

Contents

1 Basic Analysis on Optical Waveguides	1
1.1 Basic Theory of Wave Optics	1
1.1.1 Maxwell's Equation.	1
1.1.2 Matter Equation	2
1.1.3 Wave Equation	3
1.1.4 Boundary Condition for Electromagnetic Field	5
1.1.5 Poynting Vector	7
1.2 Reflection and Transmission of the Plane Waves	8
1.2.1 Snell's Laws.	9
1.2.2 Fresnel Formula	9
1.2.3 Brewster's Angle.	11
1.2.4 Total Internal Reflection.	12
1.2.5 Goos-Hänchen Shift	15
2 Transfer Matrix Method and the Graded-Index Waveguide.	17
2.1 The Transfer Matrix and Its Characteristics	17
2.2 The Eigenvalue Equation	23
2.3 WKB Approximation	25
2.4 Multilayer Optical Waveguides	28
2.4.1 Asymmetric Four-Layer Slab Waveguide	28
2.4.2 Multilayer Slab Waveguide.	33
2.5 The Transfer Matrix Treatment of the Graded-Index Waveguide	36
2.5.1 The Eigenvalue Equation	36
2.5.2 The Phase Shift at Turning Point.	40
References	42
3 Periodic Waveguides and MQW Waveguide	43
3.1 Rectangular Corrugated Periodic Waveguide	43
3.1.1 From Corrugated Optical Waveguide to Rectangular Periodic Waveguide.	43
3.1.2 Transfer Matrix and the Coupling Coefficient	46

3.1.3	Forward and Backward Traveling Waves	51
3.2	Corrugated Periodic Waveguide of Arbitrary Shape	56
3.2.1	Analytical Expression for Coupling Coefficient	57
3.2.2	Typical Corrugated Periodic Waveguide	62
3.3	Step-Index Multiple Quantum Well (MQW) Optical Waveguide	65
3.3.1	Effective Permittivity of the Infinite Periodic Multilayers	65
3.3.2	Effective Index of the MQW Waveguide	67
3.4	MQW Optical Waveguide with Arbitrary Refractive Index Distribution	72
3.4.1	Effective Index Method	72
3.4.2	Non-Effective Index Method	77
	References	82
4	Characterizing the Feature Parameters of Planar Optical Waveguide	83
4.1	Four-Layer Leaky Waveguide	83
4.1.1	Dispersion Equation	83
4.1.2	Variation in the Propagation Constant	85
4.1.3	Analytical Transfer Matrix Method	86
4.2	Prism-Waveguide Coupling System	88
4.2.1	Operational Principle and M-Line Spectroscopy	88
4.2.2	Reflectivity Formula and Attenuated Total Reflection (ATR) Spectrum	90
4.2.3	Measuring the Waveguide Layer's Thickness and RI	94
4.3	Determining the RI Profile of Inhomogeneous Waveguide	96
4.3.1	Inverse WKB Method	96
4.3.2	Inverse ATM Method	98
4.4	Measuring the Waveguide's Propagation Loss	99
4.4.1	Perturbation Analysis of the Propagation Loss	101
4.4.2	End-Face Coupling Method	104
4.4.3	Sliding-Prism Method	105
4.4.4	Digital Scattering Method	105
4.5	Evaluating Nonlinear Parameters of Waveguide	107
4.5.1	Measurement of the Electro-optic Coefficients	108
4.5.2	Evaluating the Thermo-Optical Coefficient of Polymer Layer	110
	References	111
5	Surface Plasmon Wave	113
5.1	Optical Properties of Metal	114
5.1.1	The Permittivity Constant of Metal	114
5.1.2	Elementary Electronic Theory of Metal	115

5.2	SPW on the Interface Between Metal and Dielectric.	118
5.2.1	Excitation Condition of SPW	118
5.2.2	Loss	121
5.2.3	The Excitation Scheme of the SPW	122
5.2.4	Field Enhancement Effect.	125
5.3	Measurement of Metal Film's Thickness and Permittivity by Double-Wavelength Method	126
5.3.1	Measurement Principle.	126
5.3.2	Experiment and Measurement	129
5.4	Long-Range SPW of a Metal Film Structure	130
5.4.1	Dispersion	130
5.4.2	Loss	133
5.4.3	Excitation of the LRSPW	137
5.4.4	Field Enhancement Effect of the LRSPW	138
5.5	Determination of Thickness and Permittivity of Thin Metal Films via a Modified ATR Configuration	139
5.5.1	Measurement Principle.	139
5.5.2	Experiment and Measurement	141
	References	142
6	Symmetrical Metal-Cladding Waveguide.	145
6.1	Dispersion Equation.	146
6.1.1	Dispersion Properties	146
6.1.2	TM_0 Mode and TM_1 Mode.	148
6.1.3	The Degeneracy of TM_0 Mode and TM_1 Mode.	151
6.2	Free-Space Coupling Technology.	152
6.3	Ultrahigh-Order Mode	155
6.4	WideBand Slow Light	157
6.5	Conical Reflection	159
	References	161
7	Goos-Hänchen Shift.	163
7.1	Obstacle in the Ray Theory.	163
7.1.1	Contradiction Between the Ray Theory and the Electromagnetic Field Theory	163
7.1.2	The Addition of Lateral Phase Shift.	165
7.2	Causality Paradoxes in Gires-Tournois Interferometer and Plasma Mirror	166
7.2.1	Causality Paradox in Gires-Tournois Interferometer	166
7.2.2	Interpretation of Causality Paradox in the Gires-Tournois Interferometer	167
7.2.3	Causality Paradox Associated with Total Reflection upon the Plasma Mirror	168

7.2.4	Interpretation of Causality Paradox in the Plasma Mirror	169
7.2.5	Detailed Analysis of the Optical Waveguide	170
7.3	Generalized Form of the GH Time.	172
7.3.1	Group Velocity of the Planar Waveguide	172
7.3.2	Generalized Form of the GH Time	174
7.4	Theoretical Models for the GH Shift	175
7.4.1	Stationary-Phase Approach	175
7.4.2	Gaussian Beam Model	177
7.4.3	Interference Approach	179
7.5	Enhancement of the GH Shift	181
7.5.1	Near the Brewster Angle	182
7.5.2	Surface Plasmon Resonance	183
7.5.3	Prism–Waveguide Coupling System.	184
7.5.4	Symmetrical Metal-Cladding Waveguide	185
7.6	Other Non-Specular Reflection Effects	187
	References	188
8	Optical Devices Based on the Attenuated Total Reflection	191
8.1	Optical Waveguide Filters.	191
8.1.1	Tunable Narrow Band Filter	192
8.1.2	Tunable Comb Filter	194
8.2	Analysis on the Sensitivity	195
8.2.1	Definition of Sensitivity	195
8.2.2	Physical Meaning of the Sensing Efficiency	196
8.3	Evanescent Wave Sensors.	197
8.3.1	SPR Sensor	198
8.3.2	The Leaky Waveguide Sensor.	200
8.3.3	Reverse Symmetry Waveguide Sensor	200
8.4	Oscillating Wave Sensors Based on the Light Intensity.	201
8.4.1	Aqueous Solution Concentration Sensor	202
8.4.2	Trace Chromium (VI) Sensor	204
8.4.3	Displacement Sensor	207
8.4.4	Angular Displacement Sensor	210
8.4.5	Wavelength Sensor	211
8.5	Oscillating Wave Sensors Based on the Goos–Hänchen Shift	212
8.5.1	Aqueous Solution Concentration Sensor	212
8.5.2	Displacement Sensor	213
8.5.3	Wavelength Sensor	215
8.5.4	Enhanced Superprism Effect	217
8.6	Electro-optical Devices.	218
8.6.1	Low-Voltage Electro-optic Polymer Modulator	218
8.6.2	Variable Optical Attenuator	220
8.6.3	Tunable Polarization Beam Splitter	221
8.6.4	Electric Controlling of the Beam Position.	222

- 8.7 Research on Ferrofluid 224
 - 8.7.1 Ferrofluid and Its Magneto-Optical Effects 224
 - 8.7.2 Optical Trapping and Soret Effect 227
 - 8.7.3 Magneto-optical Modulation 229
 - 8.7.4 All-Optical Modulation 235
- 8.8 Self-assembly Concentric Circular Grating 237
- References 239