

## Index

### **a**

Advanced Light Source (ALS) 127  
 advanced materials 28, 30, 261, 262  
 Advanced Photon Source (APS) 128, 141  
 allotropy 61  
 alpha magnetic spectrometer (AMS)  
 20–23  
 amorphous 58–59, 78, 110, 119, 144,  
 172, 202, 203, 205, 216, 217,  
 223–224, 261, 272, 273, 321, 327,  
 340, 341, 345  
 amplifier 105, 268–271, 311, 344  
 anode 91, 92, 186, 187, 196, 199, 220, 342  
 Anomalocaris 4, 5  
 aperiodic tilings 77  
 area distribution analysis 173  
 Arecibo 20, 25, 26  
 Argonne National Laboratory (APS)  
 128, 129, 141  
 atomic bonding 287  
 atomic distribution correlation function  
 133  
 atomic force microscopy (AFM)  
 cantilever system 281–282  
 dynamic modes 283–284  
 history of 281  
 in situ liquid detection of 287–288  
 laser system 281–282  
 non-contact modes 285–286  
 photoacoustic microscope 290  
 piezoelectric scanners 282–283  
 principle and application of 288  
 static modes 283  
 surface morphology detection principle  
 279–280  
 surface topography 286  
 tapping modes 284–285

ultrasonic atomic force microscope  
 288–290  
 atomic force spectroscopy 287  
 atomic packing factor (APF) 68–71, 322  
 Auger effect 93, 94, 104, 323  
 Auger electrons 93, 94, 104, 168, 181,  
 183–184, 346  
 Auger Electron Spectroscopy (AES) 168

### **b**

back-scattered electrons (BSE) 183, 188,  
 339  
 vs. element Z number 184–185  
 vs. secondary electron 339  
 beam-splitters 40, 42, 44, 45, 153, 154,  
 156–161, 236  
 Beijing Electron Positron Collider (BEPC)  
 128, 129  
 Beijing Synchrotron Radiation Facility  
 (BSRF) 128, 129  
 Big Bang 4–7, 14, 19, 21  
 “the bodhisattva dharma-eye” 21  
 body-centered cubic (BCC) structure 30,  
 65, 67, 69–70, 88  
 booster 126–128  
 Bose–Einstein condensate (BEC) 27  
 Bravais lattices 63–65  
 Brout–Englert–Higgs mechanism 12

### **c**

cantilever system 281, 345  
 Casimir forces 279, 287  
 cathode 89, 91–92, 170, 180, 186–189,  
 196, 199, 237, 268, 270, 271, 344  
 chemical shift 251, 265–267  
 coaxial hologram 236  
 Compton elastic scattering 272

- Compton scattering 90, 93, 137, 140, 269, 270
- condensed matter 321
- classification 28–30
  - crystal structure
    - close packing and stacking 65–67
    - coordinate transformation 72–73
    - crystal density 77
    - crystallographic plane and Miller index 73–74
    - families and symmetry 72
    - hexagonal close-packing structure 70–71
    - linear density 74–77
    - planar density 76
    - point coordinates and crystallographic directions 71
  - and materials 28
  - microstructure of 59
  - property 32, 321
  - structures and compositions 30–32
  - unit cell
    - Bravais lattices and crystal systems 63–65
    - crystal structure 61
    - lattice and motif 60–61
    - types and characteristic parameters 65
    - and unit vectors 61–62
- condensed matter physics 33–34, 129, 316, 346–347
- continuous ferromagnetic film 240
- cosmological constant 7, 8, 19, 20
- cosmological parameters 8
- Coster–Kronig transition 104
- Coulomb's law 16
- coupling constant 17, 18, 251
- cryotransmission electron microscopy 314–315
- crystal density 74–77, 79, 322
- crystal, examples 58
- crystal structure 61
- body-centered cubic 69–70
  - close packing and stacking 65–67
  - coordinate transformation 72–73
  - crystallographic plane and Miller index 73–74
  - families and symmetry 72
  - hexagonal close-packing structure 70–71
  - linear density 74–77
  - planar density 76
- crystallographic directions 71, 74
- crystallographic symmetry 72
- crystallography 55–80, 89, 129, 236, 314
- d**
- Dark Energy 5, 7–9, 15, 20, 21, 23, 26, 27, 319–321
- dark matter 5, 7, 9, 15, 20–23, 26, 34, 319–321
- de Broglie wavelength 197, 233, 234, 343
- detection unit 104
- deuterated triglycine sulfate (DTGS) 154, 160
- Diamond Light Source 131
- direct detector 172, 173
- dispersion unit 104
- dissolution forces 287
- Doppler effect 262, 264, 268, 344
- dynamic modes, AFM 283–284, 287
- dynamic theory 85
- e**
- educational analogy experiments 44–46
- Einstein, Albert 8, 197, 293
- elasticity coefficient 282
- elastic scattering process 180
- electromagnetic (EM) characterization methods 7, 321
- electromagnetic interaction strength 16
- electromagnetic lens 180, 199–200, 207, 208, 339, 341
- electromagnetic wave 5, 7, 12, 85, 89, 93, 107, 207, 248–249, 264, 299–310, 319–321
- electron beam interacts 180, 189, 191, 205, 339
- electron gun 126, 170, 179, 186–190, 198, 199, 201, 204, 216, 218, 237, 310, 340
- electron mass 10, 181, 272
- electron microscope (EM) 170, 174, 175, 179, 186, 190, 193, 196, 197, 201, 207, 208, 211, 229, 236, 237, 286, 313, 314, 316, 347
- electronic holography
  - characteristics of 233–236
  - electromagnetic field with 238–239
  - magnetic thin films field 239–240
  - magnetization pattern 240–241
  - micro distribution of magnetic field 240

- principle of 231–233
  - quantitative measurement 241–242
  - electronic interference microscopy 236
  - elementary particles 9–12, 14, 17, 18, 20, 34, 319, 320
  - energy dispersion spectroscopy (EDS)
    - 33, 167, 176, 203, 204, 217, 218, 312, 338, 347
    - vs. EDX 338
  - energy dispersive x-ray spectroscopy (EDX)
    - application
      - energy resolution 173–174
      - reliability and error 173–174
      - surface penetration 173
    - vs. EDS 338
    - principle 167–169
    - quantitative analysis mechanism of 338
    - signal processing system 173
    - vacuum system 170–171
    - x-ray detector 171
    - x-ray scattering 170
    - working principle of 338
  - environmental scanning electron microscope (ESEM) 310–312
    - principle and application of 312
  - environmental transmission electron microscope (ETEM) 215–216
    - applications
      - metal oxides, in situ reduction 220–222, 342
      - nucleation and nanomaterials growth 224–227
      - particle formation and migration 223–224
      - photocatalytic splitting, of water 222–223
      - vapor-liquid-solid 219–220, 342
    - design 216–219
    - differential pumping system 217–219
    - windowed cell approach 216–217, 342
  - European Synchrotron Radiation Facility (ESRF) 130, 131, 141
  - Everhart–Thornley detector 179, 187, 188, 310
  - excitation unit 104
  - excited state lifetime 10, 103, 137, 139, 262, 263, 265, 268, 294, 301, 308, 338, 344
  - extended x-ray absorption fine structure (EXAFS) 123
    - application 133
    - principles 124–125
    - vs. XANES 133–134
- f**
- Fabry–Pérot cavities 40
  - face-centered cubic (FCC) structure 30, 65–69, 70, 71, 74–76, 87, 88, 322, 323
  - femtosecond laser 301, 308–310
  - field emission (FE) 179, 180, 185–187, 189, 197, 199, 237, 313
  - field images
    - principle of 340
  - fingerprint analysis 120
  - first-generation holograms 236
  - first order diffraction 84
  - five-hundred-meter Aperture Spherical Telescope (FAST) 20, 25, 26
  - fluorescence microscope system 300, 301, 304
  - focus 3, 91, 170, 199, 207, 210, 216, 223, 239, 288, 299, 300, 304, 311, 315
  - Fourier pairs 152
  - Fourier transform 33, 48, 78, 116, 149–164, 253, 255, 257, 322
  - Fourier transform infrared (FTIR) spectroscopy 149
    - advantages of 329–330
      - accuracy 155
      - data handling facility 155
      - mechanical simplicity 155–156
      - signal-to-noise ratio and linearity 155
    - application 149, 162–164
      - biological materials 162
      - chemical reactions and spectra of transient species 163–164
      - detector 162–163
      - emission and chemiluminescence 163
      - microscopy and imaging 162
      - nanoscale 162
      - thermogravimetric analysis-infrared spectrometry 163
    - beam-splitter 160
    - concepts 150–153

- Fourier transform infrared (FTIR) spectroscopy (*contd.*)
- developmental history 150
  - interferogram 158–160
  - light source and laser 156
  - Michelson interferometer 156–158
  - photodetector 160–161
  - spectral range
    - far-infrared 161
    - mid-infrared 161
    - near-infrared 161–162
  - standard instrument 153–154
  - transform and signal processing system 161
- fracture analysis 190
- free electron laser (FEL) 147, 307
- free induction decay (FID) 250, 252, 254, 257
- free sensing 258
- frequency coded gradient field 256–257
- Fresnel Lorentz microscopy 239
- Friedmann equation 7
- g**
- gluons 11, 12, 14, 15, 18, 320
- gradient magnetic field 255–257
- frequency coded gradient field 256–257
  - layer selection gradient field 256–257
  - phase coded gradient field 257
- Grand Unified Theory (GUT) 9, 15, 18
- gravitational field 8, 13, 22, 248
- equation 13
- gravitational potential 13, 49
- gravitational waves 12, 13, 26, 37–39, 41–43, 47–51, 322
- gray box 8
- h**
- hadrons 10, 14, 17, 319
- hard-sphere model 56–57
- herringbone magnets 240
- Herriott delay line 45–46
- hexagonal close-packing structure 30, 65, 66, 70–72, 79, 322
- hexapole corrector 208, 209
- hexapole system 209
- Higgs boson 12, 35
- high resolution crystal detector 142
- high-angle ring dark field image (HAADF) 204–205
- holography
- development history 236–237
  - electronic 231–233
  - principle 229–231
- Hooke's law 98, 279
- “The Hubble Legacy Field (HLF)” 24
- Hubble Space Telescope (HST) 8, 21, 24, 25
- Hund's rule 56
- hydrocarbons
- chemical adsorption 132
- hyperons 10, 11, 320
- i**
- illumination system 198, 340
- imaging system 188–190, 198, 201, 303, 304
- incident electron 174, 180, 181, 183–185, 193, 195, 203, 205, 207, 310, 311, 339, 341
- indirect detector 172
- induction torque 241, 242
- inelastic scattering process 181, 182
- infrared spectroscopy 83, 143, 149, 150, 164
- interaction volume 188, 189
- interaction zone 182
- interference pattern 40, 46, 125, 133, 232, 235, 305
- interferogram 154, 156–161, 343
- International Congress of Pesticide Chemistry (IUPAC) notations 117, 118
- inversion recovery sequence 259
- isomer shift 265–266, 273
- j**
- Japanese SPring-8 128
- “Joint Committee on Powder Diffraction Standards (JCP-DS)” 91
- k**
- Karst depression 26
- kinematics theory 85
- kinetic factor 140
- l**
- Lambda hyperon 11, 320
- Larmor frequency 248, 253, 254
- Laser Interferometer Gravitational Wave Observatory (LIGO) 37

- application of 49–50, 322
  - coherent laser source 47
  - components of 322
  - Fourier change and signal processing system 48
  - fundamentals 39–46
  - history 37–39
  - interferometer detector 47–48
  - laser scanning confocal fluorescence microscope (LSCM) 299–301, 304
  - laser system 281, 300, 345
  - laser technology 154, 155
  - lattice of crystals 60
  - lattice parameters 61–63, 68, 69, 73, 90, 96
  - lattice points 57, 61
  - Laue equations 85
  - layer selection gradient field 256
  - leptons 10, 319
  - linear accelerator (LINAC) 20, 126
  - linear density 74–77, 79, 322
  - liquid phase 3, 215, 312
  - lithium-drift silicon detector 168
  - lithium tantalate (LiTaO<sub>3</sub>) 160
  - longitudinal magnification 232, 233
  - longitudinal relaxation 250, 259, 344
  - Lorentz force 22, 200, 307
  - Low Energy Antiproton Ring (LEAR) 6
  - Lytle detector 117, 326
- m**
- Mössbauer effect
    - features of 272, 344
    - fundamental of 263
    - history of 262, 263
  - Mössbauer equipment setup
    - actuating device 268
    - amplifier 271
    - data collector, processor and analyzer 271–272
    - gamma ray detector 269–270
    - gamma ray sources 269
    - and pulse height measuring system 271
  - Mössbauer spectroscopy 272, 344
    - fundamental of 264–265
    - isomer shift 265–266
    - magnetic hyperfine splitting 267–268
    - nuclear Zeeman effects 267–268
    - quadrupole splitting 266–267
  - magnetic hyperfine splitting 265, 267–268
  - magnetic resonance imaging
    - inversion recovery sequence 259
    - probe 252
    - RF generating unit 252
    - saturation recovery sequence 257, 258
    - spin echo sequence 258
    - superconducting magnet 251
  - magnetic splitting 268
  - magnetic superfine splitting 268
  - magnetic thin films 239, 240
  - magnetization pattern 240–241
  - Maki-Nakagawa-Sakata (MNS) matrix 19
  - matter
    - fundamental constants 15–20
    - fundamental forces 11–15
    - matter-wave interference under microgravity (MAIUS 1) 27
  - mercury cadmium telluride (MCT) detectors 160
  - Michelson interferometer 39, 41–47, 150, 153, 156–160, 305
    - with an optical cavity arm 45
  - microimaging uses 290
  - microscale 55–56
  - Milky Way galaxy 41
  - mineralogy 61, 111, 261, 312
  - minimum energy 56
  - monochromatic X-ray
    - physical principles of 327
  - Moseley's law 89, 105
  - motifs 60, 61, 84
  - multi-color three-dimensional fluorescence rescue microscope 303–305
- n**
- nanoscale contacts 287
  - National Science Foundation (NSF) 37
  - non-abelian gauge theory 14
  - non-contact modes, AFM 285–286
  - non resonant X-ray emission spectroscopy (NXES) 118, 326
  - non-zero mass 20
  - Nuclear Magnetic Resonance (NMR)
    - average processing of signals 254–255
    - free induction decay (FID) 254
    - generation of 248, 250, 343

- Nuclear Magnetic Resonance (NMR)  
(*contd.*)  
 gradient magnetic field 255–257  
 instrumentation of magnetic resonance  
   imaging 251–252  
 Larmor frequency 253  
 90° pulse 254  
 operating principle of 252–253  
 pre-amplifier 254  
 pulse sequences in 257–259  
 relaxation of nucleus 249–251  
 RF, generation of 253–254  
 signal reception 254  
 nuclear Zeeman effects 267–268
- o**  
 optical coherence tomography (OCT)  
   305–306  
 optical path difference (OPD) 83,  
   157–159
- p**  
 Pauli exclusion principle 56, 57  
 Penrose tiling 77, 78  
 phase coded gradient field 257  
 photoacoustic effect 290, 303  
 photoacoustic microscopy (PAM) 290,  
   302–303  
 photoelectron, wavelength 125  
 photomultiplier 139, 187, 188, 268, 270,  
   271, 299, 300, 344  
 photon, description 12  
 piezoelectric scanners 282–283  
 planar density (PD) 74–77, 79, 322  
 Plank constant 107, 234, 321  
 polycrystalline materials 97–100  
 polycrystalline plane 341  
 polymorphism 61  
 positrons 6, 22, 23  
 powder particles 190  
 power recycling mirror (PRM) 39, 40,  
   42  
 pre-amplifier 169, 254, 269  
 progenitor 49  
 propagation noise 47  
 proton excited X-ray spectrometry  
   113–114  
 pulsar 26, 38  
 pulse height measuring system 268, 271,  
   344
- q**  
 quadrupole splitting 265–267  
 quadrupole-octupole (QO) corrector  
   209, 210  
 qualitative analysis 107, 112, 149, 173,  
   174, 184, 268, 296, 325, 338, 346  
 quantitative analysis 48, 94, 95, 103,  
   105–107, 112, 113, 121, 149,  
   173–175, 299, 312, 324, 325, 338  
 quantum chromodynamics (QCD) 11,  
   14, 15  
 quarks 10, 11, 14, 17–19, 21, 319  
 quasicrystals 323  
   history 77–79  
   structural characteristics 79
- r**  
 radiation, types 50  
 radiofrequency (RF)  
   generating unit 252  
   generation of 253–254  
 Raman band 139, 140, 144  
 Raman scattering 32, 137–148, 321, 328  
 Raman spectroscopy 119, 143–147, 328  
 recoilless fraction 262  
 recording unit 105  
 relaxation process 250, 259, 344  
 resonance frequency 248–250, 253, 255,  
   282–285  
 resonant X-ray emission spectroscopy  
   (REXES) 118, 326  
 Rietveld full spectrum fitting method 94  
 Röntgen ray 89
- s**  
 SACTEM  
   characterization 341  
   principle of 341  
 saturation recovery sequence 257, 258  
 scanning electron microscope (SEM)  
   179  
   application 190–191  
   backscattered electrons and Auger  
     electrons 183–184  
   detection principle 182  
   electron beam and matter interaction  
     180–182  
   electron beam emission sources 186  
   electronic detector 187–188  
   element Z number 184–185  
   field emission 179

- history 185–186
  - secondary electrons 183, 339
  - signal processing imaging system 188–190
  - surface topography 184
  - thermionic emission 179
  - scanning module 300
  - scanning probe microscope (SPM) 288, 315, 316
  - scattered photons, detection 142, 143, 328
  - secondary electron detector 179, 182, 311
  - secondary electrons 182, 183
    - vs. backscattered electron 339
    - vs. surface topography 184
  - semi quantitative analysis 112, 325
  - semi-conductor detector 171–172
  - sensitivity 38, 39, 41, 42, 45, 47, 48, 50, 51, 106, 107, 109, 112–114, 143, 146, 150, 160, 162, 172, 216, 239, 282–284, 293–295, 303, 322, 329
  - Shanghai Synchrotron Radiation Facility (SSRF) 129–130
  - signal detection 254
  - signal recycling mirror (SRM) 42
  - $\sin^2\psi$  method 98
  - single electron scattering 86, 116
  - solid phase 3
  - solid-state detector 117, 169, 171, 326
  - spherical aberration correction (SAC)
    - application
      - atomic structure characterization 210
      - light elements differentiation 211–213
      - surface and interface research 210–211
      - development history 207–208
      - principle 207
  - spin echo sequence 258, 259
  - static modes, AFM 283
  - storage ring 127, 128, 130, 327
  - strain sensitivity 39, 41, 42
  - supercluster stellar 15, 24, 320
  - superconducting magnet 251
  - superfluidity 27–29
  - supernova explosion detection 38, 49–50, 322
  - surface topography, AFM 179, 183, 184, 285, 286, 339, 347
  - synchrotron radiation 125
    - physical principles of 327
    - produced 125
    - research centers 127
    - structure 126
  - synchrotron radiation X-ray 328
    - fluorescence spectrum analysis technology 113
  - system extinction 87, 88
- t**
- tapping modes, AFM 284–285, 346
  - thermionic electron 186–189
  - thermionic emission (TE) 179, 180, 187, 258, 259
  - thin-film transistors (TFT) 172
  - third-generation holograms 129, 237
  - three-dimensional Fourier transform (3DFT) 255
  - time domain OCT 305
  - transmission electron microscope (TEM) 193, 339, 340
    - application 202–205
      - element distribution 203–204
      - HAADF-STEM 204–205
      - microstructure and morphology 202–203
    - basic structure 198
    - bright field image 195
    - development history 195–197
    - electron beam and matter interaction 193–195
      - interaction mechanism 193–195
  - transverse magnification 232, 233
  - “triad formula” 48
  - tunnel current intensity 347
  - two-dimensional Fourier transform (2DFT) 78, 255
  - two photon microscope 301, 302
- u**
- ultra-high vacuum (UHV) 187, 199, 215, 219, 284, 286, 342
  - universe 3
    - constant 8, 17
    - features 4–8
    - physical constants 17
    - zero dimensional constants 15
  - upper computer system 105

**V**

- Valence-to-Core XES (VtC-XES) 117
- Van der Waals forces 31, 284, 285, 287, 315, 345
- vapor-liquid-solid (VLS)
  - growth 342

**W**

- Weinberg-Salam theory 14
- Wheatstone bridge 279
- Wilkinson Microwave Anisotropy Probe (WMAP) 4
- window 25, 92, 169, 173, 188, 202, 216-218, 224, 227, 342
- WKB approximation 234

**X**

- X light source 170
- X-ray absorption fine structure (EXAFS) 116, 123, 124, 133, 327
- X-ray absorption near edge structure (XANES) 116, 123
  - application 132
  - EXAFS 133-134
  - principles 123-124
- X-ray absorption spectroscopy (XAS) 115, 326
  - application 121
  - principle 115-118
  - transmission 115-117
- X-ray and materials 323
- X-ray diffraction technique 60, 83
  - absorption 93-94
  - application
    - crystal phase analysis 94-97
    - stress determination 97-100
  - cathode ray tube structure 91-92
  - development 88-91
  - principle 85
    - dynamic theory 85
    - kinematical theory 85
    - physical mechanism 86
    - scattering mechanism 86-88
    - unit cell interaction 86-88
  - scattering 92-93
- X-ray emission spectroscopy (XES) 115, 325
  - application 119-121
  - classification 118-119

- development process 119, 326
  - principle 115
  - spectroscopy 119, 326
  - X-ray fluorescence (XRF) spectroscopy 103
    - analyzer
      - classification of 324
      - structure and principle of 324
    - application 109-112
    - classification 107
    - development 109, 324-325
    - history and status of 324-325
    - principle of 324
    - theory 103-104
    - XES 325-326
  - X-ray photoelectron spectroscopy (XPS)
    - element resolution, reliability, and error 294
    - history of 293
    - spectral analysis 295-296
    - surface sensitivity 293, 294
  - X-ray Raman scattering (XRS)
    - advantages 147
    - analyze 329
    - application of 143-147, 328
      - biological research 145
      - Chinese herbal medicine 146
      - gem research 146-147
      - material science research 144-145
      - polymer materials 143-144
    - characteristics 138
    - configuration 141
    - history 139-140
    - principles 137, 138
    - probability of 328
  - X-ray scattering techniques 170
  - X-ray secondary emission spectroscopy 103
  - X-ray spectrum, characteristic 100, 104, 112, 323
  - X-ray synchrotron radiation
    - produced 125
    - research centers 127
  - X-scattered light 141-142
- Z**
- Zeeman effect 265, 267-268
  - zero filling 154, 160