

About the Editors

Mikhail A. Noginov graduated from Moscow Institute for Physics and Technology (Moscow, Russia) in 1985 with a Master of Science degree in Electronics Engineering. In 1990 he received a Ph.D. degree in Physical-Mathematical Sciences from General Physics Institute of the USSR Academy of Sciences (Moscow, Russia). Dr. Noginov's affiliations include: General Physics Institute of the USSR Academy of Sciences (Moscow, Russia, 1985–1991); Massachusetts Institute of Technology (Cambridge, MA, 1991–1993); Alabama A&M University (Huntsville, AL, 1993–1997); and Norfolk State University (NSU) (Norfolk, VA, 1997–present).

Dr. Noginov has published one book, four book chapters, over 100 papers in peer-reviewed journals, and over 100 publications in proceedings of professional societies and conference technical digests (more than 20 of them being invited papers). He is a member of Sigma Xi, Optical Society of America, SPIE, and the American Physical Society and has served as a chair and a committee member on several conferences of SPIE and OSA. Since 2003, Dr. Noginov has been a faculty advisor of the OSA student chapter at NSU. His research interests include metamaterials, nanoplasmonics, random lasers, solid state laser materials, and nonlinear optics.

Graeme Dewar earned his Ph.D. in Physics from Simon Fraser University in 1980. After stints on the faculties of Princeton University and the University of Miami, he joined the University of North Dakota in 1989 where he is currently Professor and Chair of the Department of Physics and Astrophysics. Most of his research projects have involved the interaction of electromagnetic radiation with complex media. These have included experimental investigations of the radio frequency properties of ferromagnetic metals, with an emphasis on magnetoelastic effects, and photonic crystals. His current interests are primarily in metamaterials having a tailored permittivity and permeability.

Martin W. McCall graduated in Physics from Imperial College London in 1983. His doctoral thesis, completed while he worked for an electronics company, concerned development of vector coupled-wave theory describing anisotropic diffraction in photorefractives for use in real-time image processing. After a spell at the University of Bath, UK, where he worked on nonlinear dynamics in semiconductor lasers, McCall returned to Imperial College in 1988 to work on a range of optoelectronic themes, including nonlinear coupling and mixing in

semiconductor amplifiers and laser arrays, optical interconnects, and Bragg grating physics. Sometimes referring to himself as a “reformed experimentalist,” McCall’s research is now purely theoretical. Broadly within the remit of describing the electromagnetics of complex media, he has specifically worked on chiral photonic films and negative index metamaterials. Recently he has specialized in the use of covariant methods in electromagnetism. He is currently Professor of Theoretical Optics at Imperial College London.

Nikolay I. Zheludev received his M.Sc., Ph.D., and D.Sc. from Moscow State University and joined the faculty of Southampton University in 1991. He is Deputy Director of the Optoelectronics Research Centre, University of Southampton and directs the EPSRC Centre on Nanostructured Photonic Metamaterials. His awards include a Senior Research Fellowship with the Leverhulme Trust (2001), a Senior Research Professorship of the UK Engineering and Physical Sciences Research Council (2002), and the Royal Society Wolfson Research Merit Award (2009). Prof. Zheludev is a Fellow of the Institute of Physics (London) and of the Optical Society of America. He is a member of the European Physical Society QEOD steering group and the Institute of Physics QEP steering group, and vice chaired the metamaterials group of the Physics and Engineering Research Council of the Optical Society of America. He is also Editor in Chief of the *Journal of Optics* (IOP Publishing).

Index

A

acentric order parameter, 528
active medium, 286, 420–421, 424, 426–428
amorphous polycarbonate (APC), 537
amplification length, 303–304
amplified spontaneous emission (ASE), 302, 310, 335, 387
Anderson localization, 279, 317, 371, 382–383, 391
Anderson model, 319
annihilation operator, 423
annihilation/excitation process, 425
anomalous dispersion, 652
anomalous polarizability, 403
anomalously localized states, 331, 332
anticommutation rule, 423–424
artificial magnetism, 13
artificial plasma, 12
atomic units, 508
atomic vapors, 665
atomistic Monte Carlo/molecular dynamics, 529
attenuated total reflection (ATR), 65, 532–533
attenuation factor, 529
auto-oscillation, 425, 430
axial nonlinear optical tensor, 83
axial tensor, 89

B

β factor, 315
back mirror, 361
backward light, 653
— causality and, 653, 665
— energy flow of, 653
backward waves, 2
band-edge dispersion, 663
bandwidth, 555

bandwidth/voltage sensitivity factor, 556
beam steering angle, 556
biaxial layer, 133
binary chromophore organic glass (BCOG), 527, 538
bit-error rate (BER), 664, 670
black and white group, 84
Bloch functions, 511
Bloch integrals, 488, 516
Bloch's theorem, 185
Bose-Einstein distribution, 323, 380
Bose-Einstein statistics, 381, 390
Bragg wavelength, 140
Brewster mode, 68
bulk material, 561

C

c-type tensor, 85–88
capacitive energy, 113
cascaded prism device structure, 556
causality, 654, 665–668
cavity, 360
chaotic behavior, 280
chaotic cavity lasers, 303
chaotic light, 323, 380
characteristic equation, 183
characteristic length, 597
characteristic matrix, 138
charge density, 482, 509
chemical potential, 509
chiral architectures, 139–140
chromophore, 526
— number density, 529
Clausius-Mossotti formula, 486
coherence, 278
— degree of, 377
— longitudinal, 363
— quantum, 658, 671
— transversal, 363

coherent control, 658, 670–671
 coherent emission, 278
 coherent feedback, 278, 302, 316–318,
 321, 340, 384–385
 coherent light (single-mode), 380
 coherent population oscillation (CPO),
 658–659, 664
 colorless group, 84
 complex carrier mobility, 584
 computer-generated hologram (CGH),
 162–163, 634
 conductance, 246
 continuous plasmonic phase, 120
 correlated disorder model (CDM), 577
 correlation
 — degree of, 247
 — long-range, 250
 correlation radius, 303
 coupled resonators, 661–663, 672, 673
 coupled wave theory, 628
 creation operator, 423
 critical volume, 279
 critically anomalous dispersion, 653

D

Debye-Onsager factor, 562
 decay function, 591
 decay lifetime, 443
 decoherence, 672
 defect modes, 148
 degree of level overlap, 244
 delay–bandwidth product (DBP), 664
 dendrimer, 464, 465, 535
 density functional theory (DFT), 480,
 507, 529
 density of modes, 373
 density of states, 507
 density operator, 513
 Dexter theory, 441
 dielectric function, 484
 dielectric matrix, 487
 dielectric permittivity, 528
 Diels-Alder/Retro-Alder reaction, 549
 diffusion, classical, 373
 diffusion coefficient, 245, 364
 diffusion constant, 306
 diffusion equation, 306, 310
 diffusion regime, 366, 377, 390
 diffusive model, 279

diffusive transport, 279
 dimensionless conductance g , 231, 245
 dipolar oscillator, 325, 326
 dipole moment, 423, 428
 — nonlinear dependence of, 560
 disorder, 281
 disorder parameter, 613
 disordered organic semiconductors, 579
 disordered photonic crystal laser, 340
 dispersion, 652–656
 dispersion effects, 530
 distributed feedback (DFB) laser, 332
 double-inverse-opal photonic crystal
 (DIOPC), 214
 double negative media, 8
 down-conversion, 461
 drive voltage, 555

E

ϵ_{qs}
 — capacitance-based definition of, 117
 — dipole density definition of, 117
 effective permittivity
 — multiscale approach of, 118
 — two-scale expansion of, 118
 eigenmode, 184
 eigenproblem, 184
 eigensolution, 184
 eigenvalue, 184
 electric-field-induced second-harmonic
 (EFISH) measurements, 532
 electric field operator, 449
 electrical poling, 528
 electrically poled organic material, 529
 electromagnetic cloak, 21
 electromagnetic effect, 83
 electromagnetically induced
 transparency (EIT), 658–659, 665,
 671–672
 electron-beam pumping, 387
 electronic energy transfer (EET), 440
 electro-optic (EO) device, 525
 electro-optic (EO) tensor, 528
 — principal element of, 529
 electrostatic eigenvalue (EE) approach,
 119
 electrostatic resonance, 111
 elliptical Bragg resonator, 146
 elliptical polarization, 137

elliptically polarized basis vectors, 136
emission cross section, 361
energy density enhancement, 11
energy funnel, 465
etalons, 556
exchange and correlation (XC), 509
excitation transfer function, 455
eye opening, 664

F

Fabry-Perot resonator, 361
Fano mode, 68
Faraday's law, 402
fast light, 652–654,
— causality and, 652, 665–668
— due to absorption line, 655–657
feedback intensity, 306
femtosecond-time-resolution wave-
length-agile hyper-Rayleigh-scattering
(HRS), 532
Fermi (distribution) function, 483, 511
ferromagnetic, 58
Feynman diagram, 449–450, 468
field matrix, 136
finesse, 341
first hyperpolarizability, 556
fluorescence anisotropy, 457
fluorescence lifetime, 443
fluorescence resonance energy transfer
(FRET), 445, 469
Förster distance, 444
Förster equation, 442
Fourier-transform interferometry (FTI),
674
four-level scheme, 368
four-level system, 425
fractional advancement, 664
fractional delay, 664–665
frequency scan technique, 117
fringe patterns, 363
front velocity, 665, 668
FTC-type chromophore, 537
fully atomized Monte Carlo/molecular
dynamic methods, 535

G

gain, 526
gain length, 303–304

gain medium, 360, 400–401, 405, 425,
427–429
Gaussian disorder model (GDM), 577
Gaussian statistics, 294
generalized eigenvalue differential
equation (GEDE), 120
generation length, 307
gray group, 84
Green's function, 125
group delay, 651–652, 664, 668
group index, 652–654, 663–664
group velocity, 648, 652, 657, 664–665,
668
group velocity dispersion (GVD), 652,
664
guest–host intermolecular electrostatic
interactions, 545

H

handedness, 133
heavy-tailed, 292
Heisenberg time, 265
Hermitian, 184
Herpin period, 143
higher-order dispersion, 652, 664
highest occupied molecular orbit
(HOMO), 490, 511, 577
holograms, 625
holographic diffuser, 638
Hooke's law, 581
horseshoe nanoantenna, 401, 404–405,
418, 422, 424, 427
horseshoe nanolaser, 426
horseshoe resonator, 401, 419, 425–426
hyperbolic dispersion relation, 37
hyperlens, 43

I

i-type tensor, 85–88, 98–99
image buffering, 672
image processing, 672
impedance spectroscopy, 580
incoherent feedback, 302, 305, 313
inductive energy, 113
information velocity, 665, 668
insertion loss, 555
interferometer, 673–674
intramolecular vibrational redistribution
(IVR), 465

inverse opals, 201
 invisibility cloak, 21
 Ioffe-Regel criterion, 233, 372, 382, 391

J

Jaynes-Cummings Model (JCM), 494
 jitter, 669–670

K

Kerr effect, 58
 — nonlinear, 83
 Kerr rotation, 64
 Kramers-Kronig relations, 652, 654–655,
 663, 666
 Kretschmann-Raether configuration, 67

L

ladder operator, 449
 lanthanides, 459
 laser, 302
 laser paint, 315–316
 laser speckle, 638
 lasing, 422, 426, 428
 lasing frequency, 425
 lasing threshold, 312, 379
 lattice hardening, 548
 left-handed, 8
 level spacing, 245
 level width, 244
 Lévy statistics, 290–294
 lidar, 672
 light confinement, 320
 light harvesting, 445, 463
 light localization, 317, 371
 linear electro-optic effect, 562
 linear polarizability, 560
 local density approximation (LDA), 491,
 508
 local field effect, 486
 localization length, 239, 246, 594
 localization threshold, 245
 localization transition, 231
 longitudinal dielectric function, 485
 longitudinal response, 482
 Lorentz model, 655
 loss factor, 406, 409, 420, 428
 low-coherence stimulated emission, 377
 lowest unoccupied molecular orbit
 (LUMO), 491, 511, 554, 577

lucky photons, 369

M

Mach-Zender modulator, 555
 macroscopic potential, 118
 magnetic dipole transition, 83
 magnetic moment, 406, 412, 426–427
 magnetic nanoantenna, 401
 magnetic permeability, 404–405, 413
 magnetic plasmon, 422
 magnetic plasmon resonance (MRP),
 399, 405, 417, 429
 magnetic point group, 82
 magnetic polarizability, 400, 412
 magnetization-induced second-harmonic
 generation (MSHG), 82
 magnetization-induced third-harmonic
 generation (MTHG), 96
 magneto-optics, 57–58
 — nonlinear, 82
 master equation, 183
 mean free path, 249, 281, 303
 mean path length, 307
 mean scattering length, 365
 metamaterial, 14, 626–627, 629
 — subwavelength magnetically active,
 109
 microlaser, 378
 mobility edges, 234
 mode, 278–280, 362
 — extended, 280
 — localized, 280, 372, 382
 — longitudinal, 362
 — spatially confined, 379
 — transversal, 362
 molecular first hyperpolarizability, 527
 Monte Carlo simulations, 285
 Mott states, 239
 multichromophore-containing
 dendrimers, 537
 multimode laser, 363
 multiple scattering, 230, 365

N

nano-imprint, 555
 nanolaser, 405
 — horseshoe, 426
 — plasmonic, 422, 429
 nanoparticles, 321, 324

nanorods, 320–321
near-field, 452
necklace states, 239
negative absorption, 365
negative capacitance, 580–581
negative phase velocity, 2, 9
negative propagation, 18
negative refraction, 8–10, 36, 37
negative space, 21
nonlinear Kerr effect, 83
nonlinear magneto-optics, 82
nonlinear optical coefficients, 81
nonlinear polarization, 561
nonlinearity enhancement, 659, 663, 672–673
nonresonant feedback, 302, 306, 323, 335, 360, 366
normal dispersion, 652

O

opals, 201
optical delay line, 669
optical-electrical-optical (OEO)
 conversion, 669
optical fibers, 659–661
optical frequency standards, 363
optical logic, 673
optical magnetism, 427
optical memory, 664, 671–672
optical networking, 664, 669–670, 673
optical pumping, 387
optical rectification, 556
optical switching, 673
optical transistor, 467
optical vortex, 158
optically controlled resonance energy
 transfer (OCRET), 467–468
orbital angular momentum, 158
organic electro-optic (EO) materials, 526
organic light-emitting diode (OLED),
 440
output mirror, 361

P

π -electron molecules, 526
painted-on laser, 315
particle-in-the-box problem, 489
penetration depth, 367

perfect lens, 14
permittivity matrix, 134
perturbation theory, 512
phase matrix, 137–138
phase singularity, 157, 256–258
phase velocity, 648–649
phased-array radar, 672
phonon side band, 442
photon diffusion, 309
photon localization lasers, 304, 360
photon migration lasers, 360
photon number distribution, 380
photon statistics, 278, 323, 380–381
photonic band gap, 180
photonic crystal (PC, PhC), 180, 496, 662–663, 673
photonic paint, 315
photostability figure of merit, 554
photosynthesis, 463
plane wave expansion (PWE), 222
plasmonic effects, 109
plasmonic nanolaser, 422, 429
plasmonic parameter, 113
plasmonic regime, 113
plasmonic resonance, 124
Pockels effect, 562
point group, 81
Poisson distribution, 323
Poisson equation, 516
Poisson statistics, 338, 381
polaritons, 453
polarization, 559, 626
 — nonlinear, 561
polarization density, 654
polarization function, 484, 516
polaron, 576
population inversion, 360, 390, 401, 424
Poynting fluxes, 139
principle refractive indices, 133
prism device structure, 556
probability of return, 231–232
pseudo-atomistic Monte Carlo
 calculations, 529, 535
pseudo-Brewster effect, 60
pulse broadening, 663
pulse compression, 663
pulse distortion, 652, 656, 660, 663–666
pulse spatial compression, 657
pulse velocity, 648–649, 652

Q

quality Q factor, 556
 quantized light field, 494
 quantum coherence, 658, 671
 quantum confinement, 491
 quantum cutting, 461
 quantum dots, 400, 401, 419, 429, 462, 469, 491
 quantum electrodynamics (QED), 448
 quantum well, 428
 quantum yield of emission, 367
 quasi-concentric resonator, 363

R

Rabi oscillations, 495
 radar, 672
 radiationless energy transfer, 442
 radiative energy transfer, 442
 radiative loss, 416–417
 Raman scattering, 499
 random fields, 169
 random laser
 — neodymium, 360, 383
 — nonlinear, 341
 — partially ordered, 340–341
 — simulation of, 327
 — solid state, 316
 — ZnO, 384
 random medium, 331
 rare-earth manganite, 88
 rate equation, 306, 310
 rate of exciton formation, 605
 Rayleigh-Jeans formula, 383
 Rayleigh scattering, 372
 reconfigurable optical add/drop multiplexer/demultiplexer (ROADM), 556
 reflection coefficient, 138–139
 reflection hologram, 628
 refractive index, 2, 649, 650, 652, 654–655
 relativity, 665–668
 relaxation oscillations, 366, 368, 390
 relaxation parameter, 419–420, 425
 resonance, 655–656, 661
 resonance energy transfer (RET), 440
 resonant feedback, 302, 306, 323, 335
 resonator
 — elliptical Bragg, 146

— Fabry-Perot, 361
 — horseshoe, 401, 419, 425–426
 — quasi-concentric, 363
 — stochastic, 377, 383, 390
 retarded electric field, 451
 ring microresonators, 555, 556
 rms width of the density of states, 591
 rotation angles, 133
 rotation matrices, 134
 rotation-sensing interferometer, 674
 Rydberg atom, 495

S

saturable absorption, 659
 scattering length, 377
 scattering system, 321
 second-harmonic generation (SHG), 81
 second hyperpolarizability, 556
 second-order nonlinear effects, 561
 second-order nonlinear materials, 528
 second-order nonlinear polarization, 561
 Seebeck effect, 595
 semiconductors, 659, 661
 sensitization, 461
 signal velocity, 668
 silicon photonic devices, 555
 single-mode coherent light (see coherent)
 single-shot emission spectra, 336–338
 slow light, 42, 652, 654–657, 659–663, 672–674
 — due to gain line, 655–656
 slowing factor, 663
 soft lithography techniques, 555
 sol gel glass materials, 547
 solid state random lasers, 316
 space masers, 371
 spatial confinement, 280, 330
 spatial light modulator (SLM), 163
 spatial pulse compression, 657
 speckle pattern, 169, 230, 258, 283–285, 363, 377, 389
 spectral interferometer, 673
 spectral overlap, 458, 465
 spectroscopic gradient, 445, 463, 465–466
 spectroscopic ruler, 446
 spectrum, 626
 spin coherence, 654, 671
 spiral phase plate (SPP), 162

spontaneously emitted photons, 361
 state-sequence diagram, 449–450, 461
 stimulated Brillouin scattering (SBS),
 stimulated emission, 360
 stimulated emission spectrum, 314
 stimulated emission with feedback, 387
 660–661, 665
 stimulated Raman scattering (SRS),
 660–661
 stochastic resonator, 377, 383, 390
 stopped light, 654, 671–672
 storage lifetime, 664, 671
 strip pair-one film (SPOF), 114
 strong coupling, 494
 subwavelength imaging, 46
 sum frequency generation, 562
 superexchange mechanism, 442
 superluminal communication, 653,
 666–667
 superluminal propagation, 653, 665–667
 superposition of multiple plane waves,
 164
 surface-enhanced Raman scattering
 (SERS), 502, 504
 surface plasma-polariton, 66
 surface plasmon, 76
 surface plasmon resonance (SPR), 398,
 489
 surface states, 491
 surface waves, 66
 susceptibility, 654–656, 666
 system matrix, 138

T

Talbot effect, 169
 Telcordia standards, 549
 temporal evolution of emission, 323
 Teng-Man apparatus, 533
 terahertz electromagnetic generation and
 detection, 556
 Thomas and Fermi (TF), 507
 Thouless criterion, 304, 372, 383, 391
 Thouless number, 331
 Thouless time, 265
 threshold, 381–382
 threshold condition, 305
 threshold gain, 313, 326–327, 332,
 335, 365
 threshold population inversion, 362

time-dependent density functional theory
 (TD-DFT), 529
 time of flight distributions, 257
 transient spectroscopy, 590
 transition dipole coupling, 446
 transmission coefficient, 138–139
 transmission hologram, 628
 transport mean free path, 307, 312,
 313, 365
 transport site, 576
 transversal dielectric function, 484
 transversal response, 482
 transverse electric (TE) light, 563
 transverse localization, 242
 transverse magnetic (TM) light, 563
 true time delay, 672
 tunneling, 668
 two-level amplifying system (TLS), 400

U

uncertainly principle, 450
 unified theory, 454
 united atom approximation, 535
 universality of photocurrent transients,
 583
 up-conversion, 459, 461

V

Veselago lens, 15
 virtual photon, 449, 452
 voltage-induced change in index of
 refraction, 562
 voltage-induced phase shift of light, 562
 vortex
 — generation of, 162
 — simulation of, 167
 vortex hairpins, 167
 vortex lines
 — knotted, 166
 — topology of, 159, 164–165, 169–170
 vortex loops, 166
 vortex structures, 172
 vorticity, 259

W

wave function, 483
 waveguide dispersion, 661
 wavelength conversion, 673

wavelength routing, 673
weak localization, 231
Wigner time delay, 252
whispering-galley mode, 319
white-light cavity, 675

X

x rays, 190–191, 342, 485
x-ray laser, 342

Y

Yablonovitch, Eli, 200
YAG laser, 100, 281, 321, 377–378
Young's double-slit interferometry, 309

Z

zero temperature, 482, 483, 507–508
zone plate, Fresnel, 162