Field Guide to

Visual and Ophthalmic Optics

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Visual optics is a scientific field that brings together many disciplines. Optical engineering and biology are interwoven to produce the most sophisticated imaging system known. The human visual system functions over a broad range of conditions, adapts to its surroundings and is capable of quickly processing complex visual information at enviable speeds. Many of the great names of optical physics such as Newton, Maxwell, Young, Helmholtz, and Alvarez have all made significant contributions to the field of visual optics. This book assembles much of the anatomy, physiology, and functioning of the eye, as well as the engineering and design of a wide assortment of tools for measuring, photographing and characterizing properties of the surfaces and structures of the eye. Finally, descriptions of our attempts to correct vision, reverse the aging process, and improve on Mother Nature are given.

I would like to express my gratitude to several colleagues for their help with this book. First, I'd like to thank John Greivenkamp for granting the opportunity to write this book and for his mentoring and friendship. Second, I'd like to thank Joseph Miller, whose enthusiasm for engineering is contagious, and whose ideas are always elegant. Finally, I'd like to thank Charlie Campbell for passing on a bit of his wisdom and knowledge and for providing an outlet for my babbling about Zernike polynomials.

This book is dedicated to my wonderful wife Diana, my son Max, and my daughter Marie.

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A	Accommodation
A	A-constant
a^*	Color coordinate in CIELAB space
$A(\lambda)$	Aphakic & infant retinal hazard function
$A(\theta)$	Oblique astigmatism
ACD	Anterior chamber depth
AK	Astigmatic keratotomy
ARMD	Age-related macular degeneration
ArF	Argon fluoride
Axis	Cylinder axis
B	Blue channel in RGB space
b^*	Color coordinate in CIELAB space
$B(\lambda)$	Blue light retinal hazard function
$\bar{b}(\lambda)$	Color matching function in CIE RGB space
BD	Base down
BI	Base in
BO	Base out
BU	Base up
C_A, C_B, C_C	Constants for laser exposure calculations
C^*_{uv},C^*_{ab}	Chroma
cd	Units of candelas
CIE	Commission Internationale de l'Eclairage
CK	Conductive keratoplasty
CMF	Color matching function
CSF	Contrast sensitivity function
Cyl	Cylinder power
D	Units of diopters (inverse meters)
D	Pupil diameter
d	Distance
$d\phi$	Power error
D65	6500° K reference white light source
E	Component of the first fundamental form
E_v	Illuminance
F	Component of the first fundamental form
f	Focal length
f_o	Spatial frequency
FOV	Field of view
G	Green channel in RGB Space

G	Component of the first fundamental form
$\bar{g}(\lambda)$	Color matching function in CIE RGB space
H	Mean curvature
h_{ab}, h_{uv}	Hue
HDTV	High-definition television
I_v	Luminous intensity
ICG	Indocyanine green
IOL	Intraocular lens
J0	Horizontal crossed cylinder
J45	Oblique crossed cylinder
JCC	Jackson crossed cylinder
K	Conic constant
K	Keratometry values
K	Gaussian curvature
L	Luminance
L	Axial length
L	Component of the second fundamental form
L^*, L_v, L_λ	Luminance
$L(\lambda)$	Long-wavelength cone fundamental
LA	LogMAR acuity
LASEK	Laser epithelial keratomileusis
LASIK	Laser in situ keratomileusis
LOS	Line of sight
LCA	Longitudinal chromatic aberration
lm	Units of lumens
LSA	Longitudinal spherical aberration
LTK	Laser thermal keratoplasty
lux	Units of lumens/m^2
M	Spherical equivalent power
M	Component of the second fundamental form
$M(\lambda)$	Middle-wavelength cone fundamental
MPE	Maximum permissible exposure
N	Component of the second fundamental form
n,n'	Index of refraction
n_k	Keratometric index of refraction
OCT	Optical coherence tomography
OD	Oculus dexter (right eye)

OS	Oculus sinister (left eye)
OU	Oculus uterque (both eyes)
P	Prism power
PI-PIV	Purkinje images
PAL	Progressive addition lens
PD	Interpupillary distance
PIOLs	Phakic intraocular lenses
PMMA	Polymethylmethacrylate
PRK	Photorefractive keratectomy
q'	Center of rotation of the eye
R	Radius of curvature
R	Red channel in RGB space
r	Radial position in polar coordinates
R_x, R_y	Radii of curvature along the x and y axes
$R(\lambda)$	Thermal retinal hazard function
$\bar{r}(\lambda)$	Color matching function in CIE RGB space
RGP	Rigid gas permeable
RK	Radial keratotomy
ROC	Radius of curvature
S	Snellen fraction
$S(\lambda)$	Short-wavelength cone fundamental
SEP	Spherical equivalent power
SF	Surgeon factor
SLO	Scanning laser ophthalmoscope
SLT	Selective laser trabeculoplasty
Sph	Spherical power
t	Thickness
t	Exposure time
Td	Units of troland
U	Object vergence
u^*,u	Color coordinates in CIELUV space
V	Image vergence
v^*, v'	Color coordinates in CIELUV space
$V(\lambda)$	CIE photopic response
$V'(\lambda)$	CIE scotopic response
$V^*(\lambda)$	Stockman & Sharpe corrected photopic response
W	Wavefront error
X	Tristimulus value in CIE XYZ space

x	Chromaticity coordinate in CIE XYZ space
x	Horizontal Cartesian coordinate
$\bar{x}(\lambda)$	Color matching function in CIE XYZ space
Y	Tristimulus value in CIE XYZ space
y	Chromaticity coordinate in CIE XYZ space
y	Vertical Cartesian coordinate
$\bar{y}(\lambda)$	Color matching function in CIE XYZ space
Z	Tristimulus value in CIE XYZ space
z	Chromaticity coordinate in CIE XYZ space
z	Axial Cartesian coordinate
$\bar{z}(\lambda)$	Color matching function in CIE XYZ space
$Z_n^m(\rho,\theta)$	Zernike polynomial
Δ	Units of prism diopters
ΔE	Color difference in CIELAB and CIELUV spaces
$\Delta\lambda$	Wavelength interval
Δx, Δy, Δz	Translation along Cartesian axes
Φ,ϕ	Power
Φ_a	Axial power
Φ_i	Instantaneous power
Φ_v	Luminous flux
$\Phi(\lambda)$	Radiometric power
$\kappa 1$, $\kappa 2$	Principal curvatures
λ	Wavelength
θ	Angle in polar coordinates
ρ	Normalized radial position in polar coordinates
τ	Transmission