Field Guide to

Polarization

Edward Collett

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John E. Greivenkamp, Series Editor

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John E. Greivenkamp, *Series Editor*
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Field Guide to Polarized Light

The polarization of light is one of the most remarkable phenomena in nature and has led to numerous discoveries and applications. Today it continues to play a vital role in optics. Before the 1950s there was very little activity on the foundations of polarized light. For example, answers to questions such as the nature and mathematical formulation of unpolarized light and partially polarized light were not readily forthcoming. Today there is a very good understanding of polarized light. In particular, the mathematical difficulties that had hindered complex polarization calculations were finally overcome with the introduction of the Mueller-Stokes matrix calculus and the Jones matrix calculus. Research in polarized light continues with much vigor as witnessed by the continued appearance of numerous publications and conferences.

The primary objective of this Guide is to provide an introduction to the developments in polarized light that have taken place over the past half-century. In this Guide I have tried to present the most salient topics on the subject. Hopefully, this Field Guide will enable the reader to have a good grasp of the material and most of all to allow him or her to be comfortable and even delighted with the beauty and subject of polarized light.

Finally, this Field Guide is dedicated to my wife, Mary Ann, and my children Ron and Greg. Their encouragement and support greatly simplified the task of writing this Guide.

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Frequently used variables and symbols:

B	birefringence
$\mathbf{B}(\mathbf{r},t)$	magnetic induction vector
c	speed of light in a vacuum
cp	circularly polarized
db	decibels
$\mathbf{D}(\mathbf{r},t)$	electric displacement vector
e-	extraordinary ray
ε	permittivity constant
E_{0x}	maximum amplitude in the x direction
E_{0y}	maximum amplitude in the y direction
$E_x(\boldsymbol{r},t)$	x component of the optical field
$E_y(\boldsymbol{r},t)$	y component of the optical field
$\mathbf{E}$	Jones vector
$\mathbf{E}(\mathbf{r},t)$	electric field vector
$\mathbf{F}$	force vector
H_0	Transmission of two parallel polarizers
H_{90}	Transmission of two crossed polarizers
$\mathbf{H}(\mathbf{r},t)$	magnetic field vector
HWP	half wave plate
i	angle of incidence
i_B	Brewster angle
$\mathbf{i},\mathbf{j},\mathbf{k}$	Cartesian unit vectors
$\mathbf{J}$	Jones matrix
$\mathbf{j}(\mathbf{r},t)$	electric current density vector,
$\mathbf{J}_{\mathrm{POL}}$	Jones matrix for a polarizer
$\mathbf{J}_{\mathrm{WP}}$	Jones matrix for a wave plate
$\mathbf{J}_{\mathrm{ROT}}$	Jones matrix for a rotator
$\mathbf{J}_{\mathrm{QWP}}$	Jones matrix for a quarter-wave plate
$\mathbf{J}_{\mathrm{HWP}}$	Jones matrix for a half-wave plate

Glossary (cont'd)

$\mathbf{J}(\theta)$	Jones matrix for a rotated polarizing element
k	wave number
$\mathbf{k}$	wave vector
k_1	major transmittance of a polarizer
k_2	minor transmittance of a polarizer
KDP	potassium dihydrogen phosphate
L–45P	linear –45 polarization
L+45P	linear +45 polarization
LCP	Left circular polarization
LHP	linear horizontal polarization
LVP	linear vertical polarization
μ	permeability constant
M	Mueller matrix
M_{HWP}	Mueller matrix of a half-wave plate
M_{LP}	Mueller matrix of a linear polarizer
M_{POL}	Mueller matrix of a polarizer
M_{QWP}	Mueller matrix of a quarter-wave plate
M_R	Mueller matrix for reflection
M_{ROT}	Mueller matrix of a rotator
M_T	Mueller matrix for transmission
M_{WP}	Mueller matrix of a wave plate
$M(\theta)$	Mueller matrix of a rotated polarizing element
$\mathbf{n}$	complex refractive index
n_e	refractive index of the extraordinary ray
n_o	refractive index of the ordinary ray
n_p	parallel refractive index
n_s	perpendicular refractive index
n_L	levo-rotary refractive index

n_R	dextro-rotary refractive index
n	refractive index
o-	ordinary ray
OPS	observable polarization sphere
p-	parallel polarization state
p_x	polarizer transmission coefficient (x)
p_y	polarizer transmission coefficient (y)
$\mathcal{P}$	degree of polarization
PBS	polarizing beam splitter
QWP	quarter wave plate
r	angle of refraction
$\mathbf{r}$	radius vector
RCP	right circular polarization
s-	perpendicular polarization state
S	Stokes vector
S_0	first Stokes parameter
S_1	second Stokes parameter
S_2	third Stokes parameter
S_3	fourth Stokes parameter
S_R	Stokes vector for reflection
S_T	Stokes vector for transmission
TIR	total internal reflection
UNP	unpolarized
$\mathbf{v}(\mathbf{r},t)$	velocity vector
v_x, v_y, v_z	principal velocities
V	Verdet's constant
V_π	half-wave voltage
V_m	maximum modulation voltage
WP	wave plate
x,y,z	Cartesian coordinate system

2α	coordinate on the observable polarization sphere
2ψ	coordinate angle on the Poincaré sphere
2χ	coordinate angle on the Poincaré sphere
α	auxiliary angle
$\boldsymbol{\varepsilon}$	complex dielectric constant
ε_x, ε_y, ε_z	principal dielectric constants
δ	coordinate on the observable polarization sphere
δ	phase difference
δ_x	phase of the wave (x)
δ_y	phase of the wave (y)
θ	angle of rotation
κ	absorption coefficient
ψ	orientation angle
χ	ellipticity angle
$\rho_{s,p}$	Fresnel reflection coefficients
$\rho(\mathbf{r},t)$	electric charge density
σ	conductivity
$\tau_{s,p}$	Fresnel transmission coefficients
ϕ	phase shift
ϕ_x	phase shift (x)
ϕ_y	phase shift (y)
ω	angular frequency
ω_c	cyclotron frequency
ω_L	Larmor's frequency
ω_m	modulation frequency
∇	spatial vector operator