

# Index

- ablation mechanism 43, 122–24, 130, 135, 245, 247  
ablation product 104, 128, 135, 137, 141, 158  
ablation surface 38  
ablation threshold 2, 11–12, 39, 40, 44, 46–47, 108, 112, 141–42, 158, 230, 239, 247–48, 251–52, 257, 264, 267–68, 285–86, 371, 379, 570  
single-pulse 282  
active substrate 288, 459, 463  
active waveguide 58, 457–58, 461  
adaptive pulse shape control 196  
AFM *see* atomic force microscope  
aluminosilicate glass *see* glass  
amplifier 57, 65–75, 80, 242, 301, 457–59, 461, 463, 469, 475  
regenerative 3, 65, 70, 73, 75, 524  
arrayed sphere system 363, 365  
atomic force microscope (AFM) 15, 270, 315, 355, 381, 402, 528  
avalanche ionization 7, 39, 43–44, 47, 52, 119–20, 157, 398, 406  
bandgap material 100, 112–13, 131–32, 160  
beam  
probe 397–99  
zero-order 207, 210  
beam delivery system 77–78  
beam polarization 253  
borosilicate glass *see* glass  
Bragg grating 18, 57, 66, 428, 453–55, 457, 461, 463, 467, 475  
bulk glass *see* glass  
bulk material 46, 101–3, 130, 136–37, 141, 230, 244, 256  
CBE *see* conduction band electrons  
CCD *see* charge-coupled device  
CGH *see* computer-generated hologram  
chalcogenide glass *see* glass  
charge-coupled device (CCD) 542  
chemical etching *see* etching  
chemical wet etching *see* etching  
chirped-pulse amplification (CPA) 3, 38, 62, 66–67, 69, 72, 74–76, 226, 230, 242  
computer-generated hologram (CGH) 185, 191–92, 204, 207–12  
conduction band electrons (CBE) 44, 248  
Coulomb explosion 45, 100, 122–24, 135–36, 160, 286  
CPA *see* chirped-pulse amplification  
cutting 10, 50, 27, 244, 254–56, 417, 462, 570, 582  
laser 226, 241, 254–55  
Dammann grating 538  
DFB laser *see* distributed feedback laser  
dielectric material 39, 44–45, 100, 119–22, 124, 141, 145, 147, 160, 264, 539  
inorganic 117, 121

- dielectric mirror 64, 461, 466  
dielectric nanosphere 16, 356,  
  367, 371  
dielectric sphere 354–55, 357,  
  367, 373, 378, 387  
dielectric tip 382  
dielectrics 7, 16, 38–39, 42,  
  44–45, 47, 49, 52, 57, 100,  
  102–4, 112–13, 117–20,  
  122, 136–37, 140–41, 143,  
  145, 159, 193–94, 247–48,  
  268, 272, 274, 281, 284,  
  321, 387, 580  
diffractive beam splitter 203, 207  
diffractive efficiency 435, 536–38  
diffractive optical element 58,  
  184, 202  
directional coupler 428–29,  
  435–36, 439–40, 442–44,  
  447, 473–74  
direct writing 10, 47, 58, 142,  
  237, 245, 394, 475, 491,  
  520, 523  
  femtosecond (fs) laser 19,  
    56, 82, 428, 490–91, 502,  
    507–8, 510, 512, 521, 541  
  ultrafast laser 19  
distributed feedback (DFB) laser  
  18, 461, 463, 466  
drilling 22, 25, 49, 79, 226–27,  
  241, 244, 250–52, 253–54,  
  499, 501, 570, 578, 580  
  femtosecond laser 250, 499  
  femtosecond laser pulse 251  
  femtosecond laser 3D  
    499–500  
  helical 579  
  laser 226, 250, 578, 580  
  multipulse 253  
  percussion 250  
  single pulse 250  
  3D 499, 500  
  thin film  
Drude model 108–10, 140, 249  
EDM *see* electro discharge  
machining  
electric field 7, 69, 79, 108, 119,  
  123–24, 135–41, 144, 275,  
  277–78, 285, 299, 343,  
  356–57, 444, 446  
electro discharge machining  
  (EDM) 250, 570, 572  
electro-optic modulator 444, 446,  
  491  
electroless plating 536  
electromagnetic field 120, 285,  
  354, 356, 373, 439  
electron beam 250, 324, 520  
electron beam lithography 324,  
  523  
electron cloud 126  
electron density 24, 42–43,  
  102–3, 108, 110, 113–14,  
  119, 121, 126, 131, 145,  
  149, 286  
electron emission 139–40, 142,  
  310  
electron excitation 5, 7, 102, 121  
electron gas 4, 101, 108–10,  
  112–13, 118, 132, 264  
electron–phonon coupling 4, 106,  
  108, 194, 229, 239, 264  
electron–phonon coupling rate  
  109–10  
electron–phonon coupling time 4,  
  124, 229  
electron photoemission 136–38  
electron scattering time 110  
electron temperature 4, 102,  
  108–10, 114–15, 121, 131,  
  141  
electron thermalization 107  
electron  
  emitted 139–40  
  excited 7, 64, 141, 237, 314,  
    406  
  laser-excited 102, 106, 428  
  nonthermal 106, 108–9

- nonthermalized 106
- photoexcited 396, 407
- trapped 121
- emitted electron *see* electron
- energy deposition 3, 41–42, 45, 48, 52, 145, 184, 251, 264, 285, 428
- energy-use efficiency 184–85, 199–200, 213
- EoS *see* equation of state
- equation of state (EoS) 131–32
- etch selectivity 494, 496, 499–500
- etching 55–56, 157, 159, 294, 310, 394, 310, 439, 471, 491, 493–94
  - chemical 54, 56, 159, 455, 470, 494, 499, 502
  - chemical wet 19
  - femtosecond-laser-assisted 494
  - femtosecond-laser-assisted chemical 499
  - femtosecond-laser-assisted wet chemical 491
  - plasma 46, 156, 159
  - selective 52, 55–56
  - selective (selected) laser 54, 56
  - wet 19, 494
  - wet chemical 490, 493, 499
- evolutionary algorithm 196
- FBG *see* fiber Bragg grating
- FCPA *see* fiber chirped pulse amplifier
- femtosecond laser (source, system) 120, 196, 231, 244, 245, 247, 251–53, 255, 257, 355, 382, 394, 430, 437, 457, 461, 467, 470–71, 474–75, 492, 512
- Ti:sapphire 198, 338, 339, 358, 367, 378–79, 435, 449
- femtosecond laser (pulse) ablation
  - see* laser ablation
- femtosecond laser beam 212, 467, 490, 493, 502, 508
- femtosecond-laser-assisted etching
  - see* etching
- femtosecond-laser-assisted chemical etching *see* etching
- femtosecond-laser-assisted wet chemical etching *see* etching
- femtosecond laser beam 212, 467, 490, 493, 502, 508
- femtosecond laser direct writing (FLDW) *see* direct writing
- femtosecond laser drilling *see* drilling
- femtosecond laser driven shock 25
- femtosecond laser fabrication 467
- femtosecond laser-generated groove 244
- femtosecond-laser-induced local metallization 491
- femtosecond laser-induced mechanism 433
- femtosecond laser (induced) two-photon polymerization (TPP) 531, 535–37, 539, 542, 549, 552, 558
- femtosecond laser inscription 463
- femtosecond laser (pulse)
  - irradiation 242, 387, 446, 451, 455, 471, 494, 496, 499–500
- femtosecond laser machining *see* machining
- femtosecond laser-machined part 254
- femtosecond laser material processing 253

- femtosecond laser
- microfabrication *see* microfabrication
  - microfabrication
- femtosecond laser micro(/)
- nanofabrication 521, 553, 554
- femtosecond laser micromachining
- see* micromachining
- femtosecond laser nanoshell
- scanning 552
- femtosecond laser nanostructured surface 287
- femtosecond laser patterning *see* patterning
- femtosecond laser processing 184, 197, 207, 210, 237, 367, 387, 405, 467
- femtosecond laser pulse drilling *see* drilling
- femtosecond laser pulse 120, 184, 187, 198, 212, 226, 228–29, 231, 237, 239, 241–42, 245, 248, 251–52, 371, 379, 428–30, 433, 437, 462, 466, 490, 492, 494, 496, 500, 502, 504, 538
- polarized 496
  - spatially-shaped 198
- femtosecond laser technique 436, 440, 474
- femtosecond laser 3D drilling *see* drilling
- femtosecond laser waveguide writing 432, 439, 449, 472, 474–75
- femtosecond laser writing 428, 435, 439, 442–44, 447, 453–54, 457–59, 469, 472–73
- femtosecond laser-written 440, 442, 455, 458–59, 461–63, 466, 475,
- fiber amplifier 65–66, 68, 80
- fiber Bragg grating (FBG) 47, 57, 66, 455, 461–62, 467–68
- fiber chirped pulse amplifier (FCPA) 3, 56, 68
- fiber laser 40, 67, 80
- filamentation 57, 145, 196, 248–50, 396, 440, 447
- FLDW *see* femtosecond laser direct writing
- fluorescence 55, 310, 337, 411, 451, 459, 503–5, 510, 531, 533
- Foturan glass *see* glass
- Fourier plane 190–91, 201, 207–8
- Fresnel zone plate (FZP) 47, 57–58, 535–38
- functional micromachine 520–21, 533, 535, 544–47, 559
- fused silica 18–19, 42, 47, 53, 55–59, 65, 121, 145, 147, 150, 154–56, 196, 212, 283, 396, 429, 432, 437, 439, 443–44, 451, 454–55, 471, 473, 494, 496, 502–4
- fused silica glass *see* glass
- FZP *see* Fresnel zone plate
- Gaussian beam 144, 233, 248, 257, 267
- glass
- aluminosilicate 437
  - borosilicate 18, 43, 145, 395, 397, 401, 432, 439–40, 442, 454, 474
  - bulk 52–53, 58, 416, 455
  - chalcogenide 18, 47, 58, 404
  - Foturan 56, 433, 492–94, 502–3, 508
  - fused silica 154, 156, 429, 451, 455, 471
  - lithium aluminosilicate 19, 433, 492
  - multicomponent 432

- photosensitive 19, 433, 455, 491–92, 494, 496
- porous 501
- silica glass 13, 394, 403–6, 416, 440, 447, 459
- soda-lime 358, 399, 440, 442, 444, 472
- glass chip 470
- glass transition temperature 58, 401, 414
- gold 18, 131, 137, 140, 239–40, 341, 356–58, 361–63, 365, 382, 444, 446, 582
- gold film 14, 230–31, 239, 382
- gold nanosphere 363, 366, 382–83, 387
- gold sphere 357–58, 361, 371, 378, 387
- graphite 272, 283–84
- grating structure 12, 286, 454, 466
- periodic 11–12
- HAZ *see* heat-affected zone
- heat-affected zone (HAZ) 2, 4–5, 9, 13, 24, 38–40, 45, 48–49, 104, 122, 132, 156, 231, 250, 254–55, 264
- helical drilling *see* drilling
- high-spatial-frequency LIPSS (HSFL) 268, 270, 275, 281–84, 286, 289
- HSFL *see* high-spatial-frequency LIPSS
- hydrodynamic model 103, 131–32
- hydrophobicity 24, 303, 306, 308
- integrated optofluidic device 491, 506, 510
- interaction process 40, 429
- interference lithography 520
- interferometer 186–88, 193, 397, 443–44, 471, 475
- inorganic dielectric material *see* dielectric material
- irradiation optics 76–77
- Kerr lens mode-locking 63–65
- laser ablation 2, 5, 9, 38–39, 103, 122–23, 157, 285, 315, 319, 331, 334, 337, 339, 341–43, 577
- femtosecond (pulse) 9–10, 86, 122, 157, 226, 256, 446, 499, 501
- picosecond (pulse) 22, 274, 315
- ultrafast 136
- ultrashort pulse 233
- laser cutting *see* cutting
- laser drilling *see* drilling
- laser etching *see* etching
- laser excitation 103, 106, 111, 117, 119, 130–31, 143, 145, 160, 523
- laser-excited electron *see* electron
- laser-excited matter 102–3, 108, 126, 137
- laser-induced breakdown 196
- laser-induced excitation 117, 121–22
- laser-induced free electron 115
- laser-induced periodical surface structure (LIPSS) 11, 46, 267–68, 270–72, 276–77, 283–84, 287, 295
- laser-induced plasma 157, 248, 396
- laser machining *see* machining
- laser–matter interaction 4, 40, 100–1, 104–5, 125, 130, 355
- laser microfabrication *see* microfabrication
- laser micromachining *see* micromachining

- laser patterning *see* patterning  
 laser polarization 12, 55, 270,  
     272, 275, 279, 282, 285,  
     294–95, 338, 495  
 laser tweezer 545–47  
 LCSLM *see* Liquid crystal spatial  
     light modulator  
 lens grating method 192  
 linear filtering 188–90  
 LIPSS *see* laser-induced periodical  
     surface structures *see also*  
     HSFL  
 liquid crystal spatial light  
     modulator (LCSLM) 204,  
     206, 208–9, 442  
 lithium aluminosilicate glass *see*  
     glass  
 long-period grating 467  
 low-spatial-frequency LIPSS  
     (LSFL) 268, 270, 272,  
     274–75, 277, 282–86, 289  
 LSFL *see* low-spatial-frequency  
     LIPSS  
  
 machining 39, 41, 51, 82, 225,  
     230, 233, 239, 242, 245,  
     250, 254–57, 570, 572,  
     580–81, 584  
     laser 254–55  
     femtosecond laser 255  
 Mach–Zehnder interferometer  
     (MZI) 428, 435, 443–44,  
     446, 471, 510  
 Maxwell's equations 143, 146  
 microbull 533  
 microbump 239  
 microchamber 490, 494, 504–5  
 microchannel 16, 56, 203, 433,  
     455, 457, 470–71, 490,  
     494–96, 498–99, 501–2,  
     507–8, 510, 512, 547–48,  
     553–54, 558, 581  
 microchip 505, 508  
  
 microdevice 18, 24, 56, 504, 510,  
     524, 531, 544, 558–59  
 microfabrication 227, 250, 394,  
     428, 470, 492, 519–21,  
     523, 527, 535, 538, 547,  
     559  
     high-quality 2, 4  
     femtosecond laser 437, 470  
     laser 521, 527, 529  
 microfluidic chip 471, 490–91,  
     494, 506, 510, 551, 554  
 microfluidic device 52, 56, 155,  
     446, 520–21, 547, 551–52,  
     554, 558–59  
 microfluidic structure 490–92,  
     494, 496, 499, 501  
 microfluidic system 306, 490,  
     551, 554, 558  
 microlens 19, 502–4  
 micromachining 3, 9, 10–11, 24,  
     39–42, 49, 158, 228, 244,  
     461, 570  
     femtosecond laser 11,  
     435–06, 439–40, 444, 454,  
     457, 459, 463, 466, 494,  
     500, 504, 506, 510, 512  
     laser 152  
     surface 3, 9–11, 24  
     3D 512  
     ultrafast laser 10, 156  
 micronanomachine 535, 548,  
     550–51  
 microneedle 546–47  
 micro-optical lens 490, 503, 505  
 micropatterning 244  
 micropump 490, 547–48  
     viscous 548  
 microrotor 545, 548  
 microspring 549–50  
 microturbine 549–51  
 microtweezer 546  
 microwelding *see* welding  
 MMI *see* multi-mode interference  
 mode-locking technique 63

- passive 64
- molecular dynamics 103, 135, 160, 240
- multicolor microstructure 531, 533
- multicomponent glass *see* glass
- multi-mode interference (MMI) 436, 446
- multiphoton absorption 2, 5–9, 13, 19, 24, 76, 144, 146, 149, 227–28, 239, 353, 467, 490
- multiphoton ionization 7, 42, 102, 119–21, 143, 145–46, 149, 152, 157, 248–49
- multipulse drilling *see* drilling
- MZI *see* Mach-Zehnder interferometer
- nanoaquarium 491, 506–8
- nanograting 49, 118, 154, 161, 285, 495
- nanoheater 354–55, 383, 385
- nanohole 13, 16, 270, 354–55, 358, 362, 366–67, 371–72, 374, 376, 378–79, 381, 387
- nanomachining 382, 387,
- nanoparticle 21, 59, 143, 157, 161, 267, 270, 277, 287, 300, 319, 324, 328, 332, 334, 336–37, 341, 349, 419, 531, 533, 535, 545, 549
- nanopatterning 354–57, 366–67, 371
- nanoprocessing 24, 354, 356, 369
- nanoripple 2, 11–12
- self-assembled nanostructure 56–57
- nanotip 15, 354–55, 379, 382, 387
- near-field enhancement factor 378
- nonthermal electron *see* electron
- nonthermalized electron *see* electron
- oblique incidence 279, 295, 366, 373
- OPA *see* optically parametric amplifier
- OPCPA *see* optical parametric chirped-pulse amplification
- optical attenuator 508
- optical microscopy 54, 396
- optical parametric chirped-pulse amplification (OPCPA) 40, 62, 74–76
- optical transmission microscopy (OTM) 396
- optical waveguide 7, 18–19, 47, 57, 184, 202, 394, 404–5, 412, 419, 428, 433, 439, 446, 452–54, 461, 473, 490, 496, 504, 508, 510, fabrication of 77, 435, 502
- optical parametric amplifier (OPA) 62, 74–75, 81
- optoelectronics 117–18, 161, 291, 297
- optofluidic device 470–71, 489, 491, 506, 510
- optofluidic system 490–91, 504, 512
- OTM *see* optical transmission microscopy
- passive mode-locking technique *see* mode-locking technique
- patterning 15, 21, 23, 25, 46, 197, 207, 227–28, 230–31, 237, 239, 241, 244, 257, 366, 371, 521, 570, 578
- femtosecond laser 237, 241–42

- laser 241, 574
- PCM *see* phase contrast
  - microscopy
- periodic grating structure *see* grating structure
- phase contrast microscopy (PCM) 59, 396, 399
- Phormidium* 21, 508
- phosphate glass 18, 47, 57–59, 412, 432, 451, 457–59, 461, 463
- photoexcitation 117, 142, 237, 397, 399–401, 405–7, 421
- photoinitiator 522, 524, 531, 535
- photoionization 118, 144–45, 398
- photon energy 5, 42, 76, 121
- photon–material interaction 213
- photonic crystal 17, 24, 56, 184, 394, 403, 416, 419, 524–25, 539–42, 558
- photon 5, 7, 40, 42–43, 56, 64, 102, 128, 213, 279, 286, 339–340, 453, 457, 472–74, 521–22
- photopolymerizable resin 535
- photosensitive glass *see* glass
- picosecond (ps) laser 2, 3, 10, 22–23, 25, 52, 569, 572, 585
- picosecond (ps) laser ablation *see* ablation
- plasma etching *see* etching
- plasmon resonance 143, 331–32, 336–37, 355
- plasmon 279, 356
- plastic deformation 100, 102, 104, 118, 151–52, 240
- PLD *see* pulsed laser deposition
- polarization
  - circular 253, 279, 358, 371, 542
  - linear 253, 275, 343, 358
- polarized femtosecond laser pulse
  - see* femtosecond laser pulse
- polystyrene 356–57, 367
- porous glass *see* glass
- positive refractive index change 47, 150, 196, 396, 428, 433
- probe beam *see* beam
- pulsed laser deposition (PLD) 290, 306
- pulsed laser irradiation of nanostructure 354
- pump pulse 75, 398–400
- percussion drilling *see* drilling
- photoexcited electron *see* electron
- quantum information experiment 472
- quartz glass 56, 237
- refractive index 12, 18, 43, 47, 49, 58, 64, 68, 142–44, 151–52, 248–49, 280, 287–88, 332, 336–37, 339, 355, 373–74, 376, 378–79, 396–99, 401, 404, 406, 412, 414, 416, 421, 428, 431, 433, 435–37, 444, 451, 453–55, 457–58, 466, 468, 471, 490–91, 510, 536
- change 47, 57, 58, 59–60, 82, 150, 153, 194, 196, 394, 396, 397, 398, 403–5, 407–8, 416, 421, 428–29, 433, 435–36, 440, 455, 466, 502
- increase 57, 59, 394, 428–29, 431–32, 435
- modification 18–19, 38, 47, 52, 57, 58, 60, 77, 403
- regenerative amplifier *see* amplifier

- SAM *see* self-assembled monolayer  
 scanning electron microscopy  
     (SEM) 9–10, 21, 53–54,  
     241, 255, 266, 270, 275,  
     287, 301, 318, 321, 339,  
     358, 361, 371, 379, 416,  
     536  
 self-assembled monolayer (SAM)  
     227, 237, 259  
 SEM *see* scanning electron  
     microscopy  
 selective etching *see* etching  
 selective (selected) laser etching  
     *see* etching  
 semiconductor  
     laser-excited 114  
     ultrafast laser excitation of  
         112–13  
 SEW *see* surface electromagnetic  
     wave  
 shift-variant parallel femtosecond  
     laser processing 207  
 silica glass *see* glass  
 single-photon absorption 5, 8, 16,  
     491, 521  
 single-pulse ablation threshold *see*  
     ablation threshold  
 single pulse drilling *see* drilling  
 SLM *see* spatial light modulator  
 soda lime glass *see* glass  
 spatial-domain technique 185  
 spatial frequency domain 185,  
     187–88, 209  
 spatial light modulator (SLM)  
     185, 200, 204, 212, 442  
 spatial manipulation of ultrafast  
     laser pulses *see* ultrafast  
     laser pulse  
 spatial pulse manipulation 185,  
     190, 213  
 spatial pulse shaping 197–98,  
     200–1, 204, 213  
 spatially-shaped femtosecond laser  
     pulse *see* femtosecond  
     laser pulse  
 spatiotemporal pulse manipulation  
     183, 212–13  
 spatiotemporal pulse shaping 212  
 spiral microrotor 548  
 supercritical state 314–15,  
     320–21  
 superheating 110–11, 115, 128,  
     132  
 superhydrophobicity 303–4, 312  
 surface electromagnetic wave  
     (SEW) 315, 321, 328,  
     338–39  
 surface micromachining *see*  
     micromachining  
 surface plasmon 279, 281, 283,  
     287, 378  
 surface polariton 279  
 surface-scattered wave 280  
 temporal evolution 399, 401  
 temporal manipulation 24, 184,  
     192, 213  
 temporal pulse shaping 192–95,  
     212–13  
 thermal equilibrium 3–4, 105–6  
 thermal stress 250, 400  
 thin film 13–14, 58, 156, 227–28,  
     230, 232, 234–35, 239,  
     244, 577–78  
 3D drilling *see* drilling  
 3D micromachining *see*  
     micromachining  
 threshold fluence 38, 43, 140,  
     230, 310, 371  
 Ti:sapphire 3, 56, 61–62, 64, 66,  
     69, 145, 340, 430, 435,  
     437, 439–40, 442, 444,  
     446–47, 453–04, 458–09,  
     461, 463, 466–08, 491,  
     524, 546  
 Ti:sapphire femtosecond laser *see*  
     femtosecond laser  
 TPA *see* two-photon absorption

- TPP *see* two-photon photopolymerization  
transparent material 2, 6, 9, 12, 24–25, 42, 51–53, 104, 112, 117–19, 142–43, 149–50, 152–54, 156, 184, 210, 286, 378, 394–95, 428–29, 490, 585  
internal modification of 3, 7, 18, 24  
trapped electron *see* electron trepanning 250–51  
tunneling ionization 7, 42–43, 119–20  
two-photon absorption (TPA) 13, 16, 113, 196, 523–24  
two-photon photopolymerization (TPP) 3, 16–18, 24, 521–23, 525, 527, 531, 533, 535–42, 545–47, 549, 552, 554, 556, 558–59  
two-spot irradiation 414  
  
ultrafast laser ablation *see* ablation  
ultrafast laser beam 2, 6–8  
ultrafast laser direct writing *see* direct writing  
ultrafast laser excitation 101, 104, 106–7, 109, 112–13, 116–17, 126, 154, 156, 160–61, 264  
ultrafast laser excitation of metals 132, 160  
ultrafast laser heating 110, 133  
ultrafast laser irradiation 2–4, 7–8, 11, 13, 44, 111, 382  
ultrafast laser–matter interaction 40, 135  
ultrafast laser micromachining *see* micromachining  
ultrafast laser nanostructuring 287  
ultrafast laser processing, characteristics of 2–3, 25, 394  
ultrafast laser pulse–matter interaction 40  
ultrafast laser pulse 3–4, 7, 24–25, 38, 46, 139–40, 183–85, 264, 454  
spatial manipulation of ultrafast laser pulses 185  
ultrafast laser radiation 43, 52–54  
ultrashort fs laser pulse 123, 267  
ultrashort laser ablation 104, 161  
ultrashort laser irradiation 43, 113, 132  
ultrashort laser 38–39, 46, 160  
ultrashort pulse generation 60  
ultrashort pulse laser 50, 53, 60, 125, 233, 235, 402  
ultrashort pulse laser ablation *see* ablation  
ultrashort pulses laser system 50–51  
ultrashort radiation 45–46, 78  
ultrasonic bath 493–94, 496, 499  
UV fs laser pulse 142  
  
vector pulse shaping control 213  
viscos micropump *see* micropump  
  
waveguide amplifier 457–59, 461, 463  
waveguide array 47, 428, 447, 449, 451–53  
waveguide Bragg grating (WBG) 453–55, 457, 461, 463  
waveguide fabrication 207, 440, 472  
waveguide laser 57, 428, 461–63, 466, 475  
waveguide structure 142, 437  
waveguide  
circular 430–32  
laser-written 458–59  
low birefringence 474  
photo-written 404  
wavelength dependence 358, 444

- wavelength dispersion 212  
wavelength division multiplexer (WDM) 459  
WBG *see* waveguide Bragg grating  
WDM *see* wavelength division multiplexer  
welding 52–54, 60, 254, 581–82  
wet etching *see* etching  
woodpile structure 523, 541–42  
zero-order beam *see* beam  
ZnO sphere 376, 378

