

Index

a

- Abelian 15
 ab initio 14, 203, 210
 Aizu 38, 44, 64, 65, 69, 81, 82, 320
 ambiguity in the classification of ferroic states 81
 analyser measurement 121, 122
 anapole 69, 73
 anisotropy, anisotropic 49, 61, 85, 87, 108, 121–123, 144, 151, 178, 190–195, 221–223, 230, 233–236, 249, 256, 260, 261, 277, 281–282, 286, 289, 296, 310, 314, 322–323, 326–328, 335, 336, 341, 343, 344, 358, 359, 366, 377, 378, 386, 391
 anisotropy energy 49, 61, 190–191, 193, 195, 256, 261, 289
 anisotropy measurement 121, 122, 230, 277, 282, 323, 326–327, 335, 344, 358–359, 366, 377, 378, 386
 antiferrodistortive 67, 263, 264
 antiferroelastic, antiferroelasticity 5, 67
 antiferroelectric, antiferroelectricity 5, 62, 67
 antiferroic 5, 43–44, 51, 392
 antiferromagnet, antiferromagnetic, antiferromagnetism 5, 44, 51–56, 62, 67, 73–76, 78, 81–82, 84–87, 134, 139–153, 159–160, 162–170, 183, 189–196, 202–210, 214, 231–255, 258–270, 275, 277, 279–289, 295–296, 298–300, 305, 307, 309–311, 315–317, 320, 321, 325–326, 334, 338–339, 346, 377–378, 390, 392
 antiferromagnetic vector 139–140, 145, 152, 206
 antiphase domain 38
 application 5, 14, 21, 25, 26, 42, 46, 53, 55–56, 64, 67, 74, 76, 78, 88–89, 109, 119, 141, 183, 197, 213, 251, 272–274, 287, 299, 305, 307, 311–313, 318, 323, 341, 342, 344, 356, 359, 361–363, 385, 389, 391
 atomic force microscopy (AFM) 296, 362
 axial 19, 25–27, 77, 78, 203–204
 axio-polar vector 69

b

- BaTiO₃ 64, 341, 357–360, 363, 370, 371
 β-BaB₂O₄ 114
 beam path 117–121, 125, 169
 BiFeO₃ 342–345
 antiferromagnetic order 264–266
 ferroelectric order 264
 magnetoelectric coupling effects 266–275
 synthesis and crystal structure 262–264
 Big Bang 89, 229
 birefringence 100, 130, 151, 190, 234
 Birss 142
 black-and-white groups 23
 Bloch wall, Bloch domain wall 40
 boracite 69, 70, 83, 314

- Bravais lattice 16
 buffer 215, 266, 344, 345, 348, 349, 358,
 360, 366, 368, 372–373
- c**
 causality 14
 CCD 118, 120, 128, 131
 c-domains 349, 357–361
 Čerenkov SHG 179–180
 chromium sesquioxide 137, 138,
 203–207
 classical macrospin dynamics 183–184
 clock model 221, 228
 coelastic 65
 coercive field 42, 45, 48, 50, 87, 163, 247,
 253, 258, 264, 272–274, 296, 297,
 311, 320, 344, 381
 $\text{Co}_{0.9}\text{Fe}_{0.1}$ 270–275
 colour group 23, 24, 165
 colourless groups 23, 165
 compliance 65
 composite 78, 82, 83, 86–88, 381
 composite multiferroic 82, 83, 87, 381
 conjugate field 41–45, 64, 69, 77, 78, 81,
 82, 88, 182, 213, 318, 328, 382,
 392
 critical exponent 36, 149, 222, 227
 Co_3TeO_6 305–307, 314, 321–324
 Cr_2BeO_4 83, 86, 278
 Cr_2O_3 70, 79–81, 87, 111, 121, 122,
 137–142, 144–153, 159, 161, 164,
 165, 169, 191–193, 202–205, 207,
 210, 270, 314, 320–321, 339
 critical exponent 36, 149, 222, 227
 cryostat 119, 127, 171
 c-tensor 20, 26, 27, 29, 78
 c-type 19, 20, 142, 165, 206, 207, 234
 CuB_2O_4 162–163, 203
 CuO 75, 86, 377
 Curie principle 28
 Curie temperature 35, 42, 51, 66, 85,
 108, 127, 165, 166, 185, 187, 199,
 219, 223–225, 236, 245, 252, 276,
 336–340
- d**
 damping 183, 184, 191, 260, 261
 dangerously irrelevant 227
 degree of freedom, degrees of freedom
 10, 36, 60, 106, 116, 152, 157–200,
 213, 231, 262, 305, 329
 density functional theory 225, 230, 276,
 373
 depolarising field 57–58, 62, 301, 343,
 344, 358, 366, 367, 370–373
 diamagnetism, diamagnetic 50, 61, 255
 dichroic, dichroism 70, 76, 123
 dichroic filter 123
 dielectric 25, 57, 61–63, 77, 88, 110, 123,
 207, 213, 244, 249, 259, 277, 289,
 379–381
 difference frequency generation (DFG)
 109, 386
 dipole vs. exchange 56–57
 direct exchange 47
 dispersive set-up 124
 displacive ferroelectricity 60, 85, 275
 disruptive 32, 33, 65, 375
 domain
 pattern 305–312
 state 38–39, 140, 168–171, 225–229
 states and domains 37–39
 topography 149–152, 173–181
 wall 39–40, 66–67, 88, 174–176,
 289–291, 345–357
 α -domains, α_1 -domains, α_2 -domains
 348, 349, 357–361
 180° domain 38–39, 57, 62, 70, 74,
 128–132, 145, 147, 150, 151, 159,
 165, 168–171, 175–180, 235, 237,
 238, 240, 251, 298, 330, 358
 double exchange 47
 d-wave superconductivity 376
 dynamics 116, 169, 181–200, 248, 259,
 261, 287–289, 307, 310, 336, 341,
 355–373, 386
 DyScO_3 264, 266, 270, 271, 273, 275, 276,
 344, 348, 349, 360, 361, 365–367
 $\text{Dy}_{0.7}\text{Tb}_{0.3}\text{FeO}_3$ 306, 307, 309–312

- Dzyaloshinskii–Moriya 53–54, 85, 86, 163, 190, 255, 263–266, 280, 295, 315, 317, 323
- e**
- easy axis 49, 139, 193, 195, 236, 280, 282, 283, 286, 287
- electric-field-induced second harmonic (EFISH) 108–109, 288, 289
- Ehrenfest 35, 36
- electret 64
- electric dipole 4, 5, 32, 33, 40, 46, 56–63, 73, 77, 84, 85, 91, 96–98, 105, 108–110, 141, 160, 161, 201–202, 210, 218, 219, 286, 300–301, 325, 326, 337, 339, 341, 345, 349, 366, 386, 390
- electric-dipole second harmonic generation (ED-SHG) 108–110, 115, 141–142, 147, 148, 159, 161, 163, 165, 204–207, 225, 226, 251, 252, 280–282, 292, 295, 316, 328, 338, 350, 368, 369, 377–379, 383
- electric quadrupole 96–98, 109, 140, 141, 160, 161, 210, 326, 377, 390
- electric-quadrupole second harmonic generation (EQ-SHG) 109, 115, 141–143, 159, 161, 207, 252, 280, 327, 328, 378
- electronic ferroelectricity 60
- electrostatic ferroelectricity 60
- electrostatic force microscopy (EFM) 346–347
- Elliott-Yafet 185
- enantiomorphic 21–23
- entropy 29, 49
- epitaxial 76, 86–88, 103, 214, 215, 224, 262, 264, 266–268, 271, 276, 277, 302–303, 330, 332–358, 361–365
- EuO 187–190, 276, 330, 332, 334, 336–340
- EuTiO₃ 275–276
- exchange bias 55, 88, 269–270, 275, 312
- exchange interaction 41, 47–51, 53, 54, 56, 62, 76, 81, 85, 86, 187, 233, 248, 261, 291, 302, 340, 392
- f**
- Fabry-Perot 150, 152
- Faraday effect 27–28, 184–186, 259–261, 386
- far field 117, 133, 171–173
- far-field microscopy 171–172
- femtosecond laser 115–116, 132, 197
- femtosecond laser systems with optical parametric amplifier 115–116
- Fe₃O₄ 46, 53
- Fermi energy 47, 110, 116, 160, 162, 187, 190, 194, 203, 209, 338, 352, 376, 378, 384, 385
- ferrielastic 67
- ferrielectric 62
- ferrimagnetic 53–55, 168, 169, 236, 245–248, 278, 315, 316, 334, 335
- ferro-axial 77
- ferro-axial order 45–46, 77, 325–328
- ferrodistortive 67, 390
- ferroelastic, ferroelasticity 5–6, 45, 64–67, 75, 77, 82–83, 264, 313, 325, 390
- ferroelectric, ferroelectricity 4–6, 10, 41, 45, 56–64, 67, 75–77, 82–89, 103, 125–127, 165–166, 170–176, 196–200, 207–209, 217–221, 223–231, 250–255, 262–264, 266–280, 282–291, 293–298, 302–306, 309–312, 341–359, 363, 365–373, 390
- ferroelectromagnet 82
- ferroglyotropic, ferroglyrotropy 78
- ferroic phase transition 32–41, 44, 48, 51, 56, 62, 64, 67, 290, 304, 317
- ferromagnetoelectric 78–82
- ferro-rotational 46, 313, 326, 328
- ferrotoroidic, ferrotoroidicity 44–45, 68–70, 73–76, 81, 83, 170–171, 313–325, 328, 382, 390, 392

- field energy 48–49, 52, 67, 151, 250, 289, 301, 320
 first-order phase transition 35, 42, 139, 241, 250, 300, 301, 304
 first principles 202, 203, 210, 218, 219
 flexoelectric 57, 87
 floating zone 214, 278, 295
 flux-grown, flux growth 152, 234, 245
 four-photon techniques 391
 free energy 31, 33–36, 41, 44, 45, 49, 62, 70–72, 74, 75, 78, 80, 107, 217, 221, 255–257, 307–309, 323
 frustrated state 54
 frustration, frustrated 54–55, 250, 302
 full ferroic 44
- g**
 garnet 114, 168, 169, 175, 334–336
 geometric/electrostatic ferroelectricity 60
 geometric ferroelectricity 60, 85
 giant magnetoresistance 55
 Ginzburg criterion 36
 glass filter 118, 122, 123
 glide plane 20
 Goldschmidt tolerance factor 215
 grey groups 23, 26, 164
- h**
 half-wave plate 365
 Hamilton operator 14, 60, 93–95, 104
 helimagnet, helimagnetic, helimagnetism 44, 52–53
 helimagnetic 44, 52
 Herman–Mauguin 159
 heterostructure 76, 86–88, 115, 213, 262, 270–272, 329–331, 342, 343, 347, 350, 357, 358, 360–364, 367–372, 381, 391
 hexagonal manganites 207
 antiferromagnetic order of the Mn³⁺ lattice 231–243
 DyMnO₃ 235, 236, 245, 249
 dynamic correlations 259–262
- ErMnO₃ 128–129, 167, 209, 223, 230, 235–237, 240–243, 245–249, 254–255
 HoMnO₃ 132, 167, 209, 221, 235–237, 240–243, 245–249, 254, 255
 h-RMnO₃ 214–219, 221, 223, 226–238, 240–243, 246, 247, 249–256, 258–260, 262, 278, 302
 InMnO₃ 217, 229–231
 lattice trimerisation 215–231
 LuMnO₃ 236, 249
 magnetic order of the rare-earth system 243–247
 magnetic sublattice interactions 247–250
 magnetoelectric sublattice interactions 250–259
 ScMnO₃ 236–239, 241, 249
 synthesis and crystal structure 214–215
 TmMnO₃ 245
 YbMnO₃ 245–248
 YMnO₃ 63, 125–126, 132, 165–167, 173, 174, 176, 209, 218–221, 223–226, 229, 235–238, 249, 252–255, 259–262, 368
 hidden 1, 168–171, 184, 363, 376, 378, 392
 higher-order ferroics 78–81
 holography, holographic 168
 hysteresis 42–44, 48, 50, 55, 56, 62, 64, 65, 183, 241, 243, 245–247, 250, 258, 269, 276, 286, 294, 296, 297, 303, 319, 320, 324, 392
- i**
 image resolution 127–128, 134, 177
 imaging 117, 119, 120, 127, 128, 131–133, 151, 171, 172, 174, 175, 179, 265, 277, 311, 320, 380
 improper ferroelectric, improper ferroelectricity 60–63, 85, 170, 190, 196, 218, 220, 224, 225, 227, 228, 251, 280, 289, 295, 298, 302
 improper rotation 20, 38

- incipient ferroelectric, incipiently ferroelectric 63, 275, 276
- incommensurate, incommensurability 24, 52, 163, 170, 201, 263, 265, 267, 279–287, 292, 295, 296, 302, 305, 324, 389, 391
- inhomogeneity 26–28, 86, 146, 152
- in situ 213, 331, 332, 335, 361–365, 367–371, 390
- insulator-metal transition 336, 339
- interface 57, 76, 87, 88, 159, 203, 225, 329, 330, 342–344, 348, 350–357, 361, 367, 372–373, 390
- interference 100, 102, 103, 111, 113, 118, 120, 123, 128–132, 145–149, 159, 168–180, 191–195, 202, 204–209, 236, 237, 252, 260, 284–286, 288, 297, 298, 316, 330, 334, 335, 367–369, 380, 386, 392
- ISHG 362–373
- Ising 36, 40, 84, 174, 221, 244, 245, 310, 348, 349
- Ising-Néel 174, 349
- Ising wall, Ising domain wall 40
- isomorphic 31, 32
- isomorphic phase transition 31 32
- isotropic point 223
- i-tensor 20, 25, 26, 28, 29
- i-type 19, 20, 77, 78, 142, 143, 165, 207, 234
- j**
- Jahn-Teller 58, 60, 264
- joint-order-parameter multiferroics 85
- k**
- Kerr effect 134, 183–186, 190, 276, 336
- Kibble-Zurek 229
- l**
- LaAlO_3 276, 343–345, 350–351
- LaAlO_3 on SrTiO_3 350–357
- Landau-Lifshitz-Gilbert equation 183, 184, 186, 190
- Landau-theoretical description and order parameter 33–34
- Landau theory, Landau-theoretical 33–34, 36, 280, 293–294, 309, 320, 322
- laser 6–9, 108–110, 113–120, 123–129, 131–135, 146, 150, 159–161, 168, 171, 173, 176, 179–182, 184, 185, 188, 189, 197, 215, 219, 262, 278, 298–300, 317, 330–333, 335, 341, 355–356, 363, 370, 381, 384
- latent heat 35, 36
- trimerisation 63, 85, 215–231, 233
- lattice vector 16–18, 383
- Laue diffraction 146, 378
- LiCoPO_4 73–75, 170, 171, 180, 181, 314–325
- LiFePO_4 315
- $\text{LiFeSi}_2\text{O}_6$ 75–76, 320–321, 324
- light-matter interaction 15, 29, 97, 104–105, 107, 380
- LiMnPO_4 315
- LiMPO_4 75, 314, 315
- LiNbO_3 41, 60, 64, 124–127, 175, 179–180, 200, 341, 348, 381, 383
- linear magnetoelectric effect 70, 72, 76, 78–83, 140, 152, 204, 250, 252, 256, 266, 319–320, 325, 390
- LiNiPO_4 315
- LiOsO_3 41
- Liouville equation 103
- liquid helium 119
- lithium orthophosphate 314
- local field 110–111, 207
- lone-pair ferroelectricity 60
- loop current 29, 377–378
- Lorentz force 28–29
- LuFeO_3 88, 278
- m**
- magnetically induced ferroelectric, magnetically induced ferroelectricity 83, 85–86, 278, 289, 294, 296–297

- magnetic dipole 34, 48, 57, 61, 71, 76, 96–97, 109, 140–141, 160–161, 192, 210, 337, 340, 382, 390
- magnetic-dipole second harmonic generation (MD-SHG) 109, 115, 141–143, 159, 161, 187, 204, 207, 252, 281, 282, 338
- magnetic force microscopy (MFM) 271, 273–274
- magnetic monopole 56, 72, 76, 77, 80
- magnetic point group 23, 24, 38, 75, 137, 139, 142, 152, 165, 234, 279–281, 283, 292, 295, 302, 305–307, 315, 316, 320–322, 337, 377, 378
- magnetic quadrupole 71–72, 80
- magnetisation dynamics,
magnetisation-dynamical
183–188, 191, 194, 336–337
- magnetisation vs. magneto-optics
185–186
- magnetoelectric coupling 75, 79, 82–83, 85, 87, 166, 168, 196, 209, 251–252, 255–259, 266–275, 277, 305, 390
- magnetoelectric multiferroic 82, 83, 165, 168, 278, 334
- magnetoelectric sublattice interaction 250–259
- magneto-optic, magneto-optical 27–28, 134, 182, 184–186, 190, 195, 202–203, 241, 260, 276, 306, 334, 336, 381
- magneto-toroidal order 69–73, 75, 77, 314–316, 318–321, 324
- magnetostriction 49, 86, 193
- Maker fringes 102–103, 111
- metal-insulator transition 336, 339
- metal-organic chemical vapour deposition 215, 331, 333–334
- metamaterial 379–384, 390
- microscope lens 127, 171, 172, 177
- microscopic sources of SHG in antiferromagnetic insulator 203–210
- chromium sesquioxide 203–207
- hexagonal manganites 207–209
- nickel oxide 210
- ferromagnetic metals 202–203
- minimal substitution 95
- mirror operation 3, 9, 20, 21, 38, 138, 336
- mirror plane 20, 38, 138, 326
- missing charge problem 351, 354
- Mn_2GeO_4 305–308
- MnWO_4
multiferroic domain wall 289–291
multiferroic order 279–280
poling dynamics 287–289
SHG contribution 280–284
synthesis and crystal structure 278–279
types of domains 284–287
- molecular beam epitaxy 215, 332
- Monte-Carlo simulation 177–178, 220, 221, 222, 299–301
- multiferroic hybrid domain 286, 287
- multiferroic, multiferroicity 6, 9, 10, 76, 81–89, 116, 165, 168, 170, 196, 213–214, 314, 321–324, 326, 330, 334, 342, 345, 357, 381, 390–391
- multipole expansion 69–73, 95–97, 104, 206, 207
- n**
- nanosecond laser 114–115, 146
- NbN 198–199
- near field 117, 133–134, 221, 358
- near-field microscopy 128, 172–174
- Néel temperature 51, 85, 147–148, 165–166, 235, 237, 239, 248, 253
- Néel wall, Néel domain wall 40
- Neumann principle 14, 121
- neutron diffraction, neutron scattering 139, 151, 157, 170, 234, 236, 244, 245, 247–249
- nickel oxide 210
- NiO 110–111, 160–161, 178, 192–195, 202, 210
- nondisruptive 33
- nonferroelastic ferroic 67

- non-isomorphic 31, 32
 nonisomorphic phase transitions 31
 nonlinear optical techniques 15, 157,
 184, 190, 213, 214, 225, 244, 330,
 346, 382, 391
 nonreciprocal, nonreciprocity 28, 70, 76,
 381–382
 normalisation, normalise, normalised
 36, 123–127, 145, 175, 178, 207,
 220–221, 292, 309, 365–366, 379
- o**
- observable 25, 33, 34, 40–44, 68, 73, 186,
 223, 295, 307–309, 311
 Omega molecule 197
 optic axis 108
 optical parametric amplifier (OPA)
 115–116, 118, 135, 363, 365
 optical parametric oscillator (OPO)
 114–117, 122, 123, 126, 131
 optical resolution 127, 128, 168,
 173–175, 177, 178, 240, 241, 254,
 299, 346
 optical switching 299
 order parameter 33–44, 46, 49, 53, 56,
 62–65, 67, 69–70, 73–78, 81, 84–86,
 121, 128, 139, 145, 164, 168–169,
 174–175, 182, 186, 191, 193–196,
 203, 206–207, 209–210, 224, 248,
 251–253, 259–262, 268, 270, 275,
 280, 284, 289, 292, 296, 298,
 301–302, 305–310, 313, 314, 318,
 320, 325–328, 334, 339, 375, 382
 orientation domain 38, 39, 65, 170, 178,
 216
 orthorhombic manganite 295, 357
 oxide electronics 10, 329–373
 oxygen deficiency, oxygen-deficient 236,
 245, 331
 oxygen vacancies 346
- p**
- paraelectric 57, 61, 63, 208
 paramagnetism, paramagnetic 23, 50,
 55, 57, 61, 84, 137, 141, 145–150,
 163–165, 170, 185, 245, 267, 268,
 280–282, 295, 336, 377
 parity 18, 24–27, 65, 67, 68, 70, 72, 74,
 76, 140, 141, 160, 201, 204, 205,
 208, 209, 313, 318
 partial ferroic 44
 particularisation 28–29, 75, 165, 201,
 225, 236
 PbTiO_3 360, 361, 372–373
 $\text{PbZr}_x\text{Ti}_{1-x}\text{O}_3$ 64, 171–173, 341, 347–349,
 357
 periodically poled lithium niobate (PPLN)
 381, 383
 phase diagram 33, 36, 84, 234, 235,
 241–243, 247, 262, 279, 280, 289,
 295, 296, 303, 305, 379
 phase-field simulation
 phase matching, phase match, phase
 matched 99, 102–103, 111, 114,
 179–180, 284, 380, 381, 383–384
 phase-resolved imaging 128–132
 photo-Dember effect 356
 photomultiplier 118, 120, 123, 124, 135,
 365
 photonic crystal 379–384, 390
 piezoelectric, piezoelectricity 13–15, 18,
 26, 57, 64, 67, 74, 87, 344, 381
 piezomagnetic, piezomagnetism 26, 49,
 255
 piezoresponse force microscopy (PFM)
 221, 223, 229–230, 266, 269, 271,
 272, 348, 349
 point group 20–29, 32, 33, 38, 51, 57, 62,
 64, 75, 121, 137–140, 142, 152,
 162–166, 204, 207–208, 234, 247,
 248, 277, 279–280, 283, 290, 292,
 295, 302, 305–307, 315–317,
 320–322, 324–327, 336, 337, 342,
 344, 351, 369–371, 377, 378, 383
 polar 20, 25–27, 29, 41, 57, 61, 63, 65, 69,
 84–87, 121, 183, 202, 218, 219, 230,
 276, 277, 310, 325, 346–347, 350,
 355
 polarisation switching 196, 269, 270,
 294, 344, 358

- polarisation-dependent 9, 117, 120–122, 146–149, 152, 153, 157–167, 202, 203, 272, 341
- polariser 121, 343
- polariser measurement 121, 122, 268, 269, 272, 273, 343
- polariton 99
- polarisation reversal 198, 270, 289, 294, 298
- poling 42–44, 51, 63, 64, 74, 75, 78, 102, 103, 152, 172, 173, 182, 227–228, 246, 251–254, 258, 264, 267–269, 272–275, 286–289, 291, 295–297, 302, 305, 308–310, 312, 317–320, 322, 324, 328, 335, 341, 342, 357–361, 363, 370, 381–383
- poly-twin 66, 264
- Potts model 221, 228
- precursor 202, 333, 334, 341, 353, 354, 356, 363, 386
- primary ferroic 45–46, 51, 56, 58, 65–66, 68–69, 73–78, 81–82, 213, 313–328, 392
- probe 9, 63, 89, 108, 110, 120, 122, 145, 152, 159, 164–165, 169–170, 177, 187, 201, 203, 223, 234, 259, 270–271, 283, 293, 332, 337, 351, 354, 360–361, 370, 378, 382, 385–386
- pulse 134–135, 181, 182, 192, 197
- projection 24, 117, 127–134, 167–169, 171, 176, 179, 180, 221, 225, 241, 260, 284, 315, 383
- prototype phase 32–34, 38, 39, 74, 129, 164, 165, 215–217, 219, 227, 247, 248, 250, 256, 291, 326, 327, 369
- prototype symmetry 32, 165, 226, 305–307
- pseudogap 376, 378–379
- pseudoproper 61–63, 65, 67
- pulsed-laser deposition 89, 215, 224, 330–332
- pump-probe 120–121, 135, 182, 197, 287, 386
- pyroelectric 57, 64, 166, 220, 282, 292, 321–322, 381
- q**
- quantum paraelectric 63
- quartz 7, 123, 124, 126, 130, 132, 237, 238, 384
- quasicrystal, quasicrystalline 24, 382–384
- quasi phase matching, quasi phase matched 102, 103, 381, 383
- r**
- rare earth 47, 167, 237, 241–248, 250, 256, 280, 295, 307, 309–311, 337
- RbFe(MoO₄)₂ 77, 325–328
- reflection high-energy electron diffraction (RHEED) 331–332, 335, 362–366, 368–369
- refractive index 100, 131, 143, 379, 380
- relative spontaneous strain 65
- relaxor 63
- reorientation, reorient, reoriented 3, 33, 39, 40, 42, 140, 153, 174, 191, 193–195, 210, 235, 236, 239–241, 245, 248–250, 257, 259, 267, 273, 274, 280, 289, 290, 295, 303, 304, 335, 342, 359, 363, 364
- representation 9, 108, 158–160, 201, 208, 218, 232, 280
- resonance enhancement, resonance-enhanced 101, 159–161, 267, 268
- response theory 14, 91
- rigid, rigidity 57, 196, 224, 289, 298, 305
- Rochelle salt 56
- Ruderman-Kittel-Kasuya-Yosida (RKKY) 47, 187, 189–190, 337
- s**
- scanning 74, 117, 133–134, 168, 169, 172, 173, 179–180, 266, 270, 300, 325, 332, 348, 349, 361, 369
- scanning probe microscopy 89, 270
- Schmid 69, 81, 82

- Schoenflies 158
 screening, screen, screens 47, 57, 168, 180, 228, 331, 344–346, 355–356, 366–367, 370–373, 386
 screw axis 20
 secondary ferroic 44, 45, 78, 81, 82, 151, 390
 second harmonic generation (SHG) 70, 102, 108–111, 115–134, 140–153, 157, 159, 161–181, 186–188, 190–195, 197–199, 201–210, 213–312, 313–328, 329–373, 375–381, 383–386, 390–391
 second-order phase transitions 34–36, 42, 235, 320
 seeding 114
 seignetomagnetic 82
 Shubnikov 23
 signal normalisation 123–127
 silicon 122, 124, 276, 336, 358, 380
 single-phase multiferroics 82–83, 85
 softness 39–42, 199
 Soleil-Babinet compensator 131–132
 space group 21–24, 31–33, 137, 215, 217, 225–226, 229, 231–233, 244, 248, 249, 251, 263, 278, 279, 291, 292, 295, 314, 321, 325, 326, 342
 space-group type 32
 spatial inversion 15, 18–20, 25, 68–70, 72, 74, 76, 77, 83, 89, 108, 137, 139, 158, 199, 201, 326, 381
 spatial inversion symmetry 70, 83, 139, 199, 201
 species 38, 44, 65, 320, 334
 speckle 172–173, 177, 239
 spectral identification of symmetries 166–167
 spectral resolution 10, 116, 117–127, 363
 spectroscopy 9, 110–111, 113, 116–121, 123–125, 135, 141, 146–149, 157–167, 197, 199, 200, 244, 248, 282, 292, 296, 338, 351, 371, 385
 spin canting 261, 265, 266, 315, 317
 spin-charge 196
 spin flop 140, 152–153, 165, 185, 290, 320–321
 spin glass 54–55, 266, 382
 spin-lattice 52, 192–193
 spin-momentum locking 385–386
 spin-orbit 53, 85, 86, 182, 185, 203–210, 339, 377, 384–386
 spin rotation 232, 235, 239, 240, 249, 257, 316
 spin spiral 52, 62, 87, 170, 283–285, 289
 spin wave 52, 170, 259–262, 265
 split-order-parameter multiferroics 85
 spontaneous electric polarisation 41, 60, 65, 85, 86, 280, 289, 290, 298, 321–322
 sputter deposition 331–333, 362
 Sr_2IrO_4 377, 378
 SrMnO_3 276–277, 345–347
 SrRuO_3 266, 348, 349, 360, 366–368, 370–372
 SrTiO_3 61, 199, 200, 267–269, 275–276, 350–358, 360–361, 367, 368, 370–373
 strain
 compressive 264–265, 268, 342
 tensile 264, 275–277, 342, 345–346, 360
 stripe domain 66, 264, 266, 271–274, 287, 323, 345, 366
 sublattice 10, 43, 53–54, 62, 67, 78, 82, 85, 116, 134, 162–164, 193, 207, 242–244, 247–259, 291, 295, 306, 309, 314
 sublattice selectivity 162–164
 sub-resolution 172, 177
 sum frequency generation (SFG) 106, 108, 109, 117, 118, 123, 158–161
 superconductor, superconducting 34, 85, 375–378, 392
 superexchange 47, 53, 247, 248

- switching 41, 42, 78, 83, 87, 182, 183, 192, 196, 269–271, 273, 275, 287, 289, 294, 297–302, 305, 344, 357–359
 symmetry engineering 368–370
 symmetry operation
 combinations of operations 20
 nomenclature 20–21
 rotation 18
 spatial inversion 18–19
 time-reversal operation 19–20
 translation 17–18
 synthesis 214–215, 236, 262–264, 278–279, 291–292, 332, 333
- t**
 Tanabe–Sugano diagram 138, 139, 146, 204
 TbMnO_3 62, 86, 126, 295–304, 368, 369
 TbMn_2O_5 86, 291–295
 telephotography lens 127, 171–173
 teleportation 309–312
 terahertz 109, 197–200, 358, 371, 381
 tertiary and higher-order ferroic 45, 81
 thin film 10, 61, 76, 86, 87–88, 103, 171, 173, 203, 213, 215, 224, 264, 267–268, 276–277, 302–303, 329–392
 third harmonic generation (THG) 109–110, 116, 120, 199, 334, 339, 380
 three-photon techniques 391
 three-temperature model 184, 186, 187, 189, 196
 tilted sample 128
 time reversal 3, 9, 15, 18–20, 23, 25, 27–29, 60, 63, 68–70, 72, 74, 76, 77, 79, 89, 108, 137, 139, 142, 145, 178, 185, 202, 206, 326, 381, 384–386, 390
 topography on antiferromagnetic domains 149–152
 topological defect 226–229
 topological insulator 76, 384–386
 toroidal field 45, 69, 70, 73–76, 170, 317–320, 324, 325, 328, 382
 toroidal moment 68–76, 81, 315, 321, 324, 325
 toroidal poling 319, 320, 324, 382
 toroidisation 45, 69, 314, 315, 317, 318, 325
 transition matrix elements 97, 104, 110, 161, 203
 translation domain 38–39, 62, 169–170, 226, 284, 285
 tricolour lattice 381
 trimerisation 63, 85, 215–219, 221, 225, 227–229, 233, 255
 tunnelling magnetoresistance 55
 twin, twinning, twinned 318, 328, 362
 two-dimensional terahertz time-domain spectroscopy 199–200
 two-photon sum frequency generation (2P-SFG) 106, 108, 109, 117, 118, 158, 159
 type I 84–86, 214, 215, 217, 250, 252, 262–278, 302
 type II 84–86, 114, 190, 196, 214, 278–312, 321, 322, 326
- u**
 ultrafast 182
 antiferromagnetic switching 192–195
 uniaxial 44, 65, 108, 275
 unit cell 16–18, 22, 24, 32–33, 37, 39, 43, 49–50, 57–58, 60, 62, 66–69, 71, 73–78, 87, 95–96, 138, 173, 191, 205, 215–217, 223–225, 229, 231–235, 239, 241, 245, 251, 263–266, 283, 303, 315, 321, 324–325, 331–332, 344–345, 349, 351–352, 364, 366, 369–370, 373, 378, 382
 universality 36
 universality class 36

V

virtual state 107
vortex 45–46, 69, 74, 218, 221–223,
226–229, 253, 254, 325

W

wave equation 97–103, 106, 140, 142, 390
Wadhawan 81, 82
wake-up effect 274
wave equation 97–103, 106, 142, 390
weak ferromagnetism, weakly
ferromagnetic, weak
magnetisation 53–54, 63, 164,
302

Weyl semimetal 386

Wyckoff 17, 53–54, 61, 162, 215, 314

X

X-ray diffraction 21, 70, 217, 229, 249,
257, 332, 362

Y

$\text{YBa}_2\text{Cu}_3\text{O}_{7-x}$ 376, 378, 379

Z

ZnO 41
zone boundary 67, 217–218
zone centre 61, 62, 67, 218, 219, 275

