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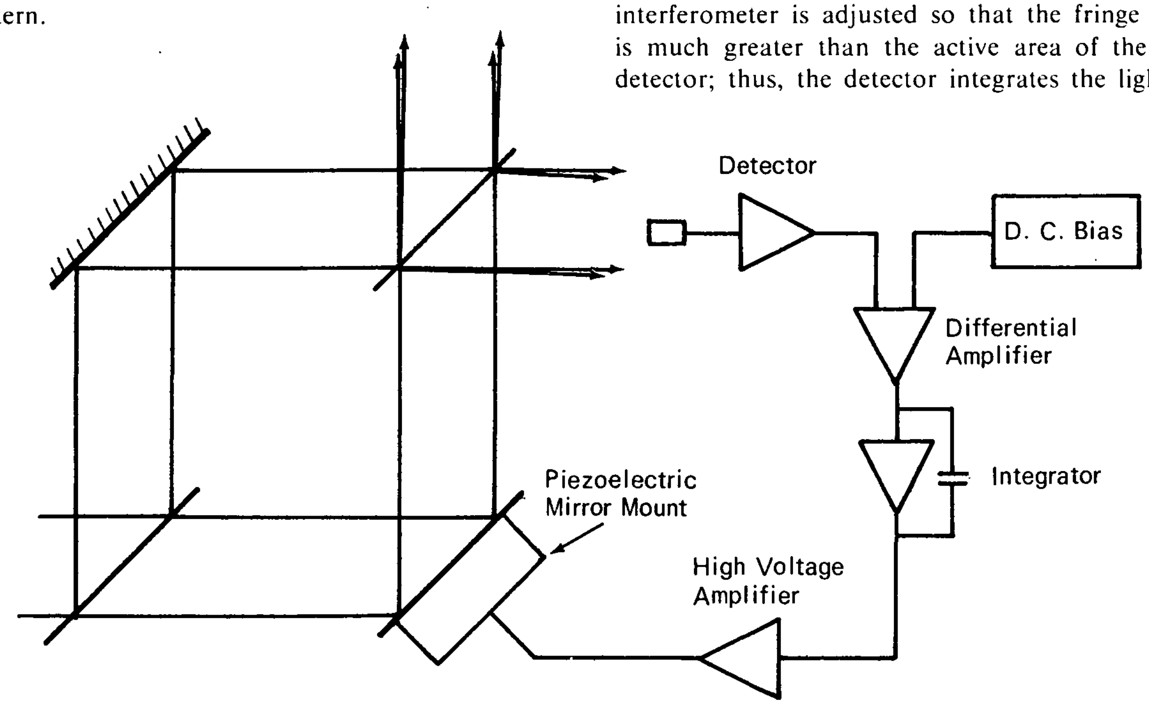
NASA TECH BRIEF

Ames Research Center

Stabilization of Interferometer Fringe Patterns

The problem:

Movement of the fringe patterns formed by an interferometer limits measurement accuracy. In some instances, it is nearly impossible to obtain measurements because the motion of components in the interferometer system causes constant shifting of the pattern.



The solution:

Motion of the fringe pattern is compensated by a closed-loop servo system that adjusts a mirror mounted on a piezoelectric crystal, so that the path difference in the interferometer is maintained at constant values at one point in the field.

How it's done:

The servo control loop consists of the interferometer, a photodetector, the servo electronics, and the servo control mirror. A small photodetector, such as a PIN photodiode, is used to sample a small portion of the output field. The interferometer is adjusted so that the fringe spacing is much greater than the active area of the photodetector; thus, the detector integrates the light from only a small fraction of the fringe. The light intensity at this point is a measure of the position of the interference fringe.

A differential amplifier amplifies the signal from the photodetector with a dc bias signal equivalent to the average intensity of the fringes. The output

(continued overleaf)

of the differential amplifier is fed to an integrator, and if the signals are equal, the charge on the integrator capacitor remains unchanged. If, however, the location of the interferometer fringes changes, the input signal will not be equal to the bias, and the integrator capacitor will charge or discharge at a rate dependent on the difference in the signals.

The output of the integrator is amplified by a high-voltage operational amplifier which drives a piezoelectric crystal. Mounted on the crystal is a mirror which serves as one element of the interferometer. Motion of this mirror will change the path length between the legs of the interferometer, and hence the location of the fringes, thus closing the loop. If the output of the differential amplifier is not zero, the change in charge on the crystal will change its length in such a manner as to return the fringes to the correct position. If the output is zero, no change is made in the piezoelectric crystal. The crystal is generally operated with a bias voltage of -700 volts for zero integrator signal so that it can be operated over a total range of 0 to -1500 volts.

The system inherently operates with a negative feedback because of the undulating nature of the interference pattern ($\cos^2$ function). The path change is always in a direction which will drive the output of the differential amplifier to zero, thus stabilizing the fringe pattern at the photodetector location.

The extent of stabilization depends on the nature of the motion to be compensated. Linear motion can be compensated equally across the whole field, while rotational motion is stabilized exactly only at the photodetector location; positions away from this point are stabilized to a degree dependent on the distance from the stabilized point. The amount of stabilization depends on the frequency and amplitude of the disturbing motion. With systems presently in use, stabilization to about 1/60 of a wavelength at very low frequencies (less than 10 Hz) has been demonstrated for noise amplitudes of greater than one wavelength. Through the use of the servo control loop system described, sinusoidal path motion of one wavelength peak-to-peak, up to frequencies of 200 Hz, can be reduced to less than 1/10 wavelength. Motions of greater than four wavelengths can be reduced to the same degree for frequencies of less than 70 Hz.

The loop gain of this system is the product of the electronic gain and the optical gain. Unfortunately, the optical system is inefficient; for example, 100 volts are needed to cause a path change of one wavelength, the geometrical multiplication is generally between 1 and 2, and the photodetector-preamplifier has a sensitivity of about 0.2 volt per wavelength. Therefore, the gain of the electronic system must be kept very high to obtain reasonable stabilization. A loop gain of about 100 is desirable at low frequencies, so that adequate high-frequency stabilization is available. Hence, there is the possibility that electronic drift will be the factor which limits the low-frequency performance of the system.

Notes:

1. Application of this system to holography with continuous wave laser sources has been successfully performed.
2. Requests for further information may be directed to:

   Technology Utilization Officer
   Ames Research Center
   Moffett Field, California 94035
   Reference: TSP71-10119

Patent status:

No patent action is contemplated by NASA.

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