

Advances in Holographic Data Storage: Optimizing Shape and Fringe Count

Rohan K. Patel and Nalini R. Rao

Rohan K. Patel, Department of Electrical Engineering,
Indian Institute of Science, Bengaluru, 560012, India

Abstract-- Holographic projection is a new wave of technology which changes the way we see things today. It has gained tremendous advantage in major fields of life including business, education, science, arts, healthcare etc. Digital holograms inherently have large information content and thereby lossless coding of holographic data is rather possible to some extent with the advent of speckled interference fringes. Our work reflects the key idea of determining the shape and fringe count which can be seen in a holographic recording media from a certain threshold distance. The application is found in data security and data compression.

Keywords-- Holographic Recording Media, Interference fringes, Holograms, Data Security, Data Compression

I. INTRODUCTION

Holography is a 3-D imaging method where the complex light wavefront reflected by objects is recorded. Obtaining image views of the object is then possible by reconstructing the recorded wavefront. Holography is a method evolved by Gabor in 1947, in which one not only records the amplitude but also the phase of the light wave. It is simply interference. During the recording process a standing –wave interference (fringe) pattern is generated where the reference beam and object beam interfere within the recording layer. This pattern can be recorded by a high-resolution photosensitive plate [1,5]. The orientation of the reference wavefront with respect to the object wavefront determines the physical parameters of the reconstruction geometry and the structure of the fringe pattern produced.

In the Fig. 1, S is an isotropic source which radiate monochromatic light of same intensity, there is a slit that divide this source into two parts S_1 and S_2 . P is a point at which these two waves i.e. reference wave and object wave interfere. When the waves interfere we get the pattern of fringes on the recording media. These fringes can be bright and dark. When the crest or trough of two waves or more waves meet, they form the bright or constructive interference. But when crest and trough of waves meet, it forms dark or destructive fringe pattern. [2, 4]

The paper starts by briefing about holography in section I. Section II describes the recording of hologram with its involved mathematical equations along with our approach regarding the structure of the fringes so formed. Section III presents number of fringes that can be obtained on a holographic recording medium. Section IV gives the conclusion of paper and ends by giving references in section V.

II. FRINGE STRUCTURE

A. Determination of structure of fringes

During the recording process a standing – wave interference (fringe) pattern is generated where the reference beam and object beam interfere within the recording layer. This pattern can be recorded by a high-resolution photosensitive plate. The fringe pattern's orientation or fringe angle is described by

$$\theta_f = \theta_{obj} + \theta_{ref} / 2$$

where θ_f is the angle at which the fringes are oriented in the photosensitive layer, and θ_{obj} and θ_{ref} are the angles of the object and reference wave with the recording media.[7]

Let the distance between source S_1 and S_2 be 'd', then from the point 'O' both source will be at 'd/2' distance (Fig. 1).

For 2-D Plane:

Y axis will be parallel to S_1S_2 . Let the coordinates of S_1 be $(0, \frac{d}{2}, D)$ and S_2 be $(0, -\frac{d}{2}, D)$.

where D is the distance between slits and recording media.

Now, path difference (Δ) will be

$$S_2P - S_1P = \Delta = [x^2 + (y-d/2)^2 + D^2]^{1/2} - [x^2 + (y + d/2)^2 + D^2]^{1/2}$$

$P(x, y, 0)$ since 2-D plane, so z-axis = 0

The shape of the reference and object wavefront will affect fringe structure, but the angular separation of their wavefront is the main determination of the fringe orientation. [3, 6]

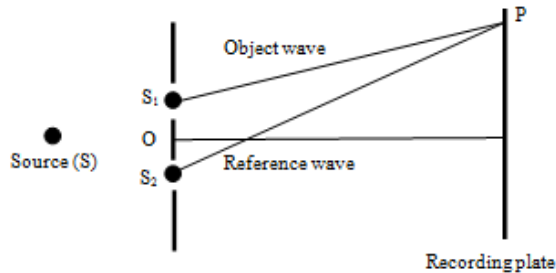


Fig. 1: Interference Fringes formation [3]

B. Recording of a hologram

Let us take an isotropic point source (which radiates the same intensity of radiation in all directions.) The source is further divided into two parts to get two individual sources for reference wave and object wave of same phase and same frequency. Amplitude of wave is represented by ‘A’.

Complex amplitude of a wave

$$A(r, t) = \left(\frac{a}{r}\right) e^{i(\omega t - kr)}$$

where, $r = (x^2 + y^2 + z^2)^{1/2}$ [5,6]

From the above amplitude equation we observe amplitude decreases as r increases.

$$\frac{[x^2 + (y + d/2)^2 + D^2]}{\{\Delta + [x^2 + (y - d/2)^2 + D^2]^{1/2}\}^2}$$

On solving the above equation we get,

$$(2yd - \Delta^2)^2 = (2\Delta)^2 [x^2 + D^2 + \frac{1}{4}(d^2 - D^2)]$$

$$Y = \pm \Delta^2 / (d^2 - \Delta^2) [D^2 + \frac{1}{4}(d^2 - \Delta^2)] \quad (1)$$

Eq. 1 represents a **HYPERBOLA**.

However, when we assume $x^2 \ll D^2$ i.e. the slits are far away from the screen, it forms a **STRAIGHT LINE** pattern fringe. [8]

Therefore, from the above derivation we acknowledge that fringes are hyperbola in shape but when screen is far from slit then it forms a straight line fringe pattern.

III. FRINGE COUNTS

Let us determine the number of fringes in a small part of hologram.

We can decide number of fringes in a small part of hologram by **calculating fringe width**. Fringe width is a distance between two

successive bright fringes or two successive dark fringes. In an interference pattern, the fringe width is constant for all the fringes. It means all the bright fringes as well as the dark fringes are equally spaced.

Let us see the fringe pattern in the Fig. 2

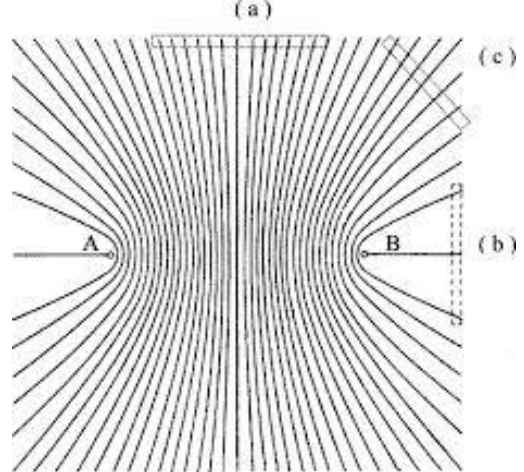


Fig. 2: Fringe pattern [9]

We can see the fringe pattern in Fig. 2, there are both bright fringes and dark fringes. Here bright fringes are shown by black solid line and dark fringes are represented by blank white space. When a wave meets at the center of fringe pattern i.e. at line (a) we get a central maxima (or zero maxima) of the fringe. We have dark fringe or first minima adjoining the central maxima, and then we have first maxima after first minima and so on. This shows that, if we take any point on vertical line (a) we will always get maxima and same for other lines.

Suppose we have a recording plate of dimension $n \times n$. Next, we take a small part of recording plate of dimension (say) $a \times a$.

Thereby, we can calculate fringe width by using formula:

$$W = \lambda D / 2d$$

(for both bright and dark fringes).

With the amount of number of countable integer fringes we can then estimate the number of fringes in area $a \times a$ and later in whole $n \times n$.

IV. CONCLUSION

In this paper, we have presented a key aspect to count number of fringes in a given holographic recording medium of certain area by assuming a linear shape of fringes which is obtained when the distance between the

recording medium and the slits is quite long. The application of the finding can be stretched out in lossless/lossy coding of data by saving the data as holograms and further using the dictionary technique to store the linear interference patterns.

V. REFERENCES

- [1] J. Goodman "Introduction to Fourier optics" Chapter-9 Holography "
- [2] Andrew Chan "Digital hologram".
- [3] Guy E. Bleiloch "Introduction to optics."
- [4] H.C. Verma "Concepts of physics volume-1".
- [5] Tung H. Jeong "Fundamental of photonics"(Module 1.10--Basic principle and application of holography).
- [6] E. S. Maniloff, D. Vacar, D. McBranch, et al., Optical Holography (Academic, New York, 1971).
- [7] N. V. Kamanina, L. N. Kaporskii, and B. V. Kotov, Optical communication. 152(4-6), 280 (1997)
- [8] E. S. Maniloff, D. Vacar, D. McBranch, et al., Optical Theory.
- [9] Huai M. Shang, Cheng Quan, Cho J. Tay, and Yua Y. Hung "Generation of carrier fringes in holography and shearography", Vol. 39, Issue 16, pp. 2638-2645 (2000), doi: 10.1364/AO.39.002638