

Contents

1 Introduction	1
P. Günter	
References	5
2 Third-Order Nonlinear Optics in Polar Materials	7
Ch. Bosshard	
2.1 Introduction	7
2.1.1 Motivation	7
2.1.2 Basic Concept of Cascading	9
2.1.3 Definition of Nonlinear Optical Coefficients	10
2.1.4 Materials Requirements for All-Optical Signal Processing	17
2.2 Optical Nonlinearities	18
2.2.1 Organic Nonlinear Optical Materials	18
2.2.2 Macroscopic Second-Order Nonlinear Optical Effects	29
2.2.3 Macroscopic Third-Order Nonlinear Optical Effects	41
2.3 Cascaded Second-Order Nonlinearities $\chi^{(2)} : \chi^{(2)}$	44
2.3.1 Second-Harmonic Generation	
and Sum-Frequency Generation	44
2.3.2 Cascading Through the Reaction Field	
in Centrosymmetric Media	45
2.3.3 Cascading Through the Local Field	47
2.3.4 Second-Harmonic Generation	
and Difference Frequency Mixing	48
2.3.5 Optical Rectification and Linear Electro-Optic Effect	51
2.3.6 Limits of the Cascaded Response in Molecular Crystals	54
2.4 Nonlinear Optical Molecules	56
2.4.1 Third-Harmonic Generation	56
2.4.2 Electric Field-Induced Second-Harmonic Generation	77
2.5 Nonlinear Optical Single Crystals	93
2.5.1 Third-Harmonic Generation	93
2.5.2 z -Scan Technique	106
2.6 Discussion and Conclusion	114
2.6.1 Second- and Third-Harmonic Generation	114
2.6.2 Cascaded $\chi^{(2)} : \chi^{(2)}$ for the Optical Kerr Effect	119
2.6.3 Final Remarks and Outlook	136

Appendix	137
A.1 Definition of Nonlinear Optical Susceptibilities	137
A.2 Conversion Between SI, cgs and Atomic Units	139
A.3 Theoretical Description of Third-Harmonic Generation	142
A.4 Theoretical Description of Electric Field-Induced Second-Harmonic Generation	148
A.5 Theoretical Description of the z -Scan Technique	149
A.6 List of Symbols and Abbreviations	151
References	153
 3 Second-Order Nonlinear Optical Organic Materials: Recent Developments	163
Ch. Bosshard, M. Bösch, I. Liakatas, M. Jäger, and P. Günter	
3.1 Nonlinear Optical and Electro-Optic Effects	163
3.1.1 Sum Frequency Generation and Optical Frequency Doubling ..	164
3.1.2 Difference Frequency Generation and Optic Parametric Oscillation/Generation	165
3.1.3 Conservation of Energy and Momentum	165
3.1.4 Linear Electro-Optic Effect	166
3.2 Material Considerations	167
3.2.1 Dispersion of the Nonlinear and Electro-Optic Coefficients ...	168
3.2.2 Symmetry Considerations for Second-Order Nonlinear Optical Materials	168
3.3 Organic Nonlinear Optical Molecules	169
3.3.1 Measurement Techniques	171
3.3.2 Discussion of Second-Order Nonlinear Optical Molecules	180
3.4 Nonlinear and Electro-Optic Single Crystals and Polymers	195
3.4.1 Measurement Techniques	195
3.4.2 Single Crystals	198
3.4.3 Poled Polymers	231
3.4.4 Inorganic Dielectrics and Semiconductors	248
3.5 Applications	252
3.5.1 Optical Frequency Conversion	252
3.5.2 Short-Pulse Laser Applications	255
3.5.3 Polymer-Based Electro-Optic Modulators	258
3.5.4 Electro-Optic Sampling	274
3.5.5 THz Generation	276
3.5.6 Thermo-Optic Switches	277
3.6 Stability of Nonlinear and Electro-Optic Materials and Their Properties	280
3.6.1 Optical Damage Threshold	280
3.6.2 Orientational Relaxation of Poled Polymers	282
3.7 Concluding Remarks and Outlook	285
References	286

4 The Photorefractive Effect in Inorganic and Organic Materials	301
G. Montemezzani, C. Medrano, M. Zgonik, and P. Günter	
4.1 Photoinduced Changes of Optical Properties and Photorefractive Effect	301
4.2 Charge Transport in Inorganic and Organic Materials	304
4.2.1 Band Transport	304
4.2.2 Hopping Transport	306
4.2.3 Geminate Recombination	308
4.3 Model Descriptions of the Photorefractive Effect and Photoassisted Orientational Gratings	309
4.3.1 Band Model of the Photorefractive Effect	310
4.3.2 Model for the Space Charge Fields in Polymers	320
4.4 Electro-Optic Response	326
4.4.1 Pockels Effect	326
4.4.2 Lattice Distortions and Electro-Optics	327
4.4.3 Molecular Reorientation	332
4.5 Measurement Techniques	336
4.5.1 Two-Wave Mixing	337
4.5.2 Bragg Diffraction	339
4.6 Applications	342
4.6.1 Thick Volume Gratings	342
4.6.2 Thin Gratings	346
4.6.3 Materials Requirements and Figures of Merit	347
4.7 Materials	349
4.7.1 Photorefractive Materials	349
4.7.2 Polymers and Liquid Crystals Showing Photorefractive and Photoassisted Orientational Gratings	355
4.7.3 Wavelength Sensitivity	361
4.7.4 Comparison of Materials Properties	362
4.8 Conclusions	365
References	367
5 Photorefractive Memories for Optical Processing	375
M. Duelli, G. Montemezzani, M. Zgonik, and P. Günter	
5.1 Volumetric Optical Data Storage	377
5.1.1 Light Diffraction Volume Gratings	377
5.1.2 Hologram Multiplexing Methods	381
5.1.3 System Architecture	385
5.1.4 Storage Capacity of Volume Media	386
5.2 Optical Pattern Recognition	393
5.2.1 Optical Correlators	393
5.2.2 Optical Pattern Recognition Using Volume Holograms	397
5.3 Holographic Associative Memories	404
5.3.1 Linear Holographic Associative Memories	404

5.3.2 Nonlinear Holographic Associative Memories	405
5.3.3 Ring Resonator Associative Memories	408
5.4 Photorefractive Materials as Volume Storage Media	409
5.4.1 Recording Schemes	410
5.4.2 Storage Capacity of Photorefractive Holographic Media	414
5.4.3 Hologram Fixing and Nondestructive Readout	418
5.4.4 Coherent Erasure and Updating of Holograms	420
5.5 Optical Correlators Using Photorefractive Crystals	421
5.6 All-optical Nonlinear Associative Memories	423
5.6.1 Thin Storage Media Implementations	423
5.6.2 Volume Storage in Associative Memories	424
5.7 Summary	430
References	431
6 Second-Harmonic Generation in Ferroelectric Waveguides .	437
T. Pliska, D. Fluck, and P. Günter	
6.1 Second-Harmonic Generation in Waveguides: Basic Concepts	437
6.1.1 Planar and Channel Waveguides	438
6.1.2 Figures of Merit for Second-Harmonic Generation in Waveguides	440
6.1.3 Phase Matching Schemes for Second-Harmonic Generation in Waveguides	447
6.2 Ferroelectric Waveguides: Overview	456
6.3 Lithium Niobate Waveguides	458
6.3.1 Titanium-Indiffused Lithium Niobate Waveguides	459
6.3.2 Proton-Exchanged Lithium Niobate Waveguides	460
6.3.3 Domain Inversion and Quasi-Phase-Matching in Lithium Niobate	467
6.3.4 Optical Damage in Lithium Niobate Waveguides	471
6.3.5 Second-Harmonic Generation in Lithium Niobate Waveguides .	473
6.4 Lithium Tantalate Waveguides	479
6.4.1 Fabrication and Properties of Proton-Exchanged Lithium Tantalate Waveguides	479
6.4.2 Domain Inversion and Quasi-Phase-Matching in Lithium Tantalate	480
6.4.3 Second-Harmonic Generation in Lithium Tantalate Waveguides	482
6.5 Potassium Titanyl Phosphate Waveguides	482
6.5.1 Fabrication and Properties of Rubidium-Exchanged Potassium Titanyl Phosphate Waveguides	485
6.5.2 Second-Harmonic Generation in Potassium Titanyl Phosphate Waveguides	486
6.6 Potassium Niobate Waveguides	488
6.6.1 Fabrication of Ion-Implanted Waveguides in Potassium Niobate	492

6.6.2 Linear Properties of Potassium Niobate Waveguides	503
6.6.3 Power-Handling Capabilities of Potassium Niobate Waveguides	506
6.6.4 Second-Harmonic Generation in Potassium Niobate Waveguides	508
6.7 Discussion and Concluding Remarks	515
References	516
Subject Index	527

Nonlinear Optical Effects and Materials

Günter, P. (Ed.)

2000, XIV, 540 p. 167 illus., Hardcover

ISBN: 978-3-540-65029-4