

Index

a

acousto-optical tunable filter (AOTF)
267, 268

active silicon interposer 33

advanced data-processing
optical data storage 265–267
real-time hyperspectral imaging
267–268

alignment tolerances 4–6, 14, 55–58, 61

anticounterfeiting smart labels 313

apodization function 137, 138

artificial neural networks *see also* deep learning
neural networks 246–247
training of 247–248

AuSn solder bumps 26

AutoML 235–237

b

ball grid array (BGA) 63

band-edge emission 181

bandgap engineering 335–339

binary cross-entropy (BCE) 217

Bragg's formula 288

Brillouine grid-sampling 220, 221

butt coupling 4, 12–13, 61

c

Cartesian coordinates 137

chip-scale integration
color centers in nanodiamond
148–154

self-assembled quantum dots 141–144

solution-based colloidal 141–144

two-dimensional materials 144–148

chip-scale solid sources 136

chitosan 340, 341

closed-loop alignments 20–21, 44

closed-ring state 329

co-package optics (CPO) 16–18, 65

co-packaging integration 63, 64

coefficient of thermal expansion (CTE)
11

coherent light 170, 171

conditional autoencoders (cAEs) 260

conditional generative adversarial neural networks (cGANs) 260

convolutional neural networks (CNNs)
231, 235, 250, 251, 254

copper pillars/bumps 26–27

coupled dipole approximation 252, 254

coupling structures 5–9, 55

cross entropy (CE) 217, 248

cycle consistency (CC) 228, 230

d

datacom transceiver module 2

DC interconnects 37

Debye–Waller factor 173

deep neural network (DNN) models
AutoML 236–237
to construct device topology 217–220
convolutional neural networks 235
forward modeling 211

- deep neural network (DNN) models (*contd.*)
 - generative modeling 212
 - inverse modeling 212
 - physics-informed neural networks 225–227
 - to predict optical response 212–217
 - to produce device topology 220–225
 - transfer learning and fine tuning 235–236
- Deep Regret Analytic GAN (DRAGAN) 222
- dielectric elastomer actuator (DEA) 335
- dielectric function 284
- digital metasurface device (DMSD) 318
- direct inverse design networks 259–260
- dual-comb spectroscopy 101
- dye-sensitized solar cells (DSSCs) 278

- e**
- edge couplers 5–7, 9, 12, 13, 22, 56–59, 61
- electrically-tunable photonic devices 341–345
- electron beam irradiation 278
- electron-cyclotron-resonance (ECR) plasma sputtering 278–279
- electronic/photonic convergence
 - fan-out wafer level packaging (FOWLP) 31–32
 - flip-chip interconnects 26–29
 - interposers integration approach 32–36
 - intra-connections 29–31
- energy band gap 286, 305
- EO-based OFC 91, 99
- evanescent coupling 7, 14, 23, 67

- f**
- Fabry–Pérot (F–P)-type devices 324
- fan-out wafer level packaging (FOWLP) 25, 31–32
- ferroelectrics 277, 286, 287, 296
- fiber optic assembly 12
- fiber-to-chip assembly 55–59
- fine tuning 235–236
- finite-difference time-domain (FDTD) 209, 248
- finite element method (FEM) 209, 248
- flexible modulation 107
- flexible optical networks 107
- flip-chip integration 189, 199–200
- flip-chip interconnects 26–29
- forward modeling 210–218, 220
- fully connected deep neural network (FCDNN) 235
- fully connected neural networks (FCNNs) 250, 251
- fully connected vs. convolutional ANNs 249–252

- g**
- GeAsSe chalcogenide glass 82
- generalized nanophotonics predictor network 252–255
- generative adversarial networks (GANs) 212, 220, 222
- generative modeling 210–212, 220–225, 227–235
- GloNET model 256
- graphene quantum dots 168, 183–186
- group velocity dispersion (GVD) regime 84

- h**
- hetero-epitaxial integration 59, 60
- heterogeneous assembly 25
- heterogeneous integration 25, 31, 32, 59, 60, 167, 195
- hexagonal boron nitride (hBN) 144, 167, 179–183
- holographic information systems 323
- hybrid bonding 28, 29
- hybrid integration 55, 59–63, 68

- i**
- indium gallium zinc oxide (IGZO) 336

indium micro balls 28
 indium tin oxide 341
 integrated nonlinear photonics
 As₂S₃ waveguide 88
 Ge waveguide 84
 InGaP and AlGaAs on-insulator
 waveguides 86
 nonlinear refractive index 76
 nonlinear wave mixing
 high-order modulation formats
 111
 nonlinear optical signal processing
 105–108
 optical performance monitoring
 110
 optical signal processing 108, 113,
 114
 64-QAM 112
 wavelength conversion 108
 optical frequency comb
 applications 101–102
 EO-based 99
 microresonator-based 91–99
 MLL-based 99–101
 SC-based 99
 refractive index 76
 saturation regime 83
 SiGe alloy 86
 structures 76
 supercontinuum
 application 77–79
 history 79–83
 traditional electrical integrated circuits
 75
 transparent window 75
 waveguide dispersion parameters 83
 integrated quantum optical circuits 135
 integrated quantum photonics 167, 168,
 186, 189
 Interposers for Electronic Integrated
 Circuits (CMOS) 33
 interposers integration approach 32
 inverse modeling 210–213, 217–220
 inverted tapers 6
 ion beam sputtering 277

k

known good dies (KGD) 7
 Kullback-Leibler (KL) divergence 231
 Kullback-Leibler divergence (KL-loss)
 262

l

laser/PIC coupling 23–25
 layered dielectric media transfer matrix
 method (LDMTMM) 214
 learning to learn 236–237
 least squares GAN (LSGAN) 222
 left-handed circularly polarized (LCP)
 316
 lens-assisted coupling 4
 lens coupling scheme 13–14
 liquid crystal-integrated tunable devices
 modulate effective refractive index
 316–318
 modulate polarization 314–316
 liquid-phase epitaxy 277
 lithography 23, 57, 59, 62, 75, 147, 151,
 154, 185, 194, 195, 213
 logic functions 114

m

magnesium (Mg) doping 327
 mean square error (MSE) 216, 248
 meta-filter model generator 218
 meta-learning 236–237
 metal–organic chemical vapor deposition
 277, 296
 metamaterial structures 6, 329
 metasurfaces 136, 156–160, 230, 235,
 256, 313–323, 331–337, 339, 343,
 344
 micro-electro-mechanical systems
 (MEMS) 329–331
 microlenses 14, 22, 23
 micropackaged laser diode 24
 microresonator-based OFC 91–99
 mode-locked laser (MLL) 99
 mode-matching condition 4, 5, 12, 13
 module packaging 10–12
 molecular beam epitaxy 277

monolithic integration 15, 23, 63, 65,
148, 153, 160, 194, 195, 202, 203
multicore, multimode fiber (MCMMF)
267, 268
multi-mode interference (MMI) device
209, 261

n

nanofabrication 75, 154, 195, 328
nanophotonic approaches 313
nanophotonic lithium niobate
optical waveguide 287–295
stirrer time effect 295–304
nanophotonic power splitter
adjoint method vs. deep learning
234–235
device generation performance
232–234
device simulation procedure 229
device structure 228
hyperparameters 234
network architecture 230–231
network training procedure 231–232
nanoporous Au 27–28
nematic phase 316
network architecture search 236–237
neural tensor network (NTN) 216
nonlinear optical signal processing
functions 105–108, 113
nonlinear wave mixing
high-order modulation formats 111
nonlinear optical signal processing
105–108
OPM 110
64-QAM 111, 112

o

OAM-multiplexing hologram 322, 323
OAM-selective hologram 323
one-to-many problems 259, 260
open-circuit voltage 278
open-loop alignment 20
open-ring state 329
optical conductivity 283, 285, 286, 305
optical coupling strategies

laser/PIC coupling 23–25
passive alignment strategies 19–20
self-alignment strategies 21–23
vision assisted alignment 20–21
optical devices 28, 75, 117, 313
optical frequency comb (OFC)
EO-based 99
microresonator-based 91–99
MLL-based 99–101
SC-based 99
optical interconnects 3–5, 3, 38, 66
optical performance monitoring (OPM)
107, 110
optical plug 23, 24
optical reflectometer 291
optical regeneration 107
optical waveguide interposer coupling
14–15
optically tunable devices
incident light direction 318, 319
orbital angular momentum (OAM)
323, 324
polarization (spin) 321, 323
wavelength 319, 320
orbital angular momentum (OAM) 323,
324

p

Packaging Design Rules (PDR) 36
phase change materials (PCMs)
switchable absorbers 324–326
thermochromic smart windows
327–329
photoluminescence (PL) 142, 176, 278,
301, 334
photonic chiplet 1, 17, 45
photonic integrated circuits (PIC)
packaging and test
advanced techniques for wafer level test
39
assembly machines 40–45
coupling structures 5
datacom transceiver module 2
design rules 36–38
fiber optic assembly 12

- module mass manufacturing 15–18
 - module packaging 10–12
 - optical interconnects 3–5
 - wafer-level test 7–10
 - photonic interposer and photonic systems
 - on chip 34–36
 - photronics inverse design
 - direct inverse design networks 259–260
 - iterative training 264
 - optimizing network layout 262
 - postprocessing 265
 - predictor network 256–259
 - quality of initial dataset 262–264
 - photronics lithium niobate 278–286
 - Phoxrot project 34, 36, 38
 - physics-informed neural networks (PINNs) 225–227, 249
 - PIC-on-board approach 15, 37
 - pigtailling 5, 12
 - plasmonic NP (pNP) 319
 - polydimethylsiloxane (PDMS) 199, 331, 335
 - polymer waveguides 14, 22–24
 - predicting neural network (PNN) 218
 - PR diffraction grating 287
 - progressive growth of GANs (PGGANs) 224
 - pulsed laser ablation (PLA) 278
 - pulsed-laser deposition (PLD) 277
 - Purcell factor 191, 194, 195, 199, 200, 202
- q**
- quantum emitters 136
 - chip-scale integration
 - color centers in nanodiamond 148–154
 - self-assembled quantum dots 141–144
 - solution-based colloidal 141–144
 - two-dimensional materials 144–148
 - deterministically positioning 154–156
 - excitation and orientation 136–141
 - quantum light-emitting diodes 186–189, 203
 - quantum light interaction, with metasurface for modulation 156–159
 - quantum light sources
 - characteristics 172–175
 - integration
 - with dielectric waveguides and cavities 191–197
 - with off-chip components 199–200
 - with optic fibers 200–202
 - with plasmonic waveguides and cavities 197–198
 - SPE-cavity coupling 190–191
 - photon statistics 168–172
 - two-dimensional (2D) materials
 - graphene quantum dots 183–186
 - hexagonal boron nitride 179–183
 - light-emitting diodes 186–189
 - transition metal dichalcogenides 176–179
 - quantum photonic integrated circuits (QPICs) 67
 - quantum photonics 67, 167, 168, 186, 189, 202
- r**
- Raman–Nath diffraction 287
 - Raman spectroscopy 78, 296
 - real-time hyperspectral imaging 267–268
 - Rectified Linear Unit (ReLU) 213, 247
 - RF interconnects 37
 - RF magnetron sputtering 277
 - right-handed circularly polarized (RCP) 316
- s**
- SC-based OFC 91, 99
 - Scherrer’s formula 288, 297
 - self-alignment strategies 21
 - self-alignment techniques 20
 - short-circuit current 278, 293
 - shortcut connection 216, 254

- $\text{Si}_x\text{Ge}_{1-x}$ 81
 silicon optical bench (SiOB) 16, 22
 single-photon emitters (SPEs) 146–148,
 170, 171, 192
 silicon photonics 53–69
 co-packaging 63–65
 emerging applications 65–68
 fiber-to-chip assembly 55–59
 hybrid integration 59–63
 opportunities and challenges 68–69
 single-photon sources 135, 136, 143,
 144, 170–175, 180, 189, 191, 200
 spatial light modulator (SLM) 267, 268,
 317
 SPE-cavity coupling 189, 190
 spot size converter (SSC) 5, 56
 squeezed light 170–172
 strong coupling regime 190, 191
 supercontinuum
 applications 77–79
 history 79–83
 super waveguide 6
 surface acoustic wave (SAW) 277, 296
 surface and volume integral methods
 248
 surface plasmon polaritons (SPP) 144,
 153, 197, 324
- t**
- Tandem DNNs architecture 220
 tandem neural network 245, 259–261
 Tauc relation 301
 3D adiabatic taper 5
 3D packaging 18, 38–39, 45
 thermal light 169–171
 thermal management 10, 37, 39
 thermal plasma spray chemical vapor
 deposition 277
 thermochromic smart windows 324,
 327–329
 thermo-optic effect 336, 338, 339
 through glass vias (TGV) 29–31
 through silicon vias (TSV) 17, 29–31
 titanium dioxide 83, 278, 335
- transfer learning and fine tuning
 235–236
 transfer matrix method (TMM) 214
 transimpedance amplifiers (TIA) 2
 transition metal dichalcogenides
 (TMDCs) 144, 167, 176–179
 transparent conductive oxide (TCO) 336
 transverse electric (TE) mode 229
 tunable photonic devices
 bandgap engineering 335–339
 biomaterials 339–341
 two-dimensional (2D) materials, quantum
 light sources 167–203
- u**
- U-Net concept 254
 U-Net to model 216
 ultradense photonic transceivers 17
 ultra-fast physics predictions
 fully connected vs. convolutional ANNs
 249–252
 generalized nanophotonics predictor
 network 252–255
- v**
- van der Waals (vdW) integration 167,
 191, 192
 vanadium dioxide (VO_2) 324
 variational autoencoders (VAE) network
 212, 223
 vector network analyzer (VNA) 9
 vertical grating coupler (VGC) 6–7, 19
 vision-assisted alignment 16, 20
- w**
- wafer-level test 1, 6–10, 12, 39–40
 waveguide array to fiber transposer
 (WAFT) 9
 weak coupling regime 189, 191, 194
- x**
- X-ray diffraction 296
- z**
- zero-phonon line (ZPL) 150, 173

