NASA TECH BRIEF
Marshall Space Flight Center

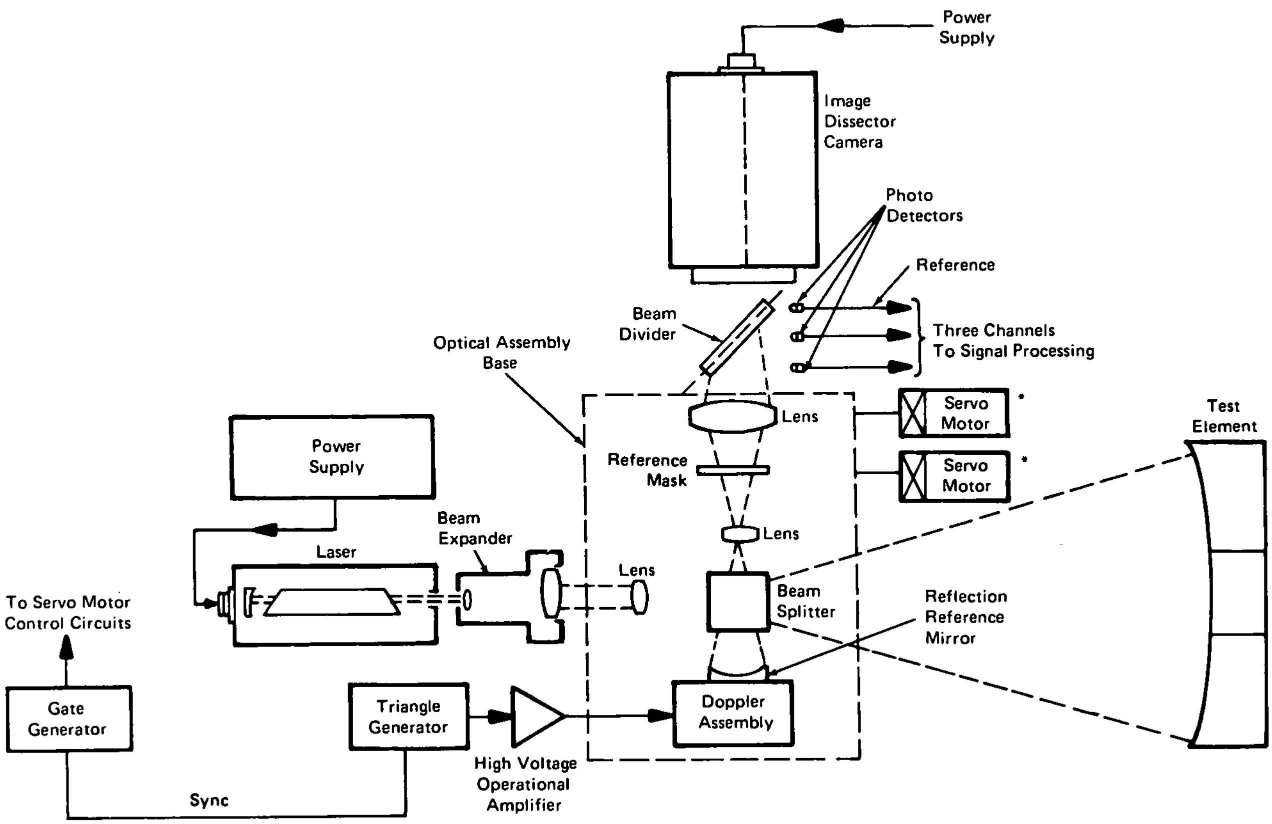
Real Time Optical Figure Sensor

The problem:

Mirrors produced for various optical systems require precise surface finishing. For this reason, mirror surfaces are checked for imperfections with sophisticated optical test equipment. Such tests, however, are error prone because of either temperature change or air disturbance within the test area.

The solution:

An optical figure sensor has been developed for measuring mirror surfaces. The sensor is compensated for interferences from temperature and air disturbances and is capable of measuring mirrors with diameters of up to 2 meters varying in f/number from f/2 to f/5.



*These components are required for drift compensation only.

(continued overleaf)

How it's done:

The figure sensor system is shown in the block diagram. A modified Twyman-Green interferometer measures both spherical and aspherical test mirror surface errors. This is a two-beam interferometer that uses a 6328-angstrom laser for a light source, an image dissector for figure error readout, and photodiodes to detect test mirror tilt at the fringe plane.

The optical layout includes an optically bonded one-inch cube beam splitter which divides the incoming laser beam into two plane wavefronts. A one-inch optical flat is used as a reference surface in one path, and an aspherical decollimating lens forms a spherical wavefront which is reflected from the mirror under test in the other path.

The interferometric output fringe pattern exciting the one-inch cube beam splitter, derived by comparing the reflected reference mirror wavefront with the reflected test mirror wavefront, is projected onto both the photodiode array and the image dissector by means of a 70/30 percent beam divider.

The mechanical translating solid-state Doppler frequency shifter uses piezoelectric elements to translate the spherical reference mirror through a range of 8 to 12 fringes, accounting for both the forward and reverse directions. This translation varies the reference mirror path length relative to the test mirror path length. An optical path length variation between the two interferometer paths is the same as an optical phase shift between the two paths, which causes the fringe pattern to alternate in intensity. A pair of photodiodes (or the image dissector and one diode) spaced apart in the fringe plane and each sensing a set of interfering rays, will produce electrical output signals that vary as the optical phase shift varies. The signal variation is sinusoidal for linear motions of the frequency shifter. The two photodiode outputs are compared electrically, and the relative phase shift between the two output signals becomes a measure of the surface error on the test mirror. By definition, a figure error on the test mirror is a relative optical path length difference between a perfect reference mirror and an imperfect test mirror surface.

A major subsystem development includes the design and fabrication of a two-axis thermal compensating mount. The mount equips the figure sensor with two translational axes to compensate for test mirror tilt relative to the figure sensor.

The resolution of the figure sensor was measured at 0.005 to 0.006 inch (0.127 to 0.152 mm) as referred to the image dissector aperture. This type of resolution is the equivalent of nearly 200 fringes across the clear aperture of the mirror.

Errors of $\lambda/100$ peak could be detected and measured after calibration based on noise output measurements, stability measurements, and tilt control. The output noise level and stability of the photodiode phase detector circuits are measured at less than $\lambda/200$ rms, and the image dissector output was also measured at less than $\lambda/200$ rms.

Note:

Requests for further information should be directed to:

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Patent status:

NASA has decided not to apply for a patent.

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