Contents

1 Nanointelligence: Information Physics Fundamentals for Nanophotonics	1
Makoto Naruse, Naoya Tate, Masashi Aono and Motoichi Ohtsu	
1.1 Introduction.	2
1.2 Optical Excitation Transfer to go Beyond the von Neumann Architecture	4
1.2.1 Fundamentals	5
1.2.2 Space-, Time-, and Energy-Related Basic Functions	7
1.2.3 Going Beyond the von Neumann Architecture: Stochastic Solution Searching	13
1.3 Nanophotonics for Security	19
1.3.1 Theoretical Foundation.	20
1.3.2 Hierarchical Hologram for Information Hiding and its Theoretical Fundamentals.	22
1.3.3 Shape-Engineered Nanostructures for Authentication Functions.	26
1.4 Stochastic Modeling of Near-Field Processes for Intelligent Material Formation	28
1.4.1 Light-Assisted Size-Regulation of Nanoparticles	29
1.4.2 Light-Assisted Nanoparticle Array Formation	31
1.5 Conclusion and Future Prospect.	35
References	36
2 DNA Self-Assembled Nanostructures for Resonance Energy Transfer Circuits	41
Chris Dwyer, Arjun Rallapalli, Mohammad Mottaghi and Siyang Wang	
2.1 Introduction.	41
2.2 Foundations for an Integrated Molecular System	42
2.3 DNA Self-Assembly.	43
2.4 RET Circuits and Logic Devices	45
2.4.1 Inputs and Outputs.	45

2.4.2	Signal Transport	46
2.4.3	Non-linear Transfer	46
2.4.4	RET-Based Logical Functions	47
2.5	Design Flow	48
2.5.1	Comparison with Other EDA Design Flows	49
2.5.2	RET Network Design as a Type-and-Site Assignment Problem	50
2.6	Metrics and Design Rules	50
2.6.1	Metrics	51
2.6.2	Design Rules	51
2.7	Design Automation Process	52
2.7.1	Scripting Language for Tool-Chain Control	53
2.7.2	Spectral Analysis Tool	53
2.7.3	Geometry Analysis Tool	54
2.7.4	Linear Approximation Tool	54
2.7.5	Physical Simulation	55
2.7.6	Batch Evaluation Tools	58
2.8	Design Examples	59
2.8.1	Design Example 1: AND5	59
2.8.2	Design Example 2: Wavelength Sequence Detector	62
2.9	Evaluation	64
2.10	Conclusion	65
	References	65
3	Smart Fold Architecture: A Nano Information System Based on a Hierarchical Structure	67
	Jun Tanida	
3.1	Introduction	67
3.2	DNA Nano Information Systems	68
3.2.1	Fundamental Concepts	68
3.2.2	DNA Information Techniques	69
3.2.3	Architectures	73
3.3	Smart Fold Architecture	77
3.3.1	Concept	77
3.3.2	Constituent Layers	79
3.3.3	System Operation	81
3.4	Applications of Smart Fold Information Systems	84
3.5	Discussion	87
3.5.1	Implications of Smart Fold Computing	87
3.5.2	Future Issues	88
3.6	Conclusion	89
	References	90

4 Photonic DNA Nano-Processor: A Photonics-Based Approach to Molecular Processing Mediated by DNA	91
Yusuke Ogura, Takahiro Nishimura, Hirotugu Yamamoto, Kenji Yamada and Jun Tanida	
4.1 Introduction	91
4.2 Photonic DNA Nano-Processor	93
4.2.1 Concept	93
4.2.2 Photonic DNA Nano-Processor as Mediator	94
4.2.3 Types of Light Usage	96
4.3 Light-Activatable DNA Nano-Processor	97
4.3.1 Activation of Sensing Function Using Light	97
4.3.2 Scheme	98
4.3.3 Experiments	100
4.4 DNA Scaffold Logic	103
4.4.1 Fundamental Scheme of Logic Operation	103
4.4.2 Features	105
4.4.3 Experiments	106
4.4.4 Analysis of Properties	108
4.5 Conclusions and Outlook	111
References	112
 5 Boolean Logic Circuits on Nanowire Networks and Related Technologies	115
Seiya Kasai, Hong-Quan Zhao, Yuta Shiratori, Tamer Mohamed and Svetlana N. Yanushkevich	
5.1 Introduction	115
5.2 BDD Logic Circuit on Nanowire Network	118
5.2.1 Basic Concept and Nanoscale Implementation	118
5.2.2 Circuit Design	120
5.2.3 Fabrication	123
5.2.4 Device Characteristics	123
5.2.5 Circuit operation	125
5.2.6 Performance	127
5.3 Reconfigurable BDD Circuit	129
5.3.1 Concept	129
5.3.2 Fabrication and Characterization	131
5.3.3 Implemented Functions and Circuit Area	134
5.4 Error Correcting BDD Circuits	135
5.4.1 Background	135
5.4.2 Error Correction Scheme	136
5.4.3 Implementation and Characterization	137
5.5 Summary	141
References	141

6	Single Photoelectron Manipulation and Detection with Sub-Nanosecond Resolution in CMOS Imagers	145
	Shoji Kawahito, Keita Yasutomi and Keiichiro Kagawa	
6.1	Introduction.	145
6.2	Single Photoelectron Manipulation by CMOS Active Pixel.	146
6.2.1	Single Photon Avalanche Diode	146
6.2.2	Achieving High Quality in CMOS Image Sensors	148
6.3	Our Method: Lateral Electric Field (LEF) Control	150
6.3.1	Concept and Implementation of LEF Control	150
6.3.2	Comparison with Transfer-Gate-Based Implementation	152
6.3.3	Simple Implementation: Draining-Only Modulation	153
6.4	Chip Implementation and Experiments	154
6.4.1	Fluorescence Lifetime Imaging Microscopy (FLIM) Image Sensor	154
6.4.2	Experimental Results	154
6.5	Conclusions.	157
	References	158
7	Engineering of a Nanometric Optical System Based on Optical Near-Field Interactions for Macro-Scale Applications	161
	Naoya Tate, Makoto Naruse and Motoichi Ohtsu	
7.1	Introduction.	161
7.2	Nanometric Optical System.	162
7.2.1	Nanophotonics.	162
7.2.2	Basics of Nanometric Optical System.	163
7.3	Modulatable Nanophotonics	165
7.3.1	Concept	165
7.3.2	Basics of Optical Energy Transfer	166
7.3.3	Modulated Emission Based on Optical Energy Transfer	167
7.3.4	Numerical Demonstration	168
7.3.5	Experimental Demonstration	171
7.3.6	Conclusion	174
7.4	Nanophotonic Droplet.	174
7.4.1	Concept	174
7.4.2	Basics	175
7.4.3	Experimental Demonstrations	176
7.4.4	Conclusion	180
7.5	Summary	180
	References	181

8 Photonic Neuromorphic Signal Processing and Computing	183
Alexander N. Tait, Mitchell A. Nahmias, Yue Tian, Bhavin J. Shastri and Paul R. Prucnal	
8.1 Introduction.	183
8.2 Neuromorphic Processing in Electronics and Photonics	185
8.3 Photonic Spike Processing.	186
8.3.1 Spiking Signals	187
8.3.2 Spike Processor: Computational Primitive.	188
8.4 Spiking Neuron Model	191
8.5 Photonic Neuron Bench-Top Model	192
8.6 Lightwave Neuromorphic Circuits	195
8.6.1 Barn Owl Auditory Localization Algorithm	195
8.6.2 Crayfish Tail-Flip Escape Response.	197
8.7 Ultrafast Learning	199
8.7.1 Synaptic Time Dependent Plasticity.	200
8.7.2 Intrinsic Plasticity	201
8.7.3 Principal Component Analysis.	201
8.7.4 Independent Component Analysis	202
8.7.5 Photonic STDP	203
8.8 Excitable Laser Neuron	205
8.8.1 Before Pulse Formation	206
8.8.2 Pulse Generation	207
8.8.3 LIF Analogy	208
8.8.4 Excitable VCSELs.	209
8.8.5 Other Spiking Photonic Devices	212
8.9 Cortical Spike Algorithms: Small-Circuit Demos.	213
8.9.1 Multistable System	214
8.9.2 Synfire Chain	215
8.9.3 Spatio-Temporal Pattern Recognition Circuit	216
8.10 Summary and Concluding Remarks	218
References	221
 9 A Nanophotonic Computing Paradigm: Problem-Solving and Decision-Making Systems Using Spatiotemporal Photoexcitation Transfer Dynamics.	 223
Masashi Aono, Song-Ju Kim, Makoto Naruse, Masamitsu Wakabayashi, Hirokazu Hori, Motoichi Ohtsu and Masahiko Hara	
9.1 Introduction.	224
9.2 Photoexcitation Transfer	226
9.3 Nanophotonic Problem Solver	227
9.3.1 The Satisfiability Problem.	227
9.3.2 Spatiotemporal Dynamics of Photoexcitation Transfer	228

9.3.3	Model of a Nanophotonic Problem Solver (NanoPS) . . .	230
9.3.4	WalkSAT Algorithm	234
9.3.5	NanoPS versus WalkSAT	234
9.4	Nanophotonic Decision Maker.	235
9.4.1	Multi-Armed Bandit Problem (BP)	235
9.4.2	Model of a Nanophotonic Decision Maker (NanoDM)	236
9.4.3	Intensity Adjuster of NanoDM	239
9.4.4	Softmax Algorithm	241
9.4.5	NanoDM versus Softmax	241
9.5	Discussion and Conclusion	242
	References	243
Index		245