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Preface

One of the most exciting, recent developments in photonics, particularly in regard to its use in medicine and disease, is the utilization of light at wavelengths beyond the visible range and the slightly longer range of short-wavelength infrared (SWIR) wavelengths at 1100–1350 nm, now known as the second optical window. Once ignored because of a lack of sensitive detectors, a third (at 1600–1870 nm) and a fourth (at 2100–2350 nm) optical window are now being utilized extensively. These wavelengths are situated at areas between water peak maxima (where absorption of light is reduced). Due to minimal absorption and scattering of light at these wavelengths, the use of these SWIR optical windows can provide less blurring, better-contrast images, and deeper penetration into tissue media compared with visible light.

With the use of these windows, extensive progress has been made in the study of diseases such as cancer, heart failure, neurocognitive disorders, and diseases of the bone, eyes, skin and teeth. In Part I of this book, investigators review new and emerging techniques based on SWIR light, including the fabrication and use of SWIR nanoparticles as luminescent nanothermometers and photothermal agents, and recent advances in the design, structure and SWIR-related biomedical applications of rare-earth doped nanoparticles (REDNs). REDNs are among the most exceptionally bright and biocompatible SWIR emitters. SWIR imaging techniques—including SWIR hyperspectral imaging for biomedical applications, and a novel wideband (VIS+SWIR) digital holographic microscopic method, based on a novel quantum-dot (QD) image sensor—are also discussed.

In Part II of this book, we explore biomedical applications that employ the SWIR optical windows for the assessment and detection of cancer. SWIR fluorescence and Monte Carlo modeling of breast cancer tissues can reveal important information on how SWIR light interacts with complex media. Recent advances in the study of urothelial carcinoma, a cancer that recurs frequently, are reviewed. SWIR light with multimodal microscopy can be utilized as a minimally invasive diagnostic technique for evaluation of this cancer. Investigators also show how SWIR light can be coupled with fluorescence endoscopy for tumor imaging, and how the assessment of gastrointestinal stromal tumors during surgery can be made using SWIR hyperspectral imaging.

In Part III of this book, we discuss biomedical applications of SWIR light in important diseases of the heart, brain, skin, and other organs. SWIR light can be utilized in the assessment of heart failure and to access difficult-to-reach areas of the brain. Investigators use SWIR imaging techniques to evaluate neurocognitive disorders and skin inflammation. SWIR light can also be employed using an otoscope to assess pediatric conditions, and with optical coherence tomography and other imaging modalities in dentistry.

Finally, Part IV provides a discussion of how artificial intelligence and machine learning can greatly enhance our ability to use SWIR windows to detect and study disease.

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We would like to thank Ms. Dara Burrows, SPIE Press Senior Editor, for her invaluable help in preparing this book. We would also particularly like to acknowledge Ms. Diana C. Sordillo, M.S., who not only co-authored a chapter, but also made valuable notes and recommendations throughout the book. Finally, we would also like to thank Mr. Vincent T. Sordillo for his technical help, and especially Mrs. Ellen R. Sordillo, M.P.A., for her support.

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Laura A. Sordillo, M.S., M.Phil., Ph.D. is an interdisciplinary researcher in optics and biophotonics whose work focuses on the discovery of novel short-wavelength infrared techniques for deep tissue imaging of the brain, bone and breast cancer, the use of spectroscopy for the assessment of neurodegenerative diseases such as Parkinson's and Alzheimer's, as well as of cancer, and the study of quantum effects in the brain and in photosynthetic systems. She is currently investigating the application of photonics to quantum computing. She is Director of Biophotonics at Allosteric Bioscience, Inc. and is a research assistant professor at The Institute for Ultrafast Spectroscopy and Lasers in the physics and electrical engineering departments at The City College of New York. She is the recipient of the Kaylie Entrepreneur Award, the MSKCC-CCNY Graduate Research Award, the 2016–2017 Grove School of Engineering Graduate Fellowship, the 2017–2018 Corning Inc. Ph.D. Fellowship Award, and the 2018–2019 Corning Inc. Ph.D. Fellowship Award. She has published more than 60 papers, holds 13 patents, and is coeditor (along with Dr. Peter P. Sordillo M.D., Ph.D., M.S.) of the recently published book *Biophotonics, Tryptophan and Disease* from Elsevier/Academic Press.

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Acronyms and Abbreviations

ACD	allergic contact dermatitis
AD	Alzheimer's disease
ADMM	alternating direction method of multipliers
AI	artificial intelligence
ANN	artificial neural network
AOM	acute otitis media
AOTF	acousto-optic tunable filter
AUC	area under the ROC curve
AuNP	gold nanoparticle
AuNS	gold nanostar
BAT	brown adipose tissue
BCa	bladder cancer
BLI	blue laser imaging
BOR	band outlier removal
CAPAD	current-activated, pressure-assisted densification
CARS	coherent anti-Stokes Raman scattering
CCD	charge-coupled device
CDR	clinical dementia rating
CEJ	cementum–enamel junction
CGM	continuous glucose monitoring
CHF	congestive heart failure
CIS	carcinoma *in situ*
CLSM	confocal laser scanning microscopy
CMOS	complimentary metal–oxide–semiconductor
CNN	convolutional neural network
CNP	carbon nanoparticle
CP	cross polarization
CPT	current procedural terminology
CSF	cerebrospinal fluid
CSNT	core/satellite nanotheranostic
CSOM	chronic suppurative otitis media
CT	computed tomography

CV	cross-validation
CW	continuous wave
CVI	CardioVerification index
DA	differential absorption
DC	downconversion
DEJ	dentinal–enamel junction
DL	deep learning
DLW	direct laser writing
DMD	digital micromirror device
DMSA	dimercapto succinic acid
DOS	diffuse optical spectroscopy
DOSI	diffuse optical spectroscopy imaging
DPBF	diphenylisobenzofuran
DS	down-shifting
DSM-5	Diagnostic and Statistical Manual of Mental Disorders
DTTA	diethylenetriamine tetraacetic acid
EDFA	erbium-doped fiber amplifier
EDTA	ethylenediaminetetraacetic acid
EPR	enhanced permeability and retention
EQE	external quantum efficiency
ESA	excited-state absorption
ESD	endoscopic submocusal dissection
ETU	energy transfer upconversion
FA	folic acid
FCN	fully convolutional network
FD	frequency domain
FDA	U.S. Food and Drug Administration
FDPM	frequency-domain photon migration
ffLDPI	full-field laser Doppler perfusion imaging
FIR	far infrared
FN	false negative
FOM	figure of merit
FP	false positive
FPR	false positive rate
FWHM	full width at half maximum
GAN	generative adversarial network
GIST	gastrointestinal stromal tumor
GRIN	graded index
Hb	hemoglobin
HF	heart failure
HIPPA	Health Insurance Portability and Accountability Act
HNLF	highly nonlinear fiber
HS	hyperspectral

HSI	hyperspectral imaging
ICG	indocyanine green
ICGVA	indocyanine green video angiography
IEE	image-enhanced endoscopy
IFT	inverse Fourier transform
IIR	intermediate infrared
IKSFA	iterative key set factor analysis
ILSVRC	ImageNet Large Scale Visual Recognition Challenge
IONP	iron oxide nanoparticle
IOS	inorganic shell
IQR	interquartile range
IR	infrared
IT	integration time
KNN	K-nearest neighbors
LCI	low-coherence interferometry
LCTF	liquid crystal tunable filter
LED	light-emitting diode
LFI	lens-free imaging
LP	long pass
LSCI	laser speckle contrast imaging
LSI	laser speckle imaging
LSTCA	laser speckle temporal contrast analysis
LV	latent variable
LWIR	long-wave infrared
MCF	multiconjugate filter
MCI	molecular chemical imaging
MCML	Monte Carlo multilayer (model)
MCT	mercury cadmium telluride, HgCdTe
MCVM	Monte Carlo (model in) voxelized media
MDA-MB-231	cell line for epithelial human breast cancer
MEE	middle ear effusion
MIR	mid-wave infrared
ML	machine learning
MLP	multilayer perceptron
MNDC	major neurocognitive disease
mNDC	minor neurocognitive disease
MNF	minimum noise fraction
MPI	meso-patterned imaging
MRI	magnetic resonance imaging
MSI	multispectral imaging
MSOT	multispectral optoacoustic tomography
MWIR	midwave infrared
NA	numerical aperture

NADH	nicotinamide adenine dinucleotide + hydrogen
NBI	narrow-band imaging
NC (or nc)	nanocrystal
NCD	neurocognitive disorder
NIR	near infrared
NIRS	near-infrared spectroscopy
NOR	no outlier removal
NP	nanoparticle
OA	osteoarthritis
OCA	optical clearing agent
OCS	optically cleared scalp
OCT	optical coherence tomography
OD	optical density
OM	otitis media
OME	otitis media with effusion
OPA	orthogonal projection approach
OS	organic shell
OSA	optical spectrum analyzer
PA	photoacoustic
PAA	polyacrylic acid
PAI	photoacoustic imaging
PAM	photoacoustic microscopy
PBM	photobiomodulation
PBS	phosphate-buffered saline
PC	principal component
PCA	principal component analysis
PCR	principal component regression
PD	photodiode
PDMS	polydimethylsiloxane
PDT	photodynamic therapy
PE	peripheral edema
PEG	polyethylene glycol
PEI	polyethylenimine
PET	positron emission tomography
PG	propylene glycol
PL	photoluminescence
PLGA	poly(lactic-co-glycolic) acid
PLM	polarized light microscopy
PLS	partial least-squares
PLSDA	partial least-squares discriminant analysis
PLSR	partial least-squares regression
PMLRL	passive mode-locked ring laser
PS	polarization sensitive

PT	photothermal
PTA	percutaneous ablation
PTT	photothermal therapy
QD	quantum dot
QDPD	quantum dot photodiode
QLF	quantitative light-induced fluorescence
QOC	questionable occlusal carious lesion
QWP	quarter-wave plate
RCM	reflectance confocal microscopy
RE	rare earth
REDN	rare-earth doped nanoparticle
ReLU	rectified linear unit
ResNet	residual network
RF	random forest
RGB	red–blue–green
RMSE	root mean-square error
RMSEP	root mean-square error prediction
RPM	remote patient monitoring
RNS	reactive nitrogen species
ROC	receiver operating characteristic
ROI	region of interest
ROS	reactive oxygen species
RT	radiotherapy
SBN	signal-to-background-noise ratio
SC	supercontinuum
SCG	supercontinuum generator
SD	spectral domain
SD	standard deviation
SFDI	spatial frequency domain imaging
SFI	speckle flow index
SHG	second-harmonic generation
SIA	spectrophotometric intracutaneous analysis
SIMPLISMA	simple-to-use interactive self-modeling analysis
SLED	superluminescent light-emitting diode
SLM	spatial light modulator
SMF	single-mode fiber
SNR	signal-to-noise ratio
SNV	standard normal variate
SOR	signature outlier removal
SPECT	single-photon emission computed tomography
SPI	single-pixel imaging
SRH	stimulated Raman histology
SS	swept source

SSS	superior sagittal sinus
S/V	surface-area-to-volume ratio
SVM	support vector machine
SVM-L	SVM classifier with a linear kernel
SWIR	short-wave infrared
SWNT	single-walled (carbon) nanotube
TCC	transitional cell carcinoma
TD	time domain
TEI	tissue erythema index
TEM	transmission electron microscopy
TFI	tissue fluid index
THG	third-harmonic generation
TM	transmission metal
TMR	transverse microradiography
TN	true negative
TOW	tissue optical window
TP	true positive
TPEF	two-photon excited fluorescence
TPR	true positive rate
TURBT	transurethral resection (of the) bladder tumor
UC	upconversion
UC	urothelial carcinoma
UCL	upconversion photoluminescence
UCNP	upconversion nanoparticle
US	ultrasound
UTUC	urinary tract urothelial carcinoma
UV	ultraviolet
VHP	Visible Human Project
VIS	visible portion of the spectral range
VIS–NIR	visible near infrared
VNIR	visible and near infrared
VPR	valley-to-peak ratio
VVMS	VeroVision® mail screener
WD	working distance
WttB	“window to the brain”
YSZ	yttria-stabilized zirconia
ZBLAN	zirconium barium lanthanum aluminum sodium fluoride