

The Laser Guidebook

Jeff Hecht

Second Edition

McGraw-Hill, Inc.

**New York San Francisco Washington, D.C. Auckland Bogotá
Caracas Lisbon London Madrid Mexico City Milan
Montreal New Delhi San Juan Singapore
Sydney Tokyo Toronto**

Contents

Preface	xiii
Chapter 1. Introduction	1
Definition and Description of a Laser	2
Differences from Other Light Sources	3
The Laser Industry	6
An Introduction to Laser Safety	8
Overview of Laser Applications	10
Bibliography	11
Chapter 2. A Brief History of the Laser	13
Stimulated Emission	14
The Coming of the Maser	14
Theoretical Groundwork for the Laser	15
The Race to Build a Laser	16
The Great Laser Explosion	17
Evolution of Practical Lasers	18
Current Trends	20
Bibliography	21
Chapter 3. Laser Theory and Principles	23
Terminology	23
Energy Levels and Transitions	24
Excitation	26
Stimulated and Spontaneous Emission	27
Population Inversions	28
Amplification and Oscillation	29
Resonators, Modes, and Beam Quality	32
Linewidth and Tuning	37
Coherence and Speckle	38
Efficiency Limitations	40
Output Power	40
Time Scales of Operation	41
Bibliography	42

Chapter 4. Enhancements to Laser Operation	43
Wavelength Enhancements	43
Changing Pulse Length	50
Amplification	56
Bibliography	56
Chapter 5. External Optics and Their Functions	59
Transmissive Optics	60
Transmissive Materials	68
Filters and Coatings	75
Reflective Optics	79
Diffractive Optics	81
Special Components and Techniques	83
Active Optical Components	86
Bibliography	89
Chapter 6. Variations on the Laser Theme: A Classification of Major Types	91
Gas Lasers	91
Solid-State Lasers	96
Semiconductor Lasers	97
Liquid Lasers	98
Laboratory Developments	98
Bibliography	98
Chapter 7. Helium-Neon Lasers	101
Internal Workings	102
Beam Characteristics	106
Operating Requirements	110
Reliability and Maintenance	112
Commercial Devices	113
Applications	116
Bibliography	119
Chapter 8. Noble Gas Ion Lasers	121
Introduction and Description	122
Internal Structure	126
Inherent Trade-Offs	130
Variations and Types Covered	131
Beam Characteristics	131
Operating Requirements	134
Reliability and Maintenance	138
Commercial Devices	139
Applications	142
Bibliography	143

Chapter 9. Helium-Cadmium Lasers	145
Internal Workings	145
Internal Structure	148
Inherent Trade-Offs	150
Variations and Types Covered	150
Beam Characteristics	151
Operating Requirements	153
Reliability and Maintenance	155
Commercial Devices	156
Applications	156
Bibliography	157
Chapter 10. Carbon Dioxide Lasers	159
Internal Workings	159
Internal Structure	161
Inherent Trade-Offs	168
Beam Characteristics	169
Operating Requirements	174
Reliability and Maintenance	177
Commercial Laser Systems	178
Applications	181
Bibliography	183
Chapter 11. Chemical Lasers	185
Internal Workings	186
Internal Structure	188
Beam Characteristics	190
Operating Requirements	192
Reliability and Maintenance	194
Commercial Devices	194
Bibliography	195
Chapter 12. Copper and Gold Vapor Lasers	197
Internal Workings	198
Internal Structure	200
Variations and Types Covered	201
Beam Characteristics	202
Operating Requirements	205
Reliability and Maintenance	206
Commercial Devices	207
Applications	207
Bibliography	209
Chapter 13. Excimer Lasers	211
Introduction and Description	212
Beam Characteristics	218
Operating Requirements	224

Reliability and Maintenance	228
Commercial Devices	230
Applications	232
Bibliography	234
Chapter 14. Nitrogen Lasers	235
Internal Workings and Structure	235
Operating Requirements	237
Reliability and Maintenance	239
Commercial Devices	239
Applications	239
Bibliography	240
Chapter 15. Far-Infrared Gas Lasers	241
Internal Workings	242
Internal Structure	244
Variations and Types Covered	246
Beam Characteristics	247
Operating Requirements	248
Reliability and Maintenance	249
Commercial Devices	250
Applications	252
Bibliography	252
Chapter 16. Other Commercial Gas Lasers	255
Carbon Monoxide Lasers	255
Nitrous Oxide Lasers	257
Xenon-Hellum Lasers	259
Visible Xenon Lasers	260
Iodine Lasers	261
Bibliography	262
Chapter 17. Dye Lasers	263
Internal Workings	264
Internal Structure	268
Inherent Trade-Offs	274
Variations and Types Covered	277
Beam Characteristics	277
Operating Requirements	285
Reliability and Maintenance	288
Commercial Devices	290
Applications	294
Bibliography	295
Chapter 18. Semiconductor Diode Lasers—Structures	297
Description	298

Internal Workings	299
Internal Structure	302
Semiconductor Laser Amplifiers	322
Bibliography	323
Chapter 19. Short-Wavelength Semiconductor Diode Lasers	325
Active Media	326
Internal Structure	330
Variations and Types Covered	330
Research Thrusts	333
Beam Characteristics	334
Operating Requirements	343
Reliability and Maintenance	347
Commercial Devices	348
Applications	349
Bibliography	351
Chapter 20. Long-Wavelength III–V Semiconductor Diode Lasers	355
Active Medium	356
Internal Structure	358
Research Thrusts	359
Variations and Types Covered	360
Beam Characteristics	360
Operating Requirements	366
Reliability and Maintenance	370
Commercial Devices	371
Applications	372
Bibliography	373
Chapter 21. Lead Salt Semiconductor Diode Lasers	375
Internal Workings	375
Internal Structure	376
Inherent Trade-Offs	378
Variations and Types Covered	378
Beam Characteristics	378
Operating Requirements	382
Reliability and Maintenance	384
Commercial Devices	384
Applications	385
Bibliography	386
Chapter 22. Neodymium Lasers	389
Active Medium	389
Energy Transfer	392
Internal Structure	394
Inherent Trade-Offs	396

Research Directions	397
Variations and Types Covered	397
Beam Characteristics	398
Operating Requirements	406
Reliability and Maintenance	411
Commercial Devices	413
Applications	414
Bibliography	416
Chapter 23. Ruby Lasers	419
Internal Workings	419
Internal Structure	420
Beam Characteristics	421
Operating Requirements	422
Reliability and Maintenance	423
Commercial Devices	423
Applications	424
Bibliography	424
Chapter 24. Tunable Vibronic Solid-State Lasers	425
Introduction and Description	426
Internal Workings and Structure	427
Research Trends and Types Covered	434
Beam Characteristics	436
Operating Requirements	441
Commercial Devices	443
Applications	444
Bibliography	445
Chapter 25. Color-Center Lasers	447
Internal Workings	447
Internal Structure	450
Variations and Types Covered	452
Beam Characteristics	452
Operating Requirements	453
Reliability and Maintenance	455
Commercial Devices	455
Applications	456
Bibliography	456
Chapter 26. Fiber Lasers and Amplifiers	457
Introduction and Description	458
Fiber Amplifier Structures and Hosts	459
Erbium-Doped Fiber Amplifiers	460
Neodymium-Doped Fiber Amplifiers	465
Bibliography	467

Chapter 27. Other Solid-State Lasers	469
Erbium-Glass Lasers	470
Crystalline Erbium Lasers	471
Holmium Lasers	472
Thulium Lasers	473
Bibliography	473
Chapter 28. Free-Electron Lasers	475
Fundamental Concepts	475
Types of Free-Electron Lasers	477
Components of Free-Electron Lasers	478
Optical Cavities and Beam Characteristics	480
Applications	480
Bibliography	481
Chapter 29. X-Ray Lasers	483
Bomb-Driven X-Ray Lasers	483
Laboratory X-Ray Lasers	484
Applications	485
Bibliography	486
Appendix. Types of Lasers	487
Index	489