

---

# CONTENTS

---

<b>Preface</b> . . . . .	<b>v</b>
<b>Introduction</b> . . . . .	<b>1</b>
<b>Chapter 1. Coherent Interaction between Atoms and Field</b> . . . . .	<b>9</b>
1. The Hamiltonian of Atom-Field Interaction . . . . .	9
2. Light Pressure Force . . . . .	18
2.1. Adiabatic states. Nonresonant potential. . . . .	24
2.2. Diabatic states. Resonant potential. . . . .	28
2.3. Atomic density-matrix equation with allowance for a recoil effect . . . . .	31
3. The Non-Adiabaticity Operator. Landau-Zener (LZ) Transitions . . . . .	33
<b>Chapter 2. Scattering of Atoms by Light</b> . . . . .	<b>45</b>
4. The Classical Picture of Scattering . . . . .	45
5. Acceleration of Atoms by Light . . . . .	58
6. Diffraction of Atoms . . . . .	68
6.1. Diffraction of a "coherent" atomic beam . . . . .	68
6.2. Experiment . . . . .	71
6.3. Bragg scattering . . . . .	73
6.4. The scattering of atoms by a quantized electromagnetic field . . . . .	76
7. The Interference of Atoms . . . . .	81

7.1. The interference of atoms scattered by a single standing wave . . . . .	82
7.2. The transfer of the spatial coherence under the Echo conditions . . . . .	85
7.3. Pulse scattering regime . . . . .	87
7.4. Nonlinear atomic interferometry . . . . .	88
7.5. The Bohm-Aaronov effect . . . . .	89
7.6. The interference of atoms in a gas . . . . .	89
7.7. Combined scattering regime . . . . .	91

**Chapter 3. Dispersion of Atoms in Light Fields . . . . . 95**

8. Dispersion of Atoms in the Periodic Light Field . . .	95
8.1. Travelling wave . . . . .	96
8.2. Atoms in a standing wave. Symmetry of the problem. . . . .	98
8.3. Dispersion law for a weak field . . . . .	100
9. A Strong Field Case. The Above-Barrier Motion . . .	103
9.1. The scalar particle in a periodic potential . . . .	104
9.2. The influence of the Landau-Zener transitions . .	105
9.3. The Bloch functions of an atom in a standing-wave field . . . . .	108
9.4. Optical characteristics of atoms in a standing-wave field . . . . .	109
10. The Under-Barrier Motion of Atoms in a Strong Field	113
10.1. The bipotential motion ( $\Delta/2 < \mathcal{E} < V_0$ ). Strong coupling approximation (small A) . . . .	113
10.2. The lifetime of bound states of atoms at large A . . . . .	117
10.3. The quasiclassical analysis of the sub-barrier motion . . . . .	122
11. Bipotential Scattering. . . . .	130

**Chapter 4. Influence of Spontaneous Radiation on Light Pressure Force . . . . . 141**

12. Equation for the Atomic Density Matrix . . . . .	142
--	-----

13. The Light Pressure Force and the Hysteresis	
Phenomenon . . . . .	150
13.1. Light pressure force in the travelling wave . . . . .	152
13.2. Light pressure force in the standing wave . . . . .	153
13.3. Peculiarities of the perturbation theory in the field of a standing wave . . . . .	155
13.4. Strong field. Quasistationary approximation . . . . .	161
13.5. Strong field. Quasiclassical approximation. LZ-transitions . . . . .	168
13.6. Friction force for fast atoms . . . . .	176
14. Light Pressure Force and Spectrum of Resonance Fluorescence . . . . .	178
14.1. Atomic correlation matrix with allowance for recoil . . . . .	178
14.2. Spectrum resonance fluorescence in the field of a travelling wave . . . . .	183
14.3. Relationship between the light pressure force and spectrum of resonance fluorescence . . . . .	186
14.4. Spectrum of resonance fluorescence in the field of a standing wave . . . . .	189
15. Cooling and Velocity Bunching of Atoms in the Light Field . . . . .	194
15.1. Deceleration of atoms in the intense standing wave . . . . .	194
15.2. Cooling of atoms by the spontaneous light pressure force . . . . .	196
15.3. Cooling of trapped ions by the light field . . . . .	196
15.4. Bunching of atoms in the velocity space . . . . .	201
16. Interference Phenomena and the Effect of Rectification of the Radiation Force . . . . .	212
16.1. Interference phenomena in the monochromatic field . . . . .	212
16.2. Interference phenomena in a weak bichromatic field . . . . .	217
16.3. Bichromatic fields of finite amplitude . . . . .	219

**Chapter 5. Kinetics of Atoms in Light Fields . . . . . 227**

**17. Kinetics of Atoms in the Travelling Wave Field . . . 228**

**17.1. The Fokker-Planck kinetic equation . . . . . 228**

**17.2. Slow bunching in velocities of atoms in the travelling wave field . . . . . 231**

**17.3. Rapid velocity bunching in the presence of magnetic field . . . . . 235**

**17.4. Influence of the light pressure on the nonlinear susceptibility of resonance atoms. . . . . 236**

**18. Kinetics of Atoms in a Weak Standing-Wave Field . . 241**

**18.1. Kinetic equation in linear approximation in the field strength . . . . . 241**

**18.2. Evolution of the velocity distribution in a weak standing-wave field. . . . . 247**

**18.3. Viscous confinement in a field of the three orthogonal standing waves . . . . . 253**

**18.4. Nonlinear susceptibility of resonance atoms in a standing-wave field. . . . . 254**

**19. Kinetic Equation for Slow Atoms in a Standing-Wave Field . . . . . 256**

**19.1. Derivation of the kinetic equation . . . . . 257**

**19.2. Properties of the kinetic coefficients . . . . . 260**

**19.3. Light pressure force in a laser beam of finite radius . . . . . 264**

**20. Scattering of Atoms by a Standing Wave in the Kinetic Regime . . . . . 267**

**21. Cooling and Localization of Atoms in a Strong Standing Light Wave . . . . . 276**

**21.1. Stationary solution of the kinetic equation. . . . . 277**

**21.2. Effective temperature of the untrapped particles . . . . . 279**

**21.3. One-dimensional lattice of cooled atoms and the channelling phenomenon . . . . . 281**

**21.4. Three-dimensional lattice of cooled atom . . . . . 285**

**21.5. Lifetime of atoms in the light-wave grating . . . . . 288**

21.6. Viscous confinement in a saturating field . . . . .	289
22. Localization of Atoms in Strong Fields . . . . .	291
22.1. Motion of atoms in the focus of a laser beam . . . . .	292
22.2. Localization of atoms by light and magnetic fields . . . . .	295
22.3. Localization of atoms in a bichromatic field . . . . .	297
23. Kinetics of Fast Atoms in a Standing Light Wave . . . . .	299
23.1. Kinetics of atoms under strong hysteresis . . . . .	300
23.2. Fokker-Planck equation for fast atoms . . . . .	302
23.3. Strong field. Bipotential kinetics . . . . .	306
24. Diffraction, Diffusion and Potential Scattering Atoms in a Standing-Light Wave Field . . . . .	308
24.1. Basic equations . . . . .	309
24.2. The case of large detunings. Spatial correlation of spontaneous and induced transitions . . . . .	311
24.3. Diffraction scattering . . . . .	315
24.4. Incoherent scattering . . . . .	317
24.5. Statistics of scattered photons . . . . .	320
25. Polarization Effects in the Resonance Light Pressure . . . . .	320
25.1. Equation for the density matrix . . . . .	321
25.2. Magnetization of atoms by the linearly polarized wave. . . . .	326
26. Density Effects . . . . .	330
26.1. Atomic collisions in a light field . . . . .	330
26.2. The interaction of atoms in a light field . . . . .	333
<b>Appendix I. Diffraction of Atoms from a Standing-Wave   Field with Smooth Temporal Envelope . . . . .</b>	<b>337</b>
<b>Appendix II. Effects of Spontaneous Relaxation in the   Transfer of Spatial Coherence under the   Echo Conditions . . . . .</b>	<b>341</b>
<b>Appendix III. General Form of the Dispersion Law for   Atoms in a Standing-Wave Field . . . . .</b>	<b>347</b>

Appendix IV. Dispersion of an Atom in a Strong Standing Wave under Small <b>Detunings</b> from Resonance . . . . .	353
Appendix V. Solution of the <b>Bloch</b> Equations Near the Standing-Wave Nodes . . . . .	363
References . . . . .	367
Subject Index . . . . .	375