

Contents

1. History of Optics	1
1.1 Past	1
1.2 Present	5
1.3 Future	7
Problems	8
2. The Main Areas of Optics	9
2.1 Geometrical Optics	9
2.2 Wave Optics	10
2.3 Quantum Optics	11
2.4 Statistical Optics	12
3. Fundamentals of Wave Optics	15
3.1 Maxwell's Equations	15
3.2 The Wave Equation	17
3.3 Waves	18
3.3.1 One-Dimensional Waves	18
3.3.2 Plane Waves	21
3.3.3 Spherical Waves	22
3.3.4 Bessel Waves	23
3.3.5 Evanescent Waves	25
3.3.6 Polarized Waves	28
3.4 Intensity of a Light Wave	30
Problems	33
4. Coherence	35
4.1 Temporal Coherence	35
4.2 Spatial Coherence	44
4.3 Spatiotemporal Coherence	50
4.4 Complex Representation of the Light Field	52
4.5 Stellar Interferometry	53
4.6 Fourier Spectroscopy	55
4.7 Intensity Correlation	57
Problems	59

X Contents

5. Multiple-Beam Interference	61
5.1 Fabry–Perot Interferometer	61
5.2 Mode Spectrum of a Laser	68
5.2.1 Interference Spectroscopy	69
5.2.2 Difference-Frequency Analysis	72
5.3 Dual-Recycling Interferometer	73
Problems	75
6. Speckles	77
6.1 Intensity Statistics	78
6.2 Speckle Sizes	80
6.3 Speckle Photography	84
6.3.1 Double-Exposure Technique	86
6.3.2 Time-Average Technique	89
6.4 Flow Diagnostics	92
6.5 Stellar Speckle Interferometry	95
Problems	99
7. Holography	101
7.1 Principle of Holography	101
7.1.1 Hologram Recording	102
7.1.2 Image Reconstruction	104
7.1.3 Location of the Images	106
7.1.4 Phase Conjugation	107
7.2 The Imaging Equations of Holography	110
7.3 Holographic Arrangements	114
7.3.1 In-line Holograms	114
7.3.2 Reflection Holograms	115
7.3.3 Transmission Holograms	116
7.3.4 White-Light Holograms	117
7.3.5 Rainbow Holograms	120
7.4 Holographic Cinematography	122
7.5 Digital Holography	123
7.5.1 Direct Simulation	124
7.5.2 Simulation with Square Light Waves	132
7.5.3 Digital hologram recording and reconstruction	133
Problems	134
8. Interferometry	135
8.1 Mach–Zehnder Interferometer	135
8.2 Sagnac Interferometer	136
8.3 Holographic Interferometry	140
8.3.1 Real-Time Method	140
8.3.2 Double-Exposure Method	140
8.3.3 Time-Average Method	142

8.4	Theory of Holographic Interferometry	142
8.4.1	Real-Time and Double-Exposure Method	142
8.4.2	Time-Average Method.....	144
8.4.3	Time-Average Method in Real Time	145
	Problems	147
9.	Fourier Optics	149
9.1	Scalar Diffraction Theory	149
9.1.1	Fresnel Approximation.....	150
9.1.2	Fraunhofer Approximation	152
9.2	Fourier Transform by a Lens	154
9.3	Optical Fourier Spectra	156
9.3.1	Point Source	156
9.3.2	Plane Wave	157
9.3.3	Infinitely Long Slit	158
9.3.4	Two Point Sources	160
9.3.5	Cosine Grating	161
9.3.6	Circular Aperture	162
9.3.7	Compound Diffracting Systems	164
9.4	Coherent Optical Filtering	167
9.4.1	Low-Pass Filter or Spatial Frequency Filter	168
9.4.2	High-Pass Filter or Dark Field Method	169
9.4.3	Phase Filter or Phase Contrast Method.....	170
9.4.4	Half-Plane Filter or Schlieren Method	172
9.4.5	Raster Elimination	172
9.4.6	Demonstration Experiment.....	173
9.4.7	Holographic Filters	173
9.4.8	Pattern Recognition	176
	Problems	179
10.	The Laser	181
10.1	The Laser Principle	181
10.2	Laser Rate Equations	183
10.3	Stationary Operation	187
10.4	Stability Analysis	188
10.5	Transient dynamics	193
10.5.1	Relaxation Oscillations	193
10.5.2	Q-Switching	194
10.5.3	Cavity Dumping.....	197
10.6	Chaotic Dynamics	199
10.7	Synchronization	204
	Problems	207

XII Contents

11. Ultrafast Optics	209
11.1 Properties of Ultrashort Pulses	209
11.1.1 Time-Bandwidth Product	211
11.1.2 Chirped Pulses	213
11.2 Generation of Ultrashort Pulses	217
11.2.1 Principle of Mode Locking	217
11.2.2 Methods of Mode Locking	221
11.2.3 Sonoluminescence	223
11.2.4 Chirped Pulse Amplification	225
11.3 Measurement of Ultrashort Pulses	229
11.4 Optical Gating	234
11.5 Optical Coherence Tomography	236
Problems	237
12. Nonlinear Optics	239
12.1 Two-Wave Interaction	239
12.1.1 Two-Photon Absorption	240
12.1.2 Two-Photon Ionization	241
12.2 Three-Wave Interaction	242
12.2.1 Second-Harmonic Generation	242
12.2.2 Sum-Frequency Generation	242
12.2.3 Difference-Frequency Generation	243
12.2.4 Optical Parametric Amplifier	244
12.3 Four-Wave Interaction	244
12.4 Multi-photon Interaction	245
12.4.1 Frequency Multiplication	245
12.4.2 Multi-photon Absorption and Ionization	246
12.5 Further Nonlinear Optical Phenomena	247
12.6 Nonlinear Potentials	248
12.7 Interaction of Light Waves	250
12.7.1 Three-Wave Interaction	252
12.7.2 Scalar Three-Wave Interaction	258
12.7.3 Second-Harmonic Generation	259
12.7.4 Optical Parametric Amplifier	262
12.7.5 Optical Parametric Oscillator	263
12.7.6 Three-Wave Interaction in the Photon Picture	264
Problems	265
13. Fiber Optics	267
13.1 Glass Fibers	268
13.1.1 Profile	268
13.1.2 Guided Waves	269
13.1.3 Attenuation	271
13.2 Fiber Sensors	273
13.3 Optical Solitons	276

Contents XIII

13.3.1 Dispersion	276
13.3.2 Nonlinearity	281
13.4 Fiber-Optic Signal Processing	284
Problems	285
A. The Fourier Transform	287
A.1 One-Dimensional Fourier Transform	287
A.2 Two-Dimensional Fourier Transform	288
A.3 Convolution and Autocorrelation	289
A.4 Properties of the Fourier Transform	290
A.5 Selected Functions and Their Fourier Transforms	292
Problems	292
B. Solutions of Problems	295
References	321
Index	333