A SIMPLE INTERFEROMETRIC MTF INSTRUMENT

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A simple law interferometric technique for measuring the modulation transfer function of an optical system is described.

1. Introduction

It is well known that the optical transfer function of an optical system can be measured using a lateral shear interferometer [1]. Several interferometers for measuring the optical or modulation transfer function have been described previously [2-10], including an ingeneous interferometric technique invented by Kelsall [8]. For all these interferometric techniques a lateral shear interferometer is used in which the shear is varied and, at the same time, the optical path difference between the two interfering beams is varied so as to produce a time varying amount of flux in the shearing interferogram. The resulting time varying signal obtained by measuring the total amount of flux in the lateral shear interferogram is proportional to the magnitude of the OTF (MTF), while the phase of the OTF can be obtained from the phase of this time varying signal. This letter describes a similar interferometric MTF measurement technique which has the unique features of simplicity and minimum number of optical components required. The technique requires the use of temporally and spatially coherent light, such as provided by most lasers.

2. Optical system

A common lateral shear interferometer for use with temporally coherent sources is a plane parallel plate where the beams reflected off the two parallel surfaces are interfered to give a lateral shear interferogram. The amount of shear is selected by the thickness and tilt of the plate. Likewise, the beam transmitted through the plate and the beam reflected off the two surfaces of the plate can be interferred to give a lateral shear interferogram as illustrated in fig. 1. The resulting interferogram has low fringe visibility; however, it does have the good feature that, unlike the case for the commonly used two reflected beams, without the use of any additional optics the interfering beams do not change direction as the plate is tilted to vary the amount of shear. As illustrated below, for our application the low fringe visibility causes no problem.

As the tilt of the plane parallel plate in fig. 1 is varied, the shear, S, between the beams reflected off the two surfaces is given by

$$S = \frac{t \sin 2\theta}{\sqrt{n^2 - \sin^2\theta}}\ , \qquad (1)$$

where t is the plate thickness, and θ is the angle of incidence as shown in fig. 1. Fig. 2 gives a plot of the

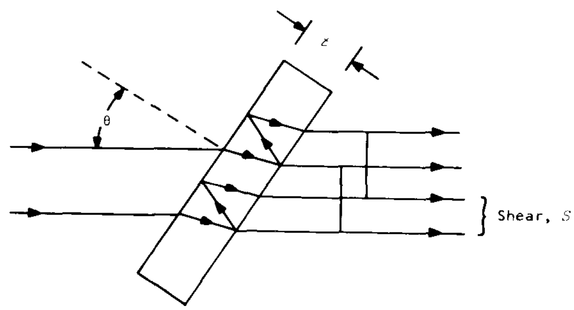

Fig. 1. Plane parallel plate lateral shear interferometer used in transmission.

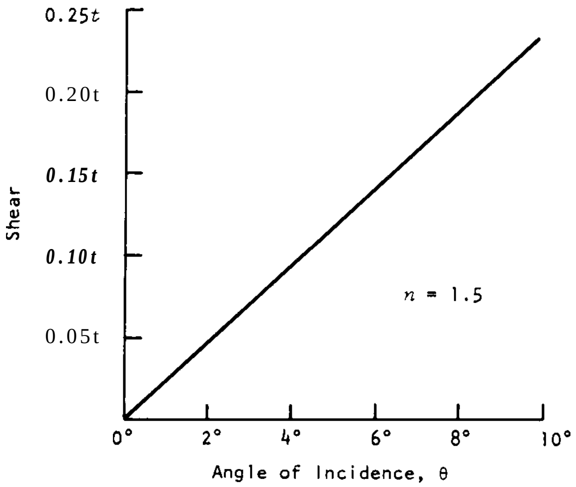

Fig. 2. Shear versus angle of incidence.

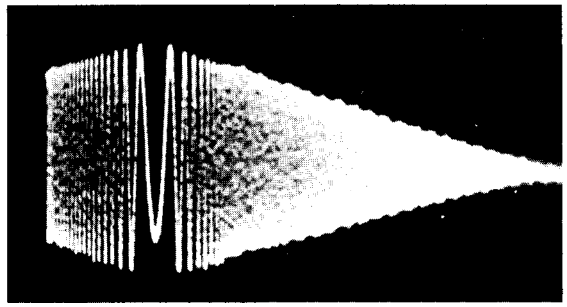

Fig. 4. MTF as displayed on oscilloscope. Vertical axis: MTF; horizontal axis: spatial frequency.

shear versus angle of incidence for refractive index n = 1.5.

As the plane parallel plate is tilted, the optical path difference for the two interfering beams changes. If δ is the change in the OPD from its value of 2nt for $\theta = 0^\circ$, δ is given by

$$\delta = 2nt\left[\sqrt{1-\frac{\sin^2\theta}{n^2}}-1\right]. \tag{2}$$

The technique for using a plane parallel plate for measuring the MTF of an optical system is straightforward. Essentially, collimated light from the system under test is incident upon the plane parallel plate. The light transmitted through the plate is focused onto a detector, whose output is displayed on an oscilloscope as shown in fig. 3. As the plate is rotated, the amplitude of the time varying signal displayed on the oscilloscope and illustrated in fig. 4, is directly proportional to the MTF of the system under test. This time varying signal is reduced since the two interfering beams have different intensities; however, since the only quantity of interest is the variation of the signal as a function of shear or equivalently spatial frequency, this reduction in the time varying signal is unimportant as long as the signal to noise is acceptable. For reasonable angles of incidence the reflection is essentially constant, so no appreciable error is introduced by changes in the intensities of the interfering beams.

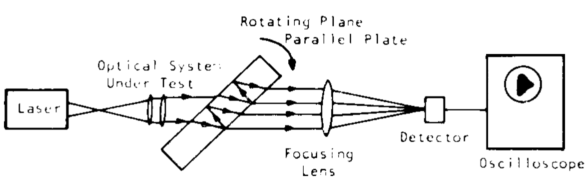

Fig. 3. Interferometric setup for measuring MTF

The disadvantage with this interferometric technique for measuring MTF is that the modulation frequency of the signal, given by the time rate of change of $(2\pi/\lambda)\delta$, is not constant as a function of θ, but rather it varies as indicated in fig. 4. Also, unless 2nt is equal to a multiple of the wavelength λ, a maximum is not obtained for zero shear, i.e. zero spatial frequency. For this reason, it is often necessary to normalize at a frequency other than zero. For some applications this may not be acceptable; however, when it is acceptable this very simple interferometric technique, which consists only of a plane parallel plate, a motor to rotate the plate, an inexpensive focusing lens, a detector and oscilloscope, is very convenient for measuring the MTF of an optical system.

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