

Principles of Lasers

FIFTH EDITION

Orazio Svelto

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FIFTH EDITION

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by Orazio Svelto

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*To my wife Rosanna
and to my sons Cesare and Giuseppe*

Preface

This book is motivated by the very favorable reception given to the previous editions as well as by the considerable range of new developments in the laser field since the publication of the third edition in 1989. These new developments include, among others, Quantum-Well and Multiple-Quantum Well lasers, diode-pumped solid-state lasers, new concepts for both stable and unstable resonators, femtosecond lasers, ultra-high-brightness lasers etc. The basic aim of the book has remained the same, namely to provide a *broad and unified description* of laser behavior at the simplest level which is compatible with a correct physical understanding. The book is therefore intended as a text-book for a senior-level or first-year graduate course and/or as a reference book.

This edition corrects several errors introduced in the previous edition. The most relevant *additions or changes* to since the third edition can be summarized as follows:

1. A much-more detailed description of Amplified Spontaneous Emission has been given [Chapt. 2] and a novel simplified treatment of this phenomenon both for homogeneous or inhomogeneous lines has been introduced [Appendix C].
2. A major fraction of a chapter [Chapt. 3] is dedicated to the interaction of radiation with semiconductor media, either in a bulk form or in a quantum-confined structure (quantum-well, quantum-wire and quantum dot).
3. A modern theory of stable and unstable resonators is introduced, where a more extensive use is made of the ABCD matrix formalism and where the most recent topics of dynamically stable resonators as well as unstable resonators, with mirrors having Gaussian or super-Gaussian transverse reflectivity profiles, are considered [Chapt. 5].
4. Diode-pumping of solid-state lasers, both in longitudinal and transverse pumping configurations, are introduced in a unified way and a comparison is made with corresponding lamp-pumping configurations [Chapt. 6].
5. Spatially-dependent rate equations are introduced for both four-level and quasi-three-level lasers and their implications, for longitudinal and transverse pumping, are also discussed [Chapt. 7].

6. Laser mode-locking is considered at much greater length to account for e.g. new mode-locking methods, such as Kerr-lens mode-locking. The effects produced by second-order and third-order dispersion of the laser cavity and the problem of dispersion compensation to achieve the shortest pulse-durations are also discussed at some length [Chapt. 8].
7. New tunable solid-state lasers, such as Ti: sapphire and Cr: LISAF, as well as new rare-earth lasers such as Yb^{3+} , Er^{3+} , and Ho^{3+} are also considered in detail [Chapt. 9].
8. Semiconductor lasers and their performance are discussed at much greater length [Chapt. 9].
9. The divergence properties of a multimode laser beam as well as its propagation through an optical system are considered in terms of the M^2 -factor and in terms of the embedded Gaussian beam [Chapt. 11 and 12].
10. The production of ultra-high peak intensity laser beams by the technique of chirped-pulse-amplification and the related techniques of pulse expansion and pulse compression are also considered in detail [Chapt. 12].

The book also contains numerous, thoroughly developed, examples, as well as many tables and appendixes. The examples either refer to real situations, as found in the literature or encountered through my own laboratory experience, or describe a significant advance in a particular topic. The tables provide data on optical, spectroscopic and nonlinear-optical properties of laser materials, the data being useful for developing a more quantitative context as well as for solving the problems. The appendixes are introduced to consider some specific topics in more mathematical detail. A great deal of effort has also been devoted to the *logical organization* of the book so as to make its content more accessible.

The *basic philosophy* of the book is to resort, wherever appropriate, to an intuitive picture rather than to a detailed mathematical description of the phenomena under consideration. Simple mathematical descriptions, when useful for a better understanding of the physical picture, are included in the text while the discussion of more elaborate analytical models is deferred to the appendixes. The *basic organization* starts from the observation that a laser can be considered to consist of three elements, namely the active medium, the resonator, and the pumping system. Accordingly, after an introductory chapter, Chapters 2–3, 4–5 and 6 describe the most relevant features of these elements, separately. With the combined knowledge about these constituent elements, chapters 7 and 8 then allow a discussion of continuous-wave and transient laser behavior, respectively. Chapters 9 and 10 then describe the most relevant types of laser exploiting high-density and low-density media, respectively. Lastly, chapters 11 and 12 consider a laser beam from the user's view-point examining the properties of the output beam as well as some relevant laser beam transformations, such as amplification, frequency conversion, pulse expansion or compression.

With so many topics, examples, tables and appendixes, it is clear that the entire content of the book could not be covered in only a one semester-course. However the organization of the book allows several different learning paths. For instance, one may be more interested in learning the *Principles of Laser Physics*. The emphasis of the study should then be mostly concentrated on the first section of the book [Chapt. 1–5 and Chapt. 7–8]. If, on the other hand, the reader is more interested in the *Principles of Laser Engineering*, effort should mostly be concentrated on the second part of the book Chap. 6 and 9–12. The *level of understanding*

of a given topic may also be suitably *modulated* by e.g. considering, in more or less detail, the numerous examples, which often represent an extension of a given topic, as well as the numerous appendixes.

Writing a book, albeit a satisfying cultural experience, represents a heavy intellectual and physical effort. This effort has, however, been gladly sustained in the hope that this edition can serve the pressing need for a general introductory course to the laser field.

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Milano

Orazio Svelto

Contents

<i>List of Examples</i>	xix
I. Introductory Concepts	1
1.1. Spontaneous and Stimulated Emission, Absorption	1
1.2. The Laser Idea	4
1.3. Pumping Schemes	6
1.4. Properties of Laser Beams	8
1.4.1. Monochromaticity	9
1.4.2. Coherence	9
1.4.3. Directionality	10
1.4.4. Brightness	11
1.4.5. Short Time Duration	13
1.5. Types of Lasers	14
1.6. Organization of the Book	14
Problems	15
2. Interaction of Radiation with Atoms and Ions	17
2.1. Introduction	17
2.2. Summary of Blackbody Radiation Theory	17
2.2.1. Modes of a Rectangular Cavity	19
2.2.2. The Rayleigh-Jeans and Planck Radiation Formula	22
2.2.3. Planck's Hypothesis and Field Quantization	24
2.3. Spontaneous Emission	26
2.3.1. Semiclassical Approach	26
2.3.2. Quantum Electrodynamics Approach	30
2.3.3. Allowed and Forbidden Transitions	31

2.4.	Absorption and Stimulated Emission	32
2.4.1.	Rates of Absorption and Stimulated Emission	32
2.4.2.	Allowed and Forbidden Transitions	36
2.4.3.	Transition Cross Section, Absorption and Gain Coefficient	37
2.4.4.	Einstein Thermodynamic Treatment	41
2.5.	Line Broadening Mechanisms	43
2.5.1.	Homogeneous Broadening	43
2.5.2.	Inhomogeneous Broadening	47
2.5.3.	Concluding Remarks	49
2.6.	Nonradiative Decay and Energy Transfer	50
2.6.1.	Mechanisms of Nonradiative Decay	50
2.6.2.	Combined Effects of Radiative and Nonradiative Processes	56
2.7.	Degenerate or Strongly Coupled Levels	58
2.7.1.	Degenerate Levels	58
2.7.2.	Strongly Coupled Levels	60
2.8.	Saturation	64
2.8.1.	Saturation of Absorption: Homogeneous Line	64
2.8.2.	Gain Saturation: Homogeneous Line	67
2.8.3.	Inhomogeneously Broadened Line	69
2.9.	Decay of an Optically Dense Medium	70
2.9.1.	Radiation Trapping	71
2.9.2.	Amplified Spontaneous Emission	71
2.10.	Concluding Remarks	76
	Problems	77
	References	78
3.	<i>Energy Levels, Radiative and Nonradiative Transitions in Molecules and Semiconductors</i>	81
3.1.	Molecules	81
3.1.1.	Energy Levels	81
3.1.2.	Level Occupation at Thermal Equilibrium	85
3.1.3.	Stimulated Transitions	87
3.1.4.	Radiative and Nonradiative Decay	91
3.2.	Bulk Semiconductors	93
3.2.1.	Electronic States	93
3.2.2.	Density of States	97
3.2.3.	Level Occupation at Thermal Equilibrium	98
3.2.4.	Stimulated Transitions	101
3.2.5.	Absorption and Gain Coefficients	104
3.2.6.	Spontaneous Emission and Nonradiative Decay	110
3.2.7.	Concluding Remarks	112
3.3.	Semiconductor Quantum Wells	113
3.3.1.	Electronic States	113
3.3.2.	Density of States	116

3.3.3. Level Occupation at Thermal Equilibrium	118
3.3.4. Stimulated Transitions	119
3.3.5. Absorption and Gain Coefficients	121
3.3.6. Strained Quantum Wells	125
3.4. Quantum Wires and Quantum Dots	126
3.5. Concluding Remarks	128
Problems	128
References	129
 4. Ray and Wave Propagation Through Optical Media	 131
4.1. Introduction	131
4.2. Matrix Formulation of Geometrical Optics	131
4.3. Wave Reflection and Transmission at a Dielectric Interface	137
4.4. Multilayer Dielectric Coatings	139
4.5. The Fabry-Perot Interferometer	142
4.5.1. Properties of a Fabry-Perot Interferometer	142
4.5.2. The Fabry-Perot Interferometer as a Spectrometer	146
4.6. Diffraction Optics in the Paraxial Approximation	147
4.7. Gaussian Beams	150
4.7.1. Lowest-Order Mode	150
4.7.2. Free Space Propagation	153
4.7.3. Gaussian Beams and the ABCD Law	156
4.7.4. Higher-Order Modes	158
4.8. Conclusions	159
Problems	159
References	161
 5. Passive Optical Resonators	 163
5.1. Introduction	163
5.2. Eigenmodes and Eigenvalues	167
5.3. Photon Lifetime and Cavity Q	169
5.4. Stability Condition	171
5.5. Stable Resonators	175
5.5.1. Resonators with Infinite Aperture	175
5.5.1.1. Eigenmodes	176
5.5.1.2. Eigenvalues	180
5.5.1.3. Standing- and Traveling-Waves in a Two-Mirror Resonator	182
5.5.2. Effects of a Finite Aperture	183
5.5.3. Dynamically and Mechanically Stable Resonators	186
5.6. Unstable Resonators	189
5.6.1. Geometrical-Optics Description	190
5.6.2. Wave-Optics Description	192

5.6.3.	Advantages and Disadvantages of Hard-Edge Unstable Resonators	196
5.6.4.	Variable-Reflectivity Unstable Resonators	196
5.7.	Concluding Remarks	200
	Problems	200
	References	203
6.	<i>Pumping Processes</i>	205
6.1.	Introduction	205
6.2.	Optical Pumping by an Incoherent Light Source	208
6.2.1.	Pumping Systems	208
6.2.2.	Absorption of Pump Light	211
6.2.3.	Pump Efficiency and Pump Rate	213
6.3.	Laser Pumping	215
6.3.1.	Laser Diode Pumps	217
6.3.2.	Pump Transfer Systems	219
6.3.2.1.	Longitudinal Pumping	219
6.3.2.2.	Transverse Pumping	224
6.3.3.	Pump Rate and Pump Efficiency	225
6.3.4.	Threshold Pump Power for Four-Level and Quasi-Three-Level Lasers	228
6.3.5.	Comparison Between Diode-pumping and Lamp-pumping	230
6.4.	Electrical Pumping	232
6.4.1.	Electron Impact Excitation	236
6.4.1.1.	Electron Impact Cross Section	237
6.4.2.	Thermal and Drift Velocities	240
6.4.3.	Electron Energy Distribution	242
6.4.4.	The Ionization Balance Equation	245
6.4.5.	Scaling Laws for Electrical Discharge Lasers	247
6.4.6.	Pump Rate and Pump Efficiency	248
6.5.	Conclusions	250
	Problems	250
	References	253
7.	<i>Continuous Wave Laser Behavior</i>	255
7.1.	Introduction	255
7.2.	Rate Equations	255
7.2.1.	Four-Level Laser	256
7.2.2.	Quasi-Three-Level Laser	261
7.3.	Threshold Conditions and Output Power: Four-Level Laser	263
7.3.1.	Space-Independent Model	264
7.3.2.	Space-Dependent Model	270
7.4.	Threshold Condition and Output Power: Quasi-Three-Level Laser	279
7.4.1.	Space-Independent Model	279
7.4.2.	Space-Dependent Model	280
7.5.	Optimum Output Coupling	283

7.6.	Laser Tuning	285
7.7.	Reasons for Multimode Oscillation	287
7.8.	Single-Mode Selection	290
7.8.1.	Single-Transverse-Mode Selection	290
7.8.2.	Single-Longitudinal-Mode Selection	291
7.8.2.1.	Fabry-Perot Etalons as Mode-Selective Elements	292
7.8.2.2.	Single Mode Selection via Unidirectional Ring Resonators	294
7.9.	Frequency-Pulling and Limit to Monochromaticity	297
7.10.	Laser Frequency Fluctuations and Frequency Stabilization	300
7.11.	Intensity Noise and Intensity Noise Reduction	304
7.12.	Conclusions	306
	Problems	308
	References	310
8.	<i>Transient Laser Behavior</i>	313
8.1.	Introduction	313
8.2.	Relaxation Oscillations	313
8.2.1.	Linearized Analysis	315
8.3.	Dynamical Instabilities and Pulsations in Lasers	318
8.4.	Q-Switching	319
8.4.1.	Dynamics of the Q-Switching Process	319
8.4.2.	Methods of Q-Switching	321
8.4.2.1.	Electro-Optical Q-Switching	322
8.4.2.2.	Rotating Prisms	323
8.4.2.3.	Acousto-Optic Q-Switches	324
8.4.2.4.	Saturable-Absorber Q-Switch	325
8.4.3.	Operating Regimes	328
8.4.4.	Theory of Active Q-Switching	329
8.5.	Gain Switching	337
8.6.	Mode-Locking	339
8.6.1.	Frequency-Domain Description	340
8.6.2.	Time-Domain Picture	344
8.6.3.	Methods of Mode-Locking	346
8.6.3.1.	Active Mode-Locking	346
8.6.3.2.	Passive Mode Locking	350
8.6.4.	The Role of Cavity Dispersion in Femtosecond Mode-Locked Lasers	356
8.6.4.1.	Phase-Velocity, Group-Velocity and Group-Delay-Dispersion	356
8.6.4.2.	Limitation on Pulse Duration due to Group-Delay Dispersion	358
8.6.4.3.	Dispersion Compensation	360
8.6.4.4.	Soliton-type of Mode-Locking	361
8.6.5.	Mode-Locking Regimes and Mode-Locking Systems	364
8.7.	Cavity Dumping	368
8.8.	Concluding Remarks	369
	Problems	370
	References	372

9. Solid-State, Dye, and Semiconductor Lasers	375
9.1. Introduction	375
9.2. Solid-State Lasers	375
9.2.1. The Ruby Laser	377
9.2.2. Neodymium Lasers	380
9.2.2.1. Nd:YAG	380
9.2.2.2. Nd:Glass	383
9.2.2.3. Other Crystalline Hosts	384
9.2.3. Yb:YAG	384
9.2.4. Er:YAG and Yb:Er:glass	386
9.2.5. Tm:Ho:YAG	387
9.2.6. Fiber Lasers	389
9.2.7. Alexandrite Laser	391
9.2.8. Titanium Sapphire Laser	394
9.2.9. Cr:LISAF and Cr:LICAF	396
9.3. Dye Lasers	397
9.3.1. Photophysical Properties of Organic Dyes	397
9.3.2. Characteristics of Dye Lasers	401
9.4. Semiconductor Lasers	405
9.4.1. Principle of Semiconductor Laser Operation	405
9.4.2. The Homojunction Laser	407
9.4.3. The Double-Heterostructure Laser	408
9.4.4. Quantum Well Lasers	413
9.4.5. Laser Devices and Performances	416
9.4.6. Distributed Feedback and Distributed Bragg Reflector Lasers	419
9.4.7. Vertical Cavity Surface Emitting Lasers	423
9.4.8. Applications of Semiconductor Lasers	425
9.5. Conclusions	427
Problems	427
References	429
10. Gas, Chemical, Free Electron, and X-Ray Lasers	431
10.1. Introduction	431
10.2. Gas Lasers	431
10.2.1. Neutral Atom Lasers	432
10.2.1.1. Helium-Neon Lasers	432
10.2.1.2. Copper Vapor Lasers	437
10.2.2. Ion Lasers	439
10.2.2.1. Argon Laser	439
10.2.2.2. He-Cd Laser	442
10.2.3. Molecular Gas Lasers	444
10.2.3.1. The CO ₂ Laser	444
10.2.3.2. The CO Laser	454
10.2.3.3. The N ₂ Laser	456
10.2.3.4. Excimer Lasers	457

10.3. Chemical Lasers	461
10.3.1. The HF Laser	461
10.4. The Free-Electron Laser	465
10.5. X-ray Lasers	469
10.6. Concluding Remarks	471
Problems	471
References	473
11. Properties of Laser Beams	475
11.1. Introduction	475
11.2. Monochromaticity	475
11.3. First-Order Coherence	476
11.3.1. Degree of Spatial and Temporal Coherence	477
11.3.2. Measurement of Spatial and Temporal Coherence	480
11.3.3. Relation Between Temporal Coherence and Monochromaticity	483
11.3.4. Nonstationary Beams	485
11.3.5. Spatial and Temporal Coherence of Single-Mode and Multimode Lasers	485
11.3.6. Spatial and Temporal Coherence of a Thermal Light Source	488
11.4. Directionality	489
11.4.1. Beams with Perfect Spatial Coherence	489
11.4.2. Beams with Partial Spatial Coherence	491
11.4.3. The M^2 Factor and the Spot-Size Parameter of a Multimode Laser Beam	492
11.5. Laser Speckle	495
11.6. Brightness	498
11.7. Statistical Properties of Laser Light and Thermal Light	499
11.8. Comparison Between Laser Light and Thermal Light	501
Problems	503
References	504
12. Laser Beam Transformation: Propagation, Amplification, Frequency Conversion, Pulse Compression and Pulse Expansion	505
12.1. Introduction	505
12.2. Spatial Transformation: Propagation of a Multimode Laser Beam	506
12.3. Amplitude Transformation: Laser Amplification	507
12.3.1. Examples of Laser Amplifiers: Chirped-Pulse-Amplification	512
12.4. Frequency Conversion: Second-Harmonic Generation and Parametric Oscillation	516
12.4.1. Physical Picture	516
12.4.1.1. Second-Harmonic Generation	517
12.4.1.2. Parametric Oscillation	524
12.4.2. Analytical Treatment	526
12.4.2.1. Parametric Oscillation	528
12.4.2.2. Second-Harmonic Generation	532

12.5. Transformation in Time: Pulse Compression and Pulse Expansion	535
12.5.1. Pulse Compression	536
12.5.2. Pulse Expansion	541
Problems	543
References	544
 Appendices	547
A. Semiclassical Treatment of the Interaction of Radiation with Matter	547
B. Lineshape Calculation for Collision Broadening	553
C. Simplified Treatment of Amplified Spontaneous Emission	557
References	560
D. Calculation of the Radiative Transition Rates of Molecular Transitions	561
E. Space Dependent Rate Equations	565
E.1. Four-Level Laser	565
E.2. Quasi-Three-Level Laser	571
F. Theory of Mode-Locking: Homogeneous Line	575
F.1. Active Mode-Locking	575
F.2. Passive Mode-Locking	580
References	581
G. Propagation of a Laser Pulse Through a Dispersive Medium or a Gain Medium	583
References	587
H. Higher-Order Coherence	589
I. Physical Constants and Useful Conversion Factors	593
 Answers to Selected Problems	595
 Index	607