Contents

List of Symbols

Symbol	**Meaning**
a	Fiber core radius
A_S	Emission area, area of cross-section
A_c	Carrier amplitude
A_m	Amplitude of the modulating signal
A_{common}	Common area of overlapping of two fibers
A_{21}	Einstein's coefficient
B_0	Brightness of the source along the direction normal to the plane of emission
$B_\perp$	Brightness of the source in the direction perpendicular to the emission plane
$B_\parallel$	Brightness of the source in the direction parallel to the emitting surface
B	Bandwidth
B_{12}, B_{21}	Einstein's coefficient
B_F	Modal birefringence
B_{max}	Maximum 3-dB bandwidth
B_{mod}	Bandwidth of a fiber limited by modal dispersion
B_r	Recombination coefficient
B_T	Transmission bandwidth of FM
b	Normalized propagation constant
C	Capacitance, constant
C_a	Input capacitance of the receiver amplifier
C_d	Capacitance of the photodetector
C_f	Capacitance associated with the feedback resistor
C_j	Junction capacitance of the photodetector
C_T	Total capacitance
c	Velocity of light in free space
C_t	Transmitter coupling loss
C_r	Receiver coupling loss
D	Total intramodal/chromatic dispersion of a fiber in ps nm^{-1}
D_{mat}	Material dispersion of a fiber in ps nm^{-1} km^{-1}
D_{tot}	Total material dispersion in ps nm^{-1} km^{-1}
D_{wg}	Waveguide dispersion of a fiber in ps nm^{-1} per km^{-1}
D_{pro}	Profile dispersion
D_{PMD}	Average value of polarization mode dispersion measured in ps/$\sqrt{}$km
D_f	Frequency deviation ratio of FM

Symbol	**Meaning**
D_L	Dispersion equalization penalty
d	Diameter of the fiber core
E	Electronic energy
E_F	Fermi energy
E_g	Bandgap energy
F_n	Noise figure
$F(M)$	Excess noise factor
f	Frequency
f_m	Frequency of the modulating signal
f_{LO}	Local oscillator frequency
f_{IF}	Intermediate frequency
f_{3dB}	3-dB bandwidth of a photodetector
G	Open loop gain
G_s	Single-pass gain
g	Degeneracy factor; laser cavity gain
g_m	Transconductance of FET
g_{th}	Threshold gain for lasing
$H(f)$	Transfer function
$H_{OL}(f)$	Open loop transfer function
$H_{CL}(f)$	Closed loop transfer function
$H_{out}(f)$	Transfer function of optical receiver output
h	Planck constant
h_{eff}	Effective height of the planar waveguide
$h_p(t)$	Input pulse shape to an optical receiver
$h_{out}(t)$	Output pulse shape
I	Electrical current/optical intensity
I_B	Current produced in a photodetector due to background radiation
I_D	Dark current in a photodetector
I_{eq}	Equivalent photodetector current
I_P	Average photocurrent
I_{th}	Threshold current for lasing of ILD
I_0	Reverse saturation current
i_{det}	Photodetector current
$i_p(t)$	Time-varying photogenerated current in a photodetector
i_{det}	Output current of a photodetector
$\langle i_s^2 \rangle$	Mean square value of the shot-noise current
$\langle i_T^2 \rangle$	Mean square value of the thermal noise current

Symbol	**Meaning**
$J_n(x)$	Bessel function of the first kind of order n and argument x
J_{th}	Threshold current density of an ILD
j	$\sqrt{(-1)}$
k	Boltzmann constant/free space propagation constant/ratio of the ionization coefficient
k_1	Propagation constant in the core region
k_2	Propagation constant in core region
L	Fiber length
L_B	Beat length in a single- mode fiber
L_{RS}	Loss due to Rayleigh scattering
S_l	Splice loss in dB
D_L	Dispersion power penalty
P_T	Transmitted power
P	Total power carried by the fiber
P_{core}	Power carried by fiber core
P_{clad}	Power carried by fiber cladding
P_R	Received power
t_r	Rise-time of an RC circuit
T_R	Receiver rise-time in nano-second
T_C	Fiber rise-time due to chromatic dispersion
t_{FWHM}	Time corresponding to full-width half-maximum
$p(t)$	Gaussian pulse in the time domain
$P_{op}(t)$	Time-varying optical power from of an intensity-modulated optical transmitter
$P(f)$	Fourier transform of the pulse $p(t)$
R_T	Effective resistance value of bias and amplifier resistances
T_{sys}	System rise-time in nano-second
q	Electronic charge
i^2_{signal}	Mean square value of the signal current
F_n	Noise figure of an amplifier
S	Signal power
N	Noise power; Group refractive index
S/N	Signal-to-noise power ratio
m^2	Mean square gain of an APD
M	Average gain of an APD; total number of modes in a fiber
M_1	Mean value (first temporal moment)
M_2	Mean-square value (second temporal moment)
M_{eff}	Effective number of modes in a curved graded-index fiber
p	Average photoelectric constant for Rayleigh scattering

Symbol	**Meaning**
P_B	Threshold optical power for stimulated Brillouin scattering
P_R	Threshold optical power required for stimulated Raman scattering
R_a	Amplifier resistance
R_b	Photodetector bias resistance
R_L	Load resistance
R_c	Critical radius of curvature for macro-bending of a multimode fiber
R_{cs}	Critical radius of curvature for macro-bending of a single mode fiber
r	Electro-optic coefficient
T_F	Fictive temperature
T_{max}	Time taken by the most oblique ray to travel a length L along the fiber
T_{min}	Time taken by the axial ray to travel a length L along the fiber
N_1	Group refractive index in the core of a fiber
n	Refractive index of any material
n_1	Core refractive index
n_2	Cladding refractive index
$n(r)$	Refractive index of the fiber material as a function of radial distance
$n(0)$	Refractive index of a graded-index fiber at the centre or axis of the core
$n(a)$	Refractive index of a graded-index fiber at the core-cladding interface and inside cladding
$n(E)$	Electric field dependent refractive index
V	V-number or normalized frequency of a fiber
$K_n(x)$	Modified Bessel function of the second kind of order n and argument x
V_π	Voltage required to create a phase difference of π in an electro-optic modulator
P	Total optical power carried by a fiber
P_{core}	Power carried by the core of the fiber
P_{clad}	Power carried by the cladding of the fiber
T	Absolute temperature
T_b	Bit period
B_T	Bit rate
B_e	Bit-error rate
n_0	Electron concentration in thermal equilibrium
p_0	Hole concentration in thermal equilibrium
N_c	Effective density of state in the conduction band
N_v	Effective density of state in the valence band
m^*n	Effective mass of electrons
m^*p	Effective mass of holes
E_c	Conduction band energy
E_v	Valence band energy

Symbol	**Meaning**
E_F	Fermi level energy
n_i	Intrinsic carrier concentration
N_D	Donor concentration
N_A	Acceptor concentration
V_0	Built-in potential
J	Bias current density
d	Thickness of the active layer
r_r	Radiative recombination rate
r_{nr}	Non-radiative recombination rate
R_r	Total radiative recombination rate
R_{nr}	Total non-radiative recombination rate
P_{int}	Optical power generated within LED
N_T	Trap density
v_{th}	Thermal velocity
R_{AU}	Rate of Auger recombination
C	Auger recombination coefficient
$T(0)$	Fresnel transmission coefficient for normal incidence
$P_{emitted}$	Emitted optical power
S	Surface recombination velocity
D_n	Diffusion coefficient of electrons
L_n	Electron diffusion length
f_{3dB}	3-dB bandwidth
$f_{(3dB\text{-}op)}$	3-dB optical bandwidth
$f_{(3dB\text{-}el)}$	3-dB electrical bandwidth
E_1	Energy corresponding to state 1
E_2	Energy corresponding to state 2
N_1	Population in the energy state E_1
N_2	Population in energy state E_2
R_{12}	Rate of absorption in presence of a radiation field
$(R_{21})_{sp}$	Spontaneous emission rate
$(R_{21})_{st}$	Spontaneous emission rate
D	Normalized waveguide thickness
$I(z)$	Optical field intensity at any point z
$g(0)$	Gain of the cavity at the peak wavelength
R_1	Reflection coefficient of the front mirror of the FP laser
R_2	Reflection coefficient of the rear mirror of the FP laser
t_d	Time delay between the application of the current pulse and attaining lasing threshold
f_r	Relaxation oscillation frequency

Symbol	**Meaning**
$\langle P_e^2 \rangle$	Square of the mean optical power
$S_{RIN}(f)$	Power spectral density of relative intensity noise
P_s	Power emitted by the source
P_F	Power coupled to the fiber
$P_{coupled}$	Power coupled to the fiber after Fresnel reflection
A_f	Fiber area
n_{th}	Threshold carrier density
r_s	Radius of the circular emitting area of the source
r_L	Radius of the micro-spherical lens
v_{in}	Input voltage
v_{out}	Output voltage
v_g	Group velocity
f_p	Fraction of the bundle area covered by the fiber core
L_F	Loss encountered at the fiber-to-fiber joint
L_{lat}	Loss due to lateral misalignment of the fibers
R_f	Feedback resistance of the TZ amplifier
$\mathcal{B}$	Magnetic induction
$B(\theta,\Phi)$	Brightness or radiance of an optical source
$\langle \delta P_e^2 \rangle$	Mean square value of power fluctuation
$\mathcal{D}$	Electric displacement
$\mathcal{E}$	Electric field vector
$\mathcal{H}$	Magnetic field
$\mathcal{L}$	Total loss/attenuation of a fiber in dB
α_f	Average loss in the fiber per km
τ_e	$(1/e)$ –full width pulse broadening due to dispersion
τ_{wg}	Group delay due to waveguide dispersion
τ	Mean lifetime of carriers
α	Absorption coefficient per km
σ	RMS pulse spreading due to dispersion; capture cross-section
$\sigma_{intramodal}$	RMS pulse spreading due to intramodal dispersion
σ_{modal}	RMS pulse spreading due to intermodal dispersion
τ_{mat}	Group delay due to material dispersion
σ_{mat}	RMS pulse spreading due to material dispersion
σ_λ	RMS spectral width of the source
σ_0	RMS pulse broadening in absence of mode coupling
σ_c	RMS pulse broadening in presence of mode coupling
$\mathcal{R}$	Responsivity of a photodetector; Fresnel reflection coefficient

Symbol	**Meaning**
$\delta\tau_{pol}$	Delay difference because of polarization mode dispersion
τ_{gx}	Group delay in x-direction (H-polarization)
τ_{gy}	Group delay in y-direction (V-polarization)
v_{gx}	Group velocity in x-direction
v_{gy}	Group velocity in y-direction
μ	Index of modulation in the case of intensity modulation
ν	Frequency of the optical signal
η	Quantum efficiency
η_{int}	Internal quantum efficiency
η_{ext}	External quantum efficiency
δ_{pol}	Differential group delay due to birefringence
δT_{mod}	Delay difference between the highest and lowest order mode
α	Attenuation (dB/km) in a fiber; absorption coefficient; electron ionization coefficient; profile index factor of a graded-index fiber
α_n	Attenuation coefficient of a fiber in nepers
$\alpha_I(l,m)$	Attenuation coefficient for a mode of order (l, m)
$\alpha(r)$	Attenuation coefficient at any radial distance r from the centre of a graded-index fiber
α_r	Bending loss
α_{IR}	Attenuation due to infrared absorption
α_{SR}	Attenuation in dB due to Rayleigh scattering
α_{uv}	Attenuation due to ultraviolet absorption
α	Average loss in a laser cavity
$\alpha(\lambda)$	Absorption coefficient of a material as a function of wavelength
Γ	Confinement factor
β	Spontaneous emission coefficient; hole ionization coefficient; z-component of the propagation constant
β_c	Isothermal compressibility
γ_R	Rayleigh scattering coefficient
ϕ_c	Critical angle measured with respect to the normal drawn on the plane of incidence
Φ_s	Total phase-shift associated with a single-pass optical amplifier
Δ	Refractive index deviation
λ	Wavelength of light
θ_c	Critical angle measured with respect to the axis of the fiber
$\theta_{0\,max}$	Maximum acceptance angle for rays to enter into the fiber
Ω	Solid acceptance angle of a fiber

Symbol	**Meaning**
ω	Angular frequency
ζ	Electro-optic coefficient
τ_{wg}	Time delay due to waveguide dispersion
ΔE_g	Energy bandgap difference in a heterojunction
ΔE_c	Energy corresponding to conduction band-edge discontinuity
ΔE_v	Energy corresponding to valence band-edge discontinuity
δ_p	Energy separation between the Fermi level and the valence band edge
δ_n	Energy separation between the Fermi level and the conduction band edge
τ_{SRH}	Mean lifetime of the carriers due to Shockley-Read-Hall recombination
τ_{AU}	Mean lifetime of carriers due to Auger recombination
Δn	Excess photogenerated carriers (electrons)
τ	Mean lifetime of the carriers
τ_r	Mean lifetime of the carriers for radiative recombination
τ_{nr}	Mean lifetime of the carriers for non-radiative recombination
τ_{eff}	Effective mean lifetime of the carriers
ω_{3dB}	3-dB angular frequency bandwidth
$\rho(\nu)$	Radiation field density
$\Delta\nu$	Frequency separation between two adjacent modes of a FP laser diode
$\Delta\lambda$	Wavelength separation between two adjacent modes of a FP laser diode
τ_{sp}	Spontaneous emission lifetime of the carriers
τ_{st}	Stimulated emission lifetime of carriers
τ_{ph}	Photon lifetime of the carriers
Φ	Photon flux density
Φ_s	Steady-state photon flux density
$T(\Phi)$	Fresnel transmission coefficient for an angle of incidence of Φ
$P(\omega)$	Power spectrum of LED output
$g(\lambda)$	Gain of the laser cavity as a function of wavelength
$m(\beta)$	Number of modes in a graded-index fiber for a given propagation constant
$\theta_{\parallel}$	Angular width of the beam in direction parallel to the plane of the *p-n* junction
$\theta_{\perp}$	Angular width of the beam in the direction perpendicular to the plane of the *p-n* junction
η_F	Fiber-to-fiber coupling efficiency
η_{lat}	Coupling efficiency due to lateral misalignment

List of Abbreviations

Abbreviation	Meaning
A/D	Analog to digital
AC	Alternating current
AGC	Automatic gain control
AM	Amplitude modulation
APD	Avalanche photodiode
ASK	Amplitude shift keying
ATM	Asynchronous transmission mode
BER	Bit error rate
CATV	Common antenna television
CCITT	International Telephone and Telegraph Consultative Committee
CCTV	Closed circuit television
CNR	Carrier-to-noise ratio
CW	Continuous wave
CWDM	Coarse wavelength division multiplexing
D/A	Digital to analog
dB	Decibel
DBR	Distributed Bragg reflector
dBm	Decibel with reference to 1 mW power
D-IM	Direct intensity modulation
DC	Depressed cladding
DC	Direct current
DF	Dispersion flattened
DFB	Distributed feedback
DH	Double heterostructure
DPSK	Differential phase shift keying
DS	Dispersion shifted
DSB	Double sideband
DWDM	Dense wavelength division multiplexing
EDFA	Erbium doped fiber amplifier
EIA	Electronics Industries Association
ELED	Edge-emitter light emitting diode
EMI	Electromagnetic interference
erf	Error function
erfc	Complementary error function
FA	Fiber amplifier

Abbreviation	Meaning
FBT	Fiber biconical taper
FDM	Frequency division multiplexing
FET	Field effect transistor
FM	Frequency modulation
FOTP	Fiber optic test procedure
FPA	Fabry-Pérot amplifier
FSK	Frequency-shift keying
FWHP	Full width half power
FWHM	Full-width half maximum
GI	Graded index (fiber)
GRIN	Graded-index (rod lens)
HB	High birefringence
HBT	Heterojunction bipolar transistor
HEMT	High electron mobility transistor
He-Ne	Helium-Neon (LASER)
NF	High frequency
IF	Intermediate frequency
ILD	Injection laser diode
IM-DD	Intensity modulation–direct detection
IO	Integrated optics
I–O	Input-output
ISI	Intersymbol interference
ISDN	Integrated services digital network
LAN	Local area network
LB	Low birefringence
LED	Light-emitting diode
LP	Linearly polarized
LPE	Liquid phase epitaxy
MAN	Metropolitan area network
MBE	Molecular beam epitaxy
MC	Matched cladding
MCVD	Modified chemical vapor deposition
MESFET	Metal semiconductor field effect transistor
MFD	Mode field diameter
MISFET	Metal insulator field effect transistor
MMF	Multimode fiber
MOSFET	Metal-oxide semiconductor field effect transistor
MOVPE	Metal organic vapor phase epitaxy
MQW	Multiquantum well
MSM	Metal-semiconductor-metal

Abbreviation	Meaning
NRZ	Non-return to zero
OEIC	Optoelectronic integrated circuit
OFDM	Optical frequency division multiplexing
OOK	On-off keying
OTDR	Optical time domain reflectometer
OVPO	Outside vapor phase oxidation
PCM	Pulse code modulation
PCS	Plastic clad silica (fiber)
PCVD	Plasma-activated chemical vapour deposition
PD	Photodiode
PDF	Probability distribution function
p-i-n-PET	p-i-n-photodetector followed by PET
PLL	Phase locked loop
PM	Phase modulation
PMF	Polarization maintaining fiber
PoLSK	Polarization shift keying
PON	Passive optical network
PSK	Phase-shift keying
RAPD	Reach-through avalanche photodiode
RIN	Relative intensity noise
RMS (rms)	Root mean square
RO	Relaxation oscillator
RZ	Return to zero
SAM	Separate absorption and multiplication (APD)
SAW	Surface acoustic wave
SBS	Stimulated Brillouin scattering
SC	Subcarrier connector
SCM	Subcarrier multiplexing
SDH	Synchronous digital hierarchy
SDM	Space division multiplexing
SHF	Super high frequency
SI	Step-index (fiber)
SL	Superlattice
SLA	Semiconductor laser amplifier
SLD	Semiconductor laser diode
SLED	Surface emitting LED
SMF	Single mode fiber
SNR	Signal-to-noise ratio
SONET	Synchronous optical network
SOP	State of polarization

Abbreviation	Meaning
SQW	Single quantum well
SRS	Stimulated Raman scattering
ST	Straight tip
TDM	Time-division multiplexing
TDMA	Time division multiple access
TE	Transverse electric
TEM	Transverse electromagnetic
TM	Transverse magnetic
TWA	Traveling wave amplifier
UHF	Ultra high frequency
VAD	Vapour axial deposition
VCO	Voltage controlled oscillator
VHF	Very high frequency
VPE	Vapour phase epitaxy
VSB	Vestigial sideband
WDM	Wavelength-division multiplexing
WKB	Wenzel-Kramer-Brillouin (method)
ZMD	Zero material dispersion
ZTD	Zero total dispersion