

# Contents

Preface	v	
<b>1</b>	<b>Derivation of the Basic Equations</b>	
1.1	Introduction .. .. .	1
1.2	Maxwell's equations .. .. .	2
1.3	Derivation of the wave equation .. .. .	2
1.4	Poynting's theorem .. .. .	4
1.5	Boundary conditions .. .. .	6
1.6	Plane waves .. .. .	6
1.7	Refraction of plane waves at plane boundaries .. .. .	8
1.8	Geometrical optics .. .. .	10
<b>2</b>	<b>A First Review of the Properties of Volume Gratings</b>	
2.1	Introduction .. .. .	13
2.2	Basic concepts .. .. .	13
2.3	Recording by plane waves .. .. .	15
2.4	Recording by a plane wave and a cylindrical wave .. .. .	17
2.5	Recording by two cylindrical waves .. .. .	19
2.6	Holographic principles .. .. .	22
2.7	Reconstruction by volume holograms .. .. .	23
2.8	Bragg diffraction of light by acoustic gratings .. .. .	31
2.9	A brief history of volume gratings .. .. .	35
2.10	An introduction to coupled wave theory .. .. .	36
2.11	Raman–Nath diffraction of light by acoustic gratings: the generation of higher-order modes .. .. .	41
<b>3</b>	<b>Dispersion Equation Theory</b>	
3.1	Introduction .. .. .	45
3.2	The dispersion equation .. .. .	47
3.3	Bragg incidence: reconstruction by a recording wave .. .. .	49
3.4	General treatment .. .. .	59
3.5	Non-parallel boundaries: a wedge-shaped transmission grating .. .. .	72

<b>4</b>	<b>One-dimensional Coupled Wave Theory</b>	
4.1	Introduction .. .. .	76
4.2	The basic model: derivation of the coupled differential equations .. .. .	78
4.3	Power conservation .. .. .	82
4.4	Solution of the differential equations .. .. .	83
4.5	Properties of the solutions .. .. .	84
4.6	Comparison with the results of dispersion equation theory; the output boundary condition .. .. .	93
4.7	Effects of change in the average permittivity of the grating	94
4.8	Non-uniform gratings .. .. .	98
4.9	Experimental results .. .. .	104
4.10	Second-order coupled wave theory .. .. .	111
<b>5</b>	<b>Higher-order Modes</b>	
5.1	Introduction .. .. .	114
5.2	Coupled differential equations for a pure phase grating at Bragg incidence .. .. .	115
5.3	A more general coupled differential equation .. .. .	117
5.4	Power conservation .. .. .	120
5.5	The optical path method .. .. .	121
5.6	Further approximations for optically thin gratings .. .. .	127
5.7	Analytic approximations for optically thick gratings .. .. .	129
5.8	Numerical results for unslanted phase gratings at Bragg incidence .. .. .	133
5.9	The effect of higher harmonics in the permittivity modulation .. .. .	136
5.10	Higher-order modes at higher Bragg angle incidence .. .. .	139
5.11	Experimental results .. .. .	141
5.12	Characteristic mode theory .. .. .	144
<b>6</b>	<b>Quasi-one-dimensional Theories</b>	
6.1	Introduction .. .. .	155
6.2	The electric field expressed in terms of the angular spectrum of the incident wave .. .. .	156
6.3	Transmission gratings at Bragg incidence .. .. .	157
6.4	Solution for locally plane phase gratings .. .. .	160
<b>7</b>	<b>Two-dimensional Theories</b>	
7.1	Introduction .. .. .	164
7.2	Coupled differential equations for a pure phase grating at Bragg incidence .. .. .	165
7.3	Recording: a more general model .. .. .	169
7.4	Coupled differential equations for a more general model .. .. .	170
7.5	Solution of the differential equations .. .. .	173
7.6	Total overlap of the recording beams .. .. .	177

7.7	Gaussian input beams .. .. .	181
7.8	The conflict between efficiency and fidelity of reproduction	186
7.9	The Borrmann effect .. .. .	187
7.10	A finite beam reflection hologram .. .. .	195
7.11	Wavefront conversion between cylindrical and plane waves	200
7.12	A solution for uniform reflection holograms .. .. .	203
<b>8</b>	<b>Multiple Gratings</b>	
8.1	Introduction .. .. .	208
8.2	Two-dimensional $N$ -coupled wave theory .. .. .	209
8.3	$N$ -wave theory versus two-dimensional two-wave theory .. .. .	214
8.4	Application of dispersion equation theory .. .. .	216
8.5	Two gratings, sequentially recorded .. .. .	220
8.6	Three gratings, simultaneously recorded .. .. .	223
8.7	A 4-port device .. .. .	226
<b>9</b>	<b>Three-dimensional Coupled Wave Theory</b>	
9.1	Introduction .. .. .	229
9.2	The general three-dimensional theory .. .. .	230
9.3	Conversion of plane waves .. .. .	237
9.4	Decoupled vector differential equations .. .. .	241
9.5	Conversion between a plane and a spherical wave .. .. .	243
9.6	Conclusions .. .. .	253
<b>10</b>	<b>Holographic Recording Materials</b>	
10.1	Introduction .. .. .	254
10.2	Silver halide photographic materials .. .. .	258
10.3	Gelatin holograms: dichromated gelatin .. .. .	278
10.4	Ferroelectric crystals .. .. .	286
10.5	Photopolymers .. .. .	293
10.6	Photochromic and photodichroic materials .. .. .	299
<b>11</b>	<b>Devices and Applications</b>	
11.1	Introduction .. .. .	305
11.2	Holographic displays .. .. .	306
11.3	Optical elements .. .. .	315
11.4	Optical couplers .. .. .	320
11.5	Acousto-optic devices .. .. .	327
11.6	Electro-optic devices .. .. .	351
11.7	Computer memories .. .. .	357
11.8	Integrated optics .. .. .	367
11.9	Real-time holography .. .. .	376
11.10	Optical properties of multilayers .. .. .	380
11.11	A surface acoustic wave Bragg device .. .. .	382
11.12	Degenerate four-wave mixing .. .. .	383

<b>12</b>	<b>Recent Developments</b>	
12.1	Rigorous coupled wave theory of planar gratings .. ..	386
12.2	Cross-coupled <i>N</i> -wave theory .. ..	390
12.3	Some further developments .. ..	393
12.4	Applications .. ..	395
<b>Appendix 1</b>	<b>Derivation of the Dispersion Equation in Terms of the Electric Flux Density .. ..</b>	<b>399</b>
<b>Appendix 2</b>	<b>A Note on the Frequency Shift in Acoustic-optic Interaction</b>	<b>403</b>
<b>Appendix 3</b>	<b>Floquet's Theory .. ..</b>	<b>405</b>
<b>Appendix 4</b>	<b>Solution of the Differential Equation <math>L(u) = \partial^2 u / \partial x \partial y + u = 0</math></b>	<b>407</b>
	References	411
	Author Index	449
	Subject Index	461