

---

# Contents

---

## Part I Preliminaries

---

<b>1</b>	<b>Introduction</b>	3
1.1	Coherence	4
1.2	Basic Optical Principles	6
1.3	Relevant Material Systems	7
1.4	Related Systems	8
1.5	Aim of the Book	8
1.6	Necessary Prerequisites	10
1.7	Suggested Reading	10
<b>2</b>	<b>Experimental Techniques</b>	11
2.1	Linear Optical Spectra	11
2.2	Pump-Probe Experiments	14
2.3	Wave-Mixing Experiments	15
2.4	Transport Phenomena	15
<b>3</b>	<b>Few-Level Systems</b>	17
3.1	Two-Level Absorbers	18
3.2	Three- and More-Level Absorbers	21
3.3	Continua	21
3.4	Fano Situations	23
3.5	Suggested Reading	24
<b>4</b>	<b>Coherent Tunneling</b>	25
4.1	Analysis of Eigenstates	25
4.2	Population Dynamics	28
4.3	Equation of Motion Approach	30
4.4	Suggested Reading	33

<b>5</b>	<b>The Semiconductor Model</b>	35
5.1	Noninteracting Particles	35
5.1.1	The $1 \times 1$ -Tight-Binding Model	35
5.1.2	The $2 \times 2$ -Tight-Binding Model	36
5.1.3	The Electron–Hole Picture	39
5.1.4	Periodic Boundary Conditions	40
5.1.5	Ordered and Disordered Systems	40
5.2	Interacting Particles	42
5.3	Electron–Phonon Interaction	43
5.4	Electron–Light Interaction	44
<b>6</b>	<b>Single-Particle Properties</b>	47
6.1	Ordered Systems	47
6.1.1	States	47
6.1.2	Eigenvalues	48
6.1.3	Density of States	51
6.1.4	Optical Spectrum	52
6.1.5	Wave Packets and Propagation	53
6.1.6	Dimerized Systems	55
6.2	Disordered Systems	55
6.2.1	States	55
6.2.2	Eigenvalues	57
6.2.3	Density of States	57
6.2.4	Optical Spectrum	58
6.2.5	Wave Packets and Propagation	58
<b>7</b>	<b>The Equation of Motion Approach</b>	61
7.1	Observables	61
7.2	Noninteracting Particles	63
7.2.1	The Two-Level Bloch Equations	63
7.2.2	An Analogy	67
7.2.3	Dynamics of Optical Excitations	69
7.2.4	The Few-Level Bloch Equations	73
7.2.5	Fano Situations	74
<b>8</b>	<b>Dynamical Equations for Semiconductors</b>	75
8.1	Noninteracting Particles	75
8.2	Interacting Particles	79
8.2.1	Hierarchy of Equations	79
8.2.2	Coherent Dynamics-Controlled Truncation Scheme	80
8.2.3	Dynamical Truncation in the Coherent $\chi^{(3)}$ Limit	88
8.2.4	Hartree–Fock Approach in the Coherent $\chi^{(3)}$ Limit	92
8.2.5	Dynamical Truncation in the Coherent $\chi^{(5)}$ Limit	93
8.3	Suggested Reading	98

---

## Part II Applications I

---

<b>9 Linear Optical Response . . . . .</b>	101
9.1 Linear Response for Two-Level Systems . . . . .	102
9.2 Linear Response for Few-Level Systems . . . . .	105
9.2.1 Continua . . . . .	106
9.2.2 Homogeneous versus Inhomogeneous Ensembles . . . . .	107
9.3 Linear Response for Fano Systems . . . . .	108
9.3.1 Numerical Results . . . . .	109
9.3.2 Analytical Discussion . . . . .	114
9.4 Linear Response of the Semiconductor . . . . .	119
9.4.1 Ordered Semiconductor . . . . .	119
9.4.2 Dimerized Lattice . . . . .	124
9.4.3 Disordered Noninteracting Semiconductor . . . . .	132
9.4.4 Disordered Interacting Semiconductor . . . . .	134
9.5 Suggested Reading . . . . .	139
<b>10 Coherent <math>\chi^{(3)}</math> Processes for Level Systems . . . . .</b>	141
10.1 Coherent $\chi^{(3)}$ Processes for Two-Level Systems . . . . .	142
10.1.1 Pump-Probe Experiments . . . . .	142
10.1.2 Coherent Spectral Oscillations . . . . .	145
10.1.3 Optical Stark Effect . . . . .	147
10.1.4 Hole Burning . . . . .	151
10.1.5 Four-Wave-Mixing Experiments . . . . .	153
10.1.6 Polarization Interference . . . . .	156
10.1.7 Photon Echoes . . . . .	157
10.2 Coherent $\chi^{(3)}$ Processes for Few-Level Systems . . . . .	159
10.2.1 Pump-Probe Experiments . . . . .	160
10.2.2 Four-Wave-Mixing Experiments . . . . .	164
10.2.3 Quantum Beats . . . . .	164
10.2.4 Dephasing due to Continua . . . . .	167
10.3 Coherent $\chi^{(3)}$ Processes for Fano Systems . . . . .	170
10.4 Homogeneous versus Inhomogeneous Ensembles . . . . .	171
10.5 Suggested Reading . . . . .	174
<b>11 Coherent <math>\chi^{(3)}</math> and <math>\chi^{(5)}</math> Processes in Ordered Semiconductors . . . . .</b>	177
11.1 Noninteracting Particles . . . . .	178
11.2 Interacting Particles . . . . .	178
11.2.1 Pump-Probe Experiments . . . . .	180
11.2.2 Four-Wave Mixing . . . . .	188
11.3 Suggested Reading . . . . .	195

<b>12 Coherent <math>\chi^{(3)}</math> and <math>\chi^{(5)}</math> Processes in Disordered Semiconductors</b> . . . . .	197
12.1 Noninteracting Particles . . . . .	198
12.1.1 Pump-Probe Experiments . . . . .	198
12.1.2 Four-Wave-Mixing Experiments . . . . .	198
12.2 Interacting Particles . . . . .	201
12.2.1 Pump-Probe Experiments . . . . .	201
12.2.2 Four-Wave Mixing in the $\chi^{(3)}$ Limit . . . . .	203
12.2.3 Four-Wave Mixing in the $\chi^{(5)}$ Limit . . . . .	211
12.3 Suggested Reading . . . . .	213
<b>13 Coherent Excitation Spectroscopy</b> . . . . .	215
13.1 Level Systems . . . . .	215
13.2 Ordered Semiconductors . . . . .	217
13.3 Disordered Semiconductors . . . . .	218
13.4 Suggested Reading . . . . .	219
<b>14 Character of Continuum Transitions</b> . . . . .	221
14.1 Four-Wave-Mixing Traces . . . . .	222
14.2 Coherent Excitation Spectroscopy . . . . .	223

### Part III Applications II

<b>15 The Semiconductor with Applied Electric Field</b> . . . . .	229
15.1 Single-Particle Properties . . . . .	230
15.1.1 Linear Optical Response . . . . .	238
15.1.2 Coherent Density Dynamics . . . . .	242
15.1.3 Coherent $\chi^{(3)}$ Processes . . . . .	243
15.1.4 Dynamical Localization . . . . .	245
15.2 Interacting System . . . . .	246
15.2.1 Linear Optical Response . . . . .	247
15.2.2 Coherent Density Dynamics . . . . .	249
15.2.3 Coherent $\chi^{(3)}$ Processes . . . . .	249
15.2.4 Dynamical Localization . . . . .	251
15.3 Suggested Reading . . . . .	252
<b>16 Mesoscopic Semiconductor Rings</b> . . . . .	255
16.1 The Model . . . . .	255
16.1.1 No Magnetic Field . . . . .	255
16.1.2 Magnetic Field Included . . . . .	257
16.2 Single-Particle Properties . . . . .	260
16.2.1 The Single-Particle Spectrum . . . . .	260
16.2.2 Persistent Currents . . . . .	261

16.3 Dynamics of the Electron–Hole Dipole . . . . .	262
16.3.1 Noninteracting Particles . . . . .	262
16.3.2 Interacting Particles . . . . .	266
16.4 Linear and Nonlinear Magneto-Optics . . . . .	269
16.4.1 Linear Optical Spectra . . . . .	270
16.4.2 Nonlinear Optical Spectra . . . . .	272
16.4.3 Influence of Disorder . . . . .	275
16.5 Suggested Reading . . . . .	277
<b>17 Coherent Density Dynamics in Disordered Semiconductors . . . . .</b>	<b>279</b>
17.1 The Two-Interacting-Particles Problem . . . . .	279
17.2 The Semiconductor Two-Interacting-Particles Problem . . . . .	280
17.2.1 The Model . . . . .	280
17.2.2 Electron–Hole Symmetry . . . . .	281
17.2.3 Dynamic-Correlation-Induced Delocalization . . . . .	283
17.2.4 Finite-Time Scaling . . . . .	285
17.2.5 Influence of Correlated Versus Anticorrelated Disorder . . . . .	286
17.3 Suggested Reading . . . . .	290
<b>18 Current Echoes . . . . .</b>	<b>291</b>
18.1 Current Generation by Coherent Control . . . . .	292
18.2 Current Decay in Disordered Semiconductors . . . . .	295
18.3 Equal Electron and Hole Masses . . . . .	297
18.4 Different Electron and Hole Masses . . . . .	297
18.5 Excitation Intensity Dependence . . . . .	299
18.6 Intraband Dynamics . . . . .	300
18.7 Suggested Reading . . . . .	303
<b>19 Problems . . . . .</b>	<b>305</b>
<b>Index . . . . .</b>	<b>315</b>