# HOE for Holography

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## Introduction

The use of holographic optical elements (HOE) in myriad of technical applications is now well-known. Herein we wish to discuss a number of specific applications in holography itself.

The chief advantages in the use of HOEs instead of classical optical equipments are three-fold: simplicity, lower cost, and higher efficiency.

Following are the specific items to be discussed:

1. Beamsplitter and combiner

2. Diffusers

3. Hologram viewer

4. Cylindrical hologram maker

## Beamsplitter and combiner

Figure 1 shows an HOE beamsplitter made by interfering two collimated beam, one at Brewster's angle from the normal, and the other 90 degrees from the first. With a uniform reference beam and an object beam varying in intensity from A to B, a grating is made with a continuously variable diffraction efficiency.

When an undiverged beam is directed at the HOE with the polarization direction as shown, two beam would emerge at 90 degrees from one another. Practically none is reflected. Depending on the location used, a different beam ratio is achieved by the emerging beams.

Beside the lower cost, there is an additional advantage of the HOE over a beamsplitter with variable reflectivity. In adjusting for different beam ratios, a slight wobble causes the reflected beam to double the error. Whereas, in the case of the HOE[1], the diffracted beam remain perpendicular to the transmitted beam, thus avoiding misalignment downstream.

Figure 2 shows the use of a similar HOE for beam combining. In this case, a grating is made by interfering

HeNe beams, one normal to the plate, the other at the Brewster's angle. Diffraction efficiencies of over 90% is achievable using silver halide emulsion.

We have successfully combined beams from HeCd, argon, and HeNe lasers with such a device, resulting in a diffraction limited output beam of white light. The overall efficiency is over 80%, much greater than using prisms.

Because of the large angular separations among the three input beams, as compared to the case using a prism, manipulations are highly simplified.

The output beam can now be handled as if it were from a single laser, and multicolor holograms can be made with a single exposure.

In our case, we pass the object beam through a 0.5 cm diameter "optical fiber", which serves to mix and diffuse it for "soft" illumination.

## Diffuser[2]

Figure 3 depict the top view of a configuration for creating a holographic diffuser. The reference beam is from the bottom at Brewster's angle. It interfere with two diffused beams from the sides, each having an intensity different from the other.

The resultant holograms, particularly if it were made on dichromated gelatin, acts as a highly efficient diffuser when the conjugate beam is diffracted through it. Such an HOE can be used for Denisyuk portraitures, as shown in Figure 4.

By sandwiching the HOE behind a photoplate, the single beam enters at Brewster's angle. The HOE diffracts most of the light into two diffused beams, thus illuminating the subject from two sides.

Because of its high diffraction efficiency, the direct light that enters the subject's eyes is minimized. At the same time, more artistic lighting is realized by the apparent three-beam illumination.

## Hologram Viewer

There are two major reasons for the lack of popularity of classical transmission holograms, inspite of the fact that it is the only type capable of recreating deep scenes with high resolution: 1. Laser light is required for illumination. 2. Much space is required behind the hologram.

With the advent of visible diode lasers, we can confidently predict that such holograms will be in increasing demand, if the space problem can be solved.

HOE offers such a solution.

When a pulsed portrait is made, the reference source location is usually several meter away. Figure 5 shows schematically how a HOE can be made to solve the play back problem.

It is created by interfering what resembles the original reference beam with one nearby. When it is illuminated by the near source, the far beam is recreated, as shown. If the hologram is sandwiched to the HOE, it becomes correctly illuminated.

Figure 6 shows a convenient design for showing <u>any</u> deep scene transmission hologram with a suitably designed HOE.

## Cylindrical Hologram Maker

We have been involved in making cylindrical holograms since 1966[3]. The usual configuration is to diverge a beam with a spatial filter plus a large negative lens so that the outer cone of light serves as reference beam, and the center portion serves as the object beam.

In addition to being rather cumbersome, this technique also limits the subject to be illuminated only by a point source directly above.

By creating a special HOE as shown in Figure 7, cylindrical holograms with diffused lighting for the subject can be made simply as shown in Figure 8.

To make the HOE, uniform light is transmitted through a large plano-convex lens with a disc of ground glass at the center. The cone of converging light, as well as the diffused light, interferes with a converging reference beam on the photoplate.

To make a cylindrical hologram, a single beam through a spatial filter enters the HOE, as shown in Figure 8. The diffracted light recreates both the diverging cone toward the film as reference, and the diffused light for illuminating the object.

The reference to object beam ratio can be adjusted by moving the point source nearer or farther from the HOE. At a far location, the gaussian beam has a flat profile at the location of the HOE, causing the reference to object beam ratio to be higher. At the nearer location, the tail of the gaussian beam serves as a weaker reference beam, resulting in a lower ratio.

## Conclusion

We have demonstrated that HOEs can help making or viewing hologram simpler, less costly, and with higher efficiency and flexibility.

## References


1. Leo Beiser, HOLOGRAPHIC SCANNING, Section 5.3, John Wiley and Sons (1988)

2. Tung H. Jeong, "Holographic Systems with HOE and Optical Fibers", SPIE Vol. 615 (1986)

3. Tung H. Jeong, "360$^{o}$ Holography", J. Opt. Soc. Am., Vol 56, No. 9, 1263-4 (1966)

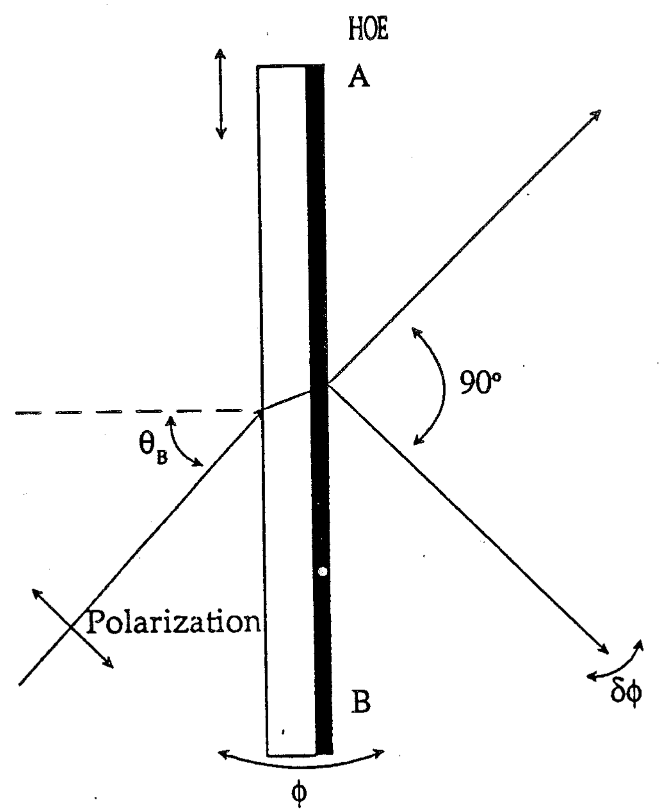


Figure 1

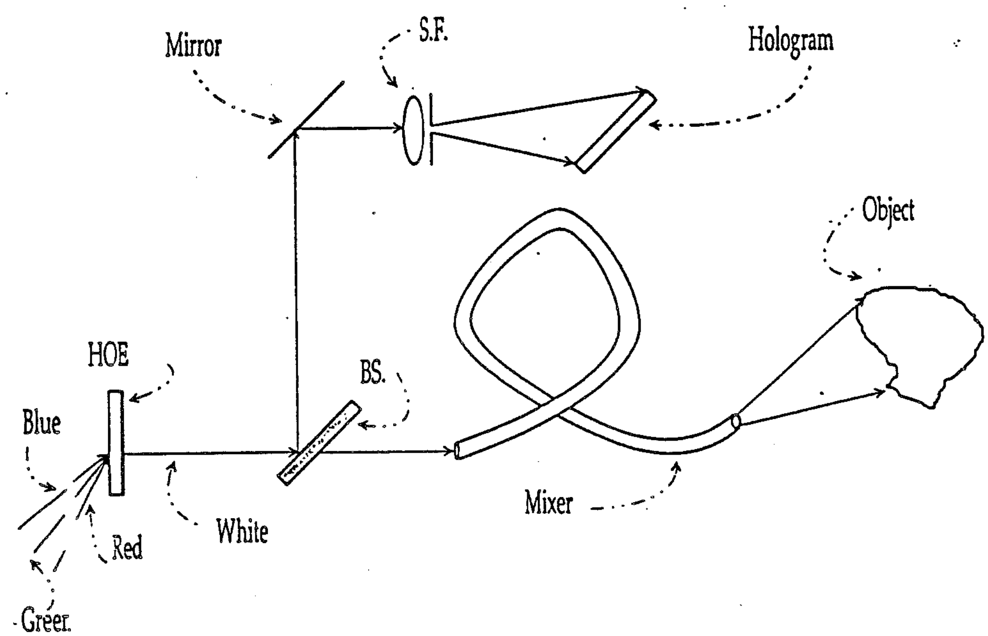


Figure 2

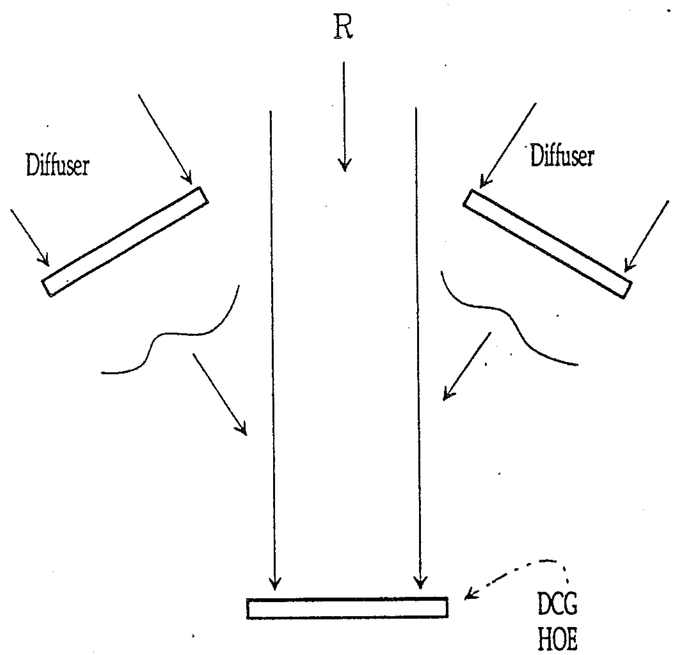


Figure 3

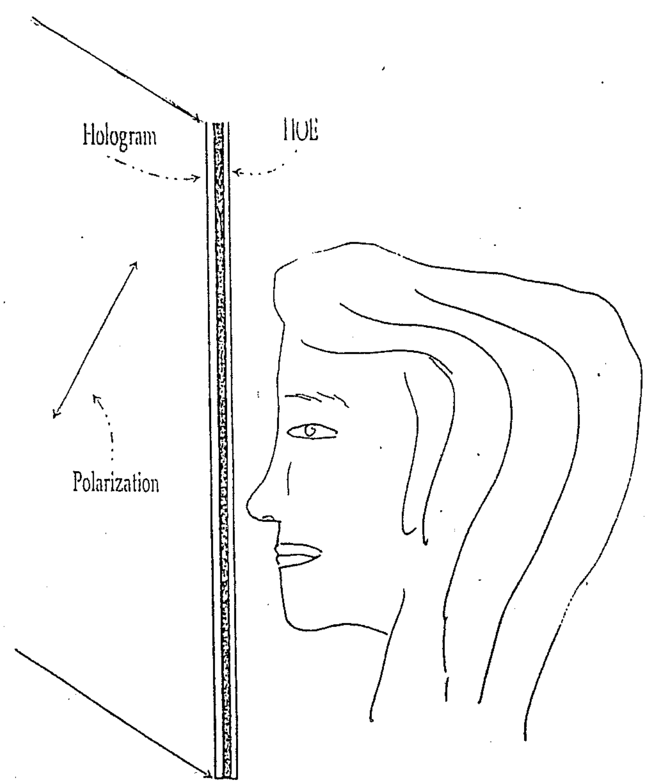


Figure 4

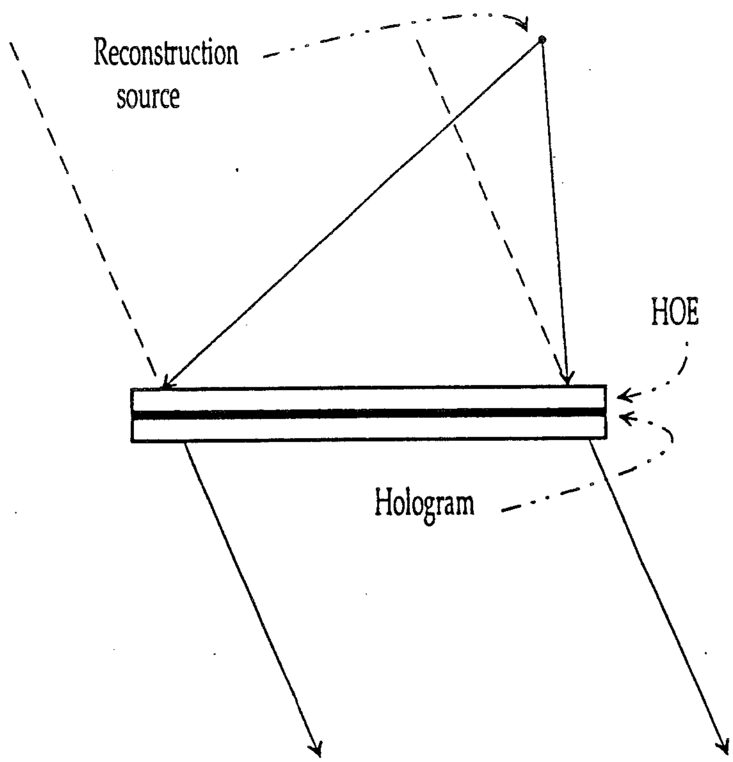


Figure 5

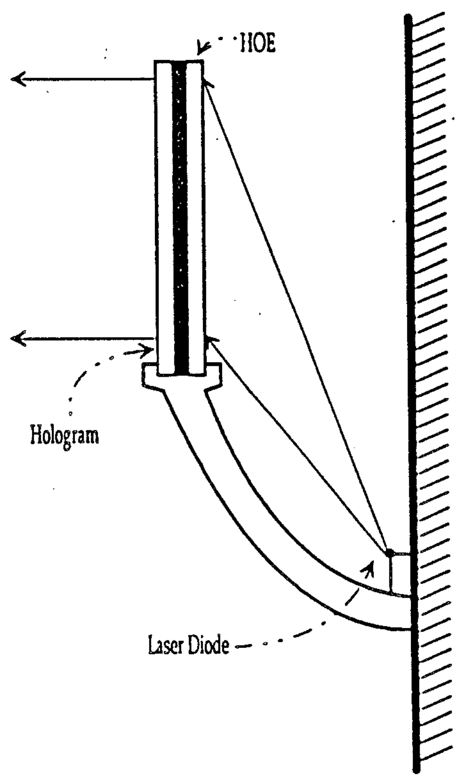


Figure 6

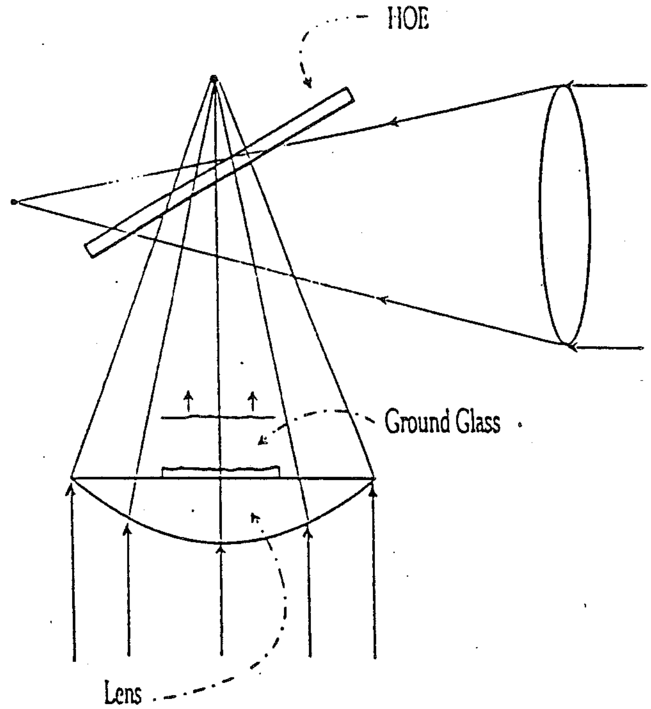


Figure 7

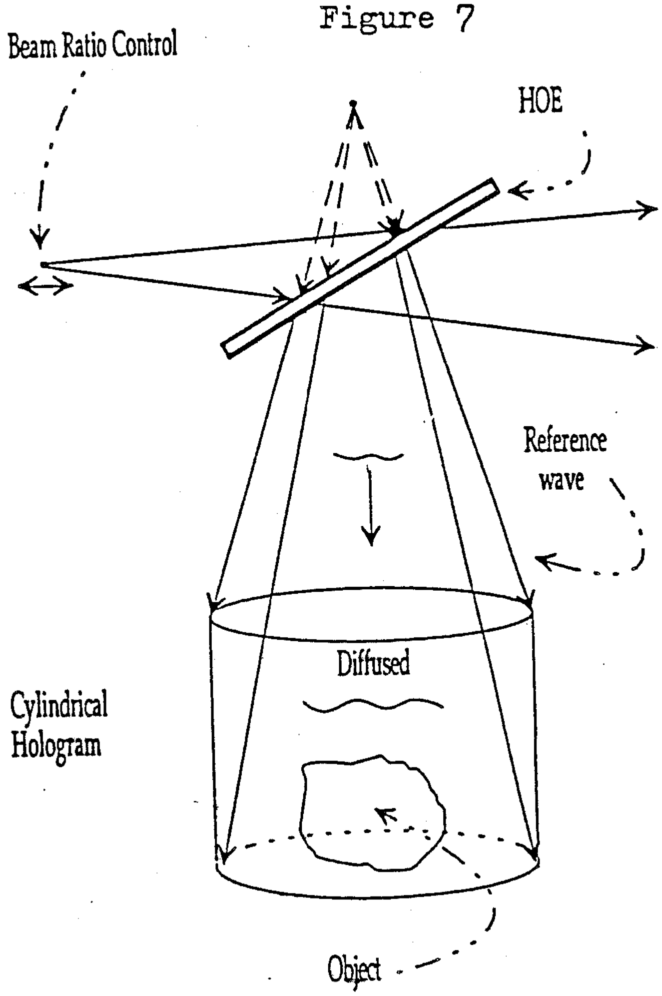


Figure 8