Fundamentals of Photonics
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SYMBOLS

Roman Symbols

a = Radius of an aperture or fiber [m]; also, Lattice constant [m]
a = Normalized complex amplitude of an optical field ($|\mathsf{a}|^2$ = photon number)
$\mathscr{a}$ = Amplitude (magnitude) of an optical wave; also, Normalized complex amplitude of an optical field ($|\mathscr{a}|^2$ = photon flux density)
A = Complex envelope of a monochromatic plane wave
$A(\mathbf{r})$ = Complex envelope of a monochromatic wave
A_ν = Complex envelope of the component of a wave at frequency ν
A = Area [m^2]; also, Element of the *ABCD* matrix
A_c = Coherence area [m^2]
$\mathscr{A}(\mathbf{r}, t)$ = Complex envelope of a polychromatic (e.g., pulsed) wave
$\mathbf{A}$ = Vector potential [$V \cdot s \cdot m^{-1}$]
$\mathbb{A}$ = Einstein A coefficient [s^{-1}]
ASE = Amplified spontaneous emission

B = Magnetic flux-density complex amplitude [Wb/m^2]; also, Bandwidth [Hz]
B_0 = Bit rate [bits/s]
B = Element of the *ABCD* matrix
$\mathscr{B}$ = Magnetic flux density [Wb/m^2]; also, Power-equivalent spectral width [Hz]
$\mathbb{B}$ = Einstein B coefficient [$m^3 \cdot J^{-1} \cdot s^{-2}$]
BER = Bit error rate

c = Speed of light; Phase velocity [m/s]
c_o = Speed of light in free space [m/s]
C = Electrical capacitance [F]
$C(\cdot)$ = Fresnel integral
C = Element of the *ABCD* matrix
$\mathcal{C}$ = Coupling coefficient in a directional coupler [m^{-1}]

d = Differential
$d\mathbf{r}$ = Incremental volume [m^3]

ds = Incremental length [m]
d = Distance; Length [m]
$\mathcal{d}$ = Coefficient of second-order optical nonlinearity [$C \cdot V^{-2}$]
$\mathcal{d}_{ijk}$ = Element of the second-order optical nonlinearity tensor [$C \cdot V^{-2}$]
$\mathcal{d}_{Ik}$ = Element of the second-order optical nonlinearity tensor (contracted indices) [$C \cdot V^{-2}$]
$\mathcal{d}(\omega_3; \omega_1, \omega_2)$ = Coefficient of second-order optical nonlinearity (dispersive medium) [$C \cdot V^{-2}$]
D = Diameter [m]; also, Electric flux-density complex amplitude [C/m^2]
D_w = Waveguide dispersion coefficient [$s \cdot m^{-2}$]
D_x, D_y = Lateral widths [m]
D_λ = Material dispersion coefficient [$s \cdot m^{-2}$]
D_ν = Material dispersion coefficient [$s^2 \cdot m^{-1}$]
D = Element of the *ABCD* matrix
$\mathscr{D}$ = Electric flux density [C/m^2]

e = Magnitude of electron charge [C]
$\hat{\mathbf{e}}_x$ = Unit vector in the x direction
E = Electric-field complex amplitude [V/m]
E = Energy [J]
E_A = Acceptor energy level [J]
E_c = Energy at the bottom of the conduction band [J]
E_D = Donor energy level [J]
E_f = Fermi energy [J]
E_{fc} = Quasi-Fermi energy for the conduction band [J]
E_{fv} = Quasi-Fermi energy for the valence band [J]
E_g = Bandgap energy [J]
E_v = Energy at the top of the valence band [J]
E_ν = Energy spectral density [$J \cdot Hz^{-1}$]
$\mathscr{E}$ = Electric field [V/m]

f = Focal length of a lens [m]; also, Frequency [Hz]
$f(E)$ = Fermi function
f_a = Probability that absorption condition is satisfied
$f_c(E)$ = Fermi function for the conduction band
f_{col} = Collision rate [s^{-1}]
f_e = Probability that emission condition is satisfied
f_g = Fermi inversion factor
$f_v(E)$ = Fermi function for the valence band
f = Frequency of sound [Hz]; also, Modulation frequency [Hz]
$\mathscr{f}$ = Focal length [m]
F = Excess-noise factor of an avalanche photodiode
$F_\#$ = F-number of a lens
$\mathscr{F}$ = Finesse of a resonator; also, Force [$kg \cdot m \cdot s^{-2}$]

g = Resonator g-parameter
$g(\mathbf{r}_1, \mathbf{r}_2)$ = Normalized mutual intensity

$g(\mathbf{r}_1, \mathbf{r}_2, \tau)$ = Complex degree of coherence
$g(\nu)$ = Lineshape function of a transition [Hz^{-1}]
$g(\tau)$ = Complex degree of temporal coherence
g_0 = Gain factor
$g_{\nu 0}(\nu)$ = Electron–phonon collisionally broadened lineshape function in a semiconductor [Hz^{-1}]
g = Degeneracy parameter
$\mathscr{g}$ = Coupling coefficient in a parametric interaction [m^{-3}]
G = Gain of an amplifier; also, Gain of a photon detector; also, Conductance [Ω^{-1}]
$G(\mathbf{r}_1, \mathbf{r}_2)$ = Mutual intensity [$\mathrm{W/m}^2$]
$G(\mathbf{r}_1, \mathbf{r}_2, \tau)$ = Mutual coherence function [$\mathrm{W/m}^2$]
$G(\nu)$ = Gain of an optical amplifier
$G(\tau)$ = Temporal coherence function [$\mathrm{W/m}^2$]
G = Rate of photoionization in a photorefractive material [$\mathrm{m}^{-3} \cdot \mathrm{s}^{-1}$]
$\mathsf{G}_n(\cdot)$ = Hermite-Gaussian functions
G_0 = Rate of thermal electron-hole generation in a semiconductor [$\mathrm{m}^{-3} \cdot \mathrm{s}^{-1}$]
$\mathbf{G}$ = Coherency matrix [$\mathrm{W/m}^2$]; also, Gyration vector of an optically active medium

h = Planck's constant [$\mathrm{J} \cdot \mathrm{s}$]
$h(t)$ = Impulse-response function of a linear system
$h(x, y)$ = Impulse-response function of a two-dimensional linear system
$\hbar$ = $h/2\pi$ [$\mathrm{J} \cdot \mathrm{s}$]
H = Magnetic-field complex amplitude [A/m]
$\mathsf{H}_n(\cdot)$ = Hermite polynomials
$\mathscr{H}$ = Magnetic field [A/m]
$\mathcal{H}(\nu)$ = Transfer function of a linear system
$\mathcal{H}'(\nu)$ = Real part of the transfer function of a linear system
$\mathcal{H}''(\nu)$ = Imaginary part of the transfer function of a linear system
$\mathcal{H}(\nu_x, \nu_y)$ = Transfer function of a two-dimensional linear system

i = Electric current [A]; also, integer
i_e = Electron current [A]
i_h = Hole current [A]
i_p = Photoelectric current [A]
i_s = Reverse current in a semiconductor p–n diode [A]
i_t = Threshold current of a laser diode [A]
i_T = Transparency current for a laser-diode amplifier [A]
I = Optical intensity [$\mathrm{W/m}^2$]
I_s = Saturation optical intensity of an amplifier or absorber [$\mathrm{W/m}^2$]; also, Acoustic intensity [$\mathrm{W/m}^2$]
I_ν = Intensity spectral density [$\mathrm{W} \cdot \mathrm{m}^{-2} \cdot \mathrm{Hz}^{-1}$]
$\mathscr{I}$ = Moment of inertia [$\mathrm{kg} \cdot \mathrm{m}^2$]

j = $\sqrt{-1}$; also, integer
J = Electric current density [$\mathrm{A/m}^2$]

J_e = Electron current density [A/m^2]
J_h = Hole current density [A/m^2]
$J_m(\cdot)$ = Bessel function of the first kind of order m
J_p = Photoelectric current density [A/m^2]
J_t = Threshold current density of a laser diode [A/m^2]
J_T = Transparency current density for a laser-diode amplifier [A/m^2]
$\mathbf{J}$ = Jones vector

k = Wavenumber [m^{-1}]; also, integer
k_B = Boltzmann's constant [J/K]
k_o = Free-space wavenumber [m^{-1}]
$k_T = (k_x^2 + k_y^2)^{1/2}$ = Lateral component of the wavevector [m^{-1}]
k_x, k_y = Components of the wavevector in the x and y directions [m^{-1}]
= Spatial angular frequencies in the x and y directions [rad/m]
$\mathscr{k}$ = Ionization ratio for an avalanche photodiode
$\mathbf{k}$ = Wavevector [m^{-1}]
$\mathbf{k}_g$ = Grating wavevector [m^{-1}]
$K_m(\cdot)$ = Modified Bessel function of the second kind of order m

l = Length [m]; also, integer
l_c = Coherence length [m]
L = Length [m]; also, Electrical inductance [H]; also, Loss factor; also, integer
L_c = Coherence length in a parametric interaction [m]
$L_n(\cdot)$ = Laguerre polynomials
$L_0 = \pi/2\mathcal{C}$ = Coupling length (transfer distance) in a directional coupler [m]
LP = Linearly polarized mode

$m = m_0$ = Electron mass or atomic mass [kg]; also, integer; also, Contrast or modulation depth
m_c = Effective mass of a conduction-band electron [kg]
m_r = Reduced mass of an atom [kg]; also, Reduced mass of an electron–hole pair in a semiconductor [kg]
m_v = Effective mass of a hole [kg]
m = Photon number; also, Photoelectron number
M = Magnification in an image system; also, Number of modes; also, integer
M = Mass of an atom [kg]
$\mathsf{M}(\nu)$ = Density of modes in a resonator or cavity [$m^{-3} \cdot Hz^{-1}$ for a 3-D resonator; $m^{-1} \cdot Hz^{-1}$ for a 1-D resonator]
$\mathscr{M}$ = Magnetization density [A/m]; also, Number of modes of thermal light; also, Figure of merit for the acousto-optic effect [m^2/W]
$\mathbf{M}$ = Ray-transfer matrix

n = Refractive index; also, integer
$n(\mathbf{r})$ = Refractive index of an inhomogeneous medium
$n(\theta)$ = Refractive index of the extraordinary wave with its wavevector at an angle θ with respect to the optic axis of a uniaxial crystal

n_e = Extraordinary refractive index
n_o = Ordinary refractive index
n_2 = Optical Kerr coefficient (nonlinear refractive index) [m^2/W]
n = Photon number
$\mathscr{n}$ = Photon-number density [m^{-3}]
$\mathscr{n}_s$ = Saturation photon-number density [m^{-3}]
$\mathfrak{n}$ = Concentration of electrons in a semiconductor [m^{-3}]
$\mathfrak{n}_i$ = Concentration of electrons/holes in an intrinsic semiconductor [m^{-3}]
N = Group index; also, integer; also, Number of atoms; also, Number of resolvable spots of a scanner
N_F = Fresnel number
N = Number density [m^{-3}]; also, $N = N_2 - N_1$ = Population density difference between energy levels 2 and 1 [m^{-3}]
N_a = Atomic number density [m^{-3}]
N_A = Number density of ionized acceptor atoms in a semiconductor [m^{-3}]
N_D = Number density of ionized donor atoms in a semiconductor [m^{-3}]
N_t = Laser threshold population difference [m^{-3}]
N_0 = Steady-state population difference in the absence of amplifier radiation [m^{-3}]
NA = Numerical aperture

p = Probability; also, Momentum [$kg \cdot m \cdot s^{-1}$]; also, Grade profile parameter of a graded-index fiber
$p(n)$ = Probability of n events
$p(x, y)$ = Aperture function or pupil function
p_{ab} = Probability density for absorption (mode containing one photon) [s^{-1}]
p_{sp} = Probability density for spontaneous emission (into one mode) [s^{-1}]
p_{st} = Probability density for stimulated emission (mode containing one photon) [s^{-1}]
p = Normalized electric-field quadrature component
$\mathscr{p}$ = Dipole moment [$C \cdot m$]
$\mathfrak{p}$ = Concentration of holes in a semiconductor [m^{-3}]
$\mathfrak{p}$ = Photoelastic constant (strain-optic coefficient)
$\mathfrak{p}_{ijkl}$ = Element of the strain-optic tensor
$\mathfrak{p}_{IK}$ = Element of the strain-optic tensor (contracted indices)
P = Electric polarization-density complex amplitude [C/m^2]
$P(\nu_x, \nu_y)$ = Fourier transform of the aperture function $p(x, y)$
P_{ab} = Probability density for absorption (mode containing many photons) [s^{-1}]
P_{NL} = Complex amplitude of the nonlinear component of the polarization density [C/m^2]
P_{sp} = Probability density for spontaneous emission (into any mode) [s^{-1}]
P_{st} = Probability density for stimulated emission (mode containing many photons) [s^{-1}]
P = Optical power [W]
P_ν = Power spectral density [$W \cdot Hz^{-1}$]

P_π = Half-wave optical power in a Kerr medium [W]
$\mathscr{P}$ = Electric polarization density [C/m^2]; also, Optical power [dBm]
$\mathscr{P}_L$ = Linear component of the polarization density [C/m^2]
$\mathscr{P}_{NL}$ = Nonlinear component of the polarization density [C/m^2]
$\mathfrak{P}$ = Degree of polarization

q = Electric charge [C]; also, Wavenumber of an acoustic wave [m^{-1}]; also, integer (mode index, diffraction order)
$q(z)$ = Complex Gaussian-beam parameter [m]
$\mathbf{q}$ = Wavevector of an acoustic wave [m^{-1}]
Q = Electric charge [C]; also, Quality factor of an optical resonator

r = Radial distance in spherical coordinates [m]; also, Radial distance in a cylindrical coordinate system [m]
$\mathbf{r}$ = Position vector [m]
$r(\nu)$ = Rate of photon emission/absorption from a semiconductor [m^{-3}]
$\mathscr{r}$ = Complex amplitude reflectance; also, Round-trip (real) amplitude attenuation factor for a wave in a Fabry-Perot resonator
$\mathfrak{r}$ = Electron–hole recombination parameter [m^3/s]
$\mathfrak{r}_{nr}$ = Nonradiative electron–hole recombination parameter [m^3/s]
$\mathfrak{r}_r$ = Radiative electron–hole recombination parameter [m^3/s]
$\mathfrak{r}$ = Linear electro-optic (Pockels) coefficient [m/V]
$\mathfrak{r}_{ijk}$ = Element of the linear electro-optic tensor [m/V]
$\mathfrak{r}_{Ik}$ = Element of the linear electro-optic tensor (contracted indices) [m/V]
R = Radius of curvature [m]; also, Electrical resistance [Ω]
$R(z)$ = Radius of curvature of a Gaussian beam [m]
R = Pumping rate [s^{-1} · m^{-3}]; also, Recombination rate in a semiconductor [s^{-1} · m^{-3}]; also, Electron–hole injection rate in a semiconductor [s^{-1} · m^{-3}]
R_t = Laser threshold pumping rate [s^{-1} · m^{-3}]
$\mathscr{R}$ = Intensity or power reflectance
$\mathfrak{R}$ = Responsivity of a photon source [W/A]; also, Responsivity of a photon detector [A/W]
$\mathfrak{R}_d$ = Differential responsivity of a laser diode [W/A]
$\mathbf{R}(\theta)$ = Jones matrix for coordinate rotation by an angle θ

s = Length or distance [m]
$s(\mathbf{r}_1, \mathbf{r}_2, \nu)$ = Normalized cross-spectral density
$s(x, t)$ = Strain wavefunction
s_{ij} = Element of the strain tensor
$\mathfrak{s}$ = Quadratic electro-optic (Kerr) coefficient [m^2/V^2]
$\mathfrak{s}_{ijkl}$ = Element of the quadratic electro-optic tensor [m^2/V^2]
$\mathfrak{s}_{IK}$ = Element of the quadratic electro-optic tensor (contracted indices) [m^2/V^2]
S = Transition strength (oscillator strength) [m^2 · Hz]
$S(\mathbf{r})$ = Complex amplitude for a radiation source [V/m^3]
$S(\cdot)$ = Fresnel integral

$S(\mathbf{r})$ = Eikonal [m]
$S(\mathbf{r}_1, \mathbf{r}_2, \nu)$ = Cross-spectral density [W/m^2 · Hz]
$S(\nu)$ = Power spectral density [W/m^2 · Hz]
$\mathscr{S}$ = Poynting vector [W/m^2]
$\mathcal{S}$ = Photon spin [J · s]
SNR = Signal-to-noise ratio

t = Time [s]
t_{sp} = Spontaneous lifetime [s]
$\mathscr{t}$ = Complex amplitude transmittance
T = Temperature [K]
T = Transit time [s]; also, Counting time [s]; also, Switching time [s]; also, Bit time interval [s]; also, Resolution time ($\mathsf{T} = 1/2B$ where B = Bandwidth) [s]; also, Period of a wave ($\mathsf{T} = 1/\nu$ where ν = frequency) [s]
T_F = $1/\nu_F$ = Inverse of resonator-mode frequency spacing [s]; also, Period of a mode-locked laser pulse train [s]
$\mathscr{T}$ = Intensity or power transmittance; also, Power-transfer or power-transmission ratio
$\mathbf{T}$ = Jones matrix
TE = Transverse electric wave
TEM = Transverse electromagnetic wave
TM = Transverse magnetic wave

u = Displacement [m]
$u(\mathbf{r}, t)$ = Wavefunction of an optical wave
$\hat{\mathbf{u}}$ = Unit vector
$U(\mathbf{r})$ = Complex amplitude of a monochromatic optical wave
$U(\mathbf{r}, t)$ = Complex wavefunction of an optical wave
$U_\nu(\mathbf{r})$ = Fourier transform of the wavefunction of an optical wave

v = Group velocity of a wave [m/s]
v_s = Velocity of sound [m/s]
v = Velocity of an atom or object [m/s]
v_e = Velocity of an electron [m/s]
v_h = Velocity of a hole [m/s]
V = Volume [m^3]; also, Voltage [V]; also, Verdet constant [m/Wb]
V_c = Critical voltage for a liquid-crystal cell [V]
V_π = Half-wave voltage of an electro-optic retarder or modulator [V]
V_0 = Built-in potential difference in a p–n junction [V]; also Switching voltage of a directional coupler [V]
V = Fiber V parameter
$\mathsf{V}(\mathbf{r})$ = Potential energy [J]
$\mathscr{V}$ = Visibility
$\mathcal{V}$ = $\mathcal{V}$-number of a dispersive medium

w = Width [m]
w_d = Width of the absorption region in an avalanche photodiode [m]

w_m = Width of the multiplication region in an avalanche photodiode [m]
W = Work function [J]
$W(z)$ = Width or radius of a Gaussian beam at an axial distance z from the beam center [m]
W_0 = Waist radius of a Gaussian beam [m]
W = Probability density for absorption of pump light [s^{-1}]
W_i = Probability density for absorption and stimulated emission [s^{-1}]
$\mathscr{W}$ = Integrated optical power in units of photon number

x = Position coordinate; displacement [m]
x = Normalized electric-field quadrature component
$x(t)$ = Inverse Fourier transform of the susceptibility of a dispersive medium $\chi(\nu)$

y = Position coordinate [m]

z = Position coordinate (Cartesian or cylindrical coordinates) [m]
z_0 = Rayleigh range of a Gaussian beam [m]; also, Rayleigh range of a Gaussian pulse traveling in a dispersive medium [m]
Z = Atomic number

Greek Symbols

α = Attenuation or absorption coefficient [m^{-1}]; also, Apex angle of a prism; also, Twist coefficient of a twisted nematic liquid crystal [m^{-1}]
α_e = Electron ionization coefficient in a semiconductor [m^{-1}]
α_h = Hole ionization coefficient in a semiconductor [m^{-1}]
α_m = Loss coefficient of a resonator attributed to a mirror [m^{-1}]
α_r = Effective overall distributed loss coefficient [m^{-1}]
α_s = Loss coefficient of a laser medium [m^{-1}]
α_p = Mean value of p for a coherent state
α_x = Mean value of x for a coherent state
$\boldsymbol{\alpha}$ = Attenuation coefficient of an optical fiber [dB/km]

$\beta = k_z$ = Propagation constant [m^{-1}]
β' = First derivative of β with respect to ω [$m^{-1} \cdot s$]
β'' = Second derivative of β with respect to ω [$m^{-1} \cdot s^2$]
$\beta(\nu)$ = Propagation constant in a dispersive medium [m^{-1}]
$\beta_0 = \beta(\nu_0)$ = Propagation constant at the central frequency ν_0 [m^{-1}]

γ = Gain coefficient [m^{-1}]; also, Coupling coefficient in a parametric device [m^{-1}]; also, Nonlinear coefficient in soliton theory; also, Lateral decay coefficient in a waveguide [m^{-1}]; also, Magnetogyration coefficient [m^2/Wb]
$\gamma(\nu)$ = Gain coefficient of an optical amplifier [m^{-1}]
γ_p = Peak gain coefficient of a laser-diode amplifier [m^{-1}]
$\gamma_0(\nu)$ = Small-signal gain coefficient of an optical amplifier [m^{-1}]
Γ = Retardation; also, Confinement factor

$\delta(\cdot)$ = Delta function or impulse function
δx = Increment of x
$\delta\nu$ = Spectral width of resonator modes [Hz]
Δ = Thickness of a thin optical component [m]; also, Fractional refractive-index change in an optical fiber or waveguide
Δx = Increment of x
Δn = Concentration of excess electron–hole pairs [m^{-3}]
Δn_T = Transparency injected-carrier concentration for a laser-diode amplifier [m^{-3}]
$\Delta\nu$ = Spectral width or linewidth [Hz]
$\Delta\nu_c$ = $1/\tau_c$ = spectral width [Hz]
$\Delta\nu_D$ = Doppler linewidth [Hz]
$\Delta\nu_{\mathrm{FWHM}}$ = Full-width-at-half-maximum spectral width [Hz]
$\Delta\nu_s$ = Linewidth of a saturated amplifier [Hz]

ϵ = Electric permittivity of a medium [F/m]; also, Focusing error [m^{-1}]
ϵ_{ij} = Component of the electric permittivity tensor [F/m]
ϵ_o = Electric permittivity of free space [F/m]

$\zeta(z)$ = Excess axial phase of a Gaussian beam

η = Impedance of a dielectric medium [Ω]; also, Electric impermeability
η_{ij} = Component of the electric impermeability tensor
η_o = Impedance of free space [Ω]
η = Quantum efficiency; also, Efficiency of power transfer; also, Power-conversion (wall-plug) efficiency
η_d = External differential quantum efficiency
η_e = Emission efficiency; also, Overall transmission efficiency
η_{ex} = External quantum efficiency
η_i = Internal quantum efficiency

θ = Angle
$\bar{\theta}$ = $90° - \theta$ = Complement of angle θ
θ_a = Acceptance angle
θ_B = Brewster angle; also, Bragg angle
θ_c = Critical angle
$\bar{\theta}_c$ = Complementary critical angle
θ_d = Deflection angle of a prism
θ_s = Angle subtended by source
θ_0 = Divergence angle of a Gaussian beam
ϑ = Threshold

κ = Elastic constant of a harmonic oscillator [$\mathrm{J/m^2}$]

λ = Wavelength [m]
λ_A = Acceptor long-wavelength limit [m]
λ_F = Wavelength spacing of adjacent resonator modes [m]
λ_g = Bandgap wavelength (long-wavelength limit) of a semiconductor [m]

λ_o = Free-space wavelength [m]
Λ = Spatial period of a grating or periodic structure [m]; also, Wavelength of an acoustic wave [m]

μ = Magnetic permeability [H/m]; also, Carrier mobility in a semiconductor [$m^2 \cdot s^{-1} \cdot V^{-1}$]
μ_e = Electron mobility [$m^2 \cdot s^{-1} \cdot V^{-1}$]
μ_h = Hole mobility [$m^2 \cdot s^{-1} \cdot V^{-1}$]
μ_o = Magnetic permeability of free space [H/m]

ν = Frequency [Hz]
ν_F = Frequency spacing of adjacent resonator modes; free spectral range of a Fabry-Perot spectrometer [Hz]
ν_s = Spatial bandwidth of an imaging system [m^{-1}]
ν_q = Frequency of mode q [Hz]
ν_x, ν_y = Spatial frequencies in the x and y directions [m^{-1}]
$\nu_\rho = (\nu_x^2 + \nu_y^2)^{1/2}$ = Radial component of the spatial frequency [m^{-1}]
ν_0 = Central frequency [Hz]

ξ = Coupling coefficient in four-wave mixing

ρ = Rotatory power of an optically active medium [m^{-1}]; also, $\rho = (x^2 + y^2)^{1/2}$ = Radial distance in a cylindrical coordinate system [m]
ρ_c = Coherence distance [m]
ρ_s = Radius of the Airy disk [m]; also, Radius of the blur spot of an imaging system [m]
ϱ = Mass density of a medium [$kg \cdot m^{-3}$]; also, Charge density [$C \cdot m^{-3}$]
$\varrho(k)$ = Wavenumber density of states [m^{-2}]
$\varrho(\nu)$ = Spectral energy density [$J \cdot m^{-3} \cdot Hz^{-1}$]; also, Optical joint density of states [$m^{-3} \cdot Hz^{-1}$]
$\varrho_c(E)$ = Density of states near the conduction band edge [$m^{-3} \cdot J^{-1}$ in a bulk semiconductor]
$\varrho_v(E)$ = Density of states near the valence band edge [$m^{-3} \cdot J^{-1}$ in a bulk semiconductor]

σ = Conductivity [$\Omega^{-1} \cdot m^{-1}$]; also, Damping coefficient of a harmonic oscillator [s^{-1}]
$\sigma(\nu)$ = Transition cross section [m^2]
σ_q = Circuit-noise parameter
σ_x = Standard deviation of a random variable x; rms width of a function of x
$\sigma_0 = \sigma(\nu_0)$ = Transition cross section at the central frequency ν_0 [m^2]

τ = Lifetime [s]; also, Decay time [s]; also, Width of a function of time [s]; also, Excess-carrier electron–hole recombination lifetime in a semiconductor [s]
τ_c = Coherence time [s]
τ_d = Delay time [s]
τ_e = Electron transit time [s]

τ_h = Hole transit time [s]
τ_m = Multiplication time in an avalanche photodiode [s]
τ_{nr} = Nonradiative electron–hole recombination lifetime [s]
τ_p = Resonator photon lifetime [s]
τ_r = Radiative electron–hole recombination lifetime [s]
τ_s = Saturation time constant of a laser transition [s]
τ_{21} = Lifetime of a transition between energy levels 2 and 1 [s]

ϕ = Angle in a cylindrical coordinate system; also, Photon flux density $[\mathrm{m}^{-2} \cdot \mathrm{s}^{-1}]$
$\phi(p)$ = Momentum wavefunction $[\mathrm{s}^{1/2} \cdot \mathrm{kg}^{-1/2} \cdot \mathrm{m}^{-1/2}]$
ϕ_ν = Spectral photon flux density $[\mathrm{m}^{-2} \cdot \mathrm{s}^{-1} \cdot \mathrm{Hz}^{-1}]$
$\phi_s(\nu)$ = Saturation photon-flux density $[\mathrm{m}^{-2} \cdot \mathrm{s}^{-1}]$
φ = Phase
$\varphi(\nu)$ = Phase-shift coefficient of an optical amplifier $[\mathrm{m}^{-1}]$
Φ = Photon flux $[\mathrm{s}^{-1}]$
Φ_ν = Spectral photon flux $[\mathrm{s}^{-1} \cdot \mathrm{Hz}^{-1}]$

χ = Electric susceptibility; also, Electron affinity [J]
χ' = Real part of the electric susceptibility χ
χ'' = Imaginary part of the electric susceptibility χ
$\chi(\nu)$ = Electric susceptibility of a dispersive medium
χ_{ij} = Component of the electric susceptibility tensor
$\chi^{(3)}$ = Coefficient of third-order optical nonlinearity $[\mathrm{C} \cdot \mathrm{m} \cdot \mathrm{V}^{-3}]$
$\chi^{(3)}_{ijkl}$ = Element of the third-order optical nonlinearity tensor $[\mathrm{C} \cdot \mathrm{m} \cdot \mathrm{V}^{-3}]$
$\chi^{(3)}_{IK}$ = Element of the third-order optical nonlinearity tensor (contracted indices) $[\mathrm{C} \cdot \mathrm{m} \cdot \mathrm{V}^{-3}]$

$\psi(x)$ = Particle position wavefunction $[\mathrm{m}^{-1/2}]$
$\Psi(\mathbf{r}, t)$ = Particle wavefunction $[\mathrm{m}^{-3/2} \cdot \mathrm{s}^{-1/2}]$

ω = Angular frequency [rad/s]
Ω = Angular frequency of an acoustic wave [rad/s]; also, Angular frequency of a harmonic electric signal [rad/s]; also, Solid angle

Mathematical Symbols

∂ = Partial differential
∇ = Gradient operator
$\nabla \cdot$ = Divergence operator
$\nabla \times$ = Curl operator
$\nabla^2 = \partial^2/\partial x^2 + \partial^2/\partial y^2 + \partial^2/\partial z^2$ = Laplacian operator
$\nabla_T^2 = \partial^2/\partial x^2 + \partial^2/\partial y^2$ = Transverse Laplacian operator