

Index

a

- acoustic bioparticle manipulation
 - acoustic radiation force on a particle 258–260
 - first-order acoustic field variables 255–257
 - governing equations in 255–264
 - second-order acoustic field variables 257–258
- acoustic biosensors
 - biochemical fundamentals 310–314
 - bulk acoustic wave modes 305–307
 - commercial 327–330
 - components 305
 - surface acoustic wave modes 307–310
 - trends 327–330
- acoustic cavitation 123, 173, 182–184, 186, 190, 193
- acoustic hologram optimization 231
 - with gradient descent approach 233
 - with stochastic gradient optimization and automatic differentiation 232
- acoustic holograms 224, 360
 - optimisation of 225
 - for Rayleigh regime spheres 224
 - temporal and spatial resolution of 237
 - types of 227
- acoustic images 93–94
- acoustic lenses
 - diffraction by gratings 87–90
 - holograms 91–95
 - reflection by curves surfaces 90–91
 - refraction by bulky lenses 84–87
- acoustic levitation 358
 - biology and medicinal applications 234–236
 - experimental automation 234–235
 - history of 217–224
 - specimen holding 234
 - 3D displays 235–236
- acoustic levitator, numerical simulations of 227
- acoustic radiation force 230–231
- angular spectrum approach 229–230
- Huygens' approach 227–228
- pressure field calculation 227–230
- spherical harmonics decomposition approach 228–229
- acoustic levitators 220–224, 227–231
 - categories and types of 218
- acoustic micromanipulation 355–361, 366, 367
 - techniques
 - acoustic tweezers 356–357
 - using bulk acoustic waves 357–361
- acoustic radiation force (ARF) 5, 15, 28, 186, 348
 - calculation, in PAL 230
 - Gor'kov method 230–231
 - spherical harmonics decomposition method 231
 - for Mie-regime spheres 228
- acoustic scattering 14–16, 127
- acoustic shadows 120

- acoustic streaming 4–5, 24–25, 38, 40–45, 47–48, 55, 57, 160, 220, 246, 252, 266–268, 280, 285, 287, 288, 354–355, 358, 360, 361, 367–368
- acoustic streaming flow (ASF) 4, 5, 16–22, 28, 46, 255, 356
- acoustic traps, types of 224–225
- acoustic tweezers 289, 344, 356–357, 359, 368
- acoustic tweezing 356, 358
- acoustic waves 21, 37
 - acoustic streaming flow 19–22
 - acousto-thermal heating 19
 - attenuation 18–22
 - configuration 12–13
 - dispersion 8
 - displacement, velocity, and pressure fields 6–7
 - dissipation 7–8
 - Dominos effect 2–3
 - elastic vs. inelastic waves 2–4
 - in fluidic media 24–28
 - frequency range mode 8, 9
 - generation and propagation 22–24
 - history 4
 - lower frequency 22–23
 - optoacoustic imaging 27
 - oscillating bubbles 25–27
 - parameters 6
 - piezoelectricity and high frequency 23–24
 - propagation 7
 - propagation mode 9–12
 - scope and ramifications 4
 - transmission and reflection 13–14
 - vibrating membranes and sharp-edge structures 25
 - viscoelastic attenuation 18–19
- acoustical vortex tweezers 360, 361
- acoustofluidic devices
 - biocompatibility 294
 - blood components 279–281
 - in cancer cells applications 281–282
 - in cell wash applications 278
 - commercial and regulatory considerations for 290–294
 - commercialization recommendations 295, 296
 - cost 291–292
 - general architecture of 249–255
 - high-volume manufacturing 292
 - in lipid particle applications 269–278
 - miscellaneous applications 289–290
 - miscellaneous cells application 282–284
 - nanoscale bioparticles manipulation 287–288
 - pathogenic bacteria 284–286
 - platelet separation 279–280
 - sterilization 292–294
 - storage and transportation requirements 294
 - WBCs separation 280–281
- acoustofluidic particle/cell manipulation 269, 270
- acoustophoresis 17, 28, 264, 266, 281, 295
- acoustophoretic bioparticle manipulation 246
 - simulation of
 - elastic material surrounding the channel 265–266
 - fluid flow 266–267
 - particle motion 267–269
 - piezoelectric actuators 264–265
- adsorption-based immobilization 311
- air viscosity 8
- Albunex® 182
- A-mode 115–116, 307
- amphiphilic drugs 188, 191
- angular spectrum approach (ASM) 226, 229, 230
- anionic genes 191
- anticancer drugs 191, 192, 194
- antigen-antibody reaction bioparticle manipulation 245
- aptamer 312–314
- Archimedean spiral gratings 89–90
- asymmetric diffraction grating 87–88

- attenuation
 by absorption 113–114
 by reflection, refraction and deflection 112–113
 by scattering 113
 TGR and DGR 114
- auscultation 67, 343
- avidin-biotin interaction 188, 313
- AWSensors X4 Advanced Multichannel QCMD system 329
- axial resolution 77, 78, 109, 120, 129
- axicon lenses 85, 86, 88
- b**
- backing 73, 75, 77, 78, 107
- back wall enrichment 120
- BAW tweezers 356, 357
- beamforming 110
- Bessel beams 85, 89, 224, 360
- biomedicine 5, 37, 57, 58
- bioparticle manipulation 244
 acoustophoretic 246
 comparison of manipulation methods 248–249
 electrokinetic 245
 hydrodynamic 244
 immunological 245
 magnetophoretic 245–246
 performance-related criteria 248
 unification of field manipulation methods 246–248
- biosensors
 biochemical mechanisms 310–314
 classification 310
 covalent immobilization 312–313
 immobilization strategies of detection element 311–314
 noncovalent immobilization 311–312
- blood brain barrier (BBB) 67, 94, 161, 162, 171, 185, 196, 366
- blood glucose level 142
- B-mode 109, 117, 119
- bone thermal index (TIB) 163
- boundary driven streaming 42, 43
- boundary element method (BEM) 224, 266, 268
- breast cancer 130
 ex vivo imaging 132–133
 in vivo imaging 130–132
- breast conserving surgery (BCS) 132
- broadband matching layer design 77
- Broyden–Fletcher–Goldfarb–Shanno (BFGS) algorithm 232
- bubble-based micromachines 361, 362
- bubble-driven acoustic microstreaming 21
- bubble-induced streaming 354
- bubble liposomes 187, 203
- bubble reagents 181–182, 187, 197, 198
- bulk acoustic wave (BAW)
 acoustic manipulation using 357–361
 biosensors 314–316
 FBAR biosensors 316
 quartz microbalance (QMB) crystal biosensors 315
 surface transverse wave biosensors 317–327
- device 249–252
 chip material 250–251
 device assembly and critical dimensions 251–252
 lid material 251
 piezoelectric actuator 249
 vs. SAW devices, advantages and disadvantages of 254–255
 mode 305–307
- c**
- carbon dioxide (CO₂)-filled MBs 181
- Cartesian diffraction grating 87
- catalytic biosensors 310
- cavitation 26–27
 acoustic 123, 173, 182–184, 186, 190, 193
 inertial 26, 161, 170, 183–188, 194, 344
 non-inertial 183–186
 stable 161, 170
- centrifugation 5, 28, 279, 287
- circular aperture transducers 78–80

- circulating tumor cells (CTCs) 281, 282
- cisplatin (CDDP) 194
- classical acoustic levitator (CAL)
 - characterization 218
 - single/multi-axis 219, 220
- classical matching layer design 76–77
- color Doppler 119
- conservation of mass 345
- conservation of momentum 256, 345
- continuous wave Doppler 118, 119
- convex probes 83, 108, 109
- covalent immobilization 312–313
 - bioaffinity bindings 313–314
- cranial-bone thermal index (TIC) 163

- d**
- Definity® 182, 187
- Depth Gain Reduction (DGR) 114
- diabetes mellitus (DM) 142, 143
- dielectrophoresis (DEP) 245, 288
- diffraction by gratings 87–90
- dispersion curves 309, 310
- DNA-directed immobilization (DDI)
 - 313
- Doppler ultrasonography 114, 118–119
- doxorubicin (DOX) 192, 194
- drag and thrust-induced acoustic
 - streaming 354–355
- drug delivery system (DDS)
 - bubble reagents 182–186
 - drug and gene loading 188–190
 - inertial and non-inertial cavitation
 - 184–186
 - modification with targeting ligands
 - 188
 - polyethylene glycol modification
 - 187–188
 - targeting and focusing 186
 - ultrasonic drug delivery
 - cancer 192–195
 - central nervous system diseases
 - 195–197
 - ultrasound responsive reagents
 - 186–192
- Duplex Doppler systems 119

- e**
- eccentric rotating mass (ERM) 22
- echogenic low temperature sensitive
 - liposomes (E-LTSLs) 191
- Eckart streaming 20, 42
- EDC/NHS coupling 313
- Eigensolver approach 231
- elastic waves 2–4, 6, 69, 75, 246, 249,
 - 250, 252, 254
- electrical impedance matching network
 - 78
- electrokinetic bioparticle manipulation
 - 245
- electrokinetic separation 248
- electromagnetic waves 3, 6
- electrophoresis (EP) 245
- ellipsoidal lenses 85
- ellipsoidal reflectors 91
- Euler angles 326, 327
- Eulerian fluid velocity 46–47
- external cavity quantum cascade laser
 - (EC-QCL) 144

- f**
- fast streaming 43–45
- Fc binding peptide 313, 314
- field projections 91–93
- film bulk acoustic wave (FBAR)
 - advantages/disadvantages 331
 - biosensors 316
- fluid-fluid interface 47–49
- focused transducers 80–83, 167
- focused ultrasound-mediated intranasal
 - brain drug delivery technique
 - (FUSIN) 185, 195, 196
- folate receptors 193
- forces
 - in acousto fluidic systems 49–57
 - bubbles 53–54
 - hydrodynamic drag force 55–57
 - liquid drop 55
 - primary acoustic radiation force
 - 49–52
 - rigid spheres 53

secondary acoustic radiation force
52–53
solid particle 54
Fresnel and fraxicon lenses 86
Fresnel-spiral zone plate 90
Fresnel zone plates 88–89

g

Gerchberg–Saxton (GS) method 232
Gor'kov approach 224
governing equation
fluids 40–49
in solids 39

h

Helmholtz number 14
Helmholtz resonators 4
high aspect ratio electrodes, for Lamb
wave devices 323
high-intensity focused ultrasound (HIFU)
67, 77, 123, 142, 161, 164–165, 185
histotripsy 67, 123, 166–169, 344
holograms 91
biomedical applications of 94–95
hydrodynamic bioparticle manipulation
244
hydrodynamic drag force 38, 55–57, 287
hydrophobic DRUGS 188–190

i

Imagent® 182
immunoglobulins (IgGs) 310, 314
immunolabeling 281, 282
immunological bioparticle manipulation
245
immunological manipulation 245, 249
impedance matching layer 73, 76, 77,
294
in vivo acoustic micromanipulation 366
in vivo actuation of micro/nanorobotic
devices 365–367
inertial cavitation 26, 161, 170, 183–188,
194, 344
inflammatory skin diseases 137
infrasonic technology 99

interdigital transducer (IDT) 24, 52, 308,
318, 325, 330
ISPTA 164
iterative angular spectrum approach
(IASA) 226

l

Lagrangian fluid velocity 46–47
Lamb wave biosensors 321, 324
lamb waves 12, 309, 310, 321–324
lateral resolution 85, 109, 120–122, 129
lenses for vortex generation 86–87
levitation
acoustic 217–237
of Mie-regime objects 224
linear acoustic equations 345, 346, 348
linear probes 108
linear resonant actuators (LRA) 23
lipid bubbles 187
lipid-shelled microbubbles 367
Liposome-Microbubble Complex
190
longitudinal waves 9, 10, 76, 100, 107,
261, 265, 316, 346, 356
Love waves 12, 308
Love-mode sensors 318–320
LOVE-Mode surface acoustic wave (SAW)
sensor 329
low intensity focused ultrasound (LIFU)
172
low-intensity pulsed ultrasound (LIPUS)
172, 173
lumpectomy 132

m

magnetic manipulation approach
248
magnetophoretic bioparticle
manipulation 245–246
mechanical index (MI) 163
metal-affinity 313, 314
metal-organic framework (MOF) 192
micro/nanorobotic devices, in vivo
actuation of 365, 367
microbubble–liposome conjugate 190

- microbubbles (MBs) 55–56, 123, 161–162, 168, 171, 181, 184–185, 189–190, 290, 362, 366–367
 - microfabrication methods 253
 - microfluidic systems 25, 28, 243
 - microfluidic technologies 38
 - microfluidics 5, 17, 21, 24, 25, 28, 57, 235
 - microrobotics research 344
 - midair acoustic levitation 236
 - Minnaert resonance 182, 191
 - M-mode 116, 181
 - mobile acoustic micromachines 361–363
 - mononuclear phagocyte system (MPS) 187, 188
 - multi-axis acoustic levitator 219, 221, 224
 - multi-particle systems 52
 - multiple matching layer design 77
 - multivariate analysis 147
- n**
- nanobubbles (NBs) 162, 190
 - nanodroplets (NDs) 162, 191
 - near field CAL 220
 - near-field acoustic streaming-based levitators 220
 - near-field standing wave acoustic levitator 222
 - nested microbubbles 190
 - Neuromodulation 94, 95, 123, 165, 172, 344
 - Newton's second law 39, 57, 72
 - non-contact transportation of levitated objects 220
 - noncovalent immobilization
 - adsorption 311–312
 - self-assembled monolayer 312
 - three-dimensional substrates 312
 - non-destructive testing (NDT) 1, 12
 - non-inertial cavitation 183–186
 - non-piezoelectric solids 39
 - non-resonant CAL 219
 - nucleotide-binding site (NBS) 314
- o**
- optoacoustic imaging 27
 - oral glucose tolerance test (OGTT) 144
- p**
- paclitaxel (PTX) 194, 196
 - parabolic reflectors 91
 - phased array levitator (PAL) 221–222
 - single sided 222–224
 - single/multi-axis 222
 - phased-array transducers (PATs) 83, 108, 228, 231
 - phase plates, in underwater acoustics 226
 - photoacoustic imaging (PAI) 127
 - of breast cancer 130
 - classification 128
 - configurations 130
 - inflammatory skin diseases 137
 - nanosecond pulsed lasers 127
 - noninvasive glucose sensing 142–148
 - noninvasive temperature monitoring 139–142
 - for skin imaging 133–139
 - wounds 137–139
 - photoacoustic microscopy (PAM) 38, 128, 129
 - photoacoustic tomography (PAT) 128, 129, 228, 229, 231
 - physical-biochemical operation principle 306
 - physical sensing mechanisms 305
 - piezoelectric ceramics 23, 73, 74, 83, 252
 - piezoelectric composites 73–75
 - piezoelectric crystals 73–74, 76, 107, 109, 119
 - piezoelectric materials
 - ceramics 74
 - composites 74–75
 - crystals 73–74
 - polymers 74
 - piezoelectric polymers 73, 74, 76
 - piezoelectric slab 75–76, 78
 - piezoelectric solids 39, 40, 68

- piezoelectricity
 longitudinal motion in a piezoelectric material 71–73
 model equations 68–70
 piezoelectric constants 70–71
- polyethylene glycol (PEG) modification 187–188
- porous three-dimensional substrates 312
- primary Bjerknes force 351, 355
- primary radiation forces 348–351, 366
- Protein A 312, 314
- Protein G 314
- protein quantification 331
- q**
- Quartz crystal microbalance (QCM)
 advantages/disadvantages 331
 biosensors 314
- Q phenomenon 121
- quartz microbalance (QMB) crystal biosensors 315
- r**
- raster-scanning optoacoustic mesoscopy (RSOM) 128, 129, 137, 138
- Rayleigh-mode SAW 307
- Rayleigh streaming flow 20, 21
- Rayleigh wave biosensors 324–325
- Rayleigh waves 11–12, 252, 308, 325, 338
- real-time artifacts 119–120
- real-time imaging 114–115, 128, 139
- reflection by curved surfaces 90–91
- refraction by bulky lenses 84–87
- revascularization surgery 137
- reverberation 120, 122
- RNA aptamer 314
- RNA interference (RNAi) 194
- s**
- Sauerbrey's equation 315
- Schiller–Naumann model 358
- Schlichting streaming 5, 20, 42
- secondary acoustic radiation forces 38, 344, 351, 353, 355, 361, 362, 364, 368
- secondary or mutual Bjerknes forces 351
- second-order system 45
- sector probes 108
- self-assembled monolayer (SAM) 311, 312
- serum albumin 182, 186
- shallow bulk acoustic wave (SBAW) 308
- sharp edge streaming 354, 355, 363
- shear bulk wave 306
- shear horizontal (SH) mode surface acoustic wave (SAW) 317
- shear waves 10–11, 306, 308
- SH-mode sensors 318–320
- shock wave lithotripsy (SWL) 67, 169–170
- SH-type BAW 308
- single/multi-axis CAL 219, 220
- singularity 86, 95, 224
- skin imaging 133–134
 for skin cancer 135–136
- slow streaming 43–45
- Snell's Law 4, 7, 14, 84, 101
- soft robotic microsystems 363–365
- soft-tissue thermal index (TIS) 163
- solid particles 47–49, 53, 54, 57
- Sonazoid® 182
- sonograms 105
- sonography 9, 105, 343
- sonoporation 67, 161, 170, 171, 184, 190, 191, 194
- sonothrombolysis 172–173, 196, 197
- SonoVue® 182
- sound, use of 343
- sound waves 1
 high-frequency sound waves 106
 propagation in a homogenous quiescent medium 347
- spherical harmonics decomposition approach 228, 229, 231
- spherical lenses 84–85
- squeeze film CAL 220
- stable cavitation 161, 170
- standing surface acoustic waves (SSAW) 253–254, 288–290

- standing waves 13
 - acoustic tweezer system 367
 - bulk acoustic tweezers 359
 - focused ultrasound tweezers 359
 - near-field levitation 221
 - stochastic gradient descent algorithm 233
 - Stokes law 190
 - strain-charge formulation 70
 - strain-field formulation 70
 - streaming flows, classification 43
 - stress-charge formulation 69–70
 - stress-field formulation 70
 - surface acoustic wave (SAW) device 100, 252
 - advantages/disadvantages 331
 - vs. BAW devices, advantages and disadvantages of 254, 255
 - device assembly and critical dimensions 254
 - interdigital electrodes 253
 - microfluidic chamber 254
 - piezoelectric actuators 252–253
 - surface acoustic wave (SGAW) mode 307–310
 - surface skimming bulk wave (SSBW) 308
 - surface transverse wave (STW) 308
 - surface transverse wave biosensors 317–327
 - crystal cuts and axis orientation 325–327
 - Lamb wave biosensors 321–324
 - Rayleigh wave biosensors 324–325
 - SH-wave and Love wave biosensors 317–320
 - surface waves 11–12, 295, 308–309, 317–318, 356
 - survivin 195
- t**
- therapeutic ultrasound
 - applications 164–173
 - biological effects 160–164
 - contrast-enhanced effects
 - microbubbles 161–162
 - nanobubbles 162
 - nanodroplets 162
 - mechanical effects
 - cavitation 161
 - safety and regulations 163–164
 - thermal effects 160
 - thermal ablation 94, 165, 344
 - thermal ablation modalities 165
 - thermal index (TI) 163
 - thickness-shear mode (TSM) bulk
 - acoustic wave 315, 316
 - 3D nanoprinted soft robotic microsystems 364
 - 3D nanoprinting 365
 - Time Gain Reduction (TGR) 114
 - time-averaged acoustically induced forces 348
 - drag and thrust-induced acoustic streaming 354–355
 - primary radiation forces 348–351
 - secondary radiation forces 351–353
 - time-averaged steady components 45
 - time-domain photoacoustic waveform spectroscopy (tPAWS) 147
 - tissue harmonic imaging (THI) 121
 - advantages 122
 - occurrence 121
 - separation 122
 - transcranial-focused ultrasound 344
 - transcription factor hypoxia inducible factor 1 (HIF1) 195
 - transducer specifications 236
 - transverse waves 10, 100, 291, 356
 - travelling waves 12–13
 - TRUFORMA product 328
 - tumor homing peptide 193
- u**
- ultrasonic imaging 103
 - beamforming 110
 - central processing unit 109
 - in diagnostic imaging 106
 - for diagnostic purposes 104

- focus 109
 - high-frequency sound waves 106
 - output display 109
 - in pregnancy 105
 - probes 107–109
 - resolution 109
 - transducer 106–107
 - ultrasonic waves
 - longitudinal waves 100
 - surface acoustic waves 100
 - transverse waves 100
 - ultrasonography
 - absorption 112
 - attenuation 112–114
 - Doppler ultrasonography 118–119
 - factors affecting 120–121
 - real-time artifacts 119–120
 - real-time imaging 114–115
 - reflection 110–111
 - refraction 111–114
 - sound tissue interaction 110–114
 - ultrasound
 - applications 102–103
 - behavior of 100–101
 - generation and detection of 67
 - longitudinal waves 100
 - power and intensity 101–102
 - transverse waves 100
 - waves 99–100
 - ultrasound beams
 - circular aperture transducers 78–80
 - focused transducers 80–83
 - phased-array transducers 83
 - ultrasound contrast agents 161, 167, 169, 181, 182, 186, 188, 194
 - ultrasound frequency, for medical imaging 343
 - ultrasound imaging, in medicine 122–123
 - ultrasound transducers
 - electrical impedance matching network 78
 - elements of 75–76
 - matching layers 76–77
 - slab 75–76
 - technologies for 68
 - ultrasound-irradiated bubbles 184
- V**
- VEGFR2 193, 194
 - virtual deterministic lateral displacement (vDLD) device 288
 - vortex tweezers 360, 361
- W**
- waves in the piezoelectric material 72–73
 - wearable SAW sensor 330
- X**
- X-linked inhibitor of apoptosis (XIAP) 195
- Z**
- zeroth-order velocity 44

