SOME INVESTIGATIONS ON THE STATISTICAL PROPERTIES OF LASER SPECKLES

By

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Thesis submitted

in fulfilment of the requirements of the

Degree of

DOCTOR OF PHILOSOPHY

to the

Indian Institute of Technology, Delhi

Oct, 1979

ACKNOWLEDGEMENTS

It gives me great pleasure in expressing my deep sense of gratitude to Professor M.S. Sodha and Shri K. Singh, Assistant Professor, for their valuable guidance, stimulating counsel, magnanimity, and ever helpful attitude during all phases of this work. I am also grateful to Professor A.K. Ghatak for his keen interest, inspiration and encouragement.

My sincere thanks are due to Prof. J.C.Dainty of Institute of Optics, Rochester and Dr. R.D.Bahuguna for very many stimulating discussions on speckles. I am very grateful to Miss Meenakshi Devi for many helpful criticisms and suggestions.

I also wish to thank Dr. A.K. Gupta, Dr. G.Bose and Mr. D.K. Srivastava for their help and cooperation.

Finally, I wish to thank Miss Neelam Dhody for her cooperation and great care in typing the thesis and to Mr. N.S. Gupta for preparing the diagrams.

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ABSTRACT

The coherent imaging of a weak diffuser which comprises of statistically uniformly distributed point scatterers in space has been studied. The dependence of contrast on the number of point scatterers and the variance of phase fluctuations with (i) uniform and (ii) Gaussian distribution has been investigated. The contrast for weak diffuser exceeds the contrast for strong diffuser for very small values of the number of point scatterers image centres within the area of the spread function of the optical system. The speckle contrast strongly depends on the micro-structure of the surface, therefore, any advantages in using speckle contrast measurements to detect surface roughness seem questionable. It has also been found that the expression for autocorrelation of intensity distribution as derived by Enloe (Bell Syst. Tech. J. 46 (1967) 1479) is in slight error. A physical interpretation of the mathematical formulation of coherent imaging of diffuse object also supports it. The error has occurred due to improper combination of terms in his equation 12. The corrected version is included.

A statistical property of importance in laser speckle is the expected number of crossings about a certain

level of intensity within an interval. We have derived an expression for the average number of crossings for a normal speckle pattern and have shown that maximum crossings occur at half the average intensity.

Unidirectional averaging of speckles formed in the far-field of a weak Gaussian diffuser with (i) truncated parabolic, (ii) Gaussian and (iii) negative exponential phase correlation function has been studied. Reduction in contrast as a function of length (in terms of speckle units) is shown graphically for various values of the width of the phase correlation function. The effect of polychromaticity has also been included for strong diffuser. As a a limiting case of point source, the results do not agree with those already obtained by Parry (Opt. Acta 21 (1974)763). The difference is due to the fact that Parry's reduction of two dimensional integral to one dimension is not correct. The correct numerical results corresponding to his Figs. 2 and 3 have also been included.

It has been found that large size weak diffuser also shows the effects of spherical aberration similar to those with small strong diffuser except differing in contrast. We have also considered the size, shape and dynamics of the speckles produced when a weak diffuser is

illuminated by a spherically aberrated lens. The study of speckles for such a case is explained on the theory of knife-edge method. The results are illustrated with the help of photographs.

The work reported in the present thesis has resulted in the following communications:

1. Statistical properties of speckles produced in the image plane of a weak diffuser (submitted). Opt.Acta.

2. On the physical interpretation of results in coherent imaging of diffuse objects (submitted) Optik.

3. Expected number of intensity level crossings in a normal speckle pattern (submitted) J. Opt. Soc.Am.

4. Unidirectional averaging of speckles produced in the far-field of a weak diffuser (submitted) Opt.Acta.

5. Effect of temporal coherence on the contrast of unidirectionally averaged far-field speckles (submitted) Optik.

6. Study of speckles with weak diffuser illuminated by spherically aberrated lens (to be submitted) J. Optics (Paris).

7. A simple method for localization of paraxial, marginal and least confusion planes (to be submitted).

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The publications which have not been included in the thesis are given below:

1. Study of laser speckles in the presence of spherical aberration.
   J. opt. Soc. Am. (1979) 69, 877.

2. Laser speckle interferometric analysis of motion.
   in 'Large Deformations' Eds. B. Karunes and N.K. Gupta, Proc. of a Symp. at I.I.T., Delhi. (Vision Books, 1975) p. 177.

3. Imaging of incoherent extended objects by a polarising microscope with crossed polarisers.
   Microscopica Acta (1977) 80, 37.

4. Some phychophysical experiments using diffraction patterns.
   (to be submitted) Vis. Res.

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