Contents

Preface to the Third Edition xiii
Preface to the Second Edition xv
Preface to the First Edition xvii

1. The Nonlinear Optical Susceptibility **1**

1.1. Introduction to Nonlinear Optics 1
1.2. Descriptions of Nonlinear Optical Processes 4
1.3. Formal Definition of the Nonlinear Susceptibility 17
1.4. Nonlinear Susceptibility of a Classical Anharmonic Oscillator 21
1.5. Properties of the Nonlinear Susceptibility 33
1.6. Time-Domain Description of Optical Nonlinearities 52
1.7. Kramers–Kronig Relations in Linear and Nonlinear Optics 58
Problems 63
References 65

2. Wave-Equation Description of Nonlinear Optical Interactions **69**

2.1. The Wave Equation for Nonlinear Optical Media 69
2.2. The Coupled-Wave Equations for Sum-Frequency Generation 74
2.3. Phase Matching 79
2.4. Quasi-Phase-Matching 84
2.5. The Manley–Rowe Relations 88
2.6. Sum-Frequency Generation 91
2.7. Second-Harmonic Generation 96

2.8. Difference-Frequency Generation and Parametric Amplification 105
2.9. Optical Parametric Oscillators 108
2.10. Nonlinear Optical Interactions with Focused Gaussian Beams 116
2.11. Nonlinear Optics at an Interface 122
Problems 128
References 132

3. Quantum-Mechanical Theory of the Nonlinear Optical Susceptibility 135

3.1. Introduction 135
3.2. Schrödinger Calculation of Nonlinear Optical Susceptibility 137
3.3. Density Matrix Formulation of Quantum Mechanics 150
3.4. Perturbation Solution of the Density Matrix Equation of Motion 158
3.5. Density Matrix Calculation of the Linear Susceptibility 161
3.6. Density Matrix Calculation of the Second-Order Susceptibility 170
3.7. Density Matrix Calculation of the Third-Order Susceptibility 180
3.8. Electromagnetically Induced Transparency 185
3.9. Local-Field Corrections to the Nonlinear Optical Susceptibility 194
Problems 201
References 204

4. The Intensity-Dependent Refractive Index 207

4.1. Descriptions of the Intensity-Dependent Refractive Index 207
4.2. Tensor Nature of the Third-Order Susceptibility 211
4.3. Nonresonant Electronic Nonlinearities 221
4.4. Nonlinearities Due to Molecular Orientation 228
4.5. Thermal Nonlinear Optical Effects 235
4.6. Semiconductor Nonlinearities 240
4.7. Concluding Remarks 247
References 251

5. Molecular Origin of the Nonlinear Optical Response 253

5.1. Nonlinear Susceptibilities Calculated Using Time-Independent Perturbation Theory 253

5.2. Semiempirical Models of the Nonlinear Optical Susceptibility 259
Model of Boling, Glass, and Owyoung 260
5.3. Nonlinear Optical Properties of Conjugated Polymers 262
5.4. Bond-Charge Model of Nonlinear Optical Properties 264
5.5. Nonlinear Optics of Chiral Media 268
5.6. Nonlinear Optics of Liquid Crystals 271
Problems 273
References 274

6. Nonlinear Optics in the Two-Level Approximation 277

6.1. Introduction 277
6.2. Density Matrix Equations of Motion for a Two-Level Atom 278
6.3. Steady-State Response of a Two-Level Atom to a Monochromatic Field 285
6.4. Optical Bloch Equations 293
6.5. Rabi Oscillations and Dressed Atomic States 301
6.6. Optical Wave Mixing in Two-Level Systems 313
Problems 326
References 327

7. Processes Resulting from the Intensity-Dependent Refractive Index 329

7.1. Self-Focusing of Light and Other Self-Action Effects 329
7.2. Optical Phase Conjugation 342
7.3. Optical Bistability and Optical Switching 359
7.4. Two-Beam Coupling 369
7.5. Pulse Propagation and Temporal Solitons 375
Problems 383
References 388

8. Spontaneous Light Scattering and Acoustooptics 391

8.1. Features of Spontaneous Light Scattering 391
8.2. Microscopic Theory of Light Scattering 396
8.3. Thermodynamic Theory of Scalar Light Scattering 402

8.4. Acoustooptics 413
Problems 427
References 428

9. Stimulated Brillouin and Stimulated Rayleigh Scattering 429

9.1. Stimulated Scattering Processes 429
9.2. Electrostriction 431
9.3. Stimulated Brillouin Scattering (Induced by Electrostriction) 436
9.4. Phase Conjugation by Stimulated Brillouin Scattering 448
9.5. Stimulated Brillouin Scattering in Gases 453
9.6. Stimulated Brillouin and Stimulated Rayleigh Scattering 455
Problems 468
References 470

10. Stimulated Raman Scattering and Stimulated Rayleigh-Wing Scattering 473

10.1. The Spontaneous Raman Effect 473
10.2. Spontaneous versus Stimulated Raman Scattering 474
10.3. Stimulated Raman Scattering Described by the Nonlinear Polarization 479
10.4. Stokes–Anti-Stokes Coupling in Stimulated Raman Scattering 488
10.5. Coherent Anti-Stokes Raman Scattering 499
10.6. Stimulated Rayleigh-Wing Scattering 501
Problems 508
References 508

11. The Electrooptic and Photorefractive Effects 511

11.1. Introduction to the Electrooptic Effect 511
11.2. Linear Electrooptic Effect 512
11.3. Electrooptic Modulators 516
11.4. Introduction to the Photorefractive Effect 523
11.5. Photorefractive Equations of Kukhtarev *et al.* 526
11.6. Two-Beam Coupling in Photorefractive Materials 528
11.7. Four-Wave Mixing in Photorefractive Materials 536
Problems 540
References 540

12. Optically Induced Damage and Multiphoton Absorption **543**

12.1. Introduction to Optical Damage 543
12.2. Avalanche-Breakdown Model 544
12.3. Influence of Laser Pulse Duration 546
12.4. Direct Photoionization 548
12.5. Multiphoton Absorption and Multiphoton Ionization 549
Problems 559
References 559

13. Ultrafast and Intense-Field Nonlinear Optics **561**

13.1. Introduction 561
13.2. Ultrashort Pulse Propagation Equation 561
13.3. Interpretation of the Ultrashort-Pulse Propagation Equation 567
13.4. Intense-Field Nonlinear Optics 571
13.5. Motion of a Free Electron in a Laser Field 572
13.6. High-Harmonic Generation 575
13.7. Nonlinear Optics of Plasmas and Relativistic Nonlinear Optics 579
13.8. Nonlinear Quantum Electrodynamics 583
Problem 586
References 586

Appendices **589**

A. The SI System of Units 589
Further reading 596
B. The Gaussian System of Units 596
Further reading 600
C. Systems of Units in Nonlinear Optics 600
D. Relationship between Intensity and Field Strength 602
E. Physical Constants 603

Index **605**