Contents

I Background in Maxwell's Electromagnetism and Maxwell's Equations 1
I.1 General Maxwell's Equations in Cartesian Coordinates 1
I.1.1 Maxwell's Equations in Free Space 2
I.1.2 Maxwell's Equations in Matter 3
I.1.3 Boundary Conditions 5
I.1.4 Constitutive Relationships 6
I.1.5 The Formulation in Fourier Space 8
I.1.6 Time Harmonic Fields and Complex Representatives 10
I.2 Special Maxwell's Equations for l.l.h.i Media 11
I.2.1 Special Maxwell's Equations in Cartesian Coordinate Systems 12
I.2.2 Special Maxwell's Equations in Orthogonal Curvilinear Coordinate Systems 12
I.2.3 Special Maxwell's Equations in Spherical Coordinate Systems 13
I.2.4 Boundary Conditions 14
I.2.5 Energy Propagation and Poynting Theorem 15
I.2.6 Momentum Propagation 17
I.2.7 Wave-Vector, Refractive Index and Impedance 18
I.2.8 Potentials 21

II Resolution of Special Maxwell's Equations 23
II.1 Special Orthogonal Curvilinear Coordinate Systems and Separability 23
II.2 Bromwich Potentials 24
II.2.1 Generalities 24
II.2.2 Transverse Magnetic Wave 25
II.2.3 Transverse Electric Wave 28
II.3 Explicit Time Harmonic Dependence 29
II.4 Use of Spherical Coordinate Systems 30
II.5 BSP-Solutions 31
II.5.1 Reduction to Ordinary Differential Equations 31
II.5.2 Harmonic Equation 32
II.5.3 Associated Legendre Equation 33
II.5.4 Spherical Bessel Equation 34
II.5.5 General Expressions for BSPs 35

III Generalized Lorenz-Mie Theory in the Strict Sense, and Other GLMTs 37
III.1 The Scattering Problem and Global Strategy 37
III.2 BSPs for the Incident Wave 39
III.3 Quadratures to Evaluate BSCs g_n^m 40
III.3.1 The First Method to Derive Quadrature Expressions 40
III.3.2 The Second Method to Derive Quadrature Expressions 45
III.3.3 Other Approaches 46
III.4 BSPs for Scattered and Sphere Waves 50
III.5 Expansions of Field Components 51
III.6 Boundary Conditions and Generalized Scattering Coefficients 55
III.7 Scattered Field Components 57
III.8 Scattered Field Components in the Far Field Region 58
III.9 Scattered Intensities 59
III.10 Phase Angle 60
III.11 Radiative Energy Balance and Associated Cross-Sections 61
III.11.1 Generalities 61
III.11.2 Incident Field Balance 62
III.11.3 Scattering Cross-Section C_{sca} 64
III.11.4 Extinction Cross-Section C_{ext} 64
III.12 Momentum Balance and Radiation Pressure 66
III.12.1 Generalities 66

III.12.2 Longitudinal Radiation Pressure (z-Direction) . . . 67
III.12.3 Transverse Radiation Pressure (x and y Directions) . . . 70
III.13 Efficiency Factors . . . 75
III.14 Complement, Other GLMTs . . . 76

IV Gaussian Beams and Other Beams . . . 89
IV.1 Gaussian Beam Description . . . 90
IV.1.1 The Solving Paradox . . . 90
IV.1.2 Elementary Description . . . 92
IV.1.3 Historical . . . 93
IV.1.4 Davis Formulation . . . 94
IV.1.5 The Order L of Approximation . . . 96
IV.1.6 The Order L^- of Approximation . . . 96
IV.1.7 Kogelnik's Model . . . 98
IV.1.8 Inaccuracies at Orders L and L^- . . . 99
IV.2 GLMT at Orders L and L^- . . . 102
IV.2.1 Radial Field Components E_r and H_r . . . 102
IV.2.2 Beam Shape Coefficients . . . 105
IV.3 Numerical Computations of Beam Shape Coefficients by Using Quadratures . . . 108
IV.4 Other Beams . . . 108

V Finite Series . . . 117
V.1 The General Procedure . . . 117
V.2 The NET Procedure for Gaussian Beams . . . 120
V.2.1 Basic Relations . . . 120
V.2.2 BSCs $g^m_{n,TM}$, n and m Even . . . 124
V.2.3 Other BSCs $g^m_{n,TM}$ . . . 130
V.2.4 BSCs $g^m_{n,TE}$ . . . 135
V.3 Numerical Computations of BSCs by Using Finite Series . . . 136
V.3.1 Dimensionless Formulation . . . 136
V.3.2 Formulae Modifications for Programming . . . 137

VI Special Cases of Axisymmetric and Gaussian Beams . . . 139
VI.1 Axisymmetric Beams . . . 139
VI.2 The LSC-Decomposition and Gaussian-Like Beams . . . 141
VI.3 Axis Location in a Gaussian Beam . . . 145
VI.4 Lorenz-Mie Theory . . . 150
VI.5 A Theorem for the Special BSCs . . . 153

VI.6 Numerical Computations of Special BSCs by Using Quadratures 155
VI.6.1 Computer Programs 155
VI.6.2 More on the Plane Wave Case 156
VI.6.3 Numerical Behaviour of Quadratures 157
VI.7 Computations of Special BSCs by Using Finite Series . . . 161
VI.7.1 The Formulation 161
VI.7.2 Routines 165

VII The Localized Approximation and Localized Beam Models 169
VII.1 Generalities 169
VII.2 The Waist Center Location Case 171
VII.2.1 The Principle of Localization 171
VII.2.2 Special BSCs 171
VII.2.3 Numerical Evidence of Validity 172
VII.2.4 Physical Evidence of Validity 174
VII.2.5 Difference of Behaviour between Rigorous Methods and Localized Approximation 175
VII.3 Axis Location Case 176
VII.4 Arbitrary Location 181
VII.4.1 A Well Posed Problem 181
VII.4.2 BSCs g_n^{+1} and g_n^{-1} for Axis Location 182
VII.4.3 BSCs g_n^m for Arbitrary Location: First Attempt 185
VII.4.4 Final Generalization 189
VII.4.5 Improved Formulation and Routines 190
VII.4.6 Examples of Results 191
VII.5 Complement on the Localized Approximation 191
VII.6 Complement on the Evaluation of Beam Shape Coefficients 195

VIII Applications, and Miscellaneous Issues 199
VIII.0.1 Measurement Techniques 199
VIII.0.2 Internal Fields and Morphology-Dependent-Resonances 211
VIII.0.3 Mechanical Effects 214
VIII.0.4 Multiple Scattering 227
VIII.0.5 Miscellaneous Topics 228

IX Conclusion 231

A Evaluation of Quadratures, Rels (III.130) and (III.131) 233

B Evaluation of Quadradures, Rels (III.151) and (III.152) 235

C Evaluation of Quadratures, Rels (III.169) and (III.170) 237

D To Reduce the Double Summations of Chapter IV to Single Summations 241

E Useful Relations to Derive the BSCs of Chapter IV 245

F Computer Programs 247