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Collimated Light Acoustooptic Lateral Shearing Interferometer

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In this Letter, a collimated light acoustooptic lateral shearing interferometer (AO/LSI) capable of variable shear is described for use with either visual or ac electronic real-time phase measurements.[1,2] The principle of operation of the AO/LSI is shown in Figs. 1 and 2. An input beam of diameter W is incident at Bragg's angle upon two acoustooptic modulators (AOM's) in series. They are shown schematically as thin gratings in Fig. 1, where the Bragg angles of the two AOM's are indicated as θ_B and θ_2. The first AOM is driven at an acoustic frequency f_1 (typically in the tens of megahertz), the second AOM at frequency $f_2 = f_1 + \Delta f$. If $\Delta f << f_1$, θ_2 is nearly the same as θ_B, as assumed in Fig. 2. It may be seen from Figs. 1 and 2 that some light is diffracted out of the zero-order beam by each AOM. The separation x between each AOM is adjusted until the two overlapping diffracted beams, which produce an interference pattern, are sheared (i.e., shifted) by an amount s. (A convenient value of s is 0.1 W.) The amount of shear can be varied by adjusting f_1 too.

In Fig. 2, it may be seen that the diffracted wave is assumed to originate from the center of each AOM. Actually, the wave is diffracted from the volume of the AOM, and the resultant wavefront exits the AOM at the angle θ_B. However, for purposes of this discussion, it is convenient to assume that the central ray of the incident wavefront is reflected (i.e., diffracted) from the center of the AOM. From the geometry of Fig. 2 together with the Bragg diffraction equation, an equation relating the various parameters of the collimated light AO/LSI can be derived:

$$sV/\lambda f_1 = (L/n) + x,$$

where V is the velocity of the acoustic wave in each AOM, L and n are the length and optical refractive index, respectively, of each AOM, and λ is the free-space wavelength of the input light.

Since the first diffraction orders produced by the first and second AOM's are Doppler frequency shifted an amount f_1 and f_2, respectively,[3,4] the irradiance of the shearing interferogram varies sinusoidally with time at a frequency Δf, and ac electronic real-time phase detection can be used. When $\Delta f = 0$, visual observation and photographic recording of the fringes are possible. For dc operation only, it is possible to use just one AOM in retroflection. That is, by sending the light beam twice through the same AOM by means of a mirror, Δf is zero. By either changing the distance between the AOM and the mirror or adjusting f_1, the shear can be varied.

The AO/LSI can be extended to produce shear in two orthogonal directions by means of four AOM's in series or by means of a beam splitter and two mirrors with two AOM's in each beam.

Since the stability of the interference fringe pattern depends only on the difference between the acoustic frequencies of the two AOM's (i.e., $f_2 - f_1$), best results are obtained when one main megahertz frequency (f_1) oscillator is used, employing a frequency mixer and an auxiliary dc-to-kilohertz adjustable oscillator to obtain $f_2 = f_1 + \Delta f$, as indicated in Fig. 1.

Experimental results for the collimated-light AO/LSI are shown in Figs. 3-4. Figure 3 is a photograph of the dc ($\Delta f = 0$) interference pattern obtained with a single AOM (Zenith model D-70R) in retroreflection for $f_1 \approx 60$ MHz or so.

Figure 4 is an oscilloscope picture of the photomultiplier-detected ac ($\Delta f = 5$ kHz) fringe pattern using two AOM's (the Zenith and an Isomet model 1201) in series. The frequency f_1 was 40 MHz; Δf was easily varied from 10 MHz down to 1 kHz. It may be seen that a fairly uni-

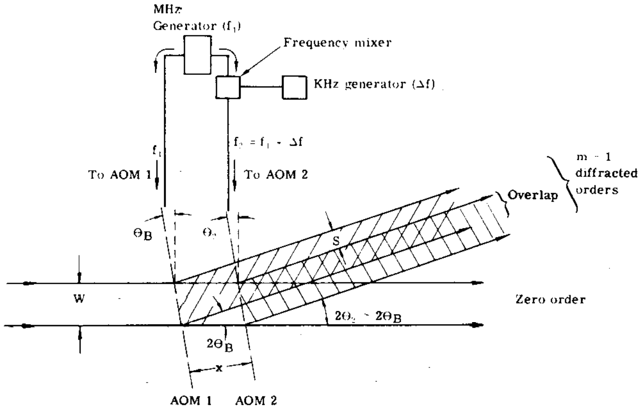

Fig. 1. Principle of operation of a collimated light acoustooptic lateral shearing interferometer (AO/LSI). The acoustooptic modulators (AOM 1 and AOM 2) are shown schematically as thin gratings.

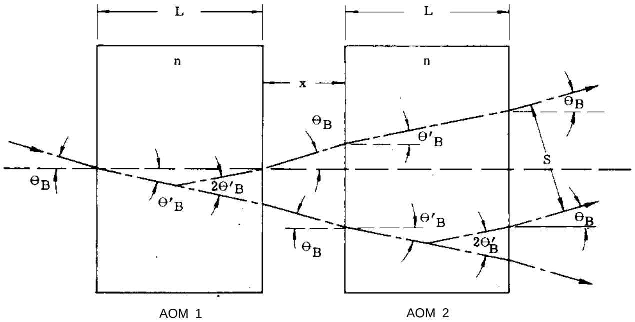

Fig. 2. Operation of the AO/LSI indicating how each AOM acts as a volume grating Bragg cell($\theta_B \cong n\theta_B{}'$).

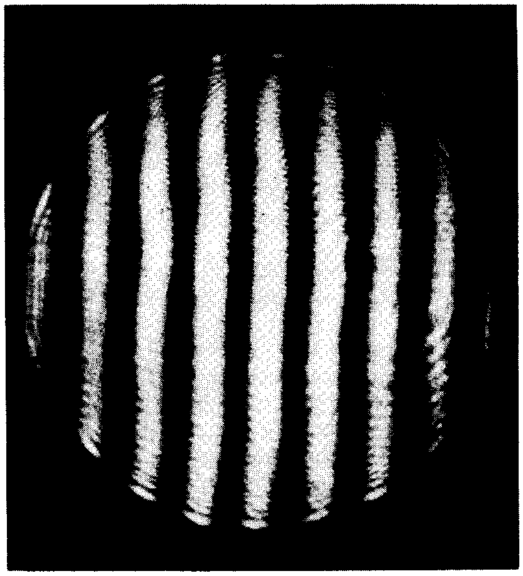

Fig. 3. The dc ($\Delta f = 0$) shearing interference pattern of an AO/LSI for some defocus of the input-laser collimator. Wavelength $\lambda = 0.6328/\mu m$.

form waveform was obtained over several cycles.

The AO/LSI has all the advantages of the grating LSI.[2] In addition, the AO/LSI is completely nonmechanical. Further, a continuously generated acoustic traveling wave in an AO/LSI gives a 100% duty cycle and thus offers the ability to keep count of the interference fringes as they pass by the detector array. (With the grating LSI there is down time because after each scan the direction of the grating must be reversed.)

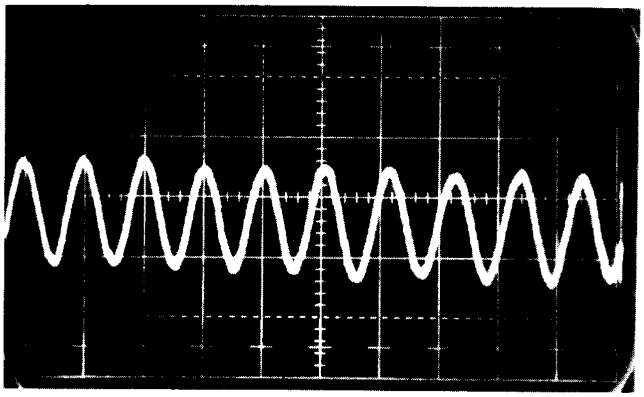

Fig. 4. Oscilloscope trace of the photomultiplier-detected ac ($\Delta f = 5$ kHz) interference pattern. Wavelength $\lambda = 0.6328\ \mu m$.

Thus, it may be concluded that a collimated light AO/LSI is feasible at visible wavelengths. It is reasonable to expect that this technique will work at infrared wavelengths.

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