

Index

- Absorption 9, 11
 - band to band 9, 10, 92–93, 95
 - free carrier 11
 - intervalence band (IVBA) 11, 92
 - optical fiber 15
 - spectroscopy 331
- ACA laser 201
- Accelerated aging 229, 231
- Activation energy 229, 231
- All-optical label swapping (AOLS)
 - 317–318
- Anemometry 335
- Arrayed waveguide grating router (AWGR)
 - 303, 317
- Arrhenius equation 229
- Asynchronous transfer mode (ATM) 307
- Autocorrelation function 154–156, 161, 328

- Bandgap energy of InGaAsP 16
- Bandgap wavelength 16
- Bernard-Duraffourg condition 10
- Bi-directional line-switched ring (BLSR)
 - 308
- Blanking 236
- Bragg condition 45, 70, 248, 365
- Bragg grating 92, 132, 157, 335
 - reflectivity 50
- Bragg propagation constant 44
- Bragg wavelength 45–46, 49–50, 57, 60–63, 65, 67–68, 70

- Brillouin scattering 291
- Bulk materials 10, 12, 35–36, 96, 126
- Buried facets laser 166
- Burn-in 230–231

- Carrier density
 - laser current 10
 - refractive index change 11
 - transparency 10
- Carrier density rate equation 27
- Chirp 232, 234
 - modulator
 - electroabsorption 237
- Clock recovery 290
- Coarse WDM 289
- Codirectional coupler 192ff, 367ff
 - bandwidth 197–198, 204
 - coupled mode equations 196
 - coupling coefficient 194
 - coupling length 195
 - detuning 195ff
 - dispersion factor 191, 197ff
 - eigenmode propagation 193, 203
 - mode spacing 199
 - tuning 198
 - tuning enhancement 199
- Coherent crosstalk 287
- Comb generator 270
- Confinement factor 71, 345–347
 - lateral 20

382 INDEX

- Confinement factor (*continued*)
 longitudinal 109
 three-dimensional 124, 128
 transverse 17ff
 two-dimensional 20
- Control board 228, 236, 240
- Control circuit 226, 228
- Coupled mode equations 46–48, 50, 365–366
 codirectional coupler 196, 369
- Coupled mode theory 46, 193, 364
- Coupling coefficient 45, 50, 52–53, 253, 362ff
 codirectional coupler 194, 203, 369
- Cross-phase modulation (XPM) 296
- Data buffer 290
- DBR laser diodes 49, 50ff, 265
 bundle-integrated 57
 butt joint 57
 digital supermode 184ff
 gain condition 56
 mode spacing 58
 phase condition 58
 sampled grating 174ff, 224ff
 superstructure grating 179ff
 temperature dependence 72
 three-section 114ff, 145, 157
 two-section 111ff
 wavelength switching 234, 236
 widely tunable 173ff
- DBR laser structures 56ff
- de Broglie wavelength 35
- Dense wavelength division multiplexing (DWDM) 289
- Density of states 35
- Detuned loading 233
- Detuning 71, 365
 modified 365
- DFB laser diodes 49, 59ff, 290
 antireflection coated 119–121
 AR/HR coated 65, 121
 arrays 259ff
 characterisation and control 221ff
 gain coupled 66ff
 mode loci 61, 64, 67
 mode map 222
 mode spacing 61
 multisection 118ff
 phase shifted 66ff, 119
 reflective facets 63
 reliability 229
 spatial hole burning 65, 68
 striped heater 131
 superstructure grating 184
 temperature dependence 72, 222
 three-section 146
 tunable twin-guide (TTG) 125ff
 wavelength accuracy 70
 wavelength stability 229
- DFB laser structure 59
- DFC laser 202
- Differential resistance 155–156, 162–163
- Dispersion
 fiber 43, 232
 material 348
 penalty 234, 348
- DS-DBR laser 184ff
- Dynamic behaviour 99ff, See also:
 Modulation
- Effective oscillator method 339
- Efficiency
 differential 29, 72
 quantum 29, 72
 tuning 93, 97, 130, 143, 157
- Einstein's relations 28
- Electronic multiplexing 292
- Energy-band diagram Dec-14
- Environmental analysis 331ff
- Erbium-doped fiber amplifier (EDFA) 293, 306
- ESCON 307
- External cavity lasers 247ff, 266
 grating tuned 248
 hybrid 251
 MEMS 250
- Failures in time (FIT) 229, 231
- Farfield 19
- Fermi-Dirac probability distribution 9
- Fiber amplifiers 169
- Fiber Bragg grating (FBG) 251, 310
- Fiber lasers 266
 array 267
 basic properties 266
 compression tuned 267
 external reflector 266

- tunable ring laser 267
- tuning range 267
- Fiber-distributed data interface (FDDI) 307
- Fibre channel 307
- Field equation 45
- Filter
 - AOTF 249, 267
 - temperature tuned 249
- Fixed-wavelength converter 303
- Fixed-wavelength networks 309
- Forward error correction (FEC) 290
- Fourier series 174
- Fourier transformation 102, 154, 174, 365
- Franz-Keldysh effect 237, 239, 241
- Free-carrier plasma effect 91ff, 234
- Fresnel formula 25
- Fresnel reflection 46, 252, 363

- Gain condition 25, See also: Oscillation condition
- Gas sensing 331
- Gigabit Ethernet 290, 309
- Grating 44
 - amplitude modulation function 174
 - binary 185ff
 - blazed 56
 - chirped 180-181
 - confinement factor 54
 - effective length 52, 253
 - fabrication 69, 177, 186
 - first order 45
 - frequency modulated 182
 - loss coefficient 49, 57
 - modulated 364
 - order 45
 - penetration depth 53
 - phase modulated 181-182
 - power reflectivity 51
 - rectangular 53-54
 - reflection bandwidth 52
 - reflection coefficients 49-51
 - sampled 174ff
 - second order 54
 - shape 54
 - sinusoidal 55
 - square 46,53
 - superimposed 185ff
 - triangular 55
 - vector 45
- Grating assisted coupler 193, 368
- Green's function 47
- Group index, See: Refractive index, group
- Guard band (GB) 316

- Heat conduction equation 356
- Heterodyning 334
- Heterostructure 12ff
 - carrier confinement 13ff
 - double heterostructure 13
 - optical confinement 14
 - separate confinement (SCH) 37
- Injection locking 270
- Integration
 - lateral 188ff
 - longitudinal 107ff, 200ff
 - technology 132ff
 - transverse 121ff, 190ff, 202ff
 - monolithic 237ff
- Integration techniques 97ff
- Intermediate reach 291
- Intermixing 241
- Internet packet size 316
- Internet protocol (IP) 308
- Interoffice application (IAP) 291
- IP routers 315
- ITU 222, 289

- Kerr effect 295
- Kramers-Kronig dispersion relation 11

- Lagrange-Sylvester formula 354
- Lambert Beer's law 331
- Langevin forces 153-154, 161
- Laser array 257ff
 - DBR 261ff
 - DFB 257ff, 266
 - externally combined 261
 - MAGIC 258
 - MGC 258
 - multistripe 257ff
 - phased array 263
 - selectable 259
- Laser diodes
 - aging 228ff
 - bias
 - current control 159, 162
 - voltage control 99, 159-160, 162

384 INDEX

- Laser diodes (*continued*)
- buried-heterostructure (BH) 22, 126
 - characterisation 223
 - fabrication 68ff
 - Fabry-Perot 23ff, 27
 - gain guided (GG) 20-23
 - index guided (IG) 19, 21-23
 - quantum well 35ff
 - linewidth enhancement factor 37
 - strained layer 36
 - quasiindex guided (QIG) 19, 21, 23
 - reliability 228ff
 - ridge waveguide (RW) 19, 23, 126, 131
 - single mode 43ff
 - spectrum 27
 - thermal properties 71
 - thermal FM response 358ff
 - thermal pulse response 355ff
 - threshold current 2-3, 22-23, 28, 35, 37, 72, 90, 97, 125-127, 140
- Laser structures 22ff
- Lattice constant 15-16
- Lattice matching 15-16, 36, 339-340
- Lifetime
- carrier 96, 144
 - differential carrier 34, 99, 142-143, 154, 328
- Line coding
- 8B/10B 307
- Line encoder 290
- Lineshape 74
- Linewidth 73ff, 182, 225
- broadening 151ff
 - bias source impedance effect 159
 - by 1/f noise 164-165
 - by fluctuations of bias source 166
 - by thermal noise 159
 - enhancement factor 11, 75, 124, 206, 232, 234, 237
 - bulk materials 11
 - external cavity laser 248
 - Schawlow-Townes-Henry 75, 153, 328
- Littman-Metcalf configuration 248, 250, 261
- Littrow configuration 248
- Local area network (LAN) 291, 307
- Long haul 309
- Long reach 291
- Look-up table 292
- Loss
- coupling 134
 - end (or mirror) 25, 43-44, 56, 58, 60-62, 64-65, 67, 75, 109, 137-138
 - internal 25, 43-44, 75
 - total 25
- Mach-Zehnder interferometer 187-189
- Mean time to failure (MTTF) 229, 231
- Membrane mirror 255
- MEMS 250, 261
- external cavity lasers 254
- Metal-organic vapor-phase epitaxy (MOVPE) 14
- Metamorphic mirrors 253
- Metropolitan area network (MAN) 289, 291, 307
- MGY laser 208
- Mitigation 291
- MMI coupler 209, 260, 263
- Mode locking 268, 270
- active 269
 - passive 269
- Mode map 222, 224ff, 231, 235
- power contours 224ff
- Mode selectivity 44
- Modes
- longitudinal 22, 25-27, 43, 72, 79-81, 83, 85-86, 88-90, 96, 99, 109, 112-113, 115, 117, 119-121, 123, 133, 137, 213, 224, 335
 - mode spacing 52
 - side modes 27, 30
 - side-mode suppression ratio 30, 43-44, 83-84, 88, 120, 127-128, 130, 151, 200, 206, 214, 225, 249-250, 260, 265, 285, 288-289, 332
 - DS-DBR laser 185
 - GCSR laser 207
 - MGY laser 209-210
 - SG-DBR laser 181
 - VCF laser 200-201
 - Y-laser 189-190
- TE 16, 343
- TM 16, 343
- transverse 16, 18-19, 23, 92, 99, 101, 125, 344
- longitudinal 116
- Modulation 141ff

- AM 146, 331
- AM/FM ratio 142
- direct 43, 181, 232–234, 257, 264–265
- external 232, 234
- FM 3, 5, 34, 99, 107, 142–146, 234, 332
- Modulation bandwidth 233
- Modulation format
 - duo-binary (DBM) 291
 - non-return-to-zero (NRZ) 291, 298
 - on-off keying (OOK) 291
 - pulse position modulation (PPM) 291
 - return-to-zero (RZ) 291, 298
- Modulator
 - electroabsorption 237ff
 - integrated 237ff
 - Mach-Zehnder 239
- Molecular beam epitaxy (MBE) 14
- Nearfield 19
- Noise
 - 1/f 152, 164ff
 - FM 153, 156, 165
 - injection recombination shot noise (IRSN) 152ff, 327–330
 - relative intensity noise 233
 - thermal 152, 155, 160–161, 163
- Nonlinear modulation 295
- Normalised frequency 345, 347
- NRZ, See: Modulation format, non-return-to-zero (NRZ)
- OEIC 295
- Optical add-drop multiplexer (OADM) 309, 310
- Optical bandpass filter 295
- Optical burst switching (OBS) 304, 313, 314
- Optical communication 1, 3, 5, 21, 43, 285ff
 - coherent 5, 151
 - WDM 1, 331
- Optical cross-connect (OXC) 310
- Optical FMCW radar 5, 325ff
- Optical internetworking forum 291
- Optical label 318
- Optical label swapping 317
- Optical label switching 317
- Optical packet switching 304
- Optical protection switching 311
- Optical signal-to-noise ratio (OSNR) 291
- Optical wavelength switch (OWS) 303
- Opto-electronic-optical (OEO) 293
- Oscillation condition 24–25, 60, 63, 66–67, 79, 108, 138, 353
 - DFB laser 59
 - transfer matrix 65
- P/I-curve 22
- Packet over SONET (POS) 308
- Packet switching 289, 304
- Parseval's theorem 182
- Passive optical network (PON) 289
- Periodic structure 44ff, 353, 362ff
- Perturbation theory 194
- Phase condition 26, 62, See also:
 - Oscillation condition
- Phase mask 69
- Phase matching 192
- Phase modulation 291
- Phase noise 160, 165, 327–329
- Photon density rate equation 27
- Photonic cross-connect (PXC) 311
- Photonic packet switching 314
- Point-to-point networks 306
- Propagation constant 7, 17, 24, 109, 343, 351, 361, 367
 - Bragg 44
 - normalized 346–347
- Protection switching 308, 312
- Pulse pre-distortion 304
- Quantum dot 38–39
- Quantum well
 - graded-index separate confinement heterostructure (GRINSCH-QW) 37
 - intermixed 135
 - multiple (MQW) 37, 135
 - separate confinement heterostructure (SCH-QW) 37
 - single quantum well 35–36
 - strained 36, 120
 - critical thickness 36
- Quantum-confined Stark effect 234, 237
- Quasi-Fermi levels 9
- Rate equations 7, 27ff, 44, 66, 75
 - carrier density 27–28, 99, 153, 161
 - multimode 30

386 INDEX

- Rate equations (*continued*)
 - photon density 27–28
 - single-mode 27
 - small-signal approximation 33, 153–154, 161
 - stationary solution 28, 157
- Recombination
 - Auger 11, 130, 157
 - bimolecular 130, 157–158
 - linear 157
 - nonlinear 98, 101, 112, 115, 123
 - nonradiative 11, 128
 - radiative 11
 - rate 10, 27, 154, 160
 - spontaneous 27, 93, 153
 - surface 165
- Reconfigurable networks 310
- Reconfigurable OADM (ROADM) 289, 310
- Reflectivity
 - field 46, 62
- Reflector
 - comb 170–171
 - distributed 361ff
- Refractive index, complex 7, 18
 - effective 17, 344, 347–348
 - effective group 26, 85, 110–111, 123
 - electric control
 - free-carrier plasma effect 91
 - quantum-confined Stark effect 95ff, 99, 131, 144
 - group 58, 70, 110, 348
 - InGaAsP 339ff
 - thermal tuning 96ff, 116
- Regeneration 292, 306
 - 1R 292
 - 2R 292
 - 3R 292
- Relative intensity noise (RIN) 285, 288–289
- Relaxation frequency 33–34, 144
- Resonance frequency 75, 232
- Roundtrip gain 24–25, 31, 80, 82, 86, 89–90, 97–98
- RZ, See: Modulation format, return-to-zero (RZ)
- Saddle points 224ff
- Sampling function 174ff
- Sampling period 176
- Schrödinger equation 35
- Screening 230
- Selective area growth 238
- Self-phase modulation (SPM) 295
- Semiconductor optical amplifier 239
- Short reach 291
- SMSR, See: Modes, side-mode suppression ratio
- SNR 302
- SOA-XPM 298
- SONET
 - line-terminating element (LTE) 293
 - loss of signal (LOS) 293
- SONET/SDH 307
- Spectral power density 155–156, 161
- Spectroscopy 331
- Spontaneous emission 28, 30, 73, 80, 158, 327–328
 - coefficient 28
- Stimulated emission 9–10, 28, 73
 - in tuning region 153
 - lifetime shortening by 142
 - rate 27
- Stop band 61–63
- Storage area network (SAN) 289, 307
- Supercontinuum sources 270
 - fiber transmission 271
- Switching time 305
- Synchronous optical network (SONET) 290
- T-AOWC 295
- Temperature coefficient 72
- Thermal FM response 358ff
- Thermal pulse response 355ff
- Thermal resistance 72, 101, 128–130, 132, 358
- Thermoelectric cooler (TEC) 289
- Thin-film filter 310
- Time-bandwidth product 232
- Transfer matrix 49, 58–59, 63, 65–66, 171, 187, 195, 203, 351ff
- Transmitter 290
- Transparency
 - bit-rate 293
 - format 293
 - modulation 293
- Transponder 290, 292
 - protocol-regenerative 293
- Tunable fiber lasers 266

- Tunable laser diodes
 - amplifier-coupler-absorber (ACA) laser 201
 - arrays 257ff
 - bundle-integrated 135
 - characterization 221ff
 - codirectionally coupled 192ff
 - control 214, 221ff
 - digital supermode (DS) DBR laser 184ff
 - direct modulation 232ff
 - distributed forward coupling (DFC) laser 202ff
 - external cavity 247ff
 - fiber transmission 234, 239, 241
 - grating-coupled sampled-reflector (GCSR) laser 206ff
 - interferometric 187ff
 - modulated-grating Y-structure (MGY) laser 208ff
 - monolithic 169ff
 - sampled grating DBR laser 174ff, 288
 - superstructure grating DBR laser 179ff
 - technology summary 265
 - thermally tuned 116, 128, 332
 - vertical cavity 252ff
 - vertical coupler filter (VCF) laser 200
 - VMZ laser 190
 - wavelength switching 234ff, 254, 265
 - Y-laser 188ff
- Tunable pulse sources 268
- Tunable waveguide lasers 268
- Tunable wavelength converter (TWC)
 - OEIC 294
 - OEO-WC 294
 - T-AOWC 294
- Tuning
 - continuity 285, 287
 - latency 285–286
 - speed 234ff, 285–286
 - stability 285, 288
 - uniformity 285, 288
- Tuning enhancement 172, 211
- Tuning range 81, 86, 97
 - ACA laser 200
 - active mode locked 269
 - comparison 211–212, 265–266
 - continuous 81, 90, 136ff, 169, 176
 - DBR array 263
 - DFB array 260–261
 - DFB cascaded array 260
 - DFC laser 206
 - digital supermode DBR laser 185
 - discontinuous 169
 - external cavity laser 249
 - fiber laser 267
 - GCSR laser 207
 - hybrid structure 251
 - MGY laser 210
 - passive mode locked 269
 - sampled grating DBR laser 178–179
 - superstructure DBR laser 181–182
 - VCF laser 200–201
 - vertical cavity laser 254–255
 - VMZ laser 191
 - waveguide laser 268
 - Y-laser 188, 190
- Tuning scheme 80–81
 - continuous 80–81, 87ff, 90, 98, 107, 111, 140, 176, 249, 262
 - discontinuous 81, 90, 107, 111, 114, 116, 118, 176
 - quasicontinuous 81, 107, 116, 118, 173
- Tunnel junction 253
- Ultra-long-haul 291, 309
- Uni-directional line-switched ring (ULSR) 308
- VCF laser 200
- Vernier effect 169ff, 251
 - additive 208
- Vertical cavity 332–333
- Vertical cavity lasers 252ff, 266
- Very short reach 291
- Virtual private network (VPN) 313
- VMZ laser 190ff
- Voltage contours 226–227
- Voltage control of laser diodes 225
- Wafer fusion 253
- Wave equation 19–20, 343
- Waveguide
 - slab 343ff
- Waveguide lasers
 - array 268
 - tunable 268
- Wavelength control 223, 225

388 INDEX

- Wavelength conversion
- amplified spontaneous emission (ASE) 298
 - carrier modulation 296
 - cross-absorption modulation (XAM) 298
 - cross-gain modulation (XGM) 296
 - DFB 299
 - dynamic carrier heating (DCH) 296
 - EAM-IWL 298
 - electroabsorption modulator (EAM) 298
 - extinction ratio 296
 - four-wave-mixing (FWM) 298
 - gain modulation 296
 - interferometric wavelength converter (IWC) 296
 - Mach-Zehnder interferometric wavelength converter (MZI-WC) 296
 - MZI-IWC 299
 - optoelectronic clock recovery 298
 - phase modulation 296
 - polarization 299
 - sensitivity 299
 - signal to noise ratio (SNR) 298
 - SOA-IWL 298
 - spectral hole burning (SHB) 296
 - T-AOWC 299
- Wavelength converter 241
- monolithically integrated 296
 - photonic integrated circuit (PIC) 296
 - semiconductor optical amplifier (SOA) 296
 - XPM-WC 296
- Wavelength locking control 292
- Wavelength switching dynamics 234ff, 304–305
- Wide area network (WAN) 307
- Wiener-Khinchine theorem 155
- Yield
- single mode 64–65, 67–68
- Y-laser 188ff