## Index

1/f noise, 248  
1D LiDAR, 8  
2D imaging, 3  
2D LiDAR, 8, 432  
3D imaging, 3  
3D mapping LiDAR, 452  

### A  
acousto-optic modulator (AOM), 288  
Aeolian Dust Experiment on Climate (ADEC), 58  
airborne laser bathymetry (ALB), 70  
Airy disk, 389  
American Society for Photogrammetry Engineering and Remote Sensing (ASPRS), 121  
analog-to-digital (A/D) converter, 190  
anterior gain, 182  
Asian Dust LiDAR Observation Network (AD-Net), 58  
ASPRS Accuracy Standards for Digital Geospatial Data, 121  
asynchronous readout, 290  
atmospheric attenuation, 466  
Atmospheric Laser Doppler Instrument (ALADIN), 44  
avto LiDAR, 452  
Autonomous Terminal Homing (ATH), 41  
autonomous underwater vehicle (AUV), 69  
avenanche photodiode (APD), 65, 233  

### B  
background noise, 242  
backscatter, 470  
beam divergence, 87, 331  
Beer’s law, 466  
binomial distribution, 275  
birefringence, 332  
birefringent crystals, 214  
bistatic LiDAR, 18  
blackbody, 242  
blackbody radiation, 3  
Boeing SpectraLab, 75  
Boltzmann’s constant, 240  

### C  
carrier-to-noise ratio (CNR), 285  
catastrophic optical destruction (COD), 206  
central limit theorem, 238  
circular polarization, 284  
CLARA, 39  
CO₂ laser, 28  
CO₂ LiDAR, 38  
coherence, 178  
coherent detection, 112  
coherent LiDAR, 3  
compressive sensing, 442  
conditional probability, 275
Continuously Operating Reference Station (CORS), 121
Cr:ZnSe, 211
cross-section, 94
Cruise Missile Advanced Guidance (CMAG), 41
crystalline quartz (SiO₂), 213
cumulative distribution function (CDF), 398
Curie temperature, 356

D
dark current, 248
dark current nonuniformity, 417
deformable mirror (DM), 104
detector angular subtense (DAS), 8
differential absorption LiDAR (DIAL), 58
digital elevation model (DEM), 127
digital holography, 12
digital terrain elevation data (DTED), 436
diode lasers, 184, 203
direct-detection LiDAR, 184
Doppler LiDAR, 415
Doppler shift, 3, 288, 393
dual-frequency liquid crystal (DFLC), 333

e
Ecole Polytechnique, France, 44
direct-emitting diode lasers, 203
eigenmodes, 441
electro-optic crystal, 195, 343
electron-bombarded active-pixel sensor (EBAPS), 117
electron-initiated avalanche photodiode (e-APD), 117
electrowetting, 338
ERASER, 64
erbium doping, 222
F
fast-steering mirror (FSM), 313
Federal Emergency Management Agency (FEMA), 131
Federal Geographic Data Committee (FGDC), 127
ferroelectric liquid crystals, 337
fiber lasers, 184, 211
field of view (FOV), 8
fixed liquid crystal polarized grating (LCPG), 365
fixed-pattern noise (FPN), 416–417
flash illumination, 479
flashlamps, 194
flicker noise, 248
focal spot, 368
foliage poke through, 66
Forward Combat System (FCS), 67
four-level laser, 193
Fourier transform, 399, 430
frame rate, 462
G
GaAs photocathode, 117
gas lasers, 184
gate time, 238
gated active 2D imaging, 64
Gaussian beam, 13, 87
Gaussian distribution, 238
Geiger-mode avalanche photodiode (GMAPD), 19, 65, 236
Geiger-mode LiDAR (GML), 120
general image quality equation (GIQE), 437
geographic information system (GIS), 131
ghost-imaging LiDAR, 293
gimbals, 309
Global Navigation Satellite System (GNSS), 121
Global Positioning System (GPS), 121
grayscale, 3, 9, 239
ground sample distance (GSD), 436, 93–94

H
heterodyne detection, 237
heterodyne mixing efficiency, 282
HgCdTe APD, 250
high range resolution, 114
holographic optical element (HOE), 92
human visibility, 429
hydrography, 70

I
ideal point response (IPR), 410
image metrics, 425
individual transmit/receive (T/R) module, 326
inertial measurement unit (IMU), 396
Infrared Airborne Radar (IRAR), 61
InGaAs LMAPD, 254
InGaAs photocathode, 117
inphase component of a beam, 283
integrated sidelobe ratio (ISLR), 411
interband cascade laser (ICL), 210
interband diode lasers, 203
intermediate frequency (IF), 190, 236
Intevac’s LIVAR® 4000 laser-gated viewer, 68
Intevac’s LIVAR® M506, 116
inverse synthetic-aperture LiDAR (inverse SAL), 149
irradiance, 9
isolation, 18

J
Jigsaw 3D LiDAR, 66
Johnson criteria, 425, 461
Jones calculus, 364

K
K(TiO)AsO₄ (KTA), 220
Kerr effect, 195, 341
Kinetic Energy Interceptor, 51
KTN, 345
KTP, 220

L
ladar, 7
Lambertian scattering, 95, 247
Laser Airborne Depth Sounder (LADS), 71
laser rangefinder, 30
laser vibrometry, 142, 394, 452, 477
laser-induced breakdown spectroscopy (LIBS), 11, 136
laser-induced fluorescence (LIF) LiDAR, 136
lasers, 178
LATAS (Laser True Airspeed System), 39
least significant bit (LSB), 239
lenslet, 322
LiDAR, 1
linear frequency modulation (LFM), 379
linear frequency-modulated waveform, 188
linear polarization, 284
linear-mode avalanche photodiode (LMAPD), 19, 236
Lissajous figure, 315
local oscillator (LO), 3
LOCUS (Laser Obstacle and Cable Unmasking System), 39
Loitering Attack Missile (LAM), 67
longitudinal modes, 197
longwave infrared (LWIR), 100
Low Altitude Navigation and Targeting Infrared for Night (LANTIRN), 65
Low Cost Autonomous Attack System (LOCAAS), 66
LOWKATER, 53

M
master oscillator power amplifier (MOPA), 200
maximum permissible exposure (MPE), 15, 464
micro-Doppler, 284
micro-electromechanical system (MEMS), 320
microlens array, 324
microscan, 390, 461
Microsoft® Kinect game system, 10
midwave infrared (MWIR), 100
Mie scattering, 101
MIT Lincoln Lab, 32
MIT/Lincoln Lab Firepond system, 38
mode-locked lasers, 198
Modular Optical Aperture Building Blocks (MOABB), 338
modulation transfer function (MTF), 433
modulation transfer function compensation (MTFC), 438
modulo $2\pi$ beam steering, 328
monostatic LiDAR, 17
MONITOR (Methane Observation Networks with Innovative Technology to Obtain Reductions), 11
multipixel–photon-counter (MPPC), 279
multiple-input, multiple-output (MIMO), 5, 10, 150
multiple–line-of-collection (LOC), 476

N
NASA Goddard Space Flight Center, 32
National Cooperative Highway Research Program (NCHRP), 132
National Digital Elevation Program (NDEP), 127
National Geospatial Agency (NGA), 396
National Imagery Interpretability Rating Scales (NIIRS), 425, 433
National Institute for Environmental Studies (NIES), Japan, 61
National Spatial Reference System (NSRS), 123
Nd:YAG laser, 28
negative binominal distribution, 239
noise-equivalent photons (NEPh), 117
noise-equivalent vibration velocity (NEVV), 411
Nyquist sampling, 385

O
Open Geospatial Consortium (OGC), 127
operational obstacle avoidance system, 36
optical coherence tomography (OCT), 71
optical parametric amplifier (OPA), 212
optical parametric oscillator (OPO), 199, 67, 212
optical path difference (OPD), 309
optical phased array (OPA), 309
orientation-patterned GaAs (OP-GaAs), 221

P
passive EO sensors, 3
Pave Tack pod, 65
peak sidelobe ratio (PSLR), 411
periodically poled lithium niobate (PPLN), 213
photomultiplier tube (PMT), 279
PMN-PT, 345
Pockels cell, 195, 341
point spread function (PSF), 8, 389
Poisson distribution, 239
polygon scanner, 320
Princeton Lightwave, 75
pseudo-random–coded waveform, 188

Q
Q switch, 184
Q-switched laser, 199
Q-switched Nd:YAG laser, 31
quadrature components of a beam, 283
quadrature detection, 283
quantum cascade laser (QCL), 184, 208
quantum efficiency, 237
Quiet Knight, 43

R
Raleigh scattering, 101
Raman LiDAR, 11, 57
range accuracy, 388
range-gated active imaging (2D LiDAR), 116
range imaging, 462
range precision, 388
range resolution, 388
range walk, 415, 418
readout integrated circuit (ROIC), 67
relative edge response (RER), 437
Risley prism, 315
root-mean-square error (RSME), 127
rotating polygon, 318
Royal Signals and Radar Establishment (RSRE), 39

S
SBN, 352
scale-invariant feature transform (SIFT), 442
scanning LiDAR, 464
separate absorption and multiplication (SAM) region, 270
separate absorption, charge, and multiplication (SACM), 253
shot noise, 241
signal-to-noise ratio (SNR), 19, 237
silicon detectors, 279
single-photon avalanche diode (SPAD), 279
single-photon LiDAR (SPL), 120
solid state lasers, 178
space-fed, phased-array steering, 326
spatial coherence, 178
spatial fly-back region, 334
speckle, 104
speckle imaging LiDAR, 143
spurious sidelobe ratio (SSLR), 411
Standoff Precision Identification in Three Dimensions (SPI-3D), 66
steerable electro-evanescent optical refractor (SEEOR), 336
stimulated Brillouin scattering (SBS), 224
Stokes parameter, 365
Strategic Defense Initiative Organization (SDIO), 51
super-Gaussian beam, 13, 87
synthetic-aperture LiDAR (SAL), 10, 146, 4, 433
synthetic-aperture radar (SAR), 4, 50

T
temporal coherence, 178
temporal heterodyne detection, 12, 281
Thanh Hoa Bridge (aka Dragon’s Jaw), Vietnam, 36
thermal noise, 240
thermoelectrical (TE) cooling, 271
three-level laser, 192
thulium-doped silica fiber lasers, 226
Ti:sapphire laser, 190
time–bandwidth product, 186
time over threshold (TOT), 279
topo-bathymetric LiDAR, 135

U
U.S. Geological Survey (USGS)
National Geospatial Program (NGP), 445
U.S. Geological Survey (USGS)
LiDAR Base Specifications, 121
unambiguous range, 386, 412
Universal Transverse Mercator (UTM), 124

unmanned aerial vehicle (UAV), 69

V
vertical-cavity, surface-emitting laser (VCSEL), 207
Video Guidance Sensor (VGS), 51
volume holographic gratings, 367

W
wide-area mapping (WAM), 476
wind sensing, 28, 481
World Geodetic System (WGS84)-based spatial referencing, 124

Z
ZnGeP₂ (ZGP), 220
Dr. Paul F. McManamon started Exciting Technology LLC after he retired from being Chief Scientist for the Air Force Research Lab (AFRL) Sensors Directorate. He is also Technical Director of the Lidar and Optical Communications Institute (LOCI) at the University of Dayton. He chaired the 2014 U.S. National Academy of Sciences Study “Laser Radar: Progress and Opportunities in Active Electro-Optical Sensing.” He was the main LiDAR expert witness for Uber in the lawsuit Uber versus Google/Waymo. He cochaired the 2012 U.S. NAS study “Optics and Photonics, Essential Technologies for Our Nation,” which recommended a National Photonics Initiative (NPI). Dr. McManamon was also vice chair of the 2010 NAS study “Seeing Photons: Progress and Limits of Visible and Infrared Sensor Arrays.”

Dr. McManamon is a Fellow of SPIE, IEEE, OSA, AFRL, the Directed Energy Professional Society (DEPS), the Military Sensing Symposia (MSS), and the American Institute of Aeronautics and Astronautics (AIAA). Dr. McManamon received the IEEE W.R.G. Baker Award in 1998 for the best paper in any refereed IEEE journal or publication (>20,000 papers). He was president of SPIE in 2006. He served on the SPIE Board of Directors for seven years and on the SPIE Executive Committee from 2003 through 2007. Dr. McManamon worked with Dr. Fenner Milton and Dr. Gerry Trunk to found the MSS, combining IRIS and the Tri-Service Radar Symposia. He worked as a civilian employee of the Air Force at WPAFB from May 1968 through May 2008. His last position for the Air Force was chief scientist for the AFRL Sensors Directorate, where he was responsible for the technical aspects of all AFRL sensing technologies, including RF and EO sensing, automatic object recognition, infrared countermeasure (IRCM), electronic warfare, and device technologies. Prior to that, he also was senior scientist for EO/IR Sensors, and acting chief scientist for the Avionics Directorate for >2.5 years. In 2006 he received the Presidential Rank Award of Meritorious Executive. He was the co-recipient of the SPIE President’s Award in 2013.