Table of Contents

Foreword
Introduction
List of Contributors
1 Negative Refraction

Martin W. McCall and Graeme Dewar

1.1 Introduction
1.2 Background
1.3 Beyond natural media: waves that run backwards
1.4 Wires and rings
1.5 Experimental confirmation
1.6 The perfect lens
1.7 The formal criterion for achieving negative phase velocity propagation
1.8 Fermat's principle and negative space
1.9 Cloaking
1.10 Conclusions
1.11 Appendices
Appendix I: The $\varepsilon(\omega)$ of a square wire array
Appendix II: Physics of the wire array's plasma frequency and damping rate
References
2 Optical Hyperspace: Negative Refractive Index and Subwavelength Imaging

Leonid V. Alekseyev, Zubin Jacob, and Evgenii Narimanov

2.1 Introduction
2.2 Nonmagnetic Negative Refraction
2.3 Hyperbolic Dispersion: Materials
2.4 Applications
2.4.1 Waveguides
2.4.2 The hyperlens
2.4.2.1 Theoretical description
2.4.2.2 Imaging simulations
2.4.2.3 Semiclassical treatment
2.5 Conclusion

References
3 Magneto-optics and the Kerr Effect with Ferromagnetic Materials

Allan D. Boardman and Neil King

3.1 Introduction to Magneto-optical Materials and Concepts
3.2 Reflection of Light from a Plane Ferromagnetic Surface
3.2.1 Single-surface polar orientation
3.2.2 Kerr rotation
3.3 Enhancing the Kerr Effect with Attenuated Total Reflection
3.4 Numerical Investigations of Attenuated Total Reflection
3.5 Conclusions
References
4 Symmetry Properties of Nonlinear Magneto-optical Effects

Yutaka Kawabe

4.1 Introduction
4.2 Nonlinear Optics in Magnetic Materials
4.3 Magnetic-field-induced SHG
4.4 Effects Due to an Optical Magnetic Field or Magnetic Dipole Moment Transition
4.5 Experiments
References
5 Optical Magnetism in Plasmonic Metamaterials

Gennady Shvets and Yaroslav A. Urzhumov

5.1 Introduction
5.2 Why Is Optical Magnetism Difficult to Achieve?
5.3 Effective Quasistatic Dielectric Permittivity of a Plasmonic Metamaterial
5.3.1 The capacitor model
5.3.2 Effective medium description through electrostatic homogenization
5.3.3 Eigenvalue expansion approach
5.4 Summary
Appendix: Electromagnetic red shifts of plasmonic resonances
References
6 Chiral Photonic Media

Ian Hodgkinson and Levi Bourke

6.1 Introduction
6.2 Stratified Anisotropic Media
6.2.1 Biaxial material
6.2.2 Propagation and basis fields
6.2.3 Field transfer matrices
6.2.4 Reflectance and transmittance
6.3 Chiral Architectures and Characteristic Matrices
6.3.1 Five chiral architectures
6.3.2 Matrix for a continuous chiral film
6.3.3 Matrix for a biaxial film
6.3.4 Matrix for an isotropic film
6.3.5 Matrix for a stack of films
6.3.6 Matrices for discontinuous and structurally perturbed films
6.3.7 Herpin effective birefringent media
6.4 Reflectance Spectra and Polarization Response Maps
6.4.1 Film parameters
6.4.2 Standard–chiral media
6.4.3 Remittance at the Bragg wavelength
6.4.4 Modulated–chiral media
6.4.5 Chiral–isotropic media
6.4.6 Chiral–birefringent media
6.4.7 Chiral–chiral media
6.5 Summary
References
7 Optical Vortices

Kevin O'Holleran, Mark R. Dennis, and Miles J. Padgett

7.1 Introduction
7.2 Locating Vortex Lines
7.3 Making Beams Containing Optical Vortices
7.4 Topology of Vortex Lines
7.5 Computer Simulation of Vortex Structures
7.6 Vortex Structures in Random Fields
7.7 Experiments for Visualizing Vortex Structures
7.8 Conclusions
References
8 Photonic Crystals: From Fundamentals to Functional Photonic Opals

Durga P. Aryal, Kosmas L. Tsakmakidis, and Ortwin Hess

8.1 Preface
8.2 Principles of Photonic Crystals
8.2.1 Electromagnetism of periodic dielectrics
8.2.2 Maxwell's equations
8.2.3 Bloch's theorem
8.2.4 Photonic band structure
8.3 One-Dimensional Photonic Crystals
8.3.1 Bragg's law
8.3.2 One-dimensional photonic band structure
8.4 Generalization to Two-Dimensional and Three-Dimensional Photonic Crystals
8.4.1 Two-dimensional photonic crystals
8.4.2 Three-dimensional photonic crystals
8.5 Physics of Inverse-Opal Photonic Crystals
8.5.1 Introduction
8.5.2 Inverse opal with moderate-refractive-index contrast
8.5.3 Toward a higher-refractive-index contrast
8.6 Tuning and Switching the Photonic Band Gap
8.6.1 Introduction: double-inverse-opal photonic crystals
8.6.2 Photonic band gap switching via symmetry breaking
8.6.3 Tuning of the partial photonic band gap
8.6.4 Switching of the complete photonic band gap
8.7 Conclusion
Appendix
References
9 Wave Interference and Modes in Random Media

Azriel Z. Genack and Sheng Zhang

9.1 Introduction
9.2 Wave Interference
9.2.1 Weak localization
9.2.2 Coherent backscattering
9.3 Modes
9.3.1 Quasimodes
9.3.2 Localized and extended modes
9.3.3 Statistical characterization of localization
9.3.4 Time domain

9.3.5 Speckle
9.4 Conclusion
References
10 Chaotic Behavior of Random Lasers

Diederik S. Wiersma, Sushil Mujumdar, Stefano Cavalieri, Renato Torre, Gian-Luca Oppo, and Stefano Lepri

10.1 Introduction
10.1.1 Multiple scattering and random lasing
10.1.2 Mode coupling
10.2 Experiments on Emission Spectra
10.2.1 Sample preparation and setup
10.2.2 Emission spectra
10.3 Experiments on Speckle Patterns
10.4 Modeling
10.4.1 Monte Carlo simulations
10.4.2 Results and interpretation
10.5 Lévy Statistics in Random Laser Emission
10.6 Discussion
References
11 Lasing in Random Media

Hui Cao

11.1 Introduction
11.1.1 "LASER" versus "LOSER"
11.1.2 Random lasers
11.1.3 Characteristic length scales for the random laser
11.1.4 Light localization
11.2 Random Lasers with Incoherent Feedback
11.2.1 Lasers with a scattering reflector
11.2.2 The photonic bomb
11.2.3 The powder laser
11.2.4 Laser paint
11.2.5 Further developments
11.3 Random Lasers with Coherent Feedback
11.3.1 "Classical" versus "quantum" random lasers
11.3.2 Classical random lasers with coherent feedback

11.3.3 Quantum random lasers with coherent feedback
11.3.3.1 Lasing oscillation in semiconductor nanostructures
11.3.3.2 Random microlasers
11.3.3.3 Collective modes of resonant scatterers
11.3.3.4 Time-dependent theory of the random laser
11.3.3.5 Lasing modes in diffusive samples
11.3.3.6 Spatial confinement of lasing modes by absorption
11.3.4 Amplified spontaneous emission (ASE) spikes versus lasing peaks
11.3.5 Recent developments
11.4 Potential Applications of Random Lasers
References
12 Feedback in Random Lasers

Mikhail A. Noginov

12.1 Introduction
12.2 Concept of a Laser
12.3 Lasers with Nonresonant Feedback and Random Lasers
12.4 Photon Diffusion and Localization in Scattering Media and Their Applications to Random Lasers
12.4.1 Diffusion
12.4.2 Prediction of stimulated emission in a random laser operating in the diffusion regime
12.4.3 Modeling of stimulated emission dynamics in neodymium random lasers
12.4.4 Stimulated emission in a one-dimensional array of coupled lasing volumes
12.4.5 Random laser feedback in a weakly scattering regime: space masers and stellar lasers
12.4.6 Localization of light and random lasers
12.5 Neodymium Random Lasers with Nonresonant Feedback
12.5.1 First experimental observation of random lasers
12.5.2 Emission kinetics in neodymium random lasers
12.5.3 Analysis of speckle pattern and coherence in neodymium random lasers
12.6 ZnO Random Lasers with Resonant Feedback
12.6.1 Narrow modes in emission spectra
12.6.2 Photon statistics in a ZnO random laser
12.6.3 Modeling of a ZnO random laser
12.7 Stimulated Emission Feedback: From Nonresonant to Resonant and Back to Nonresonant

12.7.1 Mode density and character of stimulated emission feedback
12.7.2 Transition from the nonresonant to the resonant regime of operation
12.7.3 Nonresonant feedback in the regime of ultrastrong scattering: electron–beam–pumped random lasers
12.8 Summary of Various Random Laser Operation Regimes
12.8.1 Amplification in open paths: the regime of amplified stimulated emission without feedback
12.8.2 Extremely weak feedback
12.8.3 Medium–strength feedback: diffusion
12.8.4 The regime of strong scattering
References
13 Optical Metamaterials with Zero Loss and Plasmonic Nanolasers

Andrey K. Sarychev

13.1 Introduction
13.2 Magnetic Plasmon Resonance
13.3 Electrodynamics of a Nanowire Resonator
13.4 Capacitance and Inductance of Two Parallel Wires
13.5 Lumped Model of a Resonator Filled with an Active Medium
13.6 Interaction of Nanontennas With an Active Host Medium
13.7 Plasmonic Nanolasers and Optical Magnetism
13.8 Conclusions
References
14 Resonance Energy Transfer: Theoretical Foundations and Developing Applications

David L. Andrews

14.1 Introduction
14.1.2 The nature of condensed phase energy transfer
14.1.3 The Förster equation
14.1.4 Established areas of application
14.2 Electromagnetic Origins
14.2.1 Coupling of transition dipoles
14.2.2 Quantum electrodynamics
14.2.3 Near– and far–field behaviour
14.2.4 Refractive and dissipative effects
14.3 Features of the Pair Transfer Rate
14.3.1 Distance dependence

14.3.2 Orientation of the transition dipoles
14.3.3 Spectral overlap
14.4 Energy Transfer in Heterogeneous Solids
14.4.1 Doped solids
14.4.2 Quantum dots
14.4.3 Multichromophore complexes
14.5 Directed Energy Transfer
14.5.1 Spectroscopic gradient
14.5.2 Influence of a static electric field
14.5.3 Optically controlled energy transfer
14.6 Developing Applications
14.7 Conclusion
References
15 Optics of Nanostructured Materials from First Principles

Vladimir I. Gavrilenko

15.1 Introduction
15.2 Optical Response from First Principles
15.3 Effect of the Local Field in Optics
15.3.1 Local field effect in classical optics
15.3.2 Optical local field effects in solids from first principles
15.4 Electrons in Quantum Confined Systems
15.4.1 Electron energy structure in quantum confined systems
15.4.2 Optical functions of nanocrystals
15.5 Cavity Quantum Electrodynamics
15.5.1 Interaction of a quantized optical field with a two-level atomic system
15.5.2 Interaction of a quantized optical field with quantum dots
15.6 Optical Raman Spectroscopy of Nanostructures
15.6.1 Effect of quantum confinement
15.6.2 Surface-enhanced Raman scattering: electromagnetic mechanism
15.6.3 Surface-enhanced Raman scattering: chemical mechanism
15.7 Concluding Remarks
Appendix A: Electron Energy Structure and Standard Density Functional Theory
Appendix B: Optical Functions within the Perturbation Theory
Appendix C: Evaluation of the Polarization Function Including the Local Field Effect
Appendix D: Optical Field Hamiltonian in Second Quantization Representation
References
16 Organic Photonic Materials

Larry R. Dalton, Philip H. Sullivan, Denise H. Bale, Scott R. Hammond, Benjamin C. Olbrict, Harrison Rommel, Bruce Eichinger, and Bruce H. Robinson

16.1 Preface
16.2 Introduction
16.3 Effects of Dielectric Permittivity and Dispersion
16.4 Complex Dendrimer Materials: Effects of Covalent Bonds
16.5 Binary Chromophore Organic Glasses
16.5.1 Optimizing EO activity and optical transparency
16.5.2 Laser-assisted poling (LAP)
16.5.3 Conductivity issues
16.6 Thermal and Photochemical Stability: Lattice Hardening
16.7 Thermal and Photochemical Stability: Measurement
16.8 Devices and Applications
16.9 Summary and Conclusions
Appendix: Linear and Nonlinear Polarization
References
17 Charge Transport and Optical Effects in Disordered Organic Semiconductors

Harry H. L. Kwok, Tai-Ping Sun, and You-Lin Wu

17.1 Introduction
17.2 Charge Transport
17.2.1 Energy bands
17.2.2 Dispersive charge transport
17.2.3 Hopping mobility
17.2.4 Density of states
17.3 Impedance Spectroscopy: Bias and Temperature Dependence
17.4 Transient Spectroscopy
17.5 Thermoelectric Effect
17.6 Exciton Formation
17.7 Space-Charge Effect
17.8 Charge Transport in the Field-Effect Structure
References
18 Holography and Its Applications

H. John Caulfield and Chandra S. Vikram

18.1 Introduction

18.2 Basic Information on Holograms
18.2.1 Hologram types
18.3 Recording Materials for Holographic Metamaterials
18.4 Computer-Generated Holograms
18.5 Simple Functionalities of Holographic Materials
18.6 Phase Conjugation and Holographic Optical Elements
18.7 Related Applications and Procedures
18.7.1 Holographic photolithography
18.7.2 Copying of holograms
18.7.3 Holograms in nature and general products
References
In Memoriam: Chandra S. Vikram
19 Slow and Fast Light

Joseph E. Vornehm, Jr. and Robert W. Boyd

19.1 Introduction
19.1.1 Phase velocity
19.1.2 Group velocity
19.1.3 Slow light, fast light, backward light, stopped light
19.2 Slow Light Based on Material Resonances
19.2.1 Susceptibility and the Kramers-Kronig relations
19.2.2 Resonance features in materials
19.2.3 Spatial compression
19.2.4 Two-level and three-level models
19.2.5 Electromagnetically induced transparency (EIT)
19.2.6 Coherent population oscillation (CPO)
19.2.7 Stimulated Brillouin and Raman scattering
19.2.8 Other resonance-based phenomena
19.3 Slow Light Based on Material Structure
19.3.1 Waveguide dispersion
19.3.2 Coupled-resonator structures
19.3.3 Band-edge dispersion
19.4 Additional Considerations
19.4.1 Distortion mitigation
19.4.2 Figures of merit
19.4.3 Theoretical limits of slow and fast light
19.4.4 Causality and the many velocities of light
19.5 Potential Applications

19.5.1 Optical delay lines
19.5.2 Enhancement of optical nonlinearities
19.5.3 Slow- and fast-light interferometry
References

Index