Contents

1.	Cone	erent No	niinear opties	
	By №	I.S. Fel	d and V.S. Letokhov	1
	1.1	Introd	ductory Comments	1
Ref	erenc	es		4
2.	Suna	rradian	30	
	_		d and J.C. MacGillivray (With 14 Figures)	7
	2.1		ound Material	7
	2.2	_	al Principles	9
	2.3	•	tical Treatments	13
	2.5	2.3.1	Initiation of Superradiance: Quantized Field Treatment	14
		2.3.2	Semiclassical Theory	17
	2.4		s of the Theory	22
	2.7	2.4.1	Superradiance in the Ideal Limit	22
		2.4.2	Influence of Quantum Fluctuations	25
		2.4.3	Deviations from Ideal Behavior	27
		2.4.5	Finite Inversion Time	28
			Uniform Inversion: Cooperation Length	30
			Loss	31
			Decay and Dephasing Times	33
			Feedback Initial Polarization	33
			Initial Polarization	34
		2.4.4	Further Discussion of the Basic Assumptions	35
		_,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	Neglect of Interaction of Forward and Backward Waves	35
			Limitations of the Plane Wave Approximation	36
		2.4.5	Point Sample Superradiance	38
	2.5	Relati	on to Other Coherent Phenomena	40
		2.5.1	Limited Superradiance	40
		2.5.2	Transient Phenomena in Optically Thick Media	41
		2.5.3	Stimulated and Superradiant Emission	42
	2.6	Experi		45
		2.6.1	Experimental Observation of Superradiance	45
		2.6.2	Recent Experimental Results	46
		2.6.3	Comparison with Theory	49



	2.7	Conclu	ding Remarks	52
		2.7.1	Applications	52
		2.7.2	Summary	54
	Refe	rences		55
3.	Cohe	rence i	n High Resolution Spectroscopy	
	By V	.P. Chel	ootayev (With 30 Figures)	59
	3.1	Cohere	nt Phenomena in Resonant Processes	59
	3.2	Cohere	nt Phenomena in Saturated Absorption Spectroscopy	62
		3.2.1	Standing Wave	62
		3.2.2	Probe Wave Resonances	64
			Oppositely Traveling Waves	64
			Unidirectional Waves	66
			High-Frequency Stark Effect on Doppler Broadened	
			Transitions	67
			Spectroscopic Applications. Measurement of Relaxation	
			Constants	70
			Study of Level Structures and Separation of Weak Lines	71
			Optical Instability. Generation Stability	72
			Recoil Effect	75
		3.2.3	Influence of Collisions on Coherent Processes	76
			Study of Relaxation Processes	76
			Dipole Scattering	76
			Influence of the Elastic Scattering Without Phase Randomiz-	
			ation on Resonance Characteristics	78
	3.3	Cohere	nt Phenomena in Multilevel Systems	80
		3.3.1	Resonant Processes in Three-Level Systems	80
		3.3.2	Two-Photon Resonances	85
		3.3.3	Relation to Other Phenomena	86
	3.4	Method	of Separated Optical Fields	87
		3.4.1	Two-Photon Resonance in Separated Fields	88
			Narrow Two-Photon Absorption Resonances of the Sequence of	
			Supershort Pulses in a Gas	93
		3.4.2	Resonance in Separated Fields for Two-Level Atoms	93
		3.4.3	Coherent Radiation and Macroscopic Polarization Transfer	
			in Separated Fields	97
		3.4.4	Properties of Coherent Radiation in Separated Fields	100
			Destruction of an Interference Structure and Attainment of	
			Resonances with a Radiative Width	102
			Particle Scattering	103
		3.4.5	Coherent Raman Scattering in Separated Fields	105

		3.4.6	Transient Resonant Coherent Effects	1
	Refe	rences		1
4.	Mult	iphoton	Resonant Processes in Atoms	
		-	erg, B. Cagnac, and F. Biraben (With 23 Figures)	1
	4.1	-	s Experimental Aspects of Resonant Multiphoton Transitions	
		in Ator		1
		4.1.1	Selective Pumping of an Excited Level with Multiphoton	
		,,,,,	Transition	1
		4.1.2	Intermediate Step in Other Processes	1
		4.1.3	Spectroscopy Using Broadband Lasers	1
	4.2		r-Free Two-Photon Experiments	1
		4.2.1	Principle of Doppler-Free Multiphoton Transitions	1
		4.2.2	Experimental Observation of Doppler-Free Two-Photon	
			Transitions	1
			Typical Experiment in Sodium]
			Thermojonic Detection	1
		4.2.3	Doppler-Free Two-Photon Transitions in Hydrogen	1
		4.2.4	Other Possibilities of Doppler-Free Two-Photon Transitions	
		4.2.5	Experiments with Two Different Light Sources	:
	4.3		of Two-Photon Transitions in Atoms	
		4.3.1	The Effective Hamiltonian	
		4.3.2	Solution of the Density Matrix Equation	
		4.3.3	Case of Two Waves with Complex Polarizations	
		4.3.4	Two-Photon Line Shape in Vapors	
		4.3.5	Light Shifts	
			Comparison with Experiments	
		4.3.6	Selection Rules for Two-Photon Transitions	1
	4.4	Multip	hoton Transitions	
			Generalization of the Effective Hamiltonian]
		4.4.2	Discussion of the Light Shifts	1
			Case of a Standing Wave	1
		4.4.3	Application to Multiphoton Ionization	1
		4.4.4	Doppler-Free Three-Photon Transition	1
		4.4.5	Three-Photon Selection Rules	1
	4.5	Disper	sion Near a Two-Photon Resonance	1
		4.5.1	Refractive Index for a Travelling Wave	1
		4.5.2	Refractive Indices for Two Waves of Different Frequencies	1
		4.5.3	Refractive Index for a Standing Wave	1
	4.6		ent Processes Involving Doppler-Free Two-Photon Excitation	1
		4.6.1	Free Induction Transients	1
		4.6.2	Transients in the Driven Regime	1
	Refe	rences		1

5.	Cohe:	rent Ex	citation of Multilevel Systems by Laser Light	
	Ву С	.D. Can	trell, V.S. Letokhov, and A.A. Makarov (With 25 Figures)	165
	5.1	Multil	evel Molecular Systems	165
		5.1.1	The Schrödinger Equation for Multilevel Systems in the	
			Rotating-Wave Approximation	168
		5.1.2	"Quasi-Energy" or "Dressed-States" Approach for Multilevel	
			Systems	170
			Constant Optical Electric Field	170
			Adiabatic Switching on of the Field	172
	5.2	Intera	ction of Equidistant Nondegenerate Multilevel Systems with	
		a Quas	i-Resonant Field	173
		5.2.1	Analytical Solutions for an Exactly Resonant Field	175
			Harmonic Oscillator	176
			Infinite System with Equal Dipole Moments	177
			A System with Decreasing Dipole Moments	179
			N-Level System with Equal Dipole Moments	181
		5.2.2	Does Resonance Always Result in Effective Excitation?	183
		5.2.3	Nonexact Resonance and Its Compensation by Power Broadening	186
			Step-Function Laser Pulse	187
			Adiabatically Switched-On Pulse	188
			General Estimates for Maximum Detuning	188
	5.3	Intera	action of Nonequidistant Multilevel Systems with a Quasi-	
			unt Field	189
		5.3.1	Multiphoton Resonances	191
			Rabi Frequency for Multiphoton Transitions	192
		5.3.2	Numerical Calculations for Multilevel Systems	195
		5.3.3	Dynamic Stark Effect and Frequency Shifts	202
			An Analytically Solvable Example	202
			General Approach to an Approximate Description of the	
			Dynamics of Oscillator-Type Systems	205
			Upper Subsystem—Harmonic Oscillator	207
			Upper Subsystem with Equal Dipole Moments	208
		5.3.4	"Leakage" from the Lower Quantum States into the Upper	
			Levels	208
		5.3.5	Excitation of Multiplet Systems with a Quasi-Continuous	
			Structure of Transitions	211
	5.4	Excit	ation of Triply-Degenerate Vibrational Modes of Spherical-Top	
		Moleci		215
		5.4.1	2.16.2214.224	216
			Expression of the Hamiltonian in Terms of Cartesian Creation	
			and Annihilation Operators	218

			Orders of Magnitude of Anharmonic Operators	220
			Final Form of the Vibrational Hamiltonian	221
			Comparison with Hecht's Hamiltonian	223
			The Spherical Vibrational Basis	226
			Eigenvalues of the Vibrational Hamiltonian	228
		5.4.2	Physical Significance of Vibrational Anharmonic Parameters	231
		5.4.3	Rotational States and Vibration-Rotation Bases	235
			Rigid-Rotor Wave Functions	235
			Coupled Vibration-Rotation Basis	236
			Symmetry-Adapted Vibration-Rotation Basis	237
		5.4.4	Vibration-Rotation Hamiltonian	237
		5.4.5	Dipole Transition Moments in Spherical-Top Molecules	242
		5.4.6	Experimental Determination of the Anharmonic Parameters of	
			the v_3 Mode of SF_6	244
		5.4.7	Effective-State Models for Molecular Multiphoton	
			Calculations	246
			Absorption Strength of an Ensemble of Two-Level Systems	247
			Effective-State Equations of Motion	249
			Dipole Transition Moments Between Effective States	250
			Calculation of Degeneracies and Transition Strengths	251
		5.4.8	Calculation of Multiphoton Excitation Including a Thermal	
			Distribution of Initial State	255
		5.4.9	Numerical Calculations of Multiphoton Excitation of ${\sf SF}_6$	259
	Refe	rences		266
6.	Cohe	rent Pi	cosecond Interactions	
	Ву А	. Laube	reau and W. Kaiser (With 10 Figures)	271
	6.1	Overvi	ew	271
	6.2	Theory	of Investigations	272
		6.2.1	Excitation Process	272
		6.2.2	Coherent Probing	276
	6.3	Experi	mental	280
		6.3.1	Generation of Ultrashort Laser Pulses	280
		6.3.2	Coherent Excitation and Probing Techniques	281
	6.4	Experi	mental Results and Discussion	283
		6.4.1	Modes with Homogeneous Line Broadening	283
		6.4.2	Modes with Discrete Substructure	285
		6.4.3	Modes with Inhomogeneous Line Broadening	286
		6.4.4	Vibrational Modes in Solids	288
	6.5	Intera	ction Processes	290
	Refe	rences		291

7.	Cohe:	rent Ran	nan Spectroscopy	
	Ву М	.D. Leve	enson and J.J. Song (With 32 Figures)	293
	7.1	Histor	ical Background	293
		7.1.1	Prehistory	293
		7.1.2	The Tunable Laser Era	296
	7.2	Theory		297
		7.2.1	Extended Two-Level Model for Coherent Raman Spectroscopy	2 9 8
		7.2.2	The Nonlinear Polarization	302
			Stimulated Raman Gain and Loss Spectroscopy, and the Raman	
			Induced Kerr Effect	303
			Coherent Anti-Stokes and Coherent Stokes Raman Spectroscopy	303
			Four-Wave Mixing	304
			Photoacoustic Raman Spectroscopy	304
		7.2.3	The Nonlinear Susceptibility Tensor	305
		7.2.4	Doppler Broadening	308
		7.2.5	Symmetry Considerations	310
		7.2.6	Relationship Between χ^R and the Spontaneous Cross Section	316
		7.2.7	The Coherent Raman Signal	316
		7.2.8	Focusing Considerations	319
		7.2.9	Accentric Crystals and Polaritons	322
		7.2.10	Resonant Effects and Absorbing Samples	325
	7.3	Experi	mental Techniques	330
		7.3.1	CARS in Liquids and Solids	330
		7.3.2	CARS in Gases: Pulsed Laser Techniques	334
		7.3.3	Multiplex CARS	334
		7.3.4	CW CARS	335
		7.3.5	Nonlinear Ellipsometry	336
		7.3.6	Raman Induced Kerr Effect Spectroscopy (RIKES)	337
		7.3.7	Optical Heterodyne Detected RIKES	339
		7.3.8	Stimulated Raman Gain and Loss Spectroscopy	342
		7.3.9	Four-Wave Mixing	344
		7.3.10	Signals, Noise and Sensitivity	346
		7.3.11	Signal Enhancement with Interferometers, Intra-Cavity	
			Techniques and Multipass Cells	351
	7.4	Applic	ations	353
		7.4.1	Combustion Diagnostics: Concentration and Temperature	
			Measurement	353
		7.4.2	Raman Cross Section and Nonlinear Susceptibility	
			Measurements	355
		7.4.3	High-Resolution Molecular Spectroscopy	358
		7.4.4	Raman Spectra of Fluorescent and Resonant Samples	359

7.4.5 Polariton Dispersion: Spectrosc	copy in Momentum Space 36
7.4.6 Low Frequency Modes	36
7.4.7 Vibrational and Rotational Rela	xation Measurements 36
7.5 Conclusions	36
References	
Additional References with Titles	37
Subject Index	37