SCIENTIFIC AND INDUSTRIAL APPLICATIONS OF DIGITAL HOLOGRAPHY

by

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2010

CERTIFICATE

This is to certify that the thesis entitled **"SCIENTIFIC AND INDUSTRIAL APPLICATIONS OF DIGITAL HOLOGRAPHY"** being submitted by **GYANENDRA SHEORAN** to the Indian Institute of Technology, Delhi for the award of the degree of "**DOCTOR OF PHILOSOPHY**", is a record of the authentic research work carried out by him under our supervision and guidance. He has fulfilled all the requirements for submission of this thesis, which to the best of our knowledge has reached the required standard.

The material contained in this thesis has not been submitted in part or full to any other University or Institute for the award of any other degree.

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ACKNOWLEDGEMENT

I express my profound indebtedness to my Supervisor **Prof. Chandra Shakher** for his constant encouragement, guidance and never-ending patience. Credit of introducing me to the area of digital holography goes to him.

I am highly grateful to **Dr. Dalip Singh Mehta**, **Dr. Mossaraf Hossain, Dr. Satish Dubey, Dr. Vani K. Channiwal** for their constant encouragement and inspiration. I am specially grateful to **Dr. Arun Anand** for his valuable scientific discussion and suggestions throughout my research work.

I am thankful to **Ms. Shobhna Sharma, and Mr. Ranjeet Kumar,** who has been with me during my research work in the laser applications and holography laboratory, Indian Institute of Technology, Delhi. I am also thankful to **Mr. Pradeep Kushwaha, Ms. Tulsi Anna, Mr. Ashish Pathak, Mr. Kapil Sharma, Dr. Rakesh Singh, Mr. Sunil K. Vyas, and Mr. Sarabpreet Singh** who have always been the source of inspiration to me during the present work.

Thanks are also due to the technical staff of the workshop in instrument design development centre for the help rendered by them. Particularly, **Mr. Rajaram** has been always more than eager to render helps. I am also thankful to **Mr. Surinder Singh and Mr. S. K. Bansal** for extending their valuable help at times.

The equipment used in the experiment which was purchased from **DST** project is greatly acknowledged.

At last, I express deep sense of gratitude to my parents, family members and friends whose support and inspiration in various stages of my research work in the laboratory have greatly helped me to realize this work.

Date: **24/06/2010** **Gyanendra Sheoran**

ABSTRACT

Optical interferometric techniques are more sensitive, accurate, precise and whole field in comparison to other conventional measurement techniques. These techniques are non-contact type and non-invasive. Digital holography has made possible the quantitative measurement of phase from a single hologram. This has provided a very powerful tool for optical metrology. Freedom from processing of recording material and direct availability of phase from one digital hologram has made interferometric processes faster, robust and almost real time. In this thesis the measurement of diffusion coefficient of miscible transparent liquids, monitoring the drying process of paint and detection of crack/ disbond in paint, by using lensless Fourier transform digital holographic interferometry (LLFTDHI) and tomographic imaging by swept source digital holography along with a filtering process by using the combination of sine/ cosine average filter followed by symlet wavelet are presented. The thesis is organized in five chapters –

Chapter I provides brief introduction of conventional holography and detailed description of digital holography including brief history of its development. Further, this chapter provides a brief description of different digital recording process and different numerical reconstruction techniques along with the application of LLFTDHI in optical metrology. This chapter also gives the brief outline of the research work presented in this thesis.

Chapter II describe the measurement of diffusion coefficient of binary miscible transparent liquid (aqueous solution of NaCl) using LLFTDHI. LLFTDHI is simple, easier to implement, need less optical components and is as accurate as other competitive techniques. In this method the

holograms of the diffusion process between distilled water and NaCl solution between two instances of time t_1 and t_2 is recorded and used to calculate the phase difference between them. By adding a linear phase to the calculated phase difference, the infinite fringe pattern is converted into a finite fringe pattern with two extreme points by adding a plane wave-front tilted at an angle of 0.02^{o} with the y-axis. The distance between the extreme points '*w*' in the recorded phase maps is determined after thresholding and binarization of the phase map. Using the value of the distance between the extremes '*w*', the value of diffusion coefficient is calculated. The calculated value of the diffusion coefficient achieved by this method is 1.6067×10^{-5} cm^2sec^{-1}. The measured value of the diffusion coefficient deviates approximately 1.06% from the value given in the handbook of electrolyte solutions by V. M. M. Lobo (Elsevier, 1989).

Chapter III deals with a potential industrial/ commercial application of LLFTDHI i.e. the visualization of drying process, crack in the surface of the paint and disbonding of the paint on the surface by monitoring the dynamics of the interference phase map between two wave-fields scattered from the surface of the paint during the drying process at two different times.

Wavelength scanning digital interferometric holography allows three dimensional tomographic images to be extracted with an improved signal to noise ratio (SNR), a more flexible scanning range, and an easier specimen size selection. In this chapter IV, a new method of swept-source digital holography (SS-DH) using a super-luminescent diode (SLD) as the broadband light source and an acousto-optic tunable filter (AOTF) as the frequency-tunable device is presented. With such an arrangement the wavelength range 800nm-870nm can be achieved. The angular spectrum approach to the scalar diffraction theory is used to reconstruct the images for each wavelength. The proposed swept source system provides a sufficiently broad range of tunability and can increase the axial range and the resolution of the reconstructed tomographic images using digital holography.

In any coherent imaging including digital holography and interference phase map made by digital holographic interferometry, the noise or other forms of contamination disturb the measured data. Frequently, unwrapping errors occur in isolated discontinuity points in low SNR region. These points are not the part of the actual intereference phase of the interferogram. It is difficult to distinguish between real phase jumps and jumps due to noise because they follow the same mathematical condition. Therefore there has to be a relationship between phase and preservation, noise removal and in the design of the filter. Many filtering techniques have been proposed to condition the phase before the unwrapping procedure. Chapter V describes sine/ cosine average filtering followed by symlet wavelet filtering is suggested to improve the interference phase map obtained by digital holographic interferometry because the suggested filtering technique is expected to have the capacity to preserve the border of the phase fringes and remove the isolated discontinuities like speckles and false phase fringes.

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