

## Index

- Abbe number 14, 65, 68, 70, 171, 249  
 absorption coefficient 10  
 absorption loss 9, 10  
 absorption spectra 12  
 achromatic lens 76, 78  
 activation energy of diffusion 50  
 active ions 89  
 Ag-doped glass 218, 220, 225, 228  
 AlF<sub>3</sub>-based fluoride glass 121  
 AlF<sub>3</sub>-fluoride 118, 259  
 alkali-free glass 29  
 aluminoborate 254, 256, 257, 260  
 aluminosilicate 174, 254–61  
 amplification  
   characteristics 112, 140, 141  
   Er<sup>3+</sup>-doped fibers 110  
   Nd<sup>3+</sup>-doped fiber 113  
   Pr<sup>3+</sup>-doped fiber 115  
 amplifier of radiation 84  
 amplified spontaneous emission (ASE) 110, 113, 114  
 annealing point 16, 29  
 applications 127, 261  
   GRIN materials 59  
   nonresonant glass materials 180  
   optical nonlinear materials 166  
   semiconductor-doped glasses 211  
 Au-doped glasses 220  
 Auger recombination 198  
 average dispersion 14
- band filling effect 190, 231  
 band theory of semiconductor 182  
 batch mixture 16  
 BGO model 171  
 Bi<sub>2</sub>O<sub>3</sub>-containing glasses 180  
 blocking effect 191, 231  
 Bohr magneton 243  
 Bohr radius 187  
 borate 99, 100, 102, 103, 116, 251, 254–59, 261  
 borate glass 30  
 borosilicate 134, 138, 139, 174, 177, 257–59, 261  
 branching ratio 93, 99, 115
- bridging oxygen 28  
 bulk laser glass 96
- capillary force 24  
 cavity 88  
 Ce<sub>2</sub>O<sub>3</sub>-aluminoborate 254  
 Ce<sup>3+</sup>-phosphate 260  
 CdS<sub>x</sub>Se<sub>1-x</sub>-doped glass 188, 189, 191–93  
 CdS<sub>x</sub>Se<sub>1-x</sub> filter glass 191, 199, 211  
 CdSe-doped glass 194, 200, 202  
 CdTe-doped glass 202, 203  
 chalcogenide fiber 107, 108, 121, 123, 181  
 chalcogenide glass 10, 37, 100, 102, 122, 124, 132, 178, 180, 250, 253  
 chelating agent 26  
 chemical-tempered glass 50  
 chemical vapor deposition (CVD) 18  
 choride 100–3  
 chromatic aberration 64, 66, 68  
 chromatic property 64  
 clad pump fiber laser 133  
 colloid formation 44  
 commercial silicate glass 29  
 concentration gradient 65, 66  
 concentration profile 62, 63, 70, 75, 76  
 concentration quenching 95, 96, 103, 116  
 confinement  
   dielectric 216  
   electron or hole 187  
   exciton 187  
   quantum 188, 189, 193, 217  
   strong 188, 189, 194  
   weak 189, 203  
 composite materials 214–16  
 container glass 17  
 co-operative relaxation 95  
 co-operative up conversion 94, 96  
 coordination number 26  
 core-clad structure 20  
 critical cooling rate 33  
 cross section 85, 93, 99, 100, 113, 114, 121  
 cross relaxation 94, 95, 117  
 crystal glass 17

crystal growth rate 5  
 crystal-liquid interface energy 6  
 crystallization 8, 38  
 Cu-doped glass 218–20, 222–5, 228  
 CuBr-doped glass 209  
 CuCl-doped glass 207–9  
 CuCl microcrystallite 205, 206, 208  
 Cu-implanted SiO<sub>2</sub> 221  
 current sensor 263  
 CVD technique 107

darkening effect 197  
 degenerate four-wave mixing 163  
 dehydration of silanol 24  
 design  
   radial gradient index profiles 61  
     achromatic lens 76  
 diamagnetic glass 249, 250, 252, 263  
 diamagnetic materials 245  
 diamagnetic susceptiblity 245  
 diamagnetic terms 248  
 differential thermal analysis (DTA) 8  
 diffusion coefficient 62, 69, 71, 76  
 diffusion constant 50  
 diffusion equation 62  
 diffusion parameter 62–4, 71  
 dip-coating 27  
 dispersion 12, 65, 66, 75, 76, 78, 249  
 double ion-exchange technique 69  
 Drude's theory 212  
 drying control chemical additive (DCCA) 25  
 Dy<sup>3+</sup>-doped glasses 122  
 Dy<sup>3+</sup>-doped chalcogenide glass 123, 124

effective linewidth 93  
 effective number of Bohr magnetons 249, 251, 258  
 effective transition wavelength 251, 258, 260  
 electric glass 17  
 electron confinement 187  
 electronegativity 26  
 electric-field effect 216  
 energy transfer 83, 94, 95  
 enhancement of nonlinearity 193, 204  
 Er<sup>3+</sup>-doped  
   glasses 96  
   glass waveguide lasers 133  
   fiber amplifier 110  
   waveguide laser 137  
   waveguide amplifier 140  
 Er/Yb waveguide laser 142  
 EuO-aluminoborate 254  
 Eu<sup>2+</sup>-aluminoborate 260  
 excited state absorption, ESA 110, 111, 113–5  
 exciton 186, 203  
 exciton confinement 187  
 excitonic enhancement 203  
 excitonic optical nonlinearity 207

fabrication  
   channel waveguide structure 133  
   index gradient 62  
   parameters 62

fabrication techniques 67, 107, 209, 228  
 Faraday effect  
   fundamentals 246  
   in glass 249  
   temperature dependence 250  
 Faraday rotation 246, 262  
 Fermi smearing 218, 220, 221  
 fiber amplifiers 106, 109  
 fiber lasers 106  
   fabrication technique 107  
 fiber laser oscillator 123, 125, 126  
 figure of merit 113, 118, 119, 208, 224, 225  
 filter glasses 189, 191, 197, 211  
 flame hydrolysis deposition, FHD 133  
 fluorescence lifetime 83, 93, 118, 119, 120, 124  
 fluoride-based glass 121  
 fluoride glass 10, 32, 108, 116, 121  
 fluorophosphate 99, 100, 104, 105, 112, 113, 254–9  
 fluorophosphate glass 35  
 fluorozirconate 102, 112, 113, 116, 121, 127  
 fluorozirconate glass 32  
 fluorozirconate fibers 113, 114  
 focusing constant 61, 63, 64  
 forward DFWM 164  
 four-level system 86, 90  
 four-level lasing scheme 90  
 fundamentals  
   Faraday effect 246  
   laser physics 82  
   nonlinear optics 160  
   optical properties of metal 212  
   semiconductor 182

gain 86, 88, 114, 117, 123  
 germanate 99, 100, 102, 103  
 germanate glass 31  
 giant pulse laser 30  
 glass ceramics 38, 132  
 glass fiber 16  
 glass structure 2  
 glass transition 1  
 glass transition temperature 8  
 gold ruby 45  
 graded type 21  
 gradient index glass 58  
 gradient index profile 61, 62  
 gradient-refractive index 30  
 GRIN lens array 60  
 GRIN rod lens 58–60  
   large diameter 68, 69, 71, 76  
   small diameter 59, 60

halide glass 32  
 heat treatment for nucleation 41  
 heavy metal halide glass 32  
 heterogeneous nucleation 42  
 high index glass 253  
 high index oxide glasses 176  
 hot electron 217–19, 221, 222  
 hydrolysis 18, 22  
 hypercritical drying 25

- index difference,  $\Delta n$  63, 64, 69, 72, 76  
 index gradient 62  
 index-modifying  
   cation 71, 72  
   dopant 70  
   ion 62, 65  
 industrial glass 17  
 InF<sub>3</sub>-based host glasses 121  
 InF<sub>3</sub>/GaF<sub>3</sub>-based fluoride fiber 121  
 infrared transmitting glass 32  
 inhomogeneous broadening 85  
 intensity dependent response 195, 196  
 intensity parameter 92, 98, 124  
 interband transition 212, 213, 217, 219, 223  
 interdiffusion technique 72  
 intraband transition 213, 217, 221  
 intrinsic absorption 9  
 intrinsic scattering loss 9  
 ion exchange 5, 50, 67, 133, 134  
 ionic conductivity 35
- Judd-Oflet (J-O) 92  
 J-O approach 97, 99
- Kerr shutter 168, 181  
 Kerr effect 167
- laboratory ware 17  
 Larmor frequency 245, 247  
 laser glass 82, 89  
 laser oscillation 88  
 laser parameters 91, 96  
 law of additivity 4  
 lifetime 83  
 line strength 92, 93  
 line width 85, 93, 98, 100  
 linear refractive index 15, 162  
 Lines' model 171  
 local electric field effect 216  
 Lorentz-Lorenz equation 12
- magnetic dipole moment 243  
 magnetic property 243  
 magnetism of materials 243  
 magnetic susceptibility 244, 246  
 magnetization 244  
 magneto-optical glass 242  
 marker fringe method 165  
 matrix elements 92, 97  
 mean free path theory 214  
 melt-quenching technique 15  
 memory-switch 38  
 metal alkoxide 22  
 metal-doped composite materials 216  
 metal-doped glasses 212, 218, 226  
 metal halide 18  
 metastable immiscibility spinodal decomposition 46  
 microlens array 79  
 micro-phase separation 42  
 modified chemical vapor deposition (MCVD) 21  
 modified ion-exchange technique 67, 68
- molar enthalpy of fusion 6  
 molar entropy of fusion 6  
 molar refraction 13  
 molar volume 6  
 molecular stuffing technique 70  
 multi-mode fiber 20, 107  
 multiphonon decay rate 101–3  
 multiphonon emission 83  
 multiphonon relaxation 94, 101, 116  
 multiphonon process 101, 102
- nano-particle color center 44  
 Nd<sup>3+</sup>-doped glasses 96  
 Nd<sup>3+</sup>-doped fiber 113  
 Nd<sup>3+</sup>-doped waveguide laser 134  
 Nd<sup>3+</sup>-doped waveguide amplifier 140  
 network former 2  
 network modifier 2  
 nonbridging oxygen 28  
 nonlinear absorption coefficient 163  
 nonlinear characteristics  
   CdS<sub>x</sub>Se<sub>1-x</sub>-doped glasses 191  
   metal-doped glasses 226  
   sharp-cut filter-glasses 190, 191  
 nonlinear index change 105  
 nonlinearity of dielectric materials 169  
 nonlinear mechanisms 216, 229  
 nonlinear optical glass 159  
 nonlinear optical properties 173  
   measurement 163  
   metal-doped glasses 218  
   semiconductor-doped glasses 210  
   weak confinement 203  
 nonlinear optical response 206  
 nonlinear polarization 160, 216  
 nonlinear refractive index 12, 15, 162, 169–71, 173  
   CdS<sub>x</sub>Se<sub>1-x</sub>-doped glasses 192  
   chalcogenide glasses 178  
   high index oxide glasses 176  
   optical glasses 174  
 nonlinear response time 180, 181, 194, 223, 230  
 nonlinear susceptibility 15, 161, 162, 218, 230  
   chalcogenide glasses 180  
   metal particles 219  
   optical glasses 174  
   strong confinement case 189  
 nonoxide glass 116  
 nonradiative decay 83  
 nonradiative probability 83  
 nonradiative recombination 201  
 nonradiative relaxation 93, 101  
 nonradiative transitions probability 93  
 nonresonant 162  
   glass materials 180, 181  
   nonlinear glasses 168, 173  
   nonlinearities 228  
 nonresonant optical nonlinearities 171  
 nonsilicate glass 29  
 nuclear contributions 172  
 nucleating agent 42

270

nucleation rate 5  
 numerical aperture (NA) 62, 68, 70, 116

optical glass 173, 174, 249, 250, 252  
 optical fiber 20, 106  
 optical isolator 261  
 optical Kerr effect 167  
 optical Kerr shutter 168  
 optical loss  
 optical nonlinearity of the medium 161  
 optical nonlinear mechanisms 216  
 optical properties  
   metal 212  
   semiconductor 185  
   semiconductor-doped glasses 187  
 optical pumping 86  
 optical switching 211  
 optical transmission curve 10  
 oscillator strength 13  
 output power 89, 125, 136  
 outside vapor-phase deposition (OVD) 21  
 oxide glass 98, 116, 132, 174, 250  
 oxy-halide glass 35  
 oxygen plasma 18  
 oxyhydrogen flame 18

paramagnetic glasses 250, 261  
   Verdet constant 255, 256  
 paramagnetic ions 246, 249  
 paramagnetic materials 246  
 paramagnetic terms 249  
 partial charge 26  
 partial leaching technique 71  
 Pb<sup>2+</sup>-containing glasses 175  
 PbF<sub>2</sub>/InF<sub>3</sub>-doped fluoride glass 121  
 PbO-containing glasses 175, 246  
 PbO-silicate 174, 176, 177  
 peak wavelength 93, 98, 99, 100  
 phase change 167  
 phase separation 46, 70  
 phase conjugate 163, 166  
 phonon vibration 95  
 phonon energy 94, 102, 116, 118–20  
 phosphate 69, 99, 100, 102–5, 112, 135, 137–41,  
   174, 251, 254–60  
 phosphate glass 30  
 photoannealing effect 198, 201  
 photoconduction 38  
 photodarkening 38, 195, 198  
 photoluminescence 38  
 planar microlens array 79  
 plasma resonance 218, 220, 224  
 population inversion 85  
 porous glass 47, 70  
 porous Vycor 48  
 polarizability 13  
 polycondensation 22  
 Pr<sup>3+</sup>-doped  
   chalcogenide fiber 123  
   chalcogenide glasses 122  
   glasses 118, 119

*Index*

fiber amplifier 115  
 fluoride glasses 116  
 fluoride fiber 116, 117  
 transparent glass 132  
 preform 20, 107, 108  
 probabilities  
   radiative process 83  
   nonradiative process 83  
 pump power 88, 114, 123, 125, 142  
 pump-prone technique 165

quantum confinement 187–9, 193, 216, 217  
 quantum efficiency 83, 93, 116, 118, 119, 124  
 quantum size effect 189

radial gradient, r-GRIN 58  
   applications 59  
   index profile 61  
   lenses 61  
 radiative decay 83  
 radiative lifetime 83, 93, 99, 100, 118, 119, 124  
 radiative process 84  
   probabilities 83, 84  
 radiative quantum efficiency 83  
 rapid quenching 36  
 rare-earth containing glasses 254  
 rare-earth-doped  
   chalcogenide glasses 132  
   fibers 112  
   fiber laser oscillator 128  
   glass waveguide lasers 138  
   ridge-shape waveguide lasers 134  
   silica fiber 107  
   waveguide lasers 140  
 rare-earth fiber laser 129  
 rare-earth ions 90  
 Rayleigh scattering 10  
 reactive ion etching, RIE 133  
 refractive index 11  
 refractive index profile 62  
 refractive index dispersion 75, 78  
 resonant cavity 88  
 response time 221  
   nonlinear 180, 181, 194, 223, 230  
 rod lens 58–60  
 Russel-Sounders multiplet notation 90

self-focusing effect 105  
 semiconductor  
   fundamentals 182  
   band theory 182  
   optical properties 185  
 semiconductor-doped glasses 182  
   applications 211  
   excitonic optical nonlinearity 207  
   nonlinear optical properties 210  
   optical properties 187  
 semiconductor glass 32  
 sharp-cut filter glasses 190, 191  
 sheet glass 16  
 silica 107, 111, 125, 137–41, 174

- silica glass 10  
 silicate 68, 98–104, 116, 139, 141, 174, 254–7, 261  
 silicate glass 28, 98, 99, 101, 102  
 silicon alkoxide 22  
 silicon methoxide (TMOS) 23  
 single mode fiber 20  
 slope efficiency 89, 138  
 small metal particles 214  
 soda-lime silica glass 9, 136  
 softening point 29  
 sol-gel technique 71  
 sol-gel process 22, 71, 210, 211, 226–8  
 soot 18  
 solder glass 30  
 spin-coating 27  
 spherical gradient 58, 78  
 spontaneous emission 84  
 spontaneous emission probability 93  
 standard deviation 63, 71  
 state filing 192, 194, 231  
 stimulated emission 82, 84  
 stimulated emission cross section 85, 93, 99, 113, 118, 119, 124  
 strain point 29  
 stress 66, 72, 105  
 strong confinement 188, 189, 194  
 structural relaxation 8  
 super-cooled liquid 5  
 surface crystallization 42  
 surface plasma resonance 215, 216, 218  
 surface trap 200, 201  
  
 Tb<sup>3+</sup>-aluminosilicate 260  
 TbF<sub>3</sub>-fluorophosphate 254  
 Tb<sub>2</sub>O<sub>3</sub>-alumonoborosilicate 254  
 TeO<sub>2</sub> glass 175  
 telluride glass 32  
 tellurite 99, 100, 102, 103  
 temperature-coefficient optical path length 105  
 TiO<sub>2</sub>-containing glasses 175  
 thermal expansion coefficient 66, 76  
 thermal stability 33  
 thermal stability of a glass 8  
 thermomechanical properties 105  
 third harmonic generation 165  
  
 third-order  
   nonlinear polarization 216  
   nonlinear susceptibility 105, 163, 170, 192, 194, 205, 216, 217  
   terms 161  
 three-level system 86, 90, 194, 195  
 three-level lasing schemes 90  
 threshold 83, 139  
 threshold-switch 38  
 transition metal 12  
 transition probability 84, 91, 92, 251, 255, 258, 260  
 transparent glass ceramics 132  
 trap level 195, 196, 201  
   deep 200  
   origin 202  
 trivalent lanthanide 89, 90  
 TV funnel 17  
 TV panel glass 17  
  
 unidirectional gradient index 71  
 up-conversion 127, 129, 130  
   process 127, 130  
   co-operative 96  
  
 vapor-phase axial deposition (VAD) 21  
 Verdet constant 246, 248, 251, 255  
   diamagnetic glasses 250, 252  
   paramagnetic glasses 255, 256  
   temperature dependence 250, 261  
 viscosity 5  
  
 waveguide lasers 133  
   applications 142  
   oscillator 134  
 waveguide amplifier 133, 140  
 weak confinement 189, 203  
  
 YABC glass 34  
 Yb<sup>3+</sup>-doped fiber laser 131, 133  
  
 ZBLAN glass 32  
 Zeeman splitting 244, 247  
 ZrF<sub>4</sub>-based glass 121  
 ZrF<sub>4</sub>-fluoride 118, 257–9  
 z-scan method 166