Contents

1. Ray Optics 1

1.1 Reflection and Refraction 1
Refraction 1
Index of Refraction 1
Reflection 2
Total Internal Reflection 3
Reflecting Prisms 4
1.2 Imaging 5
Spherical Surfaces 5
Object–Image Relationship 6
Use of the Sign Convention 8
Lens Equation 8
Classification of Lenses and Images 11
Spherical Mirrors 12
Thick Lenses 13
Image Construction 15
Magnification 16
Newton's Form of the Lens Equation 17
Lagrange Invariant 18
Aberrations 19

2. Optical Instruments 20

2.1 The Eye (as an Optical Instrument) 20
2.2 Basic Camera 22
Photographic Emulsion 23
Sensitometry 25
Resolving Power 27
Depth of Field 28
2.3 Projection Systems 29
2.4 Hand Lens or Simple Magnifier 30
2.5 Microscope 32
2.6 Telescope 33
Pupils and Stops 33
Field Stop 35
Terrestrial Telescopes 35
2.7 Resolving Power of Optical Instruments 36
Camera 37
Telescope 37

Microscope 38
2.8 Optical Waveguides 39

3. Light Sources and Detectors 43

3.1 Radiometry and Photometry 43
Radiometric Units 43
Photometric Units 45
Point Source 46
Extended Source 47
Diffuse Reflector 48
Image Illuminance 49
Image Luminance 51
3.2 Light Sources 53
Black Bodies 54
Color Temperature and Brightness Temperature 57
Line Sources 58
Light-Emitting Diodes (LED) 61
3.3 Detectors 62
Quantum Detectors 62
Thermal Detectors 67
Detector Performance Parameters 69

4. Wave Optics 73

4.1 Waves 73
Electromagnetic Waves 75
Complex Exponential Functions 75
4.2 Superposition of Waves 76
4.3 Interference by Division of Wavefront 77
Double-Slit Interference 78
Multiple-Slit Interference 80
4.4 Interference by Division of Amplitude 82
Two-Beam Interference 82
Multiple-Reflection Interference 83
4.5 Diffraction 85
Single-Slit Diffraction 87
Interference by Finite Slits 90
Fresnel Diffraction 90
Far and Near Field 93
Babinet's Principle 95
4.6 Coherence 96
Time Coherence 97
Spatial Coherence 99
Coherence of Thermal Sources 100
4.7 Theoretical Resolution Limit 100
Two-Point Resolution 100

Coherent Illumination 101
Diffused, Coherent Illumination 102

5. Interferometry and Related Areas 106

5.1 Diffraction Grating 106
Blazing 107
Chromatic Resolving Power 108
5.2 Michelson Interferometer 109
Twyman-Green Interferometer 111
5.3 Fabry-Perot Interferometer 112
Chromatic Resolving Power 112
Free Spectral Range 114
5.4 Multilayer Mirrors and Interference Filters 115
Quarter-Wave Layer 115
Multilayer Mirrors 116
Interference Filters 117

6. Holography and Fourier Optics 118

6.1 Holography 118
Off-Axis Holography 120
Zone-Plate Interpretation 122
Amplitude and Phase Holograms 123
Thick Holograms 124
6.2 Optical Processing 125
Abbe Theory 125
Fourier Series 128
Fourier-Transform Optics 130
Spatial Filtering 132
Phase Contrast 134
Matched Filter 136
6.3 Transfer Functions 138
Impulse Response 138
Optical Transfer Function 139
Coherent Transfer Function 141
Diffraction-Limited Transfer Functions 141
MTF of Photographic Films 143

7. Lasers 144

7.1 Amplification of Light 144
Optical Amplifier 145
7.2 Optically Pumped Laser 148
Output Power 150
Q-Switched Laser 151
Mode-Locked Laser 152

7.3 Optical Resonators 154
Transverse Modes 156
Gaussian Beams 158
Stability Diagram 160
Coherence of Laser Sources 161
7.4 Specific Laser Systems 162
Ruby Laser 162
Neodymium Laser 164
Organic-Dye Lasers 166
Helium-Neon Laser 167
Ion Lasers 168
CO_2 Lasers 169
Other Gas Lasers 169
Semiconductor Lasers 169

8. Electromagnetic and Polarization Effects 171

8.1 Reflection and Refraction 171
Propagation 171
Brewster's Angle 172
Reflection 173
Internal Reflection 175
Interface Between two Dense Media 176
Reflection from Metals 176
8.2 Polarization 176
Birefringence 177
Wave Plates 179
Glan–Thompson and Nicol Prisms 180
Dichroic Polarizers 181
Optical Activity 182
8.3 Nonlinear Optics 182
Second-Harmonic Generation 183
Phase Matching 184
Optical Mixing 185
8.4 Electrooptics, Magnetooptics and Acoustooptics 187
Kerr Effect 187
Pockels Effect 188
Electrooptic Light Modulation 189
Acoustooptic Beam Deflection 190
Faraday Effect 191

References 193

Subject Index 197