

# Contents

<b>1</b>	<b>Introduction</b>	<b>1</b>
1.1	Ways to control the emission of light	1
1.2	From the control of light to the control of atoms and molecules	7
1.3	On the aims of this book	10
<b>2</b>	<b>Elementary radiative processes</b>	<b>12</b>
2.1	Spontaneous emission	12
2.2	Stimulated absorption and emission	15
2.3	Recoil effect and Doppler effect	18
2.4	Resonant excitation of a two-level system free from relaxation	22
2.5	Resonant excitation of a two-level system with relaxations	26
2.6	Radiation-scattering processes	33
<b>3</b>	<b>Laser velocity-selective excitation</b>	<b>35</b>
3.1	Doppler broadening of optical spectral lines	35
3.2	Homogeneous broadening mechanisms	38
3.3	Doppler-free saturation spectroscopy	40
3.4	Ultrahigh spectral resolution	49
<b>4</b>	<b>Optical orientation of atoms and nuclei</b>	<b>54</b>
4.1	Optical orientation of atoms	54
4.2	Radio-frequency spectroscopy of optically oriented atoms	58
4.3	Spin-exchange optical pumping	61
4.4	Coherent effects and optically oriented atoms	62
4.5	Applications of optically pumped atoms	64
<b>5</b>	<b>Laser cooling of atoms</b>	<b>68</b>
5.1	Introduction. History of ideas	69
5.2	Laser radiation force on a two-level atom	72
5.3	Quantum fluctuation effects. Temperature limits of laser cooling	76
5.4	Doppler cooling	77
5.5	Laser polarization gradient cooling below the Doppler limit	83
5.6	Cooling below the recoil limit	87



**x Contents**

<b>6</b>	<b>Laser trapping of atoms</b>	<b>92</b>
6.1	Optical trapping	92
6.2	Magnetic trapping	100
6.3	Magneto-optical trapping	103
6.4	Gravito-optical and near-field traps	106
6.5	Optical trapping of cold atoms—new tools for atomic physics	109
<b>7</b>	<b>Atom optics</b>	<b>113</b>
7.1	Introduction. Matter waves	113
7.2	Reflection of atoms by light	114
7.3	Laser focusing of an atomic beam	120
7.4	Diffraction of atoms	127
7.5	Atom interferometry	130
7.6	Atomic holography	135
7.7	Towards atom nanooptics	135
<b>8</b>	<b>From laser-cooled and trapped atoms to atomic and molecular quantum gases</b>	<b>138</b>
8.1	Introduction	139
8.2	Bose-Einstein condensation of atomic gases	141
8.3	Fermi-degenerate quantum atomic gases	148
8.4	Formation of ultracold molecules	150
8.5	Molecular quantum gases	155
<b>9</b>	<b>Laser photoselective ionization of atoms</b>	<b>158</b>
9.1	Introduction	158
9.2	Resonance excitation and ionization of atoms	159
9.3	Photoionization detection of rare atoms and radioactive isotopes	168
9.4	Laser photoionization separation of isotopes, isobars, and nuclear isomers	175
<b>10</b>	<b>Multiphoton ionization of molecules</b>	<b>182</b>
10.1	Photoselective resonance ionization of molecules	183
10.2	Resonance-enhanced multiphoton ionization (REMPI) of molecules	185
10.3	Laser desorption/ionization of biomolecules	189
<b>11</b>	<b>Photoselective laser control of molecules via molecular vibrations</b>	<b>198</b>
11.1	Vibrationally mediated photodissociation of molecules via excited electronic states	199
11.2	Basics of IR multiple-photon excitation/dissociation of polyatomic molecules in the ground state	201
11.3	Characteristics of the IR MPE/D of polyatomic molecules	208
11.4	Intermolecular selectivity of IR MPE/D for laser isotope separation	218
11.5	Prospects for mode-selective MPE/D by IR femtosecond pulses	221



<b>12 Coherent laser control of molecules</b>	224
12.1 Introduction to coherent optimal control	225
12.2 Coherent control using wave packets	226
12.3 Coherent control using quantum interference	229
12.4 Optimal feedback control	230
12.5 Coherent optimal control by tailored strong-field laser pulses	232
12.6 Coherent control of large molecules in liquids	234
12.7 Perspectives	235
<b>13 Related topics: laser control of microparticles and free electrons</b>	238
13.1 Laser trapping of microparticles	238
13.2 Laser control of free-electron motion	244
<b>14 Concluding comments</b>	251
<b>References</b>	273
<b>Index</b>	303