

Index

- 3-aminopropyltriethoxysilane (APTES) 104, 106, 199, 201
- α -hemolysin (α -HL) 1, 4–7, 14, 32
 α -HL, *see* α -hemolysin
 α -HL nanopore 3, 13–14, 16, 18–19, 21–22, 27, 30–31
 α -syn, *see* α -synuclein
 α -synuclein (α -syn) 99, 101–102
 α -thrombin 144–145
ABEL, *see* Anti-Brownian ELecktrokinetic
ABEL trap 213–214, 217–221, 225, 227–238, 243
acetone 104–105, 239
acousto-optic deflectors (AODs) 51–52
AFM, *see* atomic force microscopy
Ag/AgCl electrodes 10–11, 27–29
agarose gel 162, 164–165
agarose gel electrophoresis (AGE) 68, 162, 165
AGE, *see* agarose gel electrophoresis
allophycocyanin (APC) 232–233, 235
amino acids 5, 17, 19
Anti-Brownian ELecktrokinetic (ABEL) 213, 216, 218
anti-Brownian trapping 213–214, 216–228, 230, 232, 234, 236, 238, 240, 242, 244
- AODs, *see* acousto-optic deflectors
APC, *see* allophycocyanin
APC trimers 232–233
aptamer-protein complexes 135
aptamers 129, 132, 134, 136–137
APTES, *see* 3-aminopropyltriethoxysilane
atomic force microscopy (AFM) 125–127, 129, 131–132, 135, 152, 154, 159–161, 165–166, 175, 184, 192
ATP hydrolysis 19, 184, 187
AuNPs, *see* gold nanoparticles
azides 124, 153
- β -cyclodextrin 20
 β -D-glucose 87, 104, 107
back-focal-plane interferometry (BFPI) 53–54
background fluorescence 82–83, 86
background photons 224
bacteriophage 64
beads
ferromagnetic 194
magnetic 177, 184, 191, 195, 198
BFPI, *see* back-focal-plane interferometry
bilayer capacitance 29–30
bilayer characterization 29–30

- biliproteins, single 231
- binding
 - coupling of 126–127
 - ligand 24
 - protein-complex 138
 - single-protein 191
- binding affinities, high 24, 26
- biomacromolecules 2, 17, 19, 22, 43
- biomolecular interactions 44, 91, 121, 131, 134–137, 139, 141, 143, 145, 147, 149, 154, 215
- biomolecules 56, 61, 79–80, 86–87, 91, 93, 95, 102, 105–106, 126, 131, 151, 154, 159, 161, 173–176, 183–184, 198, 215, 217, 219, 227, 229, 231, 234, 236, 238
 - ligand 95–96
 - nanometer-sized 216
 - single 174, 177, 197, 234, 237
- biophysics, single-molecule 2, 59
- biosensing 122, 161
- biosensing applications 7, 158, 161
- biotin 86, 104, 124, 132, 137, 153–154, 191
- biotin groups 152–153, 164
- blurring effect 179
- boric acid 162, 164–165
- bovine serum albumin (BSA) 86, 145, 199, 202
- Brownian motion 11, 55, 214–215
- BSA, *see* bovine serum albumin
- capillary electrophoresis 217
- Cas9 protein 141
- catalase 87, 104–105, 107
- catalysis 89, 215
- CCD, *see* charge-coupled device
- cellular processes 44, 88
 - force-generating 44
- charge-coupled device (CCD) 50
- chloramphenicol 199, 201
- chromatin remodeling 94
- conformations, linear 131–132
- constant-force extension
 - measurements 63
- Cre recombinase 143
- crystal structures 3, 7, 13, 232
- CsgG 6–7
- cyanobacteria 233–234
- cyclodextrin 26
- cysteine 21
- cytoskeleton 63, 174, 195
- data acquisition 8, 10, 103
- data analysis 12–13, 31, 66, 70, 107, 183, 244
- denaturants 5, 18
- detection 3, 16, 20, 53, 57, 80–81, 121, 125–133, 139, 151, 159, 191
 - single-molecule 82, 126, 128
- detection optics 226–227, 242
- detectors 56, 83
 - single-photon 242
- diffusion coefficient 221, 235–236, 244–245
- DNA 14, 16, 22–23, 43, 56, 59–60, 62, 66–68, 87–88, 92, 94–95, 97, 102–103, 108, 122–123,

- 128, 130, 135, 142, 144, 159, 161, 174, 181, 184, 186–191, 197, 236–237
- constrained 150
- forked 96, 98
- human telomeric 88
- information-carrying biomolecule 122
- plasmid 7
- short 96, 183, 186, 191
- single-stranded 1, 3, 60, 91, 238, 241
- viral 64
- DNA aptamer 20, 136
- DNA duplexes 139, 141, 148
- DNA extension 187, 190, 197
- DNA frames 138, 143–144
- DNA gyrase 187, 197
- DNA molecules 57, 190
 - single 88
- DNA nanostructures 122, 126–127, 136, 140, 144, 146, 158, 160–161
- DNA nanotechnology 138, 147
- DNA nanotensioner 96–98
- DNA origami 96, 121–128, 130–140, 142, 144–148, 150–152, 154–156, 158, 160–162, 164–166
 - design 123, 140–141, 146, 160, 162, 164
 - frame 136, 138, 141–145, 147–151
 - frame design 139, 143–144
 - nanodevice 130, 144
 - nano pores 5
- nanostructures 121, 125–126, 130–131, 133, 135–138, 140–142, 144–145, 152, 155–158, 160–161
- platforms 137, 142, 154, 159, 161
- pliers 130, 132
- rectangle 155, 163
- rectangular 127, 166
- for single-molecule biosensing 125
- for single-molecule sensing and analysis 121
- solution 165
- surface 152, 156
- technique 122, 128
- templates 153–154
- DNA origami structures 123
 - use of 157–158
- DNA overstretching transition 186
- DNA packaging motor 64
- DNA polymerase 22–23, 145
- DNA-protein interactions 56
- DNA sequences 16, 64, 133, 145, 150, 154, 188–189
- DNA strands 14, 16, 103, 129, 139, 149–150, 188–189
- DNA topoisomerases 186–187
- DNA topology 60, 135, 138
- DNA translocation 14, 91–92, 94
- drag 55, 162–163
 - viscous 55
- drag force 180, 197
- dumbbell-shaped protrusions 127–128
- Dynabeads 177, 183, 202

- elastic modulus 59–60
- electric field 11, 45–46, 217, 238
- electrokinetic forces 216, 218
- electrolyte buffers 27, 29
- electromagnets 178, 197
- enzymatic adaptors 24
- enzyme motors 15–16
- enzymes 22–24, 64, 88, 125, 142–145, 187
- motor 15, 22–23
- Escherichia coli* 6, 27, 58, 97, 145, 187, 199
- ethanol 104, 106, 239, 243
- eukaryotes 88, 91, 94

- Faraday cage 9, 27, 29
- FCS, *see* fluorescence correlation spectroscopy
- FECs, *see* force-extension curves
- Field-Programmable-Gate-Array (FPGA) 224–225
- fluorescence 25, 57, 81–82, 84, 96, 99–101, 196, 234
 - relative 99
- fluorescence correlation spectroscopy 215
- fluorescence correlation spectroscopy (FCS) 215
- fluorescence imaging 196
 - single-molecule 214, 217
- fluorescence resonance energy transfer (FRET) 4, 79–82, 84, 86, 88, 90, 92–94, 96, 98–100, 102, 104, 106, 108, 126, 160, 234, 236
- fluorescent dyes 142, 146, 155–158, 160–161, 230
- fluorescent labels 228
- fluorescent molecules 83, 227, 234
- fluorophore labeling 81, 84–85
- fluorophores 4, 57, 81, 84, 86, 93, 96, 100, 155, 160, 230
 - green 155
- force-based single-molecule manipulation methods 96
- force-extension curves (FECs) 59–60, 70
- force jump measurement 204
- force-ramp measurement 61–62
- force spectrometer 140
- Forster radius 156
- FPGA, *see* Field-Programmable-Gate-Array
- FRET, *see* fluorescence resonance energy transfer
- FRET efficiencies 81, 84, 93, 156
- interfluorophore 93
- fused silica 219, 221, 240
- fused silica coverslips 239–240

- G-protein-coupled receptors (GPCRs) 91
- G-quadruplex formation 147, 149–150
- Gaussian function 13
- gene cloning 200
- glucose oxidase 87, 104–105, 107
- gold nanoparticles (AuNPs) 129, 155–159

- GPCRs, *see* G-protein-coupled receptors
- hexadecane 11, 27–28
- hidden Markov modeling 70, 84, 183
- HIV-1 integrase 90
- Holliday junction 57, 84, 87, 93, 122
- human prothymosin 90
- human topoisomerase 137
- hydrogen peroxide 104, 106, 239, 241
- IHF, *see* integration host factor
- ILPR, *see* insulin-linked polymorphic region
- insulin-linked polymorphic region (ILPR) 149–150
- integration host factor (IHF) 189–190
- intracellular RNA/protein assembly 92
- Kalman filter 223–225
- Kalman gain 224
- kinesin 63–64, 146
- ligands 101, 132, 135–136, 175, 195
- macromolecules 2, 81
- magnetic tweezers 175, 184–185, 187, 189, 191, 193, 195
- force calibration of 180
- freely-orbiting 195–196
- principles and technical details of 176–177, 179, 181, 183
- transverse 176, 182, 186
- vertical 176, 182, 186, 197
- magnets 178, 194, 200, 203
- permanent 178, 182, 197, 200
- malaria protein biomarkers 129
- MDSA Approximation 47–48
- membrane capacitance 12
- molecular machines 43
- molecular motors 43, 63, 97, 150, 174–175, 184, 187, 193, 198, 215
- motor protein behavior 141, 146
- motor proteins 15, 63, 146
- cytoskeleton filaments 65
- MspA, *see* *Mycobacterium smegmatis* porin A
- MspA nanopore 6, 15–16, 21, 23
- multiprotein interactions 237
- Mycobacterium smegmatis* porin A (MspA) 1, 6–7, 14–15, 24
- nanopore enzymology 23–24
- nanopore sequencing 1, 6, 13–15, 17, 22–23
- nanopore tweezers, single-molecule picometer-resolution 23
- nanopores 2–5, 9–12, 14–15, 17–19, 21–22, 25–26
- nucleic acid conformations 126, 146–151
- nucleic acid detection 126–127, 129, 131, 133

- optical trapping 45, 59, 68
- optical trapping theory 45, 47
- optical traps 43, 45, 53–57, 60, 69, 216
- optical tweezers 44, 49, 51–53, 59, 61, 63, 66, 68
 - force calibration in 54–55
 - manipulating 140
 - for manipulation of single molecules 43–44, 46, 48, 50, 52, 54, 56, 58, 60, 62, 64, 66, 68, 70
 - nanophotonic 57
 - theory of 48
 - traditional 56–57
- PAFRET, *see* photoactivation FRET
- parafilm 86, 199, 201
- patch-clamp amplifier 4, 9–10, 26–27, 29
- PBS, *see* polarizing beam splitters
- PDGF, *see* platelet-derived growth factor
- peptides 17–18, 139
- phi-29 connector protein 6
- photo protection system 104
- photoactivation FRET (PAFRET) 81
- photonic behavior 135, 154
- photonic techniques 121, 154–155
 - for biotechnological applications 154–155, 157, 159
- photothermal heating 158–159
- PIFE, *see* protein induced fluorescence enhancement
- platelet-derived growth factor (PDGF) 134
- polarizing beam splitters (PBS) 49–50, 199, 201–202
- potassium hydroxide 239, 241
- potassium ions 133, 148–149
- protein analytes 134
- protein assembly 122
- protein binding 137, 194
- protein biochemistry 237
- protein biosynthesis 64
- protein complexes 193, 229, 231
 - photosynthetic antenna 231
- protein cross-links 189
- protein dissociation pathway 235
- protein folding 65, 70, 174, 192, 198, 236
 - nascent 65
- protein folding energy 70
- protein folding kinetics 2
- protein GB1 domain 204
- protein induced fluorescence enhancement (PIFE) 236
- protein monomers 7–8, 24
- protein motion 143
- protein nanopore 8, 18
 - catalytic 24
 - catalytic fusion 24
- protein oligomerization 8, 237
- protein precipitation 8
- protein purification 191
- protein screening 8
- protein sequencing 17, 19
 - direct 17
- protein structural dynamics 89
- protein translocation 18–19

- protein unfolding 18, 175–176, 191–192
- proteins 24–25
- acceptor-labeled 96
 - B-form DNA binding 150
 - core histone 140
 - crosslinker 174
 - disordered 90, 92
 - disordered tau 229
 - engineered 18
 - ferric hydroxamate uptake 6
 - fluorescent 102
 - force-dependent 194
 - glucose-binding 23
 - helicase gp41 188
 - HIV-1 nucleocapsid 149
 - human specificity 6
 - multivalent 136
 - muscle 192
 - mushroom-shaped 6
 - natural 85
 - nucleoid association 189
 - nucleosome 136
 - photosynthetic antenna 231
 - single-strand DNA binding 188
 - small enzyme 24
 - transmembrane 7
 - wild-type 235
- Z-form DNA binding 150
- QPD, *see* quadrant photodiode detector
- quadrant photodiode detector (QPD) 53
- Raman signals 158
- RNA 5, 22, 43, 62, 65, 87–89, 91, 93, 102, 174, 184, 187
- RNA polymerase 43–44, 64, 141, 145
- scanning probe microscopy (SPM) 2, 175
- SDS, *see* sodium dodecyl sulfate
- SERS, *see* surface-enhanced Raman spectroscopy
- SIFA, *see* surface-induced fluorescence attenuation
- single-molecule analysis 1, 135–136, 141, 151, 157
- by biological nanopores 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32
- single-molecule analytes 3, 159
- single-molecule biophysics 2
- single-molecule biosensing 79–80, 82, 84, 86, 88, 90, 92, 94, 96, 98, 100, 102, 104, 106, 108, 125–126, 134, 159–160
- single-molecule biosensing assays 160
- single-molecule biosensors 121–122, 124, 126, 128, 130, 132, 134, 136, 138, 140, 142, 144, 146, 148, 150, 152, 154, 156, 158, 160, 162, 164, 166
- single-molecule chemistry 21, 25
- single-molecule enzymology 22, 25
- single-molecule fluorescence 2, 138, 196, 214
- single-molecule fluorescence spectroscopy 56

- single-molecule force measurements 45
- single-molecule force spectroscopy 61, 175
- single-molecule Forster resonance energy transfer/single-molecule fluorescence resonance energy transfer (smFRET) 4, 22, 79–85, 87–93, 95–99, 101–102, 107–108, 215, 237
- four-color 94
 - multicolor 93–94
 - three-color 93–94
- single-molecule kinetics 22, 24
- single-molecule manipulation 44, 59–61, 63, 173–174, 176, 188
- by magnetic tweezers 173–174, 176, 178, 180, 182, 184, 186, 188, 190, 192, 194, 196, 198, 200, 202, 204
 - by magnetic tweezers of nucleoside triphosphate 188
 - optical tweezers-based 65
- single-molecule photoactivation FRET 96
- single-molecule picometer-resolution nanopore tweezers (SPRNT) 23–24
- single-molecule sensing 30, 107
- single-molecule sensing applications 25
- single-molecule sensitivity 158–159
- single-molecule spectroscopy 56, 232
- single nucleotide polymorphisms (SNPs) 125, 129–130
- single-protein molecules 19
- smFRET, *see* single-molecule Forster resonance energy transfer/single-molecule fluorescence resonance energy transfer
- SNPs, *see* single nucleotide polymorphisms
- sodium dodecyl sulfate (SDS) 19
- sodium hypochlorite 27
- solid-state nanopores 4–5, 9–10, 12, 25
- SPM, *see* scanning probe microscopy
- SPRNT, *see* single-molecule picometer-resolution nanopore tweezers
- SpyCatcher protein 202
- ssDNA 3, 6, 11, 14, 60, 91–92, 122, 129, 146, 152, 188, 244
- Staphylococcus aureus* 4, 6
- streptavidin 67, 69, 86, 103, 105, 107, 127, 137, 145, 152–154, 191
- streptavidin binding 127, 129, 153–154
- sulfuric acid 104, 106, 239, 241
- supercoiling 186–187
- surface-enhanced Raman spectroscopy (SERS) 126, 154, 158–160
- surface-induced fluorescence attenuation (SIFA) 81, 93, 98–99, 102

- TB, *see* trypan blue
TIR, *see* total internal reflection
TIRF, *see* total internal reflection fluorescence
total internal reflection (TIR) 2, 82–83, 196
total internal reflection fluorescence (TIRF) 2, 139, 146, 196
transitions, binding mode 91
trypan blue (TB) 100
tweezers
 magnetic torque 181
 metal 238, 240, 243

unfolded proteins 90, 191
translocations of 18

unfolding, force-induced 194
unwinding 97, 188

vinculin 194, 197
vinculin binding 194

WLC, *see* worm-like chain
worm-like chain (WLC) 59, 61, 88, 185

X-shaped conformation 132, 139, 147, 151

Z-form binding protein Z $\alpha\beta$ 150
Z-form DNA 148, 150
zero mode waveguides (ZMWs) 155, 157–158
ZMWs, *see* zero mode waveguides