SCIENTIFIC AND ENGINEERING APPLICATIONS OF DIFFRACTIVE OPTICAL ELEMENTS

by

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Dedicated to

my parents

CERTIFICATE

This is to certify that the thesis entitled, **"SCIENTIFIC AND ENGINEERING APPLICATIONS OF DIFFRACTIVE OPTICAL ELEMENTS"**, being submitted by **Mr. Shashi Prakash,** to the Indian Institute of Technology, Delhi, for the award of the degree of **"DOCTOR OF PHILOSOPHY"**, is a record of the bonafide research work carried out by him under my supervision and guidance. He has fulfilled the requirements for submission of this thesis, which to the best of my 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 degree or diploma.

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Date: 23/7/02

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ABSTRACT

Diffractive optical elements (DOEs) are a class of optical components, which work on principle of diffraction of light. These are generally produced either by conventional holography or computer generated masks and fabricated using photolithography, laser beam writing, electron beam writing and other VLSI based techniques. Over the past few decades all these techniques have advanced significantly and the manufactured diffractive/hybrid diffractive elements have been satisfactorily used in optical systems such as super market scanners, fiber-optic interconnects/multiplexers-demultiplexers in fiber optic communication systems, head up displays in fighter aircrafts, solar concentrators, optical computing and in many other systems where it is difficult to use conventional optical systems. In the present thesis some applications of these diffractive elements in imaging and metrology have been discussed. The thesis is organized in five chapters, the details of which are given below.

Chapter I provides a brief introduction about design, fabrication and applications of DOEs. The principles of holographic imaging, details about the recording materials such as silver halide emulsions, dichromated gelatin, photo-resist, and variation of diffraction efficiency with thickness of recording material and refractive index modulation etc. for thick phase transmission holograms have also been discussed. Further, this chapter gives introduction to Talbot effect, Talbot interferometry and shearing interferometry.

Chapter II presents imaging in laser and white light using thick phase transmission hololenses. Configuration for recording of hololenses and optimized conditions for their playback to achieve compact imaging system for working under white light condition have been discussed.

The developed two hololens imaging system was able to resolve ≅ 30 lines/mm. This Chapter also deals with spatial frequency filtering using two thick phase hololenses.

Chapter III deals with application of Talbot interferometry for real time vibration measurement. A moiré pattern is formed between the Talbot image reflected from the object and a grating identical to beam splitter grating in the Talbot interferometer. The real time displacement of the point on a vibrating object is measured as a function of time by monitoring the intensity variation produced by the motion of moiré fringes. Using this technique, the amplitude of out-of-plane vibration, as well as the temporal phase lag between the driving force and the membrane oscillation of the loudspeaker has been determined. The technique is capable of measuring amplitude of vibrations from few microns ($\cong 10\mu m$) to few hundred microns in the frequency range of fraction of an Hz to several kHz. Technique has also been used to study the amplitude of vibration of the loudspeaker membrane as a function of driving force.

Vibration analysis using shearing interferometry and interferometric grating has been given in Chapter IV. Parallel plate shearing interferometry combined with moiré readout has been used to monitor/measure out-of-plane vibrations of loudspeaker membrane, excited by periodic and non-periodic force. Moiré fringes are produced between the fringe pattern from the shear plate and the interferometric grating recorded by photographing the fringe pattern generated by the shear plate. As in the case of vibration measurement using Talbot interferometry, this technique is capable of measuring vibration amplitude from few microns ($\cong 10\mu m$) to few hundred microns in the frequency range of fraction of an Hz to several kHz. This Chapter also deals with vibration analysis of reflecting object in time-average mode using the shearing interferometry and interferometric grating.

Chapter V presents a testing technique for collimation of light using Talbot interferometry with circular gratings. A theoretical model was developed for determination of sensitivity of measurement for collimation testing. Procedure to determine the sensitivity of measurement for collimation of optical systems is demonstrated. Experiments were performed with collimating lenses of different focal lengths and different grating separations. Experimental results of the investigation are presented which are in good agreement with the theoretical predictions. Experimental result reveals that collimation testing technique with circular gratings is more sensitive than that with linear and dual field gratings. Circular gratings are symmetrical about the center of the ring system and are aligned with center lying on the optic axis; hence they are immune to misalignment because of rigid body rotations in the plane perpendicular to the optic axis.

The work reported in this thesis has resulted in following research publications:

Shakher, C., and Prakash S., "Monitoring/measurement of out-of-plane vibration using shearing interferometry and interferometric grating" Optics and Lasers Eng, 38 (2002) 269-277.

Shakher C., Prakash, S., Dayanand, and Kumar, R., "Collimation testing with circular gratings", Applied Optics 40 (2001), 1175-1179.

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