NASA TECH BRIEF
Ames Research Center

Sensitive Holographic Detection of Small Aerodynamic Perturbations

The problem:

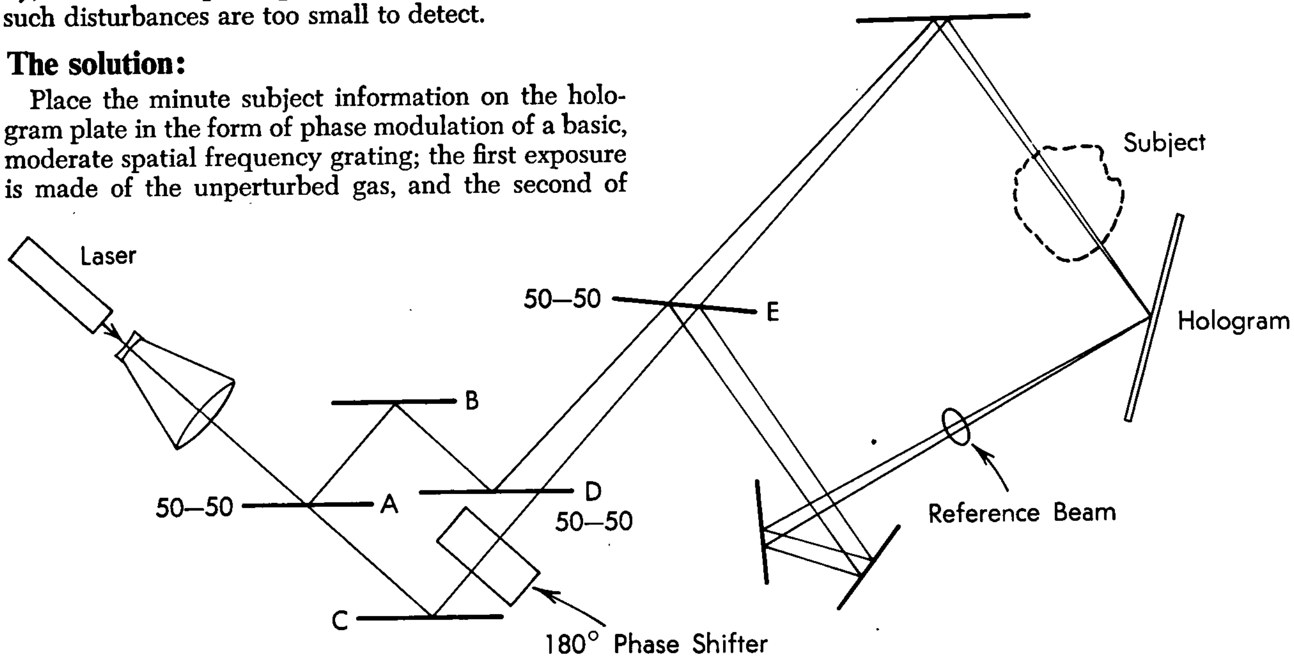
To enhance the sensitivity of holographic techniques for detecting the very small aerodynamic disturbances which are caused by variations in gas density of the order of 1/10 wavelength or less; ordinarily, the minute optical phase retardations caused by such disturbances are too small to detect.

The solution:

Place the minute subject information on the hologram plate in the form of phase modulation of a basic, moderate spatial frequency grating; the first exposure is made of the unperturbed gas, and the second of the gas in the perturbed state. Since the system responds only to changes in the subject between exposures, perfect optics are not required. The readout resembles that from a double exposure, subfringe, holographic interferogram, that is, the subject perturbations show up as brightenings on a dark background.

How it's done:

To produce the phase modulations, the subject and reference beams in the holographic apparatus are each separated into two component beams. The angle between the components is small and is the same for both subject and reference. As shown in the figure, mirrors A, B, C, and D form two beams at a small angle; beamsplitter E divides these into subject and reference beam pairs.



In the first exposure, the two components of the subject beam interfere with each other at the hologram, producing effectively a single wave with an

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amplitude that varies sinusoidally as the hologram is traversed; the same is true for the reference wave. The interference between the subject and reference beams thus has an intensity which varies like a $\sin^2$ function for the relatively slow variations corresponding to the fringes produced by the narrow angle between components. Superimposed on these slow variations are the fine holographic fringes corresponding to the large angle between the subject and reference beams.

For the second exposure, a phase shift of 180° is introduced into one component of the subject beam and the corresponding component in the reference beam. The phase shift causes a displacement of the slow variation of the intensity at the hologram so that the intensity varies like a $\cos^2$ function; the fine fringe holographic component is not changed. In view of the fact that $\sin^2 + \cos^2 = 1$, the sum of the two envelope intensities is constant. Thus, a hologram produced in the absence of a change in the subject is simply a uniform grating of fine fringes which diffracts only a plane wave upon reconstruction. However, if the object introduces a small differential phase shift between the two exposures, the phase (position) of the fine fringes for the second exposure with the $\cos^2$ envelope will be shifted accordingly. Upon reconstruction, the output wave, instead of being plane, will have a small phase wrinkle on it with the amplitude of the phase wrinkle set by the small phase shift caused by the subject. This phase wrinkle diffracts light at the small angle from the primary reconstruction, and the intensity of this diffracted light reveals the magnitude of the original, small optical perturbation made by the subject.

Notes:

1. The following documentation may be obtained from:

   National Technical Information Service
   Springfield, Virginia 22151
   Single document price $3.00
   (or microfiche $0.95)

   Reference:
   NASA CR-114274 N71-17271),
   Holographic Instrumentation Studies

2. No additional documentation is available. Specific questions, however, may be directed to:

   Technology Utilization Officer
   Ames Research Center
   Moffett Field, California 94035
   Reference: B72-10209

Patent status:

No patent action is contemplated by NASA.

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TRW Systems Group, TRW, Inc.
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