

# *Introduction to Statistical Optics*

EDWARD L. O'NEILL

*Department of Physics, Worcester Polytechnic Institute*

DOVER PUBLICATIONS, INC.  
New York

# Contents

---

## Chapter 1. GREEN'S FUNCTION AND LINEAR THEORY

1-1 Linear second-order differential operators . . . . .	1
1-2 Self-adjoint operators . . . . .	3
1-3 Nonself-adjoint operators . . . . .	5
1-4 The inhomogeneous equation . . . . .	5
1-5 Determination of the Green's function . . . . .	6
1-6 The principle of linear superposition in optical image formation . . . . .	10

## Chapter 2. SPATIAL VERSUS TIME FILTERS

2-1 Time filters . . . . .	13
2-2 Classification of input signals . . . . .	15
2-3 Random signals . . . . .	17
2-4 Optical spatial filters . . . . .	20
2-5 The optical contrast transfer function . . . . .	22
2-6 An idealized illustration . . . . .	25
2-7 Image motion . . . . .	27

## Chapter 3. INTRODUCTION TO GEOMETRICAL OPTICS

3-1 Fermat's principle and Snell's law of refraction . . . . .	30
3-2 Sign convention . . . . .	32
3-3 Refraction matrix . . . . .	32
3-4 Translation matrix . . . . .	34
3-5 Paraxial approximation . . . . .	36
3-6 Image formation . . . . .	37
3-7 The cardinal points . . . . .	38
3-8 Illustrations . . . . .	40

## Chapter 4. THE GEOMETRICAL THEORY OF ABERRATIONS

4-1 Wave aberration function . . . . .	46
4-2 Geometrical versus physical optics . . . . .	47
4-3 Equations for the ray intercepts . . . . .	49
4-4 Optimum balancing of third- and fifth-order spherical aberrations . . . . .	58
4-5 The Maréchal method of aberration balancing . . . . .	62
4-6 An illustration, a single reflecting surface . . . . .	66
4-7 Zernike polynomials . . . . .	68

## Chapter 5. DIFFRACTION THEORY OF IMAGE FORMATION

5-1 General considerations . . . . .	70
5-2 Basic diffraction problem . . . . .	72

5-3 Equations governing image formation . . . . .	75
5-4 Diffraction by a slit . . . . .	79
5-5 The Michelson stellar interferometer . . . . .	80
5-6 Diffraction by a circular aperture . . . . .	83
<b>Chapter 6. ANALYSIS AND SYNTHESIS</b>	
6-1 General considerations . . . . .	86
6-2 Small aberrations . . . . .	87
6-3 Amplitude and phase variations in one dimension . . . . .	89
6-4 Amplitude and phase variations in two dimensions . . . . .	95
6-5 Random phase errors . . . . .	99
6-6 The synthesis problem, coherent illumination . . . . .	101
<b>Chapter 7. STATISTICAL METHODS</b>	
7-1 Random scenes . . . . .	105
7-2 Further statistical considerations; graininess and granularity . . . . .	109
7-3 Checkerboard model . . . . .	113
7-4 Overlapping circular grain model . . . . .	115
<b>Chapter 8. MATRIX AND COHERENCE THEORY</b>	
8-1 Introduction: Wolf's mutual coherence function . . . . .	122
8-2 Image formation . . . . .	124
8-3 Matrix theory . . . . .	127
<b>Chapter 9. THE THEORY OF PARTIAL POLARIZATION</b>	
9-1 Introduction . . . . .	133
9-2 Jones method . . . . .	135
9-3 The coherency matrix formalism . . . . .	137
9-4 The Stokes parameters and the Mueller method . . . . .	142
9-5 Selected topics . . . . .	146
<b>Appendix A. FOURIER-BESSEL SERIES AND INTEGRALS</b>	
A-1 Fourier series . . . . .	157
A-2 Fourier integral . . . . .	159
A-3 Fourier theory in two dimensions . . . . .	160
A-4 The convolution theorem . . . . .	161
A-5 The sampling theorem . . . . .	163
<b>Appendix B. PROBABILITY AND ENTROPY THEORY</b>	
B-1 The binomial, Poisson, and normal distributions . . . . .	166
B-2 The concept of entropy . . . . .	167
B-3 The illumination matrix in the coherent limit . . . . .	172
<b>INDEX</b> . . . . .	177