List of symbols

Note in advance: symbols that are used locally, i.e., within a subchapter only, are not included in the following list.

Symbols

= equal to
≈ approximately equal to
~ very roughly equal to
∝ proportional
≡ identical to
≠ not equal to

α	beam quality
α_p	power absorption coefficient
β	angle of incidence
γ	ray angle
Γ	angular magnification
δ	focal spot diameter (spot size of focus), or diameter of an image point
δ_B	spot size of focus, or diameter of an image point when this is purely diffraction limited
δ_0	spot size of focus, or diameter of an image point with respect to first dark strip or ring
δx, δy	width of an image point or spatial resolution in x-resp. y-direction
ε	dielectric function or relative dielectric constant
ε_0	dielectric permittivity of vacuum
η_e	external quantum efficiency (with respect to a single pixel)
η_i	internal quantum efficiency (with respect to a single pixel)
η_g	fill factor
θ	angle of aperture or angle of diffraction
θ_0	diffraction angle for first zero position
θ_max	diffraction angle corresponding to $k_{x,\mathrm{max}}$ or $k_{y,\mathrm{max}}$; $\sin(\theta_\mathrm{max}) = NA$
θ_t	telecentricity value
κ	deformation coefficient, conic parameter
λ	wavelength of light
Λ	penetration depth
μ_0	magnetic permeability of vacuum
ν	frequency in general or frequency of the incident photon, in particular
ν_d, ν_e	Abbe numbers
$\Delta\nu_\mathrm{ampl}$	amplifier bandwidth

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Π_G, Π_P	Gaussian distribution, Poisson distribution
ρ	difference between the reciprocal curvature radii of a thin lens
ρ_E	amplitude reflection coefficient
ρ_P	power reflection factor, reflectance
σ	standard deviation
σ_ampl	noise of the (pre-)amplifier
σ_dark	dark signal noise (rms number of noise electrons)
$\sigma_\mathrm{e,tot}$	total noise of a single pixel (rms number of noise electrons in total)
σ_pe	signal noise of the photoelectrons resulting from photon noise only
σ_ph	photon (or shot) noise
σ_pix	total noise of a single pixel (rms number in ADU; corresponds to $\sigma_\mathrm{e,tot}$)
σ_read	read noise
τ_E	amplitude transmission coefficient
τ_f	film transmittance
τ_P	power transmission factor, transmittance
τ_read	read (out) time
ϕ	phase
Φ	luminous resp. radiant power, flux
Φ_pix	radiant flux or luminous flux of a pixel of the sensor
φ	angle
$\Delta\varphi$	angular resolution
Ψ	angle of view, angle of field
ω	angular frequency
Ω, $\Delta\Omega$	solid angle
$\mathbb{A}$, $\mathbb{B}$, $\mathbb{C}$, $\mathbb{D}$	elements of optical ray transfer matrix
A, A_im	area, area of image
A_en, A_ex, A_eff	area of entrance resp. exit pupil, effective area
A_pix	total area of a single pixel
A'_pix	photosensitive area of a single pixel
a_2, a_4, a_6	aspheric coefficients
a_i, a_o	image distance, object distance
a_n, a_f, a_hf	near point distance, far point distance, hyperfocal distance
$B_\mathrm{obj}(x, y)$	brightness distribution within the object
$B_\mathrm{im}(x, y)$	brightness distribution within the image
$\widetilde{B}(k_x, k_y)$	Fourier spectrum of $B(x, y)$
B_pix	brightness of an image point (i.e., a "pixel" within the image)
B'_pix	B_pix after image processing; units are ADU or counts later on, a screen transfers B'_pix, e.g., into radiant flux in W or radiant intensity in W/sr or something similar
b_r	brightness ratio
c	velocity of light in vacuum
CF	crop factor

C_j	junction capacitance of a photodiode
C_L	calibration constant for light meters
C_o, C_i	constants in object resp. image space
C_pix	capacity within a pixel
d, d_sensor, d_FF	diagonal of image format, of sensor, of full format
d_ar	thickness of antireflection layer
D	diameter
D_eff	effective usable diameter of the lens mount
D_en, D_ex	diameter of entrance pupil, diameter of exit pupil
D_im	diameter of image circle
D_p	pinhole diameter
DR	dynamic range
dr	depth resolution
DS	number of steps within the signal range
DS_max	maximum number of steps within the signal range
$\mathscr{E}$	electric field
$\mathscr{E}_\mathrm{obj}(x, y)$	electric field distribution within the object plane
$\mathscr{E}_\mathrm{im}(x, y)$	electric field distribution within the image plane
e	elementary charge
e_Ho, e_Hi	distance from reference plane E to principal plane H
E, E_v, E_e	illuminance resp. irradiance
E_il	illuminance of incident light
E_pix	illuminance that is incident on a single pixel
e_No, e_Ni	distance from reference plane E to nodal plane N
EV	exposure value
F	fluence (identical with radiant exposure)
F_pix	fluence that is incident on a single pixel
$\overline{F}_\mathrm{pix}$	average F_pix on the pixel
FWC, N_full	number of electrons that could be accumulated at maximum within a single pixel
$f(x)$	function in general
$f_\#$	f-number (= f/D)
$f_\mathrm{\#crit}$	critical f-number
f_Ei	back focal length
f_Eo	front focal length
f_norm, $f_\mathrm{norm,FF}$	focal length of normal lens
f, f_o, f_i	focal length, object resp. image focal length
G	gain
G_a	amplifier gain
G_c	conversion gain
G_i	input referred conversion gain
G_out	output referred conversion gain

h	Planck's constant
h	ray elevation from optical axis, off-axis image distance
H_{av}, H_{m}	recommended average exposure, film exposure at threshold
h_{i}	image height
H, H_{v}, H_{e}	luminous resp. radiant exposure
H_{pix}	luminous exposure that is incident on a single pixel
I	intensity
I_{pe}	photo current of one pixel
I_{dark}	dark current
I_{pix}	intensity that is incident on a single pixel (prior to losses)
I'_{pix}	intensity that is incident on a single pixel after loss-correction, i.e., intensity on the photo diode surface
$\overline{I}_{\mathrm{pix}}$	average I_{pix} on the pixel
j_{pe}	photo current density of one pixel
J_{v}, J_{e}	luminous resp. radiant intensity
$\vec{k}$	wave vector
k	absolute value of the wave vector
k_{cutoff}	cut-off frequency
k_x, k_y, k_z	spatial frequencies
$k_{x,\mathrm{max}}$, $k_{y,\mathrm{max}}$, k_{max}	maximum possible spatial frequency for a given optical system in x- or y-direction, respectively, or in general
k_{B}	Boltzman's constant
K_{m}, K'_{m}	luminous efficacy
l	length
l_{eff}	effective available distance in camera body
l_{opt}	optical path length
l_{ot}	optical tube length
L, L_{v}, L_{e}	luminance resp. radiance
m	integer number
$\mathbf{M}_{\mathrm{L}}$, $\mathbf{M}_{\mathrm{os}}$	lens matrix, ray transfer matrix of the optical system
m_{o}, m_{i}	slope in object resp. image space
M_{p}	pupil magnification
M, M_{v}, M_{e}, M_{rel}, $M_{\mathrm{rel,FF}}$	magnification
n, n_{o}, n_{i}, n_0, n_1, n_2, n_{s}, n_{ar}	refractive index
NA, NA_{o}, NA_{i}	numerical aperture, in object respectively image space
N_{e}	number of electrons generated within one pixel (this includes, e.g., N_{pe} and N_{dark})
$N_{\mathrm{e,min}}$	minimum value of N_{pe}
$N_{\mathrm{e,max}}$	maximum value of N_{pe}

ΔN_e	uncertainty of the number of electrons generated within one pixel (usually rms value; due to noise)
N_{eff}	effective value of number of read out electrons
N_h	number of pixels in horizontal direction, e.g., of a screen or sensor
N_v	number of pixels in vertical direction, e.g., of a screen or sensor
N_{period}	number of pixels within one period of a test grating (for a PDA)
N_{pe}	number of photo-generated electrons within one pixel
N_{ph}	number of photons illuminating one pixel (prior to losses)
$N_{ph,th}$	minimum number of photons that are necessary to provide a signal beyond read noise background (prior to losses)
$N_{ph,sat}$	maximum number of photons that could be collected within one pixel to get FWC (prior to losses)
$N_{ph,18}$	number of photons (prior to losses) to achieve $18\% \cdot N_{full}$
N'_{ph}	number of photons incident to one pixel (after loss-correction)
N_{dark}	number of charges contributing to dark current within one pixel
N_{read}	number of charges due to read noise within one pixel (rms value)
N_{reset}	number of charges due to reset noise within one pixel (rms value)
N_{SB}	value of the space bandwidth number SBN
N_{full}	number of electrons that could be accumulated at maximum within a single pixel
OD, OD_{min}, OD_{max}	optical density
p	pixel size
P	power
P_o, P_i	points in object resp. image space
q	(single) charge
q_{pix}	signal charge per pixel
q_{ph}	charge generated per photon
q_{full}	saturation value of q_{pix}
Q, Q_v, Q_e	luminous resp. radiant energy
$\mathcal{R}$	resolution
r	radius, radius of spherical lens
R	$1/\lambda$ (corresponds to $k = 2\pi/\lambda$)
R_{cutoff}	cut-off frequency
R_{out}	resistance; the output voltage is measured at that resistor
R_{pix}	responsivity
R_{MTF0}	spatial frequency, where the MTF becomes zero
R_{MTF10}	spatial frequency, where the MTF becomes 10%
R_{MTF50}	spatial frequency, where the MTF becomes 50%

R_N	Nyquist frequency
R_S	sampling frequency
R_x, R_y, R_z	spatial frequencies (sometimes space-frequencies)
R_φ	spatial frequency with respect to the observation angle of the eye
$R_{x,max}$, $R_{y,max}$	maximum possible spatial frequencies for a given optical system
S	signal in general
S_{pix}	signal generated within a single pixel in ADU
S, S_{ISO}, S°_{DIN}	sensor speed, sensitivity
s_{DOF}, s_{DOFoc}	depth of field, depth of focus
s_i, s_o	magnitude of object resp. image distance
S_i, S_o	image resp. object size
T	transmission, or sometimes absolute temperature
T_F	transmission function, which describes losses of light before it is incident on the photosensitive region of the photodiode
T_{film}	film transmission
t	time
t_L	lens thickness
t_s	lens separation
t_x	exposure time resp. shutter speed
U_{bi}	photodiode built-in voltage due to diffusion
U_d	photodiode voltage
u_o, u_i	diameter of circle of confusion in object and image space
u_p, u_d	diameter of projection blur, diffraction blur
U	voltage (in general)
U_{max}	maximum voltage at the photodiode
U_{out}	output voltage per pixel
U_{eff}	effective value of a voltage (rms value)
U_{read}	effective value of read out voltage noise (rms value)
U_{reset}	reset voltage
U_r	photodiode reverse bias voltage
V, V_i	refractive power
v_{Ho}, v_{Hi}, v_{No}, v_{Ni}	distance from vertices to cardinal points in a thick lens
$V_{ph}(\lambda)$, $V'_{ph}(\lambda)$	photopic resp. scotopic standard luminosity function
W	energy in general
W_{ph}	photon energy
W_{pix}	(radiant) energy that is incident on a single pixel
W'_{pix}	energy that is incident on a single pixel (after loss-correction)
W_g, W_{ph}	band gap energy, photon energy
$WF_r(x, y)$, $WF_i(x, y)$	real wave front, resp. ideal wave front
$\Delta WF(x, y)$	wave front aberration
X, Y	image width, height
X_o, Y_o	width resp. height of an object (size in x- resp. y-direction)

x, y, z	space coordinates
x_o, x_i	x-coordinate, in the object plane resp. image plane
x_0	position of the first zero point int the image plane: distance from the optical axis
$X_{e,\lambda}, X_{v,\lambda}$	radiometric resp. photometric quantity
z_a	astigmatic difference
z_s	longitudinal spherical aberration

Abbreviations

1D	one dimension
2D	two dimension
ADC	analogue-to-digital (A/D) converter
ADU	analogue digital unit; this is equal to DN (digital numbers), DV (digital values) or counts, respectively
APS	active pixel sensor
APS-C	film-/sensorformat
AR	anti reflection
BSI	back side illumination
c. c.	complex conjugate
CCD	charge coupled device
CDS	correlated double sampling method
CF	crop factor
CFA	color filter array
CIS	CMOS Image Sensor
CMOS	complementary metal oxide semiconductor
CSF	contrast sensitivity function
DN	digital number; same as ADU
DNG	digital negative
DU	digital unit; same as ADU
DOF	depth of field
DR	dynamic range
DRI	dynamic range increase
DS	number of data steps or depth steps
DSC	digital still camera (in contrast to, e.g., a video camera)
DSLR	digital single lens reflex camera
DSLM	digital single lens mirrorless camera
DSNU	dark signal non-uniformity
EBI	equivalent background illumination
epi layer	epitaxial layer
ESF	edge spread function
EUV	extreme ultraviolet

EV	exposure value (= aperture stop, f-stop)
FF	fill factor
FFC	flat field correction
FO	fibre optics
FPN	fixed pattern noise
FT	Fourier transformation
FWC	full well capacity
FWHM	measured at full width at half maximum
HDR	high dynamic range
HV	high voltage
IC	integrated (electronic) circuit
iCCD	intensified CCD
iFT	inverse Fourier transformation
IR	infrared
LDR	low dynamic range
lp	line pair
lp/PH	number of line pairs within the picture height
l/PH	number of lines within the picture height
LCD	liquid crystal display
LSF	line spread function ($\mathrm{LSF} = \int_y \mathrm{PSF}(y)\mathrm{d}y$)
MCP	micro channel plate
MOS	metal oxide semiconductor
MOSFET	metal oxide field effect transistor
MP	mega pixel (unit used for cameras)
MTF	modulation transfer function
$\mathcal{MTF}$	modulation transfer function for the field
NA	numerical aperture
NIR	near infrared
OD	optical density
OECF	opto-electronic conversion function
OMA	optical micro lens array
OLPF	optical low pass filter
PC	personal computer
PDA	photo diode array (this may be 1D or 2D; in a more general sense, also CCD or CMOS may be regarded as PDA)
pixel	picture element
PH	picture height (or height of an image or sensor)
PW	picture width (or width of an image or sensor)
PRNU	photo response uniformity
PTF	phase transfer function
OPD	optical path difference

OTF	optical transfer function
$\mathcal{OTF}$	coherent transfer function sometimes termed as amplitude transfer function (for the field)
PSF	point spread function
$\mathcal{PSF}$	point spread function for the field (coherent point spread function)
PTC	photon transfer curve
QE	quantum efficiency
EQE	external quantum efficiency (or overall quantum efficiency)
IQE	internal quantum efficiency
RGB	red green blue
RMS, rms	root mean square
ROI	region of interest
SBN	space bandwidth number (term is used for both, one or two dimensions)
SBP	space bandwidth product
sCMOS	scientific CMOS
SFR	spatial frequency response
SLR	single lens reflex camera
SLT	single lens translucent
SQF	subjective quality factor
SNR	signal-to-noise-ratio
TBP	time bandwidth product
TSV	through-silicon *via*
TTL	through the lens
UV	ultraviolet
vis	visible light range
VN	visual noise
WF	wave front
WFA	wave front aberration
XR	X-ray
XUV	extreme ultraviolet