CONTENTS

PREFACE

CHAPTER ONE
AN INTRODUCTION TO LASERS AND MASERS **1**

1-1 Lasers, Masers, and Quantum Electronics 1
1-2 Basic Principles of Maser Action 4
1-3 Spontaneous Versus Stimulated Emission 25
1-4 Some Important Practical Maser Devices 27
1-5 Some Additional Maser Systems 54
1-6 Special Properties of Laser Light 59

CHAPTER TWO
ELECTRIC-DIPOLE TRANSITIONS:
THE CLASSICAL ELECTRON-OSCILLATOR MODEL **67**

2-1 The Classical Electron-Oscillator Model 67
2-2 Response of the Classical Oscillator Model to an Applied Signal 72
2-3 The Response of Real Electric-Dipole Atoms 80
2-4 Reaction Back on the Electromagnetic Field: Equivalent Circuit 84
2-5 The Complete System: Cavity Plus Atoms 92

CHAPTER THREE
LIFETIME AND COLLISION BROADENING OF ATOMIC TRANSITIONS **99**

3-1 Lifetime Broadening of an Atomic Resonance 100
3-2 Broadening of an Atomic Resonance by Dephasing Collisions 103
3-3 Collision-Broadening and Energy-Decay Effects in Real Atoms 110
3-4 Collision Rates in Real Gases 119

CHAPTER FOUR
MAGNETIC-DIPOLE TRANSITIONS:
THE CLASSICAL MAGNETIZED-TOP MODEL **125**

4-1 Magnetic Properties of Individual Atoms: The Classical Magnetized-Top Model 126
4-2 Precessional Motion of the Magnetized-Top Model 130
4-3 Collections of Magnetic Dipoles: DC Paramagnetic Susceptibility 134
4-4 Collections of Magnetic Dipoles: Relaxation Processes 145
4-5 Collections of Magnetic Dipoles: The Bloch Equations and their Solutions 150
4-6 Reaction Back on the Electromagnetic Field: Equivalent Circuit 167
4-7 Population Differences and Rate Equations 174

CHAPTER FIVE
THE FUNDAMENTALS OF MASER AMPLIFICATION **180**

5-1 Population Inversion, Negative Resistance, and Negative Temperature 181
5-2 Cavity Maser Amplifiers: Equivalent Circuit 188
5-3 Resonant Negative-Resistance Amplification: Gain and Gain-Bandwidth Product 194
5-4 Traveling-Wave Maser Amplification: The Plane-Wave Case 207
5-5 Traveling-Wave Maser Amplification: Regenerative Traveling-Wave Amplifiers

CHAPTER SIX
RATE EQUATIONS FOR ATOMIC TRANSITIONS **237**

6-1 Rate Equation for a Two-Level System 238
6-2 Saturation of a Two-Level Transition 244
6-3 Rate Equations for Multiple-Energy-Level Systems 249
6-4 Low-Frequency and High-Frequency Rate-Equation Approximations 254

CHAPTER SEVEN
MICROWAVE SOLID-STATE MASERS **258**

7-1 The Three-Level Microwave Maser 259
7-2 Microwave Traveling-Wave Masers 274
7-3 Applications of Microwave Solid-State Masers 285

CHAPTER EIGHT
OPTICAL RESONATORS AND LENS WAVEGUIDES **293**

8-1 Periodic Focusing Systems: Ray Approach 294
8-2 Gaussian Light Beams: Diffraction Approach 304
8-3 Mode Properties of Stable Optical Resonators 321
8-4 Higher-Order Gaussian Beam Modes and Resonator Modes 328
8-5 Planar and Related Resonators: Fox and Li Approach 335

CHAPTER NINE
DOPPLER BROADENING:
HOMOGENEOUS AND INHOMOGENEOUS TRANSITIONS 346

9-1 Homogeneous versus Inhomogeneous Line Broadening 346
9-2 Doppler Broadening of Atomic Transitions 352
9-3 Other Broadening Mechanisms for Optical-Frequency Transitions 360
9-4 Effects of Inhomogeneous Broadening on Laser Operation 363

CHAPTER TEN
OPTICAL MASERS (LASERS)

10-1 Laser Pumping Methods 374
10-2 Laser Oscillation Conditions: Gain and Population Inversion 391
10-3 Laser Oscillation Conditions: Oscillation Frequency and Frequency Pulling 404
10-4 Rate Equations for a Laser Oscillator 411
10-5 Steady-State Solutions: Saturation and Laser-Power Output 422
10-6 Optimum Laser Output Coupling 431
10-7 The Laser Threshold Region 437
10-8 Laser Amplitude Fluctuations and Spiking 443
10-9 A Laser Lumped Equivalent Circuit 449

CHAPTER ELEVEN
SPONTANEOUS EMISSION AND NOISE

11-1 Spontaneous Emission 462
11-2 Blackbody Radiation and Noise in Electric Circuits 470
11-3 Maser Noise in Negative-Resistance Electric Circuits 482
11-4 Noise Problems in Practical Maser Amplifiers 490

APPENDIXES

A Atoms, Quantum Energy Levels, and Energy-Level Populations 499
B Thermodynamic Derivation of Negative Temperature 502
C Mirror Reflection and Transmission Coefficients 504
D Group Velocity 506
E Optical Cavity Q 508

INDEX 513