Contents

1. Introduction 1

2. Absorption and Emission of Light 5
2.1 Cavity Modes 5
2.2 Thermal Radiation and Planck's Law 9
2.3 Absorption, Induced, and Spontaneous Emission 11
2.4 Basic Photometric Quantities 15
2.4.1 Definitions 16
2.4.2 Illumination of Extended Areas 18
2.5 Polarization of Light 20
2.6 Absorption and Emission Spectra 22
2.7 Transition Probabilities 26
2.7.1 Lifetimes, Spontaneous and Radiationless Transitions 27
2.7.2 Semiclassical Description: Basic Equations 29
2.7.3 Weak-Field Approximation 32
2.7.4 Transition Probabilities with Broad-Band Excitation 34
2.7.5 Phenomenological Inclusion of Decay Phenomena . 35
2.7.6 Interaction with Strong Fields 37
2.7.7 Relations Between Transition Probabilities, Absorption Coefficient, and Line Strength 41
2.8 Coherence Properties of Radiation Fields 42
2.8.1 Temporal Coherence 43
2.8.2 Spatial Coherence 44
2.8.3 Coherence Volume 46
2.8.4 The Coherence Function and the Degree of Coherence 49
2.9 Coherence of Atomic Systems 54
2.9.1 Density Matrix 54
2.9.2 Coherent Excitation 56
2.9.3 Relaxation of Coherently Excited Systems 58
Problems 58

3. Widths and Profiles of Spectral Lines 61
3.1 Natural Linewidth 62
3.1.1 Lorentzian Line Profile of the Emitted Radiation .. 62
3.1.2 Relation Between Linewidth and Lifetime 64
3.1.3 Natural Linewidth of Absorbing Transitions 66
3.2 Doppler Width 70

Bibliografische Informationen
http://d-nb.info/984910743

digitalisiert durch DEUTSCHE NATIONAL BIBLIOTHEK

3.3 Collisional Broadening of Spectral Lines 75
3.3.1 Phenomenological Description 75
3.3.2 Relations Between Interaction Potential, Line Broadening, and Shifts 80
3.3.3 Collisional Narrowing of Lines 84
3.4 Transit-Time Broadening 84
3.5 Homogeneous and Inhomogeneous Line Broadening 88
3.6 Saturation and Power Broadening 90
3.6.1 Saturation of Level Population by Optical Pumping 90
3.6.2 Saturation Broadening of Homogeneous Line Profiles 92
3.6.3 Power Broadening 93
3.7 Spectral Line Profiles in Liquids and Solids 95
Problems 97

4. Spectroscopic Instrumentation 99
4.1 Spectrographs and Monochromators 99
4.1.1 Basic Properties 101
4.1.2 Prism Spectrometer 111
4.1.3 Grating Spectrometer 115
4.2 Interferometers 124
4.2.1 Basic Concepts 124
4.2.2 Michelson Interferometer 125
4.2.3 Fourier Spectroscopy 129
4.2.4 Mach–Zehnder Interferometer 131
4.2.5 Sagnac Interferometer 134
4.2.6 Multiple-Beam Interference 136
4.2.7 Plane Fabry–Perot Interferometer 144
4.2.8 Confocal Fabry–Perot Interferometer 152
4.2.9 Multilayer Dielectric Coatings 157
4.2.10 Interference Filters 162
4.2.11 Birefringent Interferometer 165
4.2.12 Tunable Interferometers 169
4.3 Comparison Between Spectrometers and Interferometers 170
4.3.1 Spectral Resolving Power 170
4.3.2 Light-Gathering Power 173
4.4 Accurate Wavelength Measurements 174
4.4.1 Precision and Accuracy of Wavelength Measurements 175
4.4.2 Today's Wavemeters 178
4.5 Detection of Light 188
4.5.1 Thermal Detectors 191
4.5.2 Photodiodes 198
4.5.3 Photodiode Arrays 208
4.5.4 Charge-Coupled Devices (CCDs) 210
4.5.5 Photoemissive Detectors 212
4.5.6 Detection Techniques and Electronic Equipment ... 224

4.6 Conclusions 231
Problems 231

5. Lasers as Spectroscopic Light Sources 235
5.1 Fundamentals of Lasers 235
5.1.1 Basic Elements of a Laser 235
5.1.2 Threshold Condition 236
5.1.3 Rate Equations 238
5.2 Laser Resonators 241
5.2.1 Open Optical Resonators 242
5.2.2 Spatial Field Distributions in Open Resonators 245
5.2.3 Confocal Resonators 247
5.2.4 General Spherical Resonators 250
5.2.5 Diffraction Losses of Open Resonators 251
5.2.6 Stable and Unstable Resonators 253
5.2.7 Ring Resonators 258
5.2.8 Frequency Spectrum of Passive Resonators 260
5.3 Spectral Characteristics of Laser Emission 262
5.3.1 Active Resonators and Laser Modes 263
5.3.2 Gain Saturation 266
5.3.3 Spatial Hole Burning 268
5.3.4 Multimode Lasers and Gain Competition 269
5.3.5 Mode Pulling 273
5.4 Experimental Realization of Single-Mode Lasers 274
5.4.1 Line Selection 275
5.4.2 Suppression of Transverse Modes 279
5.4.3 Selection of Single Longitudinal Modes 281
5.4.4 Intensity Stabilization 288
5.4.5 Wavelength Stabilization 291
5.5 Controlled Wavelength Tuning of Single-Mode Lasers 302
5.5.1 Continuous Tuning Techniques 303
5.5.2 Wavelength Calibration 308
5.5.3 Frequency Offset Locking 310
5.6 Linewidths of Single-Mode Lasers 310
5.7 Tunable Lasers 314
5.7.1 Basic Concepts 314
5.7.2 Semiconductor-Diode Lasers 315
5.7.3 Tunable Solid-State Lasers 321
5.7.4 Color-Center Lasers 325
5.7.5 Dye Lasers 329
5.7.6 Excimer Lasers 346
5.7.7 Free-Electron Lasers 349
5.8 Nonlinear Optical Mixing Techniques 352
5.8.1 Physical Background 353
5.8.2 Phase Matching 358
5.8.3 Second-Harmonic Generation 360
5.8.4 Quasi Phase Matching 366

5.8.5 Sum-Frequency and Higher-Harmonic Generation . 368
5.8.6 X-Ray Lasers 373
5.8.7 Difference-Frequency Spectrometer 377
5.8.8 Optical Parametric Oscillator 380
5.8.9 Tunable Raman Lasers 384
5.9 Gaussian Beams 388
Problems 394

Solutions 397

References 425

Subject Index 453