CONTENTS

PREFACE vii

I. Introduction

1. Emergence of Modern Optics as a Branch of Electrical Engineering 1
2. Mathematical Character of Electro-Optical Engineering 1
3. Mathematical Methods of Modern Optics 2
4. Some Limitations of Operational Formulation of Optical Image Formation and the Need for Boundary-Value Solutions in the Study of Diffraction of Electromagnetic Waves in Optics 2
5. Grating Equation as an Example of Boundary-Value Solution of a Diffraction Problem 4
6. Gratings as Information Carriers in Optics (Application to Wavefront-Reconstruction Imaging) 8
7. Optics and Communication Theory. Historical Background 13

References 14

II. Diffraction Theory (Qualitative Introduction)

1. The Two Aspects of the Diffraction of Light 16
2. Theoretical Calculation of Energy Distribution in Diffraction and of Spectral Diffraction Patterns 16
   - 2.1. Electromagnetic Boundary-Value Solutions 16
   - 2.2. Image-Formation Solutions Using Huygens' Principle 21
3. Image-Formation Theory and Optical Signal Processing in Fourier-Transform Formulation 24

References 25

III. Image Formation in Noncoherent Light (Elements and Definitions)

1. Image of Point Source 26
2. Summation of Light from Several Source Points Reaching One Image Point 27
3. Spread Function 28
4. Image of Extended Source in Noncoherent Light 29
5. Method of Computing Image Intensities and Transfer Functions 29
6. Analysis of Image Formation in Terms of Spatial Fourier Space 31
7. Physical Significance of Spread Function and of Fourier-Space Analysis of Image Formation 33
   - 7.1. Point Source (Dirac Delta Function) ⟶ Diffraction Pattern—Spread Function 34
   - 7.2. Sinusoidal Intensity Objects ⟶ Spatial Frequency-Response Function—Fourier Transform of Diffraction Pattern 34
8. Application of "Fourier-Space" Representation to "Synthesis" of Object-Functions 37

References 37

IV. Coherence Characteristics of Light (Experimental Characterization)

1. Introduction 38
2. Characterization of Coherence 38
2.1. Correlation Method 38
2.2. Alternate Way of Looking at Time Coherence (Interference Theory) 40
a. Monochromatic (single-frequency) light 40
b. Polychromatic light (noncoherent source) 41
2.3. Comparison of the Correlation and Interferometric Method 42
2.4. Narrow Spectrum (Flat-Top Line) 42
2.5. Photoelectric Interferometry with Gaussian Line Shapes, in Interferometers with Moving Mirrors 43
2.6. Physical Significance of Power Spectra 45
a. Case of a single-frequency signal 45
b. Case of a multiple-frequency signal 47
2.7. Heterodyne Analysis of Signals, Beat Frequencies, etc. 48
a. Beat frequencies between coherent waves and relativistic effect for light reflected from moving mirrors 48
b. Parallelism tolerances for the two interfering waves in photoelectric interferometry and heterodyning experiments 51
c. Photoelectric mixing of incoherent light 54
d. Photoelectric mixing of coherent laser light with noncoherent thermal light 54
2.8. Spatial Coherence 57
2.9. Partial Coherence with Extended Noncoherent Source 60
a. Two-slit (Young) interferometer and Michelson's stellar interferometer 63
2.10. Intensity Correlations in Partially Coherent Fields 66
2.11. Intensity Interferometers 66
a. Method No. 1 66
b. Method No. 2 68
References 69

V. Image Formation in Coherent Light

1. Introduction 70
2. Coherent Illumination 70
2.1. Example 1. Illumination of an Extended Field by a Point Source .. 70
2.2. Example 2. Equivalence of Coherent Object and Coherently Illuminated Object 70
3. Image Formation in Coherent Light, Considered as Double Diffraction .. 72
4. Abbe and Rayleigh Resolution Criteria 74
5. Transfer Functions in Coherent and Noncoherent Light 76
6. Phase-Contrast Filtering 77
7. Optical Filtering with Holographically Matched Spatial Filters 79
7.1. Realization of the Complex Filter and of Filtering Operation 83
8. Optical Computing, Correlating, and Signal Processing 86
8.1. Spectrum Analyzers 86
8.2. Optical Cross Correlators 89
9. Interferometry and Optical Image Synthesis (Complex Amplitude Addition) by Successive Addition of Holographic Intensities in a Single Hologram 90
References 96

VI. Theoretical and Experimental Foundations of Optical Holography (Wavefront-Reconstruction Imaging)

1. Background and Experimental Foundations 98
2. Theoretical Foundations 100
2.1. The Recording Process 106
2.2. The Reconstruction Process 108
2.3. Physics of the Method 109
2.4. Magnification 111
2.5. Resolution 114
3. High-Resolution Fourier-Transform Holography 116
3.1. Introduction 116
3.2. Physical Principles of High-Resolution Lensless Fourier-Transform Holography 120
3.3. Mathematical Analysis of Lensless Fourier-Transform Holography. 121
3.4. Comparison of Fourier-Transform and Fresnel-Transform Holography for High-Resolution Imaging 124
4. Resolution-Retrieving Compensation of Source Effects in Holography... 127
4.1. Concise Analysis 128
4.2. More Formal Analysis 133
4.3. Concluding Remarks 137
5. Coherence Requirements in Holography 137
6. Summary and Results 139
7. Electron Microscopy and X-Ray-Hologram Microscopy 143
8. Conclusion 144
9. Holography with Noncoherent Light 149
9.1. Holographic Fourier-Transform Spectroscopy with Spectrally Noncoherent Light 151
9.2. Image-Forming Holography with Spatially Noncoherent Light 158
References 161

VII. Fourier Transforms, Convolutions, Correlations, Spectral Analysis, and the Theory of Distributions

1. Fourier Transforms 164
1.1. Some Properties of Fourier Transforms 165
1.2. Linearity 165
1.3. Translation Theorem 165
1.4. Reciprocal Translation Theorem 166
1.5. Table of Fourier-Transform Properties 167
1.6. Two-Dimensional and Multidimensional Fourier Transforms 168
1.7. Scale Change in Fourier Transforms 168
1.8. Fourier Transform of the Complex Conjugate of a Function 169
1.9. Fourier Cosine Transforms and Fourier Sine Transforms 169
1.10. Symmetry Relations 169
2. Convolution Integrals 170
2.1. Definition of Convolution 170
2.2. Multidimensional Convolutions and Convolutions of Several Functions 170
2.3. Convolution Theorem (Fourier Transform of Convolution Integral). 171

3. Correlation Functions 174
3.1. Definition of Correlation Functions 174
3.2. Transforms of Correlation Functions 174
4. Distributions 177
4.1. Definitions 177
4.2. Impulse Response of a Linear System 178
4.3. Response of a Linear System to an Arbitrary Input Function 178
5. Spectral Analysis 179
References 180

Reprinted Papers

A New Microscopic Principle ..... by D. Gabor 181
Nature **161**, *No.* 4098, 777–778 (1948)

Microscopy by Reconstructed Wave-Fronts .... by D. Gabor 184
Proc. Roy. Soc. (*London*) **A197**, 454–487 (1949)
Introduction 184
The Principle of Wave-Front Reconstruction 187
Illumination by a Homocentric Wave 189
Reconstruction with Homocentric Illumination 193
The Spurious Part of the Reconstruction in Homocentric Illumination 195
Improving the Separation by Masking and Other Means 201
Illuminating Waves with Astigmatism and Spherical Aberration 202
Reconstruction in the Presence of Spherical Aberration and Astigmatism .. 206
Coherence Criteria 208
The Optical Reconstruction 210
Experimental Tests 214
Conclusion 219
References 220

Microscopy by Reconstructed Wave-Fronts: II .. by D. Gabor 221
Proc. Phys. Soc. (*London*) **64** (Pt. 6), No. 378B, 449–469 (1951)
1. Introduction 221
2. The Principle of Wave-Front Reconstruction 222
3. Theory of Image Formation in the Transmission Method 225
4. The Reconstruction 231
5. Coherence Criteria 233
Transverse Coherence 233
Longitudinal Coherence 234
Chromatic Coherence 235
The Coherent Current 235
6. Conditions for the Taking of Holograms 237
7. The Dark-Field Method of Reconstruction 238
References 241

AUTHOR INDEX 243
SUBJECT INDEX 246