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Fundamentals of Fiber Lasers and Fiber Amplifiers

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and to my wife Katerina
and my children William and Daria

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Contents

Symbols

A_{21}	Einstein A coefficient (probability of spontaneous decay)
B_{12}, B_{21}	Einstein B coefficients
b	Normalized propagation constant
A_{eff}	Effective cross-section area of the fiber core
D_{chrom}	Chromatic dispersion
d_{np}	Depletion region of p-n junction
d_n, d_p	Depletion regions in n- and p-type side of the junction
E	Energy
E_F	Fermi energy
F	Energy fluence
f	Oscillator strength of the transition
$f_{F-D}(E,T)$	Fermi function (Fermi–Dirac probability)
F_{etalon}	Finesse of the etalon
g	Gain coefficient
G	Gain factor
h	Planck constant
$\hbar = \frac{h}{2\pi}$	Reduced Planck constant (or Dirac's constant)
I	Laser intensity
k_B	Boltzmann constant
L	Length
L_{eff}	Effective length of the fiber
L_{lss}	Large-scale self-focusing characteristic length
L_{sss}	Small-scale self-focusing characteristic length
L_{loss}	Intracavity incidental loss
M	Number of modes
M_{lens}	Magnification of the lens system
N	Concentration
N_a, N_d	Concentration of acceptor and donor impurity
ΔN	Population inversion
$\bar{n}_i$, $\bar{n}_f$	Normalized population inversions
$\overline{n}_{th}$	Threshold population inversion

n	Refractive index
n_0	Linear refractive index
n_2	Nonlinear refractive index
$\Delta n = n_{core} - n_{clad}$	Refractive index difference
P	Laser power
P_{cr}	Critical power of self focusing
P_p	Pump power
P_a	Absorbed pump power
P_{pcr}	Critical pump power required to achieve transparency of the signal wavelength
P_{out}	Output power
P_{th}	Laser power threshold
R	Reflectivity
$S_{core/clad}$	Cross-sectional area of the core or of the cladding
T	Transmission
T_g	Group delay
t_p	Laser pulse width
V_g	Group velocity
V_{ph}	Phase velocity
V	Volume
V	V-number
$V_{PCF}(\lambda)$	V- parameter for photonics crystal fiber
β	Propagation constant
β_{ph}	Phase constant (real part of the wavenumber k)
Δ	Relative (or fractional) refractive index difference
Γ	Spontaneous relaxation line-width of the process
Γ^{-1}	Phonon lifetime
Γ_{tot}	Total, single pass logarithmic loss of the laser cavity
μ or α	Absorption coefficient
σ	Cross-section of the transition
v or ω	Optical frequency
v_0 or ω_0	Central frequency of the transition
v_p	Pump frequency
Δv, $\Delta\omega$	Spectral line-width
λ	Wavelength
τ	Upper-level lifetime
η_{slope}	Laser slope efficiency
$\Delta\beta_{FWM}$	Phase mismatch in four-wave mixing process
Θ_B	Brillouin angle (angle between the scattered wave vector and the initial pump wave vector)
Θ_{BR}	Brewster angle
Ω	Effective phonon frequency

$\Omega_{2,4,6}$	Judd–Ofelt parameters
γ	Nonlinear interaction constant
Λ	Fiber Bragg grating period
σ_{DC}	Material DC conductivity

Abbreviations

ASE	Amplified spontaneous emission
ATR	Attenuated total reflectance
BEL	Broad area laser
CW	Continuous-wave
XPM	Cross-phase modulation
DC	Double clad
FWM	Four-wave mixing
FBG	Fiber Bragg grating
FSR	Free spectral range
LD	Laser diode
LMA	Large mode area
LP	Notation for modes in optical fibers (linearly polarized)
MCVD	Modified chemical vapor deposition
MM	Multi mode
MOPA	Master oscillator power amplifier
NA	Numerical aperture
NCPM	Noncritical phase matching
PM	Polarization maintained
PPLN	Periodically poled lithium niobate
QPM	Quasi-phase matching
SBS	Stimulated Brillouin scattering
SHB	Spectral hole burning
SM	Single mode
SPM	Self-phase modulation
SRS	Stimulated Raman scattering
TIR	Total internal reflection
TC	Triple clad

Some of the Most Important Fundamental Optical Constants

$k_B = 1.3806488 \times 10^{-23} \frac{J}{K}$

$h = 6.62606957 \times 10^{-34} J \times \text{sec}$

$\hbar = 1.054571726 \times 10^{-34} J \times \text{sec}$

$c_0 = 2.99729458 \times 10^{8} \frac{m}{\text{sec}}$