

A STUDY ON HOLOGRAPHIC MOTION PROBLEMS

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PREFACE

Holographic interferometry¹⁻⁶ has now become an important method for nondestructive analysis of motion of three dimensional objects with finished smooth, partially finished or rough surfaces. The technique can be used through real-time, multiple exposure or time-average approach. Even though much has been done to develop the technique, work is still going on for its full utilization under realistic conditions. In this context, the present thesis is mainly devoted to some problems of holographic interferometry such as time-average holography when a preexposed or postexposed medium is employed for the recording, time average holographic interferometry of severe motions, time average holography of constant acceleration motion, triple exposure stroboscopic holographic interferometry, and holographic analysis of motion of objects vibrating sinusoidally with uniform slow drift.

A few other problems where motion or displacement is involved are also included. These are - role of preexposure or post-exposure in mechanical stability requirements during holographic recording, use of the time-average technique in linear hologram recording without using an intense reference beam, the recording linearity in multiple-exposure holography, and holographic recording of moving objects.

The above work is reported herein, in the following chapters.

CHAPTER-I

REDUCTION IN HOLOGRAM RECORDING TIME BY THE METHOD OF
PREEXPOSURE OR POSTEXPOSURE AND ITS ROLE IN SOME ASPECTS
OF MOTION PROBLEMS

Due to low sensitivity of recording materials employed in holography, exposure times of even several minutes are common when ordinary cw lasers are employed. In order to overcome this difficulty, Hallock⁷ suggested to preexpose or postexpose the recording medium uniformly and to record the main hologram fringes on the same medium for a significantly less time. The technique is also useful when the available laser power is limited or when the object can not be illuminated intensely due to the radiation damage to it. Further it finds application when a linear recording without using an intense reference beam is desired. A general analysis of the technique is presented in this chapter.

Reduction in the exposure time for the main record reduces the requirements of mechanical stability during the recording process. After briefly discussing other available methods to meet the mechanical stability requirements, the role of pre-exposure or postexposure is discussed and compared with scanned beam holography⁸.

In motion analysis by time-average holography⁵, the reduction in the exposure time increases the measurement range in case of constant velocity motion. This is discussed in detail.

Finally, some aspects of holography, such as the effective

beam-intensity ratio and the reconstruction efficiency are discussed, when the time-average recording is performed on a preexposed or postexposed medium.

While eliminating the intense reference beam by the method of preexposure or postexposure, the reconstruction efficiency can be retained by maintaining the resulting exposure. This is discussed in Appendix-A.

CHAPTER-II

TIME-AVERAGE HOLOGRAPHY WHEN THE OBJECT MOTION IS ONLY DURING A PART OF THE TOTAL EXPOSURE INTERVAL AND IT'S APPLICATION TO INCREASE THE MEASUREMENT RANGE

In this chapter is presented a detailed analysis of time-average holographic interferometry for the case when the motion is only for a part of the total exposure time. In this, for a part of the time the hologram is recorded with the object in static position and for the remaining exposure with the object in motion. This increases fringe-spacing and intensity on the reconstructed pattern and thus helps in the holographic measurement of severe motions. Detailed solutions of the technique are obtained and discussed for step-motion, sinusoidal vibration and constant velocity motion. The visibility of the reconstructed fringes is also discussed in detail for these motion forms.

CHAPTER-III

USE OF TIME-AVERAGE HOLOGRAPHY IN LINEAR HOLOGRAM RECORDING WITHOUT INTENSE REFERENCE BEAM

It is found that a time-dependent phase modulation of the object or the reference beam, uniformly over the recording plane, can give a high effective reference to object beam intensity ratio. This helps in the linear recording without using an intense reference beam. The general theory of the technique is presented with a discussion of its effect on the reconstruction efficiency. A technique to retain the reconstruction efficiency by maintaining the hologram fringe contrast and the average exposure while eliminating the intense reference beam is also presented.

CHAPTER-IV

RECORDING LINEARITY IN MULTIPLE-EXPOSURE HOLOGRAPHY

Incoherent superposition of holograms or the multiple exposure holography is now used in many interferometric and other applications. In this chapter, the recording linearity of this type of hologram has been studied from the point of view of beam intensity ratio. It has also been found that there is a one-to-one relationship between the multiple exposure holography and the time-average holography as far as the recording linearity is concerned. Specific analysis is also presented for the double-exposure holographic interferometry.

CHAPTER-V

HOLOGRAPHIC RECORDING OF MOVING OBJECTS

In the holographic recording of a moving object, the signal beam path length at the recording plane changes during the exposure interval resulting in an unstable fringe pattern. This gives a degraded image of the object on reconstruction. However, under some specific conditions of the holographic system orientation⁹⁻¹² and employing a pulsed laser¹³, the signal beam path length does not change effectively even when the object is moving fast. In this chapter, we discuss these conditions in detail for general forms of motion. Specific discussions are made for three important motion forms - constant velocity motion, constant acceleration motion, and sinusoidal vibration.

CHAPTER-VI

SOME SPECIFIC MOTION PROBLEMS

This chapter deals with some specific problems of holographic interferometry.

Characteristic function of time-average holography is evaluated and discussed when the object is moving with constant acceleration. This helps in analysis of the motion from reconstructed image of the object under this type of motion.

If an object is vibrating sinusoidally with an uniform slow

drift, the reconstruction will display fringes representing the combined effect of both the components of the motion. A Moire technique, which is to superimpose two reconstructed patterns of slightly different exposure times is suggested to separate out the two components of the motion.

A triple-exposure technique is also discussed which reduces the recording time during the pulsed illumination in stroboscopic holographic interferometry to half that is required in the corresponding double exposure method^{14,15}. It has also been found that monitoring of the bright reconstructed fringes is easier in the suggested technique.

Recording time during the pulsed illumination in stroboscopic holographic interferometry can also be reduced by increasing the exposure time with the object in static position and reducing the exposure time accordingly during the pulsed illumination. This is discussed in Appendix-B.

A part of the work reported in this thesis has resulted in the following research articles:-

1. **Holographic images of objects moving with constant acceleration**, Appl.Opt., 10, 672 (1971).
2. Performance of pre- or postexposed holograms, Appl.Opt., 10, 2195 (1971).
3. Time-average holography of objects vibrating sinusoidally with uniform slow drift, Phys.Lett., 35A, 460 (1971).
4. Use of pre- or postexposure in holographic measurement of high velocities, Phys.Lett., 36A, 279 (1971).
5. A new method for linear recording in holography, Optica Acta, 19, 39 (1972).

6. A new method for linear recording in holography retaining the reconstruction efficiency, *Optica Acta*, 19, 709 (1972).
7. Some aspects of holography when the time-average recording is performed on a preexposed or postexposed medium, *Appl.Opt.*, 11, 2933 (1972).
8. Recording linearity in multiple-exposure holography, *Nouv.Rev. d'Opt. Appl.*, 3, 185 (1972).
9. Holographic recording of moving objects, *Nouv.Rev. d'Opt. Appl.* (In press).
10. A triple-exposure technique to reduce recording time in stroboscopic holographic interferometry, *Optics Communications*, 6, 295 (1972).
11. A technique to retain the hologram reconstruction efficiency in elimination of the intense reference beam by the method of pre- or postexposure, *Optica Acta* (In press).
12. A direct approach to reduce recording time in stroboscopic holographic interferometry, communicated.

In addition to the work reported in detail in the thesis, the author has also to his credit the following publications related with motion analysis by holography:

1. Use of phase holograms for phase-difference amplification, *Optics Communications*, 2, 444 (1971).
2. Performance of thin phase recording emulsions in holographic motion analysis, *Phys.Letters*, 37A, 165 (1971).
3. Time-average holography with thin phase recording materials, *Nouv. Rev.d'Opt. Appl.*, 3, 85 (1972).

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