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Hologram Transmission via Television

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Holography, or wavefront reconstruction photography, was first demonstrated by Gabor[1,2,3] over fifteen years ago, and it has been the subject of increased investigation over the last five years since the advent of lasers. Possible applications of holography suggest themselves in the fields of three-dimensional and multicolor television.[4] Furthermore, the statistics and redundancy of the hologram of an image may be deliberately made quite different from those of the original image. This has obvious possibilities in encoding schemes for television transmission in general. In this communication we report a first experimental step in this direction, namely the successful transmission via television of a Fresnel type of hologram in which the original object was a transparency.

In conventional two-dimensional hologram construction a transparency is illuminated from behind by a monochromatic, spatially-coherent light wave which then impinges on a photographic plate. This interferes with a reference or carrier wave derived from the same source that strikes the plate at an angle. A record, or hologram, is thus made of both the amplitude and phase of the light transmitted by the transparency. Reconstruction may be achieved by illuminating the hologram with a monochromatic, spatially-coherent light wave. This results in the production of a real image, a virtual image, and a direct wave. Most experimenters in the field have used relatively large angles between the reference and object beams, and the recording has been done on Kodak Spectroscopic plates with 649F emulsion. In the television experiment about to be described, the limited resolution of the equipment required the use of angles of less than one degree between the object beam and reference beam, and would severely limit three-dimensional and multicolor capabilities. The use of these small angles raised the problem of reconstructing the real image without interference from either the direct wave or the virtual image. This was solved by the use of a Fourier transform method which is described in the discussion of the reconstruction process. All recordings were on Poloroid Type 55 P/N film.

The experiment was basically a simple one designed to explore the technique for transmitting a hologram on television and recovering the image. Essentially the experiment consisted of transmitting a hologram of a transparency on television, recovering the hologram at the receiving end, and reconstructing the original image. The recovery was accomplished by photographing the hologram at the receiving end of the system, and then performing the reconstruction separately.

The hologram formation system is shown in Fig. 1. The light source is a He-Ne laser operated at 6328 Å and internally apertured to insure that it operated in the lowest order transverse mode. The output of the laser passed through a microscope objective which imaged the beam to a spot where a pinhole was placed to remove any imperfections in the beam caused by the transmission through the end mirror of the laser and the microscope objective. The beam was then allowed to diverge and fill the aperture of a lens which was located a focal distance away from the pinhole. At this point the beam was collimated and entered what was essentially a Mach-Zehnder interferometer. This was used to obtain as small an angle as desired between the reference and object beam. The angle, and consequently the interference fringe spacing, was adjusted by means of the final beam splitter. The transparency was placed in one arm of the interferometer and the reference beam passed through the other arm. Both beams then impinged directly on the vidicon without a lens and formed the hologram. This

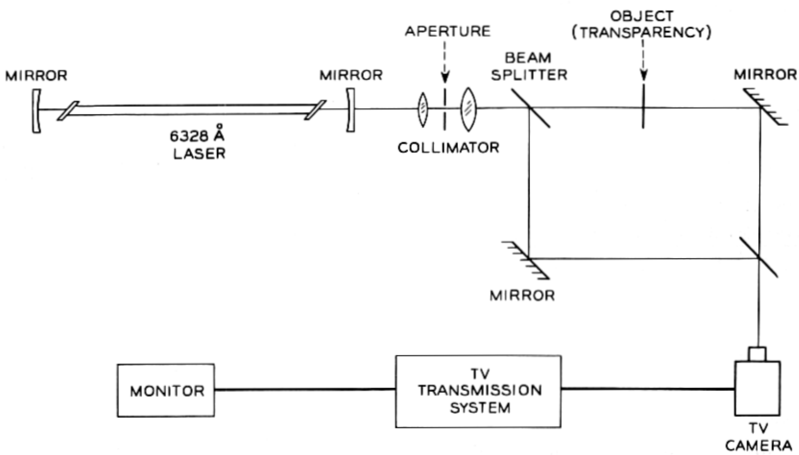

Fig. 1 — Block diagram of the hologram formation system.

signal was then transmitted to a television monitor and the resulting display was photographed.

The hologram reconstruction system is shown in Fig. 2. Everything up to and including the collimator is as shown in Fig. 1. The hologram, which is a Polaroid transparency, is placed in the collimated beam at the front focal plane of the lens and its Fourier transform appears in the back focal plane. At this point a filter, which is essentially an aperture, occults both the main beam and the virtual image beam. A second lens is used to perform another Fourier transform to give an image of the hologram minus the filtered information. The reconstruction of the object transparency, or real image, is then formed at the equivalent distance from the hologram image that the object transparency was from the vidicon.

Fig. 3 contains a photograph of the real image of a hologram transmitted by television. The original object was an opaque transparency containing the transparent word BELL underlined by three transparent lines. The angle between the reference and object beam was approximately 18 minutes of arc corresponding to a fringe spacing of approximately 122 microns on the front surface of the vidicon. This corresponds to an electrical frequency of 2.3 MHz for the standard (525 line) television system used. The photograph of the hologram pattern on the kinescope was made at an exposure of 1/5 second at f/16, and the photograph of the reconstructed image was made at an exposure of 30 seconds without a lens.

In this experiment, we have not detected any noticeable degradation

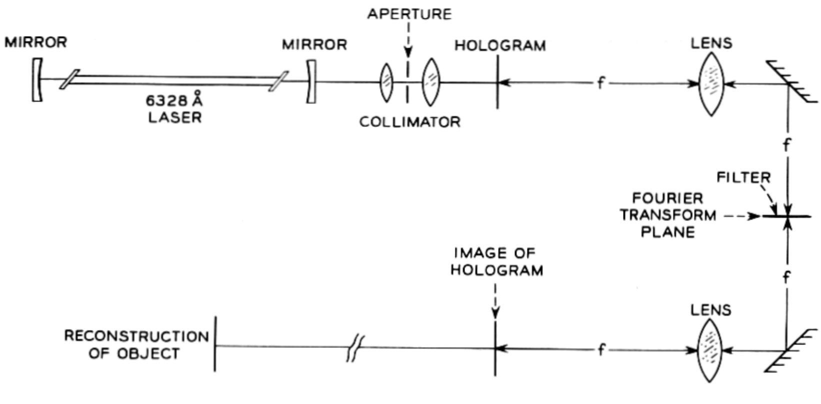

Fig. 2 — Block diagram of the hologram reconstruction system.

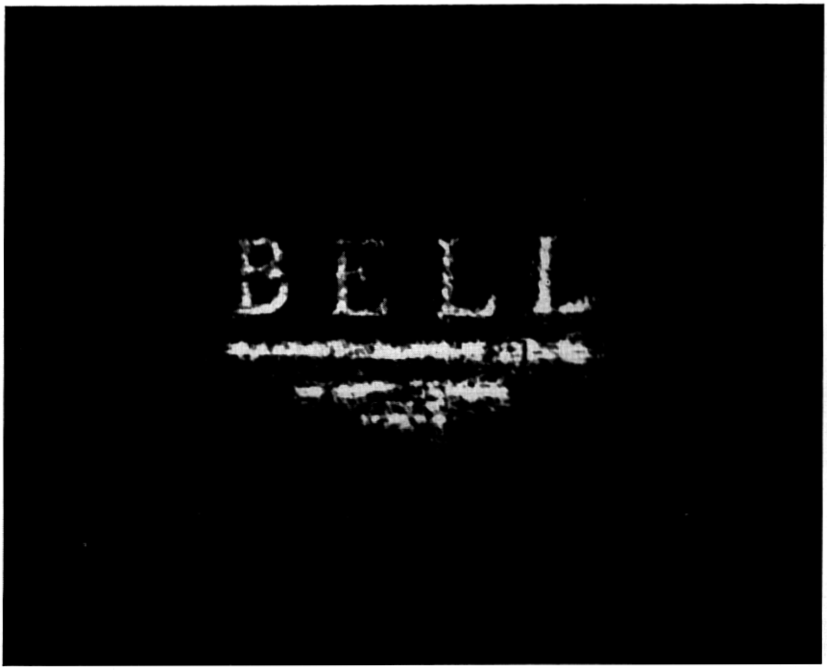

Fig. 3 — Photograph of the reconstructed real image of a hologram transmitted via television.

of the image due to nonlinearity in the television system. On the other hand, there was a distinct degradation due to the "noise" introduced by the many optical components, and any nonlinearities in the television system were also overshadowed by the degradation caused by the nonrigidity of the Polaroid transparency. These problems are amenable to solution.

This experiment is a first step in the direction of a holographic television system. One important additional result of this work is that it pointed out the usefulness of viewing the laser output at any point in the optical system directly on a television monitor.

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Laser Cavities with Increased Axial Mode Separation

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Single axial mode operation of gas lasers may be achieved either by reducing the mirror separation, L, until the mode separation, $c/2L$, is comparable to the oscillation line width, $\Delta\nu_a$, or by using mode suppression or filtering techniques.[1, 2, 3] When the line width exceeds ≈ 3 gc (as in an argon ion laser for example), L must be less than 5 cm for an unstabilized laser and less than 10 cm for a laser stabilized at line center.* Lasers of this length have several disadvantages, the most serious of which (in the case of ion lasers) results from the close proximity of the Brewster windows to the discharge. In the case of the 6328 Å He-Ne laser, restricting the laser tube length to a few centimeters limits the available single axial mode output power to about 1 mw.

This brief describes two additional mode suppression techniques which permit single axial mode operation with mirror separations much larger than $c/2\Delta\nu_a$.

In common with other techniques,[3] mode suppression is achieved by splitting the beam and using a three-mirror cavity;* however, the specific configurations described in this note are believed to be new and may possibly be advantageous in certain circumstances.

The first technique is most simply understood by referring to Fig.

* The mode competition effects reported by Rigrod and Bridges (Electron Device Research Conference, University of Illinois, Urbana, June, 1965) for ion lasers may permit some increase of these lengths.

* It has been pointed out by E. I. Gordon and J. E. Geusic that all mode suppressors using a beam splitter and three mirrors are probably members of the same class of devices characterized by the microwave magic tee with two shorted arms.