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<u>Abstract</u>

We present a holographic element capable of projecting dynamic stereo images, and allowing the observer to see through the device, for possible use as a head up display in aircraft.

I. Introduction

Methods to provide an observer with a stereo image must furnish each eye with a slightly different perspective, so that the observer's brain can generate a three dimensional view. Available methods include holography, lenticular screens, selective goggles of various types, and optical systems involving lenses, beamsplitters, or both.

The purpose of the present communication is to describe a holographic optical element [HOE] which can provide dynamic stereo images without the use of goggles, and with the ability of the observer to see through the stereo display. Such a device could be useful as a head up display in aircraft or automobiles, or as a visual aid to machine assembly or surgery.

II. Experimental

The device is based on a volume reflection holographic optical element which contains two sets of Bragg planes. Each set of Bragg planes diffracts light from a two-dimensional source to the appropriate eye to achieve a stereo effect. During recording, laser beams were directed at angles 45° from the normal to the plate on one side, and 4° from the normal on the other side. The formation and reconstruction geometries are shown in Fig. 1. Such an arrangement is not by itself satisfactory since the diffracted light from each object tends to overlap that of the other, creating a double image rather than a stereoscopic one.

One possible modification is to mask a portion of the HOE during exposure, to limit the area of each set of Bragg planes. A plate of this type was made by exposing 60 % of an Agfa 8E75 plate at 633 nm with an energy of 0.25 J/m^2, rotating the plate by 180° about its normal and making a second exposure with the opposite side of the plate masked. The plate was developed in PAAP developer[1] to a density of 1.5 in the singly exposed regions and 3.0 in the doubly exposed part, and bleached in ammonium dichromate[2]. The masking procedure was successful in limiting the diffracted light to the intended eye. However, the image area was reduced from 4"by 5"; moreover, the singly exposed area of the HOE had both a higher reconstruction wavelength and twice the diffraction efficiency as the section of overlap in the center of the plate. This gave an unacceptable difference in image quality for display purposes.

A more successful solution involved using a system of lenses and aperture stops to project the two dimensional image onto the HOE. The system was designed so that exit pupils were projected on the observers eyes to limit the diffracted light in each beam to the appropriate eye. Referring to Fig. 2, the lenses were: Lens 1: Single element, focal length=166 mm, diameter=102 mm; Lens 2: Double element, focal length=150 mm, diameter=50 mm, with 12.5 mm aperture stop. The arrangement resulted in an 8° angular spread of the diffracted image, which was adequate for viewing at a distance of 0.5 m (20"). Again, a test plate was made by exposing an Agfa 8E75 plate at 633 nm with an energy of 0.3 J/m^2, rotating the plate by 180° about its normal and making a second exposure. It was developed in PAAP to a density of 2.6 and bleached in ammonium dichromate. Such processing can give 30% diffraction efficiency for one set of Bragg planes; however for two sets, the diffraction efficiency was about 9% for each. This was adequate for demonstration

purposes. With two transparencies of perspective drawings as source material, an observer perceived a good stereo effect. In this system, the viewing angle over which the three dimensional image could be seen was unavoidably restricted as a result of the small exit pupil needed to maintain single eye selectivity in viewing the stereoscopic images. The angle of view can be improved, and a greater sense of three dimensional realism achieved, by projecting four images of different perspective, rather than two. For this purpose, four sets of Bragg planes are required. Since there are now four input and four output channels, the angles must be chosen with care to avoid multiple images occupying the same space. For this design, source beams were assumed incident at -55° and 55° with respect to the normal of the HOE, with their images diffracted at -12° and 12° (respectively) from the normal. The second set of Bragg planes diffracted beams incident at -35° and 35° to output beams at 4° and -4°. The four image HOE was implemented using two plates each containing two sets of Bragg planes. CW-C2 developer was used in conjunction with PBQ-2 bleach in processing[3], to achieve 62% diffraction efficiency for one set of Bragg planes, and 20% for two.

III. Discussion

Reflection HOE's capable of projecting stereo images have been made and evaluated. Silver halide media were used for demonstration purposes, however higher performance media such as dichromated gelatin or photopolymer would be more appropriate for a practical device, particularly one containing many sets of Bragg planes. In particular, a full color four image device would contain twelve sets of Bragg planes; several layers of photopolymer could be laminated to minimize the loss of diffraction efficiency.

HOE's of the type presented here are envisaged as an extension of see-through HOE's currently used as head-up displays in aircraft. Current displays are two dimensional and monochrome. A see-through device capable of projecting three dimensional images could also be used to project markers or images on industrial assembly areas or surgical fields for training purposes.

REFERENCES

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2.   P.M. Boone, "Some problems associated with processing Agfa-Gevaert 8E75HD sheet film for reflection holography", SPIE 600, 172, (1985).
3.   D.J. Cooke, and A.A. Ward , "Reflection hologram processing for high efficiency in silver halide emulsions", Appl. Opt. 23, 934, (1984).
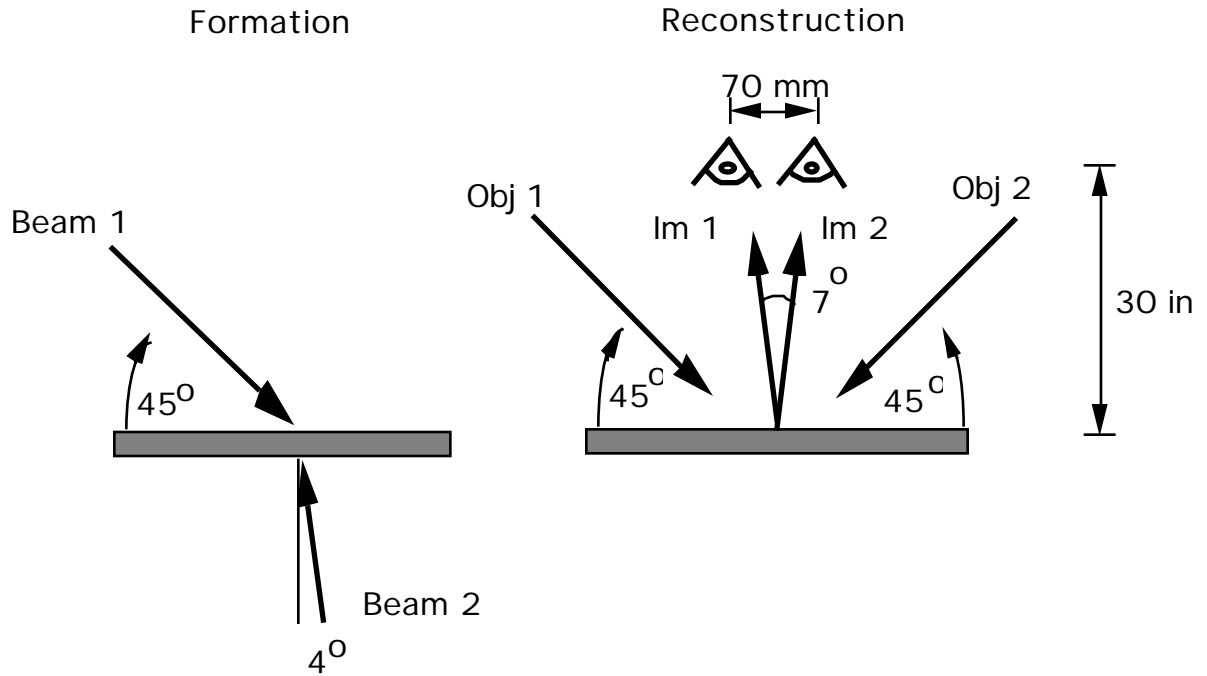
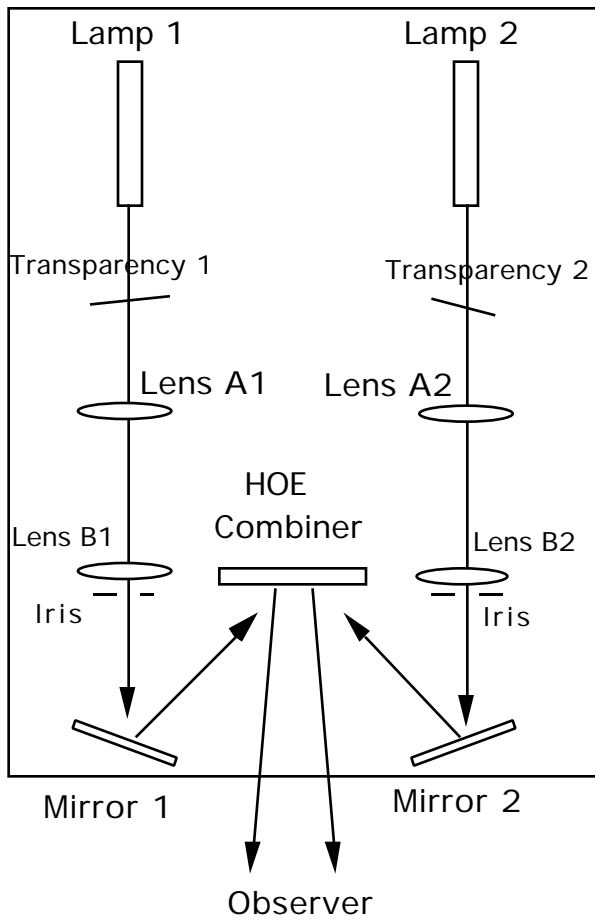Figure 1. Formation and reconstruction geometries for a stereoscopic HOE combiner.

Figure 2. Configuration for demonstration of stereoscopic HOE combiner.