Vladimir M. Shalaev

Nonlinear Optics of Random Media

Fractal Composites
and Metal-Dielectric Films

With 51 Figures

Springer

Contents

1. Electromagnetic Properties of Random Composites.	
A Review of Basic Approaches	1
1.1 Introduction to Random Media: Fractals, Self-Affine Surfaces and Percolation Composites	1
1.2 Mean-Field Theories and Numerical Techniques	5
1.3 Spectral Representation	9
1.4 Critical Behavior of Conductivity and Dielectric Function in the Percolation Model	10
2. Surface-Enhanced Nonlinear Optical Phenomena	15
2.1 Introduction	15
2.2 Surface-Enhanced Optical Responses	17
2.2.1 Kerr Optical Nonlinearity	17
2.2.2 Four-Wave Mixing	18
2.2.3 Raman Scattering	19
2.2.4 High-Order Harmonic Generation	19
3. Small-Particle Fractal Aggregates	21
3.1 Introduction	21
3.2 Basic Theoretical Approaches	24
3.2.1 Coupled Dipoles	24
3.2.2 Polarizability of a Monomer	26
3.2.3 Eigenmode Expansion	27
3.2.4 Quasi-Static Approximation	29
3.3 Absorption Spectra of Fractal Aggregates	33
3.4 Local-Field Enhancement in Fractals	38
3.5 Near-Field Imaging and Spectroscopy of Hot Spots	41
3.6 Surface-Enhanced Optical Nonlinearities in Fractals	46
3.6.1 Qualitative Consideration and Estimates	46
3.6.2 Enhanced Raman and Rayleigh Scattering	48
3.6.3 Nearly Degenerate Four-Wave Mixing	53
3.6.4 Optical Kerr Effect	60
3.7 Local Photomodification in Fractals	64
3.8 Fractals in Microcavities	69

4. Self-Affine Thin Films	75
4.1 General Approach	75
4.2 Linear Optical Properties	78
4.3 Enhanced Optical Phenomena on Self-Affine Surfaces	81
4.3.1 Raman Scattering	82
4.3.2 Second-Harmonic Generation	84
4.3.3 Third-Harmonic Generation	89
4.3.4 Kerr Optical Nonlinearity and Four-Wave Mixing	93
4.4 Nano-Optics of Fractal Aggregates Deposited on a Surface	95
4.4.1 Sample Preparation and Numerical Simulations	95
4.4.2 Fractal-Surface-Enhanced Nonlinear Nano-Optics	96
5. Random Metal-Dielectric Films	101
5.1 Introduction	101
5.2 Giant Field Fluctuations	104
5.2.1 Linear Response	105
5.2.2 Nonlinear Response	107
5.2.3 Numerical Model	111
5.2.4 Field Distributions	113
5.3 Scaling Theory for High-Order Field Moments	118
5.3.1 Percolation and Anderson Transition Problem	118
5.3.2 Resonance Excitations at $\epsilon_d = -\epsilon'_m$	120
5.3.3 Scaling Renormalization and Collective Resonances at $ \epsilon_m /\epsilon_d \gg 1$	124
5.3.4 Comparison of Surface-Enhanced Phenomena in Fractal and Percolation Composites	130
5.4 Some Experimental Results	134
5.4.1 Near-Field Nano-Optics	134
5.4.2 Surface-Enhanced Raman Scattering	137
5.4.3 Kerr Optical Nonlinearity and White-Light Generation	139
5.5 Percolation-Enhanced Nonlinear Scattering	141
References	149
Index	157