Index

Acoustic-optic (A-O) modulator, 43, 141, 148–151. See also Q-switching
Acceptance angle, 215
Alexandrite laser, 195
Ammonia maser, 83
Ampere’s law, 10
Ar-ion laser, 235, 237, 268
ArF laser, 261
Argon laser, 1, 106, 126
Atoms, 63

Bandgap energy, 183, 184
Bandwidth, 113, 118
white light, 55
Bar-code scanner, 5
Baseball in the Gouda cheese model, 34
Bending loss (in optical fiber), 221
Bennett, William R., Jr., 232
Birefringence, 30, 34, 138, 139, 163, 168, 205, 206, 208, 210. See also Polarization
Birefringent filter, 26, 33, 121, 122
Boltzmann distribution, 73
Bragg modulator, 148
Brewster’s angle, 20, 38, 40, 122, 228, 230
Brightness, 10, 17, 40–42
compared to intensity, 42

Carbon dioxide laser, 1, 4, 68, 84, 108, 129, 145, 225, 226, 228, 239
excitation, 242. See also Gas laser
flowing-gas, 244
gas-dynamic, 246
optics for, 246
output power, 243
sealed—tube, 243
transversely excited atmospheric (TEA), 246
types of, 243
vibrational modes, 240
vibrational transition, 240
waveguide, 243
Cavity dumping, Q-switching, 143, 144, 146–148, 151. See also Pulsed laser partial, 147
Cavity laser, 137, 186, 212. See also Laser resonator
Chemical laser, 84, 239, 246, 247
Chemical oxygen–iodine laser (COIL), 247
Chromium, 83, 84, 141, 173, 192, 195, 270
Circulating power, 87–93, 96, 99, 133, 134, 143, 151, 169, 217, 271
CO₂ laser. See Carbon dioxide laser
Coherence, 55, 60, 113, 115, 225, 231, 232, 235. See also Laser light
spatial, 60
temporal, 60, 113
Color separator, 4
Communications, laser applications, 3, 184, 216, 265
Compact disc, 46
Conversion efficiency, 156, 158, 160, 169, 267
Coolant, 194, 197–200, 203, 205, 207, 209
Cr:LiSAF laser, 269, 271
Cr:ruby laser, 112, 141, 202, 204, 270
lamp pumping, 192. See also Ruby laser
Cutting applications, 3, 213, 239

Deuterium fluoride laser, 227
Diffraction, 57–60, 90, 137, 243
Diffraction grating, 46, 267, 270, 279, 281
Diffraction-limited mode, 102
Diode laser, 1–3, 5, 84, 136, 175, 177,
179–181. See also Semiconductor laser;
Solid-state laser
bandwidth, 182
charge carriers, 181
compounds, 184
diode arrays, 185
double heterostructure, 181
intracavity optical power, 181
stacks, 185
wavelength, 183, 184
Diode-pumped solid-state laser, 195
Directionality, 55, 56, 202. See also
Coherence; Laser light
Dispersion, 17, 20, 22, 162, 163, 166, 168,
260, 278, 279
Distributed-feedback (DFB) laser, 183
Distributed Bragg reflector, 183
Divergence, 41, 42, 56–61, 99, 105, 160,
164, 185, 186, 213, 217, 230, 235,
250
Doping optical fibers, 216
Doppler broadening, 116, 117, 118, 231
Double-clad fiber, 218
Dye laser, 2, 52, 126, 129, 148, 151, 191,
259, 265–268, 270–272, 274, 275, 277

EDFA, 4, 172, 194, 217, 265. See also
Erbium-doped fiber amplifier
Efficiency, 169, 170, 185, 192, 195,
197–199, 202, 205, 208, 210, 211,
215, 230, 234, 236, 237, 239, 244,
249, 267, 272
Einstein, Albert, 14
Electromagnetic wave, 7, 8, 66
plane, 11
spherical, 11
transverse, 7
wavefront, 10
Energy distribution, 73. See also Energy level

Boltzmann distribution, 73
four-level laser, 82
L.A.S.E.R, 79
population inversion, 77
pumping mechanism, 83
three-level laser, 82
Energy level, 63–70, 72, 74–76, 78, 82, 83,
85, 116, 172, 194–197, 202, 210,
211, 226–228, 232, 233, 236, 239,
240, 251, 267. See also Energy distribution
atomic, 63
molecular, 66
spontaneous emission, 65
stimulated, 65
Energy nomograph, 115
Er laser, 273
Er:glass laser, 199, 265
Erbium, 194, 199, 216
Erbium ion (Er3+) laser, 194
Erbium-doped fiber amplifier, 4, 173, 194,
217, 265
Erbium-fiber laser, 195
Etalon, 123, 124, 125, 260, 267. See also
Laser bandwidth; Fabry–Perot interferometer
Excimer laser, 225, 226, 228, 249–261. See also
Gas laser
applications, 259
electrical considerations, 253
handling the gases, 255
Excimer molecules, 251
Excitation, 242
Excited-state absorption (ESA), 267
External cavity diode laser, 183
Fabricating optical fibers, 218
Fabry–Perot interferometer, 43, 49, 52, 63,
111, 123
Faraday's law, 10
Feedback for fiber lasers, 219
Fiber Bragg grating, 220
Fiberoptics, 194, 232, 265
Fixed-wavelength laser, 1, 155
Fluorescence, 198, 268
Four-level laser, 82
Free-electron laser, 85
Fundamental mode, 102

Gain and loss, 90
Gallium aluminum arsenide (GaAlAs) laser, 184
Gallium arsenide (GaAs) laser, 179
Ar-ion laser, 235
excitation, 229
He–Ne laser, 232
Krypton laser, 235
media and tubes, 228
optical characteristics, 230
spectral width, 230
transitions, 226
tubes, 228
wavelengths, 236
wavelengths, 230
Gauss's law, 9, 10
Gaussian beam, 58, 59, 62, 102, 103, 105–107, 160. See also Fundamental mode
propagation, 101
Glass laser, 2, 192–194, 208, 234
Graphics applications, 4
Grocery stores, 5
He–Ne laser, 55
Heat-treating, 3
Heisenberg uncertainty principle, 263
Helical-core fiber, 222
Helium–cadmium (He–Cd) laser, 227
principles of, 232
structure of, 234
Herriott, Donald R., 232
Ho laser, 199
Ho:YAG laser, 195
Holycy fibers, 222
Holmium, 194, 216
Huygens, Christian, 21
Huygens wavelength, 23
Huygens wavelet, 23, 34, 35, 36, 37
Huygens' principle, 21
Infrared light, 155, 203
Intensity, 3, 13, 14, 22, 40, 41
Interference, 12, 43–46, 52
constructive, 45
destructive, 45
Fabry–Perot interferometer, 49
optical, 43
Intercavity harmonic generation, 168
Ion laser, 124, 147, 124, 225, 226, 235, 236, 238. See also Gas laser
Kerr cell, 140
Kerr effect, 277
Kr–ion laser, 235
Krypton fluoride (KrF) laser, 251
Krypton-ion laser, 147
L.A.S.E.R., 79
Lamp pumping, 201
Large-mode-area fibers, 221
Laser applications, 3
construction projects, 5
graphics, 4
grocery stores, 4
light-shows, 5
medicine, 4
military, 5
negatives, 4
platemakers, 4
printers, 4
printing plates, 4
publishing, 4
research, 4
sawmills, 5
telecommunication systems, 3
Laser bandwidth, 113–119, 121. See also Bandwidth
broadening mechanisms, 116
measuring, 113
reducing, 113, 118
Laser excitation, 229
Laser gyroscope, 5, 235
Laser light, 1–5, 43, 55, 56, 58, 60. See also Light
coherence, 60
directionality, 56
monochromaticity, 55
Laser mirrors, 95
Laser printer, 3, 4
Laser resonator, 43, 56, 63, 87
circulating power, 88
gain and loss, 90
laser mirrors, 95
oscillator–amplifier, 94
relaxation oscillations, 92
Laser resonator (cont.)
   saturation, 91
   unstable resonators, 94
Laser threshold, 92
Laser-broadening mechanisms, 116
Lasers in research and medicine, 4
LASIK procedure, 4, 261
Lens, 18, 19, 45, 60, 61, 105, 112, 160, 186, 206, 208, 218, 260
Light, 7. See also Laser light, Light propagation
   electromagnetic waves, 7
   wave–particle duality, 10
Light propagation, 17
   refractive index, 17
Liquid laser, 2, 205
Longitudinal mode, 109

Magnetic field, 8, 10, 15, 17, 24, 28, 52
Maser, 83, 226
Master oscillator/power amplifier, 200
Materials processing, 3
Maxwell, James Clerk, 8
Maxwell’s equations, 8
Measuring laser bandwidth, 113
Measuring the output of pulsed lasers, 129
Medical applications of lasers, 194, 202, 260, 265, 274
Microlaser, 201
Military applications of lasers, 5, 85, 192, 207, 242, 246, 247, 259
Modelocking, 143
   applications, 152
   cavity dumping, 143
   frequency-domain, 151
   Q-switching, 143
   time-domain, 148
Molecules, 63, 66
Monochromaticity, 55, 56, 113. See also Laser light
   Nd:glass laser, 192, 194, 202
   Nd:YAG laser, 1, 2, 96, 104, 108, 111, 112, 131, 132, 150, 155, 171, 173, 191,
   192, 194, 195, 197, 198–201, 205, 207, 208, 210, 263, 265, 268, 270, 271, 273, 274, 278
Neodymium laser, 1, 84, 113, 216. See also Nd:YAG laser
Nitrogen laser, 88, 266
Nonlinear converter, 271
Nonlinear optics, 2, 21, 33, 155
   birefringent phase-matching, 161
   higher harmonics, 169
   intracavity harmonic generation, 168
   optical parametric oscillator, 170
   quasi-phase-matching, 165
   Raman laser, 172
   second-harmonic generation (SHG), 158
Numerical aperture, 215

Optical interference, 43
Optical parametric oscillation (OPO), 170
Optics for CO_2 lasers, 246
Organic dye laser, 2
Oscillator–amplifier, 94

   Phase matching, 158, 161, 163–165, 273
   birefringent, 161
Phase matching, 155, 161
Photoelectric effect, 12, 14
Photolithography, 258, 260, 261
Photons, 7, 14–16, 65, 66, 80–82, 84, 87, 88, 90–93, 99, 116, 133–135, 141, 146, 151, 157, 158, 170, 172, 179, 180, 182, 184, 188, 189, 196–198, 211, 226, 249, 250, 253, 259, 261, 271. See also Energy levels
Plane wave, 10, 21, 23, 57, 58, 59, 62
Pocket cell, 139
Polarization, 17, 24–26, 29, 30, 32–34, 38, 40, 55, 66, 81, 121, 135, 138, 139, 143, 151, 162–165, 195, 199, 206, 230, 235
components, 26
Polarization vector, 25
266, 268, 271
Power output, 129, 148, 185, 186, 206, 210
Prism, 20, 55, 56, 119–122, 126, 136, 211, 238, 260, 270, 273, 279
Pulse repetition frequency (prf), 130, 141, 143
Pulsed laser, 2, 90, 94, 95, 129–131, 147, 153, 159, 169, 217, 268, 271
Pumping fiber lasers, 217
Pumping mechanism, 83–85
Q-switching, 129, 131. See also Cavity dumping, Modelocking
A-O Q-switches, 136
dye Q-switches, 140
E-O Q-switch, 138
mechanical Q-switch, 135
types of Q-switches, 135
Quantum cascade laser, 189
Quasi-phase-matching, 165

Radio-frequency (rf) energy, 84
Raman laser, 172
Raman–Nath modulator, 148
Raman spectroscopy, 172
Range finder, 5
Ranging, 104, 112, 152, 153
Refractive index, 17, 19, 30, 32, 34, 35, 38, 40, 138, 139, 162, 163, 179, 181, 182, 206, 215, 218, 220, 260
Relaxation oscillation, 92–94, 132, 145
Resonator mode, 99
Robotics, 3
Ruby laser, 173, 192, 202, 204. See also Cr:ruby laser

Saturation, 91
Sawmill, laser applications, 5
Second-harmonic generation (SHG), 155, 157, 158, 160, 165, 168, 271
Semiconductor laser, 175. See also Diode laser
array, 185
bandwidth, 182
carriers, 180
frequency-selective feedback, 183
optically pumped semiconductor laser, 187
physics of, 175
quantum cascade laser, 189
stacks, 185
vertical cavity, surface-emitting laser, 185
wavelength, 183
Semiconductor manufacture, 225, 260
Semiconductor physics, 175
n-doped semiconductor, 176
p-doped semiconductor, 176
Single-mode laser, 122–124
diode pumping, 195
diode-pumping geometry, 199
pump diodes, pulsing, and packaging, 199
lamp pumping, 201
materials, 191
scaling diode-pumped lasers to high power, 207
thermal issues, 205
Solid-state laser materials, 191
Spatial energy distribution, 99
Spectroscopic laser, 192
Spectroscopy, 114, 153, 172
Spherical wave, 10, 11, 23
Spontaneous emission, 65
Stability criterion, 107
Stimulated Brillouin scattering, 217
Stimulated Raman scattering, 172, 217
Stimulated emission, 65

Telecommunications, 3, 184
TEM₀₀ mode, 101
Thermal birefringence, 206. See also Birefringence
Thermal issues in solid-state lasers, 207
Thermal lensing, 205, 206
Thermodynamics, 74
Thin disc lasers, 209
Three-level laser, 82, 83, 202, 210. See also Energy distribution
Thulium, 194, 195
Tissapphire laser, 192, 195, 259, 263, 265, 268, 270–272, 274, 277, 278
Total internal reflection, 19, 136, 181, 215–218
Transverse resonator mode, 100
Tunable laser, 1, 259, 263, 266, 268, 271, 272
Ultrafast laser, 261, 263, 265, 268, 274, 278, 279, 281
Ultraviolet light, 1, 2, 8, 184, 200, 220, 225, 249, 272
Unstable resonator, 94

Vertical cavity, surface-emitting laser (VCSEL), 186–188
Vibrational laser, 239
Vibrational transitions, 240

Water coolant, 94
Wave–particle duality, 10

Wavelength of diode lasers, 183
Wavelength changing, 20
Wavelength-division multiplexing, 3
Welding, 3

Yb laser, 202, 204, 211
Yb:YAG laser, 197, 198, 204, 210, 212
YLF laser, 195
Young’s double-slit interference, 12, 14, 43, 46–49
Ytterbium-doped fiber laser, 2
Yttrium aluminum garnet (YAG) laser, 192