

Contents

Part 1 Survey of laser systems

1.1	Survey of laser systems	
	W. SCHULZ	3
1.1.1	Introduction	3
1.1.2	Principles and experiments	4
1.1.2.1	Nonlinear amplification	4
1.1.2.2	Selection of optical modes or directional selectivity	6
1.1.2.3	Feedback resonator and regenerative amplification	7
1.1.3	Technical implementation, performance and applications	9
1.1.3.1	Gas laser systems	9
1.1.3.1.1	CO ₂ laser systems	9
1.1.3.1.2	Excimer laser systems	10
1.1.3.1.3	Argon-ion laser systems	10
1.1.3.1.4	Helium-neon laser systems	10
1.1.3.2	Solid-state laser systems	11
1.1.3.2.1	Diode-pumped solid-state laser systems	12
1.1.4	Advanced design and short-pulse solid-state laser systems	13
1.1.4.1	Fundamentals of laser performance	14
1.1.4.1.1	Resonator design	14
1.1.4.1.1.1	Rod end-pumped design	14
1.1.4.1.1.2	Rod side-pumped design	14
1.1.4.1.1.3	Slab side-pumped design	15
1.1.4.1.1.4	“Innoslab” end-pumped design	15
1.1.4.1.1.5	Disc end-pumped design	15
1.1.4.2	Advances in laser performance	15
1.1.4.3	Resonator design	16
1.1.4.4	Slitting with pulsed solid-state laser	17
1.1.4.5	Processing with higher harmonics	18
1.1.5	High-power diode laser (HPDL) systems	20
1.1.5.1	Packaging technology	21
1.1.5.2	Multiplexing the emission of single bars	22
1.1.5.3	Coherent coupling	23
1.1.5.4	Direct applications with low beam intensity	24
1.1.5.5	Cutting and welding	24
	References for 1.1	27

Part 2 Short and ultrashort pulse generation

2.1	Ultrafast solid-state lasers	
	U. KELLER	33
2.1.1	Introduction	33
2.1.2	Definition of Q -switching and mode-locking	35
2.1.2.1	Q -switching	35
2.1.2.2	Mode-locking	36
2.1.3	Overview of ultrafast solid-state lasers	39
2.1.3.1	Overview for different solid-state laser materials	39
2.1.3.1.1	Solid-state laser materials	40
2.1.3.1.2	Mode-locked rare-earth-doped solid-state lasers	66
2.1.3.1.3	Mode-locked transition-metal-doped solid-state laser	67
2.1.3.1.4	Q -switched ion-doped solid-state microchip lasers	68
2.1.3.1.5	Ultrafast semiconductor lasers	69
2.1.3.1.6	Ultrafast fiber lasers	73
2.1.3.2	Design guidelines of diode-pumped solid-state lasers	73
2.1.3.3	Laser cavity designs	76
2.1.3.3.1	Typical picosecond lasers	76
2.1.3.3.2	Typical femtosecond lasers	77
2.1.3.3.3	High-power thin-disk laser	78
2.1.4	Loss modulation	79
2.1.4.1	Optical modulators: acousto-optic and electro-optic modulators	79
2.1.4.2	Saturable absorber: self-amplitude modulation (SAM)	79
2.1.4.2.1	Slow saturable absorber	82
2.1.4.2.2	Fast saturable absorber	82
2.1.4.3	Semiconductor saturable absorbers	83
2.1.4.3.1	Semiconductor dynamics	83
2.1.4.3.2	Typical self-amplitude modulation (SAM) from semiconductor saturable absorbers	85
2.1.4.3.3	Semiconductor saturable absorber materials	86
2.1.4.3.3.1	InGaAs/GaAs/AlGaAs semiconductor material system	86
2.1.4.3.3.2	GaInAsP/InP semiconductor material system	86
2.1.4.3.3.3	GaInNAs semiconductor material	87
2.1.4.3.3.4	AlGaAsSb semiconductor material	87
2.1.4.3.3.5	GaAs wafer for $\approx 1 \mu\text{m}$	87
2.1.4.3.3.6	Semiconductor-doped dielectric films	87
2.1.4.3.4	Historical perspective and SESAM structure	88
2.1.4.4	Effective saturable absorbers using the Kerr effect	90
2.1.4.4.1	Transverse and longitudinal Kerr effect	90
2.1.4.4.2	Nonlinear coupled cavity	90
2.1.4.4.3	Kerr lens	91
2.1.4.4.4	Nonlinear polarization rotation	92
2.1.4.5	Nonlinear mirror based on second-harmonic generation	92
2.1.5	Pulse propagation in dispersive media	92
2.1.5.1	Dispersive pulse broadening	92
2.1.5.2	Dispersion compensation	94
2.1.5.2.1	Gires-Tournois interferometer (GTI)	96
2.1.5.2.2	Grating pairs	96

2.1.5.2.3	Prism pairs	99
2.1.5.2.4	Chirped mirrors	100
2.1.6	Mode-locking techniques	102
2.1.6.1	Overview	102
2.1.6.2	Haus's master equations	102
2.1.6.2.1	Gain	105
2.1.6.2.2	Loss modulator	106
2.1.6.2.3	Fast saturable absorber	106
2.1.6.2.4	Group velocity dispersion (GVD)	106
2.1.6.2.5	Self-phase modulation (SPM)	107
2.1.6.3	Active mode-locking	108
2.1.6.4	Passive mode-locking with a slow saturable absorber and dynamic gain saturation	110
2.1.6.5	Passive mode-locking with a fast saturable absorber	112
2.1.6.6	Passive mode-locking with a slow saturable absorber without gain saturation and soliton formation	114
2.1.6.7	Soliton mode-locking	115
2.1.6.8	Design guidelines to prevent Q -switching instabilities	119
2.1.6.9	External pulse compression	120
2.1.7	Pulse characterization	121
2.1.7.1	Electronic techniques	121
2.1.7.2	Optical autocorrelation	121
2.1.7.3	New techniques: FROG, FROG-CRAB, SPIDER,	123
2.1.7.3.1	FROG, SHG-FROG, FROG-CRAB	123
2.1.7.3.2	SPIDER	124
2.1.7.3.3	Comparison between FROG and SPIDER techniques	125
2.1.8	Carrier envelope offset (CEO)	126
2.1.9	Conclusion and outlook	129
2.1.10	Glossary	131
	References for 2.1	134

Part 3 Gas lasers

3.1	Gas laser systems	
	R. WESTER	171
3.1.1	Introduction	171
3.1.2	Threshold pump power density	172
3.1.2.1	Line Broadening	174
3.1.2.1.1	Natural line broadening	174
3.1.2.1.2	Doppler broadening	175
3.1.2.1.3	Pressure broadening	175
3.1.3	Excitation mechanisms	176
3.1.3.1	Gas discharge excitation	176
3.1.3.2	Electron-beam excitation	177
3.1.3.3	Gas-dynamic excitation	178
3.1.3.4	Chemical excitation	179
3.1.4	Gas discharges	180
3.1.4.1	Elementary processes in gas discharges	180

3.1.4.2	Electron distribution function	182
3.1.4.2.1	Similarity laws	183
3.1.4.2.2	Characteristic frequencies	183
3.1.4.2.3	Rate coefficients	184
3.1.4.2.4	Approximate solutions of the Boltzmann equation	184
3.1.4.2.5	Charged-particle densities	185
3.1.4.2.6	Ambipolar diffusion	186
3.1.4.3	Electromagnetic field	187
3.1.4.4	Neutral gas	188
3.1.4.5	Discharge instabilities	189
3.1.4.5.1	Thermal instabilities	189
3.1.4.6	Discharge types	190
3.1.4.6.1	Glow discharges	191
3.1.4.6.1.1	Secondary processes	191
3.1.4.6.2	High-pressure glow discharges	192
3.1.4.6.3	High-frequency glow discharges	192
3.1.4.6.3.1	Boundary layers in high-frequency discharges	193
3.1.4.6.4	Microwave discharges	194
3.1.4.6.5	Arc discharges	195
	References for 3.1	197
3.2	CO₂ laser and CO laser	
	J. UHLENBUSCH, W. VIÖL	205
3.2.1	CO ₂ laser	205
3.2.1.1	Fundamentals of CO ₂ laser discharge	205
3.2.1.2	Practical design of cw CO ₂ lasers	206
3.2.1.2.1	Sealed-off lasers	207
3.2.1.2.2	Lasers with slow axial flow	207
3.2.1.2.3	Lasers with fast axial flow	207
3.2.1.2.4	Transverse-flow lasers	208
3.2.1.2.5	Gas-dynamic lasers	208
3.2.1.3	Practical design of pulsed CO ₂ lasers	208
3.2.1.3.1	Transversely excited atmospheric-pressure lasers	208
3.2.1.3.2	Q-switched low-pressure lasers	209
3.2.2	CO laser	209
3.2.2.1	Fundamentals of CO laser process	209
3.2.2.2	Practical design of cw CO lasers	210
3.2.2.2.1	Sealed-off lasers	211
3.2.2.2.2	Lasers with axial and transversal flow	211
3.2.2.2.3	Pulsed CO lasers	211
	References for 3.2	212
3.3	Femtosecond excimer lasers and their applications	
	S. SZATMÁRI, G. MAROWSKY, P. SIMON	215
3.3.1	Introduction	215
3.3.1.1	Advantages and difficulties associated with short-wavelength lasers	215
3.3.1.2	General features of dual-wavelength laser systems	216
3.3.1.3	Comparison of high-power solid-state and excimer lasers	217
3.3.1.4	Seed pulse generation	219

3.3.1.4.1	General features of hybrid dye/excimer lasers	219
3.3.1.4.2	Hybrid solid-state/excimer lasers	219
3.3.2	Short-pulse amplification properties of excimers	220
3.3.3	Critical issues for a high-power excimer amplifier	223
3.3.3.1	Nonlinear effects, attainment of minimum pulse duration (spatially evolving chirped-pulse amplification)	223
3.3.3.2	Amplification in media having nonsaturable absorption	225
3.3.3.2.1	ASE content, nonsaturable absorption, limitations on the cross-section	225
3.3.3.2.2	Off-axis amplification	226
3.3.3.2.3	Multiple-pass off-axis amplification schemes	229
3.3.3.2.4	Requirements for the discharge geometries of off-axis amplifiers	230
3.3.3.3	Limited energy storage time (interferometric multiplexing)	230
3.3.3.3.1	Limitations on multiple-pass amplification	231
3.3.3.3.2	Optical multiplexing	231
3.3.3.3.3	Interferometric multiplexing	232
3.3.3.4	Focusability of short-wavelength high-intensity lasers	233
3.3.3.4.1	Pulse front distortion, spatially dependent temporal broadening	233
3.3.3.4.2	Origin of phase-front distortions in dual-wavelength laser systems	234
3.3.3.4.3	Active spatial filtering	234
3.3.3.4.4	Spectral filtering	235
3.3.3.4.5	Optimization of off-axis amplifiers for minimum phase-front distortion	238
3.3.3.4.6	Beam homogenization method for short-pulse excimers	238
3.3.3.4.7	Focusability measurements	239
3.3.4	Application of short laser pulses	242
3.3.4.1	Application of short laser pulses for plasma generation	242
3.3.4.2	Micromachining of materials with subpicosecond UV pulses	244
	References for 3.3	248
3.4	Ion lasers and metal vapor lasers	
	W. SEELIG	255
3.4.1	Introduction	255
3.4.2	Properties of gas discharge laser media	256
3.4.3	Noble gas ion lasers	259
3.4.3.1	Excitation mechanism	259
3.4.3.2	Operating characteristics	261
3.4.3.2.1	Neutral gas depletion	261
3.4.3.2.2	Axial gas pumping	262
3.4.3.2.3	Transition regions	262
3.4.3.2.4	Magnetic fields	263
3.4.3.2.5	Summary of operation parameters	263
3.4.4	Helium metal ion lasers	265
3.4.4.1	Excitation mechanism	265
3.4.4.2	Operating characteristic of the continuous He–Cd laser	266
3.4.5	Self-terminating metal vapor lasers	268
3.4.5.1	Excitation mechanism	268
3.4.5.2	Operating characteristics	269
	References for 3.4	272

3.5	Excimer lasers	
	U. SOWADA	275
3.5.1	Introduction	275
3.5.2	Wavelengths and stimulated emission cross sections	275
3.5.2.1	Rare-gas halogen excimers	275
3.5.2.1.1	Rare-gas monohalides	275
3.5.2.1.2	Polyatomic rare-gas halogen excimers	277
3.5.2.2	Rare-gas excimers	278
3.5.2.3	Halogen excimers	278
3.5.3	Chemical reactions in the discharge	278
3.5.4	Beam properties	284
3.5.4.1	Pulse energy and pulse duration	284
3.5.4.2	Output power	284
	References for 3.5	285
3.6	Gasdynamical lasers, chemical lasers	
	M. HUGENSCHMIDT	289
3.6.1	Introduction, historical background	289
3.6.2	Gasdynamic lasers (GDLs)	290
3.6.2.1	Conventional combustion-driven GDLs	290
3.6.2.1.1	Population inversion due to gasdynamic processes	290
3.6.2.1.2	GDL fuels and energy requirements	292
3.6.2.1.3	Numerical modeling and simulations	293
3.6.2.1.4	Population densities and small-signal gain achieved in gasdynamic lasers	295
3.6.2.1.5	Power extraction	296
3.6.2.1.6	Simplified calculation of small-signal gain, analytical approximations	297
3.6.2.1.7	Specific experimental investigations, realization of pulsed laser systems	299
3.6.2.1.8	Optical cavity design	299
3.6.2.2	Downstream mixing GDLs	300
3.6.2.3	Gasdynamic CO ₂ laser by detonation of solid explosives	301
3.6.3	Fast-flow electric discharge lasers (EDL)	301
3.6.3.1	Electrically excited fast-flow or gasdynamic CO lasers	301
3.6.3.2	Electrical discharge excited gasdynamic CO ₂ lasers	304
3.6.3.3	Miscellaneous	305
3.6.4	Chemical lasers	306
3.6.4.1	Fundamental processes, vibrational, rotational and translational temperatures	306
3.6.4.2	Specific reactions and operation principles of chemical lasers	307
3.6.4.3	Discussion and evaluation of chemical laser systems	308
3.6.4.3.1	Iodine lasers	308
3.6.4.3.1.1	Pulsed systems, photolytically initiated iodine lasers (PIL)	308
3.6.4.3.1.2	Continuous-wave iodine lasers (COIL)	309
3.6.4.3.2	HCl and HBr lasers	310
3.6.4.3.2.1	Pulsed HCl lasers and HBr laser studies	310
3.6.4.3.2.2	Continuous-wave laser excitation	311
3.6.4.3.2.3	Numerical analysis	311
3.6.4.3.3	CO lasers	311
3.6.4.3.3.1	Pulsed CO lasers	312
3.6.4.3.3.2	Continuous-wave CO lasers	313
3.6.4.3.4	HF, DF lasers	314

3.6.4.3.4.1	Pulsed HF, DF lasers	314
3.6.4.3.4.2	Continuous-wave HF or DF lasers	320
3.6.4.3.5	Transfer chemical lasers	325
3.6.4.3.5.1	Pulsed transfer chemical (TCL) CO ₂ lasers	326
3.6.4.3.5.2	Continuous-wave DF-CO ₂ transfer chemical lasers	327
3.6.4.3.6	Miscellaneous	331
3.6.4.3.6.1	Pulsed NO laser	331
3.6.5	Concluding remarks	332
	References for 3.6	333
3.7	Iodine lasers	
	K. ROHLENA, J. BERÁNEK	341
3.7.1	Principles of operation	341
3.7.2	Laser transition cross-section	342
3.7.3	Iodine photodissociation lasers	344
3.7.3.1	Pumping kinetics of the iodine photodissociation laser	344
3.7.4	Chemical oxygen iodine laser (COIL)	346
3.7.4.1	Generators of the excited oxygen (SOG)	347
3.7.4.2	Pumping kinetics of the chemical oxygen-iodine laser	348
3.7.4.3	All-gas chemical oxygen-iodine lasers	349
3.7.5	Outlook	350
	References for 3.7	351
Index	357

Part 1

Herziger, G. (Ed.)

2007, XV, 369 p., Hardcover

ISBN: 978-3-540-26033-2