# DESIGN AND DEVELOPMENTAL ASPECTS OF HOLOGRAPHIC SIGHT FOR RIFLES AND CARBINE

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## ABSTRACT

The development and improvement of holographic sight is continuing with better accuracy, reduced size and greater simplicity. In this work, for a given requirement, a holographic sight was designed and developed to get an optimum performance of the parameters like – range, field of view, elevation, and windage adjustments of the stable image of the reticle for zeroing in on the target. It is achieved by considering the critical aspects of optical, mechanical and electronic circuitry for controlled light output in the device. The design incorporates a laser diode light source and a pair of holographic elements (reticle and collimator) to make the sight achromatic, thus avoiding sighting errors due to laser diode wavelength drift. The complete assembly of the holographic sight consists of only four components namely, laser diode, holographic collimator, plane mirror and the reticle hologram. The virtual image of the reticle can be adjusted to coincide with the impact point of the bullet by adjusting the laser diode position.

**Key words:** Holographic optical elements, laser diode, optical and mechanical design, reticle

## 1. INTRODUCTION

Generally, the in-service rifle and carbine have iron sights. In addition, a day light telescope sight and a passive night sight have been provided to the rifle to enhance the accuracy and night engagement of targets. Even though these sights are extremely useful and effective for aimed firing, their utility in Close Quarter Battle (CQB) role of Rifle and Carbine is limited. Quick and accurate aiming is essential to achieve the desired effect in CQB role. Hence, there is a requirement of providing a sighting system in keeping with the latest technological developments.

At present, there are two types of systems, Red dot and Reflex sights, which provide the capability to aim at the targets by using short range guns. Red dot sight, a tubular type, uses refractive or reflective optics to generate a collimated image of a luminous reticle or a Light Emitting Diode. This collimated image appears to be projected out to a point at infinity, which makes the image of the reticle appear to the user to be projected onto the target. Parallax compensation is not perfect in these types of sights. While these systems can be fabricated using conventional lenses and mirrors, Holographic recording of reticle image ( Holographic gunsight[1, 2] ) can make the system considerably more compact and parallax- compensated.

In this paper, system design of holographic sight based on a pair of holographic recordings, one record of a reticle and another record of a collimating lens with an off-axis arrangement have been worked out. Both the recorded plates are mounted in their respective housings in such a way that the diffracted light from the holographic collimator is made to illuminate the holographic reticle display window. This sight is required to meet the functional aspects of range, field of view, weight, zeroing of center dot of the virtual reticle image and other electronic control features of the laser light.

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Optical Technologies for Arming, Safing, Fuzing, and Firing III,
edited by William J. Thomes Jr., Fred M. Dickey, Proc. of SPIE Vol. 6662, 666207, (2007)
0277-786X/07/$18 · doi: 10.1117/12.731314

## 2. SYSTEM DESIGN CONSIDERATIONS OF HOLOGRAPHIC WEAPON SIGHT

General requirements in the design of holographic sight are:

i. Size of the reticle and Maximum peripheral vision covering the entire display window to get maximum field of view
ii. Reticle Hologram recorded with a standard reticle (circle with center dot & quarter ticks)
iii. Compensation for wavelength shift and temperature change
iv. Holographic collimator recorded with a parallel beam of light
v. Movement provided to the laser diode for elevation and windage adjustments of the reticle pattern for zeroing
vi. Other controlled parameters like ON and OFF, brightness control of the reticle image, auto-shut off and indication of blinking of image when the battery starts getting discharged
vii. Night vision compatibility is given in the electronic system. Intensity gets reduced when the Image Intensifier tube is switched ON
viii. Mechanical Base of the sight to fit on the rifle with a mount

### *2.1 Design and development of reticle:*

As Holographic weapon sight is aimed for Closer Quarter Battle purpose, a standard reticle indicating a Circle with a center dot and quarter ticks has been designed and developed on a BK7 glass for a range of about 100 yards. At 100 yards, the 6 feet man completely covered within the circle and center dot represent the center position of the man. It is also used for fast aiming purpose. For this purpose, the circle has the size of 65 moa and dot has the 1 moa at 100 yards. To meet these requirements, the circle size of 3.815 mm and dot size of 0.058 mm were designed with ZEMAX software and chosen to project the required image with a doublet at 100 yards to cover 1 moa.

### 2.2 Recording of reticle hologram:

Standard setup for hologram recording is arranged by using NEWPORT vibration free table and other holography setup components. Recording of reticle hologram involves setting up of an optical set-up as shown in Fig. 1, in which He – Ne laser light is split into two parts by beam splitter. One beam passes through a spatial filter to reduce unwanted

Fig 1. Experimental Set-up for Recording Reticle

information (noise) in the beam. The emerged light from the spatial filter will be incident on the reticle mask. The image of the reticle is projected to the recording plane by using projection lens. Second beam is made to pass through the spatial filter and collimated by a lens. This collimated beam coincides with object beam at recording plane. These two mutually coherent beams produce interference pattern on the PFG 01 recording plate. One of the beam contains the information of the object (reticle) and hence it is called object beam. The other beam called reference beam is reproduced in the reconstruction of the hologram to generate the object beam. An important aspect of the recording geometry is the selection of the reference beam (divergent/collimated). The requirement to produce the same reference beam (and hence the same divergence) is difficult to meet when the laser diode is used for display. In the present design, we have used collimated reference beam, which is a link to facilitate the use of a He – Ne laser for recording and a laser diode for display. In these studies, Silver halide sensitized gelatin (SHSG) technique[3] is used for the production of phase transmission holographic reticle to have about 90% diffraction efficiency.

**2. 3 Compensation for wavelength shift and temperature change:**

The availability of low cost visible laser diodes makes it viable to produce holographic gun sights for the commercial market. However, the emission wavelength of a laser diode increases with temperature by as much as 0.25nm/°c and the diffraction angle of a hologram increases with wavelength. So the resultant beam from laser diode will be elliptical. A stable aiming pattern is not possible by simply illuminating the reticle hologram directly with a laser diode.

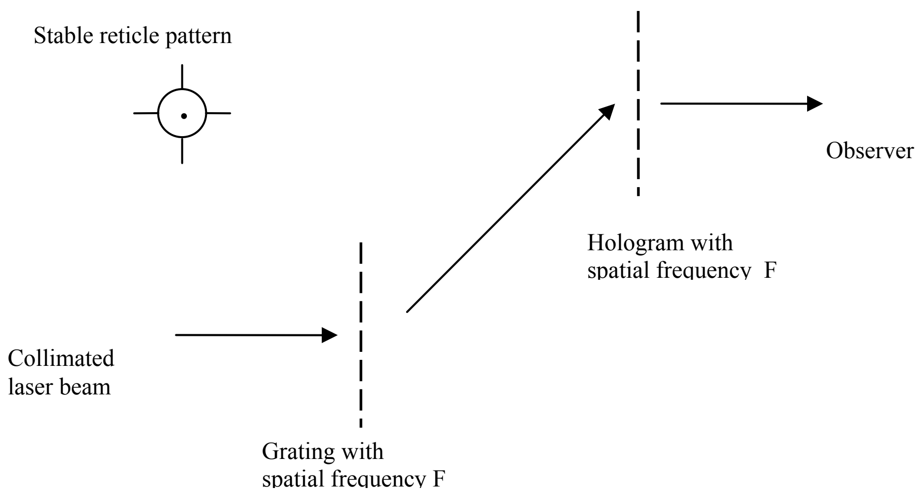


Fig.2. Basic concept of passive wavelength drift compensation

Temperature change causes the shift of wavelength in a laser diode. This wavelength shift produces the corresponding shift of diffraction angle of the hologram. The relation between wavelength (λ) and diffraction angle (θ) is (for normal incidence)

$$\text{Sin}\,\theta = F\,\lambda \qquad (1)$$

where 'F' is the spatial frequency of grating.

This means that the temperature change shifts the position of the virtual image (reticle). This disturbs the zero – in setting of the reticle with the weapon (rifle or carbine). A better approach is to passively compensate for the dispersion. The concept of achromatization is met by using a holographic grating with the same spatial frequency as of reticle hologram. The collimated beam is diffracted first by grating, which is then used to illuminate the reticle hologram as shown in Fig.2.

The diffraction angle (θ) of the grating can be defined as

$$\text{Sin } \theta = F \lambda - \text{Sin } i \quad (2)$$

where i is the incident angle.

This diffraction angle (θ) of the grating becomes the incident angle of the illuminating beam for the hologram. The output beam angle ($\theta_0$) after diffraction by the hologram (i. e the angular position of virtual image) is

$$\text{Sin } \theta_0 = F \lambda - \text{Sin } \theta \quad (3)$$

Using equation (2) this becomes

$$\text{Sin } \theta_0 = F \lambda – (F \lambda - \text{Sin } i)$$

$$\text{Sin } \theta_0 = \text{Sin } i \quad (4)$$

Output beam angle ($\theta_0$) becomes independent of wavelength (λ). Wavelength change does not affect the position of the virtual image (reticle).

In the earlier versions, the diffraction grating is recorded by two collimated beams. The angle between the two beams is the same as the recording of hologram of the reticle. Thus, spatial frequency remains the same for both the hologram of reticle and the grating. This is exactly true for the central point in the reticle image which is also the aim point for the holographic sight.

The emission wavelength can vary significantly with temperature which causes a shift in reticle position. In the next generation sight [2], holographic grating and collimating reflector are used to compensate this effect. However, this adds an additional component in the device. To reduce the extra component for a compact device, the function of collimation and temperature compensation are incorporated in one element. This element is basically a holographic collimating lens with the same spatial frequency as that of a reticle hologram. It replaces the conventional collimator in the device. The device holographic collimator works as good as with the diffraction grating.

### *2.4 Recording of Holographic Collimator lens:*

A Holographic collimator is made by recording the interference pattern of two beams viz., diverging beam (reference beam) and the collimated beam (objective beam) derived from the same laser source. The recorded interference pattern is processed to obtain a hologram. If the hologram is illuminated by a collimated beam of light from the opposite side, the light will focus to the point where the spatial filter was located while the construction of the hologram and this hologram will act as a holographic lens.

In this device, off-axis holographic lens is required. The optical geometry for recording of the holographic collimator is shown in Fig.3. Coherent light from a laser source splits into two parts by a beam splitter. One of the beams is made to pass through a spatial filter to produce a divergent beam. Another beam is made to pass through a spatial filter and collimated by a well - corrected lens.

The Holographic Optical Element (HOE) collimator is constructed by the superposition of a divergent beam (reference) and a collimated (object) beam at an angle 45 degrees on the same side of the plate. After recording and processing the recorded PFG 01 plate by using the procedure, as it is done in the case of reticle hologram, Collimated beam can be obtained from HOE collimator at an angle of 45° to the axis, by illuminating it with an original reference beam.

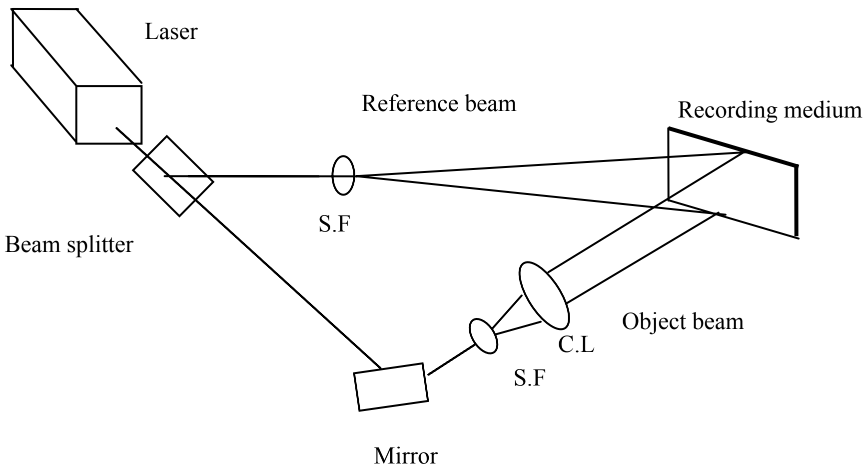


Fig.3. Set-up for recording of the HOE Collimator

**2.5 Reconstruction of the reticle image from the Hologram:**

The holographic weapon sight (HWS) shown in Fig. 4 employs four major components, namely, laser diode, holographic collimator, mirror and reticle hologram.

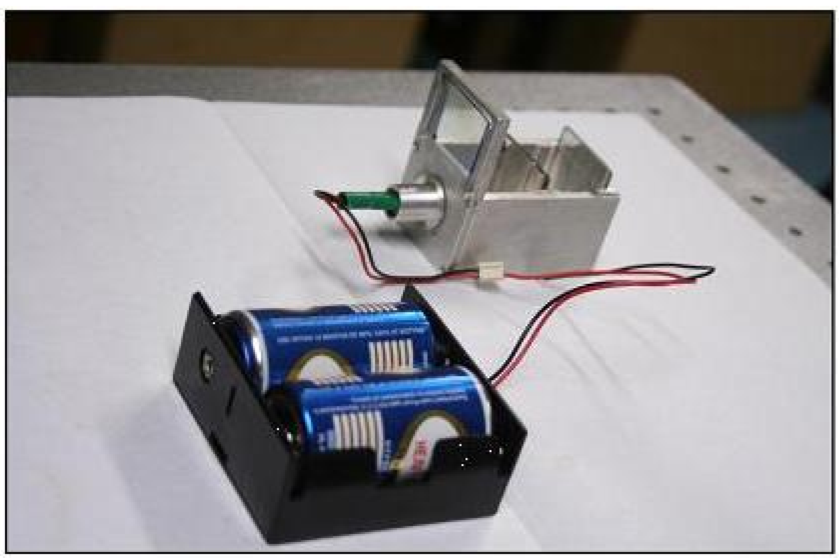

Fig.4. Set-up for the reconstruction of Holographic Weapon Sight (H.W.S)

When divergent beam from a laser diode of wavelength 635 nm passes through this holographic collimator initially, it acts as a transparent glass plate. Then this divergent beam reaches the mirror and returns to the holographic collimator. Since the optical path traveled by the laser beam up to this point is equal to the focal length of the holographic lens, the collimated beam generates in the direction of first order diffraction. Thus, this holographic lens acts as an off axis holographic collimator at this point. The collimated beam acts as reference beam for reticle hologram and the virtual image (Fig.5) of the reticle is seen by the observer. Laser diode, holographic lens and mirror are placed at the bottom portion of the device with the reticle hologram on the upper side. For target scene, the reticle hologram acts as transparent glass window. Thus its field of view is limited only by the size of the window. It is almost equivalent to view by naked eye and hence provides unlimited field of view practically. Thus, unit magnification target scene is observed with the superimposition of the holographic pattern (reticle) through the window of holographic sight.

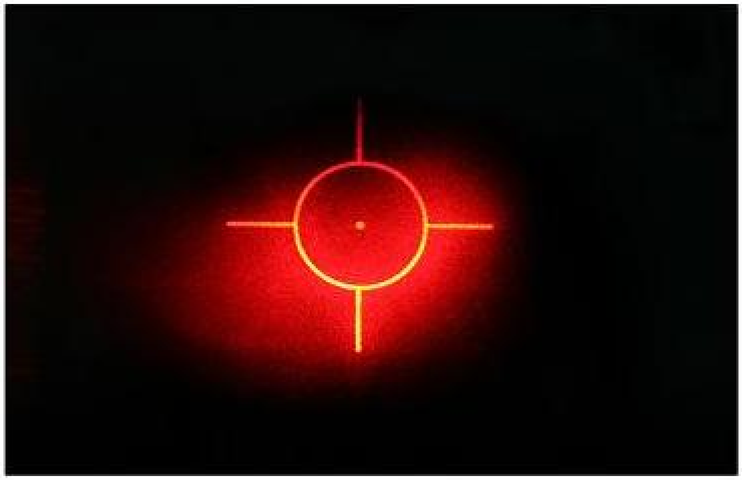

Fig.5. Reconstructed image of the Reticle

**2.6 Mechanical housing of the Holographic sight:**

A combination of two holographic sub-systems (Holographic reticle & Holographic collimator) is mounted in respective housings for the reconstruction of virtual image of the reticle and to aim at the target as shown in Figs. 6 & 7. Quick target acquision is achieved with both the eyes open through the display window of size 33x26mm. A mirror is provided to the holographic collimator for folding the optical path, thereby reducing the size of the device. It is essential for HWS to have zeroing adjustment to enable coincidence of the aiming dot with the axis of the weapon at the specified distance. For this purpose, holographic reticle (image) needs to be moved in horizontal and vertical planes. This is achieved by moving the collimated beam of light coming from the optical channel. The required movement can be provided to any of the optical components like laser source, Holographic collimator and mirror. Giving movement to either collimator and mirror makes the mechanical movement complicated when compared to the movement of the laser diode. As the collimator and mirror are large in size, precise movement cannot be provided. In laser source movement, when a small movement is provided, a sufficient amount of reticle movement is observed. Due to this reason, movement of laser is being adopted as on date.

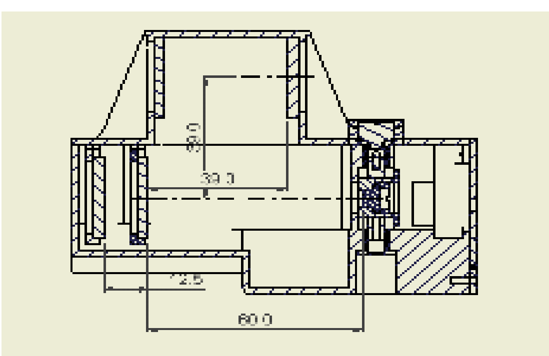


Fig. 6. Cross section of the sight

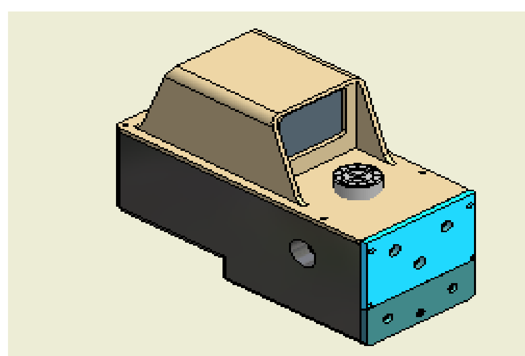

Fig. 7 . Holographic weapon sight

### 2.7 Electronics to control the Laser beam output:

Holographic Sight, used by the shooter, is to align the targets with precision, speed and highest aiming accuracy. It helps in enhancing the response time of weaponry. A virtual aiming reticle pattern is created by a holographic display window by illuminating it with a bright red laser beam allowing quick target acquisition. A laser diode is used for generating the laser beam. To control the brightness of the laser diode, Pulse Width Modulation is used instead of varying the applied voltage to the laser diode as it causes distortion in the pattern. One touch operation of night mode (with reduced brightness) is provided in the system. And also the user can change the brightness as per his wish. The system goes to power save mode automatically if the system is idle to save the power. The low battery indication is also provided by flashing the display at regular intervals. All the above features are implemented using a single cycle micro controller. The system is powered by two batteries (1.5 Volts each), which are commercially available. The power consumption of the system is also very less to provide long life to the batteries. Further, the holographic reticle in the sight has been designed to be instantly visible in any lighting conditions, instinctive to centre regardless of the shooting angle and to remain in view while sweeping the engagement zone. Gunner can open both his eyes in shooting with this sight. The gunner can also see through any portion of the window even if the laminated window is shattered. Complete reticle remains visible in the target scene in this extreme case and the gunner can still shoot the target. This is by virtue of the holographic recording of the reticle pattern in the complete window.

## 3. CONCLUSION

In this work, a holographic sight, used by the operator on a short – range gun, for fast acquisition, aligning the target with precision and aiming accuracy using an in-built reticle hologram was designed and developed. It helps in enhancing the response time of weaponry. Projecting the reticle image to infinity reduces the operator's fatigue, reaction time and ensures aiming accuracy in sight by eliminating parallax between the aiming reticle and distant object. Holographic sight allows the user to shoot quickly with both eyes open, provides large peripheral vision and desired accuracy when used with the in-service Rifle and Carbine in Close Quarter Battle role.

## ACKNOWLEDGEMENT

Authors wish to thank the Director, National institute of Technology, Warangal for allowing this work to be presented in the SPIE symposium.

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