits the instrument. The test wavefront can be shaped to match the flat or concave of the test surface or system by using a diverging lens or beam expander.




*Twyman-Green interferometer schematic*

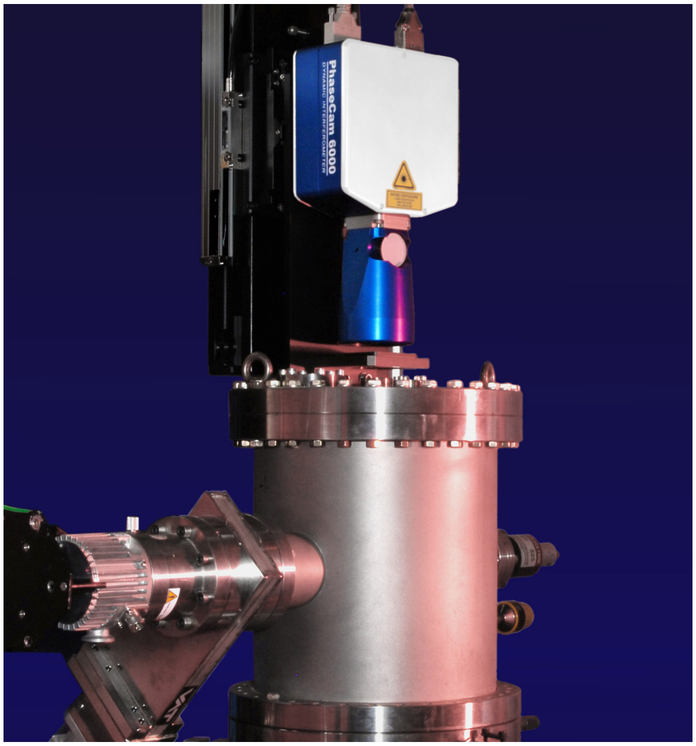
4D Technology's Twyman-Green interferometers use a polarization-based Dynamic Interferometry® technique to collect all phase data simultaneously, in just a few microseconds. Such short acquisition time produce excellent measurements even in very noisy environments.

## Twyman-Green Advantages and Applications

Twyman-Green interferometers have several key advantages.

### Compact Design Fits Challenging Locations

The compact optical design makes for a small measurement head, which is easy to position in challenging locations and tight spaces. The laser source can be coupled to the head via a fiber optic cable, moving heat-generating elements away from the optics.




*PhaseCam Twyman-Green interferometers measuring into an environmental test chamber (Courtesy CNRI)*

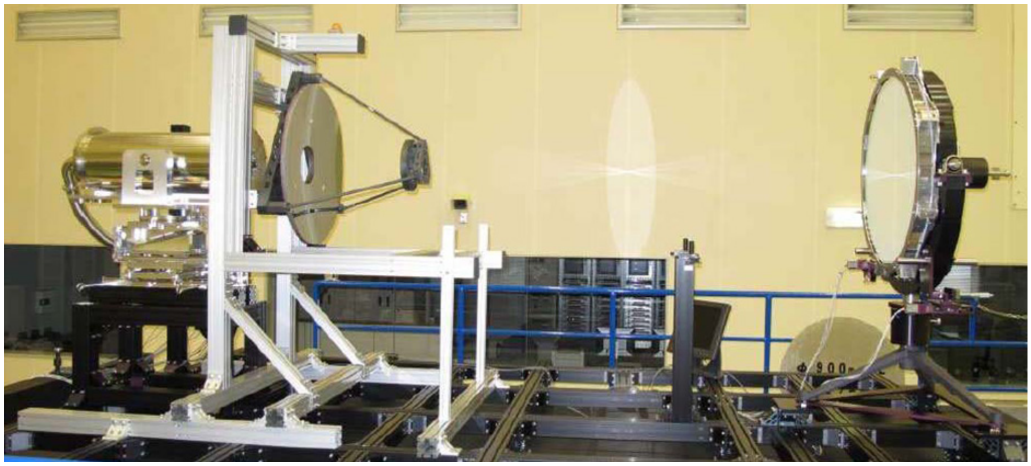
*Twyman-Green interferometers are compact and vibration-immune, excellent for long path measurements, remote operation, noisy environments, and measurement of both low and high return systems, without a pellicle*

### Vibration-Immune for Long Path Measurements

PhaseCam interferometers are inherently vibration immune. Because the design is much more light-efficient than a Fizeau, integration times can be more than 10X shorter, making it possible to measure with the interferometer located many meters from the test optic.

*PhaseCam completing Center of Curvature test for the Webb Space Telescope (courtesy NASA Goddard)*

This advantage is particularly critical when measuring large optics, or when measuring over long paths, where isolation systems would be prohibitively expensive. The interferometer does not even need to be coupled to the test optic, further simplifying setup.



*Vacuum-compatible PhaseCam inside a large vacuum chamber (courtesy JAXA)*

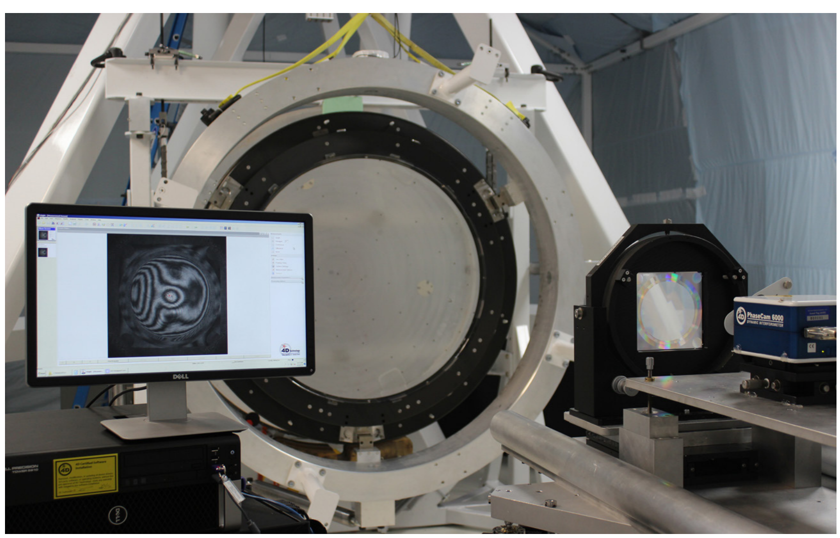
**Remote Operation for Measurement Towers, Chambers**

Motorized control of all functions means that a PhaseCam Twyman-Green can be operated remotely in measurement towers, vacuum chambers, environmental chambers, and other challenging locations.

Because the instrument is dynamic, it can measure through a port into a vacuum or thermal chamber. Or, it can be placed within its own pressure vessel and controlled remotely.

**Beam Balance to Measure Low Return Systems or Highly Reflective Surfaces**

PhaseCam systems include a polarization control to match the energy in the test and reference beam and optimize fringe contrast. This feature significantly improves the measurement noise floor and vertical resolution to support a wide range of test surface reflectivities and low return setups. One such application is measurements that require a computer-generated hologram (CGH) element. A CGH is typically very lossy, but the PhaseCam's light efficiency, small aperture and beam balance control make it possible to measure off-axis parabolas, aspheres, etc., with a CGH element.



*PhaseCam Twyman-Green measuring an aspheric optic through a CGH (Courtesy AOS)*

Other PhaseCam Twyman-Green advantages include:

- completely on-axis optical design for high resolution and accuracy
- no expensive reference optics for lower cost measurements
- no calibration required, since the PhaseCam has no mechanical phase-shifter
- extremely small and light measurement head (<4.5 kg, 10 lb) is much easier to position and align, particularly in confined spaces, measurement towers, etc.

### Disadvantages

Because of its small aperture, a Twyman-Green interferometer is not well suited for measuring larger convex or flat surfaces.

Also, since the reference surface is not external to the system, a reference measurement of the baseline interferometer cavity needs to be stored and subtracted from measurements. This is typically accomplished on-the-fly and does not add a measurement step.

## Summary

Both Fizeau and Twyman-Green laser interferometers are well-established systems for measuring precision optics, and each excels in particular applications. 4D Technology offers mature product lines for both types of interferometers, with a range of wavelengths, mounts, and accessory optics.

If you are primarily familiar with Fizeau interferometers, we encourage you to review the **PhaseCam Twyman-Green Interferometers** page to learn more about these compact systems for high-resolution optical measurement.