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FIRST MONTHLY LETTER REPORT ON IMAGE ENHANCEMENT

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(1 September 1966 to 30 September 1966)

7 October 1966

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In [redacted] Task Order No. 18, we will investigate spatial filtering techniques to enhance images aberrated by motion of the optical system when the image was recorded. In [redacted] Proposal TO-B 30-66 it was illustrated that such image enhancement is possible if the impulse response of the optical system can be recovered from the image itself. Ignoring the fact that no general technique now exists to do this, we will attempt to demonstrate that specially constructed aberrated images containing the impulse response of the aberrated system can be enhanced significantly by the proposed filtering technique. 25X1 25X1

Essentially, the filtering operation entails multiplying the Fourier transform of the aberrated image by a Fraunhofer hologram of the impulse response, and the reciprocal of the square of the transformed impulse response. When this product is retransformed the separation property of the Fraunhofer hologram reconstruction permits us to isolate the corrected image in the absence of aberrations. The success of this operation depends on the ability to critically record the Fourier transform of the aberrated impulse response in the form of an inverse amplitude filter and also as a hologram filter and then process all transparencies to a $|\gamma| = 2$. Choice of recording media and the development of very reproducable processing techniques will be significant factors in determining the degree to which the linear approximations implied above can be satisfied.

The spatial filter will be constructed in two parts: (a) a Fraunhofer hologram of the impulse response, and (b) a transparency with transmittance proportional to the inverse magnitude squared of the transfer function. Although a technique for constructing images containing a reproducable aberrated impulse response is a non-trivial experimental problem, it was felt that the hologram construction was the more difficult task. Consequently, at the end of the first month, a modified Mach Zender interferometer (identical in principle with that used by Vander Lugt*) was set up for the construction of the holograms (Figure 1). Several other possible approaches (i. e., prisms in a beam, mirror systems, and Fourier transforms with a point reference) were considered but since all of these techniques involved space sharing in the light beam, which limits the available format, the Mach Zender was considered preferable.

Because of the importance of the hologram construction process, it seems appropriate in this report to discuss some of the construction details of the interferometer, its capabilities and limitations. The location of various elements are illustrated in Figure 2. An Optics Technology Model 170 AC continuous gas laser is used as the light source which transmits, in a single mode, approximately 0.3 mW at 6328 Å. A microscope objective is used to bring the laser light to a focus at a 5µ pinhole and geometrically defines the source for a 20" focal length, f/10 collimating lens, L_2. An intense, reasonably uniform 2" diameter beam is obtained with this arrangement.

In the construction of holograms, the intensity of the reference beam must be greater than that of the object beam to provide a positive hologram function. In a transform hologram, the relatively high energy density at the lower spatial frequencies demanded that the reference beam intensity be greater than that of the object beam

*A. Vander Lugt, "Signal Detection by Complex Spatial Filtering", IEEE Trans. IT-10, 139-145 (April, 1964) before it passed through the transform lens. To minimize the use of filters and unnecessary loss of light, the object beam was formed by reflecting approximately 4% of the incident beam from the uncoated side of a high quality optical flat that was used as the first beam splitter, BS1. The beam splitters were 2" diameter, 0.250" thick, optical quality quartz with both sides flat to $1/20\lambda$, and parallel to $1/10\lambda$.) To minimize interference fringes between the front and back surfaces, the rear surface was coated with a single layer dielectric anti-reflection coating. (If necessary, multiple layer coatings can be obtained that reduce the reflectivity from the 1.0% to 1.5% typical of single coatings to about 1/4%.) The second beam splitter, BS2, is identical to the first except that the side toward the reference beam has a 55-65% reflective coating that further attenuates the transmission of the object beam. Both beam splitters have 45° mounts provided with small angular adjustments. Careful, no stress mounting of the optical flats gives a relatively clean elliptical field with a usable 35 mm format. Two $1/4\ \lambda$ mirrors (M_1 and M_2) are mounted on micrometer rotation stages; the first mirror, M_1, is firmly attached in place; the second mirror, M_2, is mounted on a precision translation platform. A 10" focal length, f/5 lens, L_2, is used for the transform lens in the object beam.

To record the hologram on film, a Leica focusing slide has been mounted on a small precision crossfeed table that facilitates accurate positioning of the film plane. The final alignment procedure of all elements is a very laborious task which need not be discussed. Suffice it to say that provision for fine adjustment, on each element has made it possible to set-up and adjust the system to the desired accuracy.

Several 35mm films have sufficiently high resolution to be used for recording the holograms. Recordak Micro-File AHU has been used because of the photographic speed (ASA 100), high resolution (200 - 500 ℓ/mm) and good behavior under positive reversal processing.

In initial experiments with holograms of a high contrast resolution target, reconstructions were achieved with resolution on the order of 14 ℓ/mm. These experiments were done on a standard [redacted] optical bench. Due to the extreme 25X1 sensitivity of the Mach-Zender arrangement, the fringes due to the interference of the two beams were found to be unstable because of vibrations transmitted in the building. To reduce this problem a special 8 foot optical bench was mounted on a massive granite slab (see Figure 1) and more rigid mounting procedures were used to hold the interferometer elements in place. Since we are working simultaneously on both film development procedures and resolution tests, there is no concrete data to report at this time.

During the coming month emphasis will be placed in procuring imagery that contains the same aberrations so that a group of images can be corrected with one hologram filter. Work will also proceed in determining the capabilities of the interferometer system for filter fabrication and also experimenting with films and processing techniques to obtain optimum combinations.

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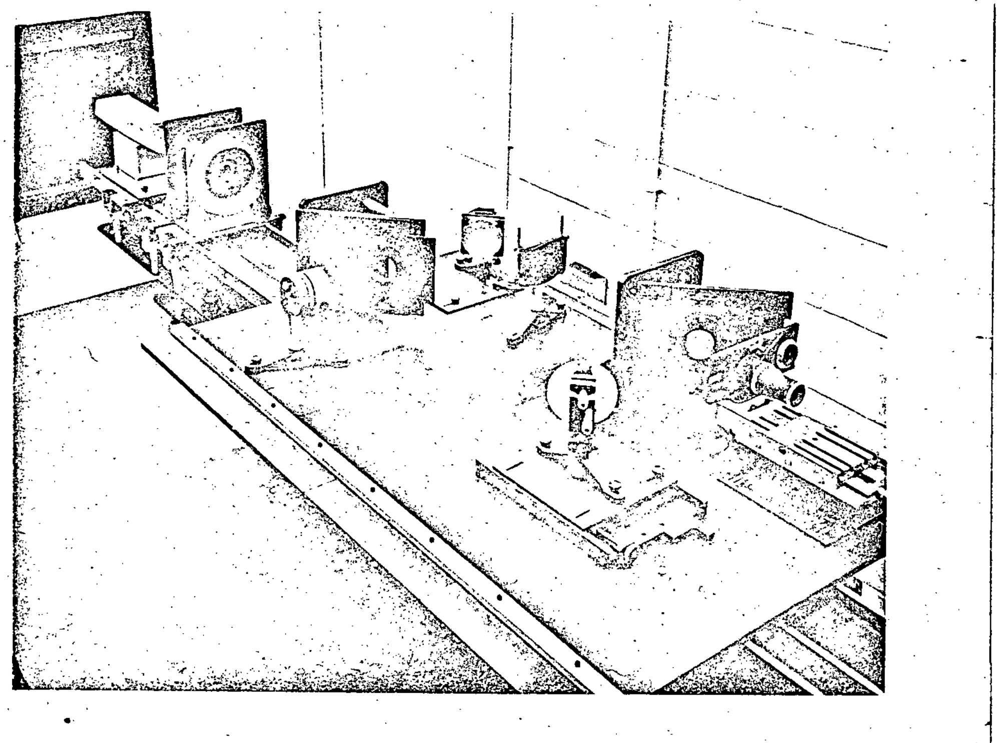

Figure 1. Modified Mach Zender Interferometer

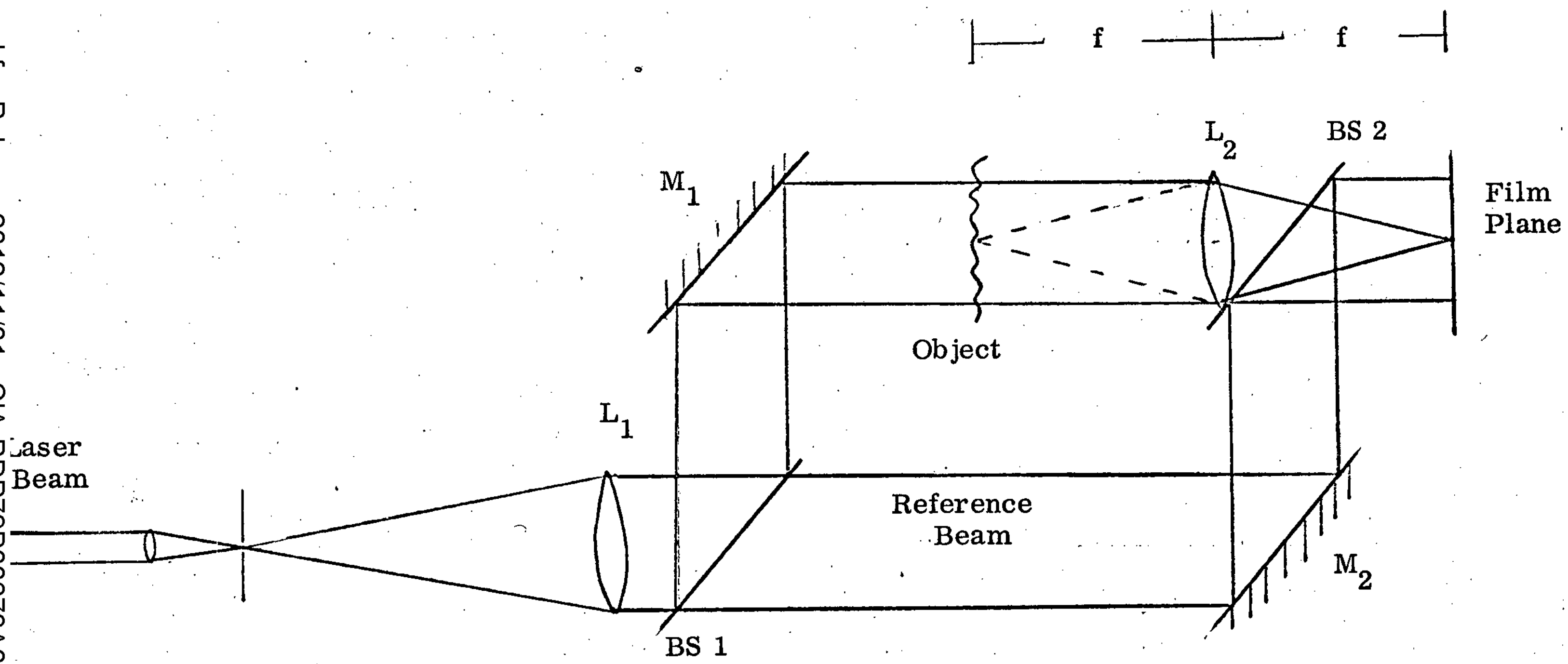

Figure 2. Schematic of Modified Mach-Zender Interferometer

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