Important Optical Fiber Design Formulas PDF

Formulas
Examples
with Units

List of 31
Important Optical Fiber Design Formulas

1) Fiber Design Characteristics Formulas

1.1) Delta Parameter Formula

Evaluate Formula

Formula

$$\Delta = \frac{\eta_{core}^{2} - \eta_{clad}^{2}}{\eta_{core}^{2}}$$

Example

$$0.0907 = \frac{1.335^{2} - 1.273^{2}}{1.335^{2}}$$

1.2) Graded Index Length of Fiber Formula

Evaluate Formula

Formula

$$n_{gr} = L \cdot \eta_{core}$$

Example with Units

$$1.6688 = 1.25\,\text{m} \cdot 1.335$$

1.3) Group Delay Formula

Evaluate Formula

Formula

$$V_g = \frac{L}{T_d}$$

Example with Units

$$2.5E{+}8\,\text{m/s} = \frac{1.25\,\text{m}}{5e\text{-}9\,\text{s}}$$

1.4) Normalised Propagation Constant Formula

Evaluate Formula

Formula

$$b = \frac{\eta_{eff} - \eta_{clad}}{\eta_{core} - \eta_{clad}}$$

Example

$$0.2742 = \frac{1.29 - 1.273}{1.335 - 1.273}$$

1.5) Normalized Frequency Formula

Evaluate Formula

Formula

$$V = \sqrt{2 \cdot N_M}$$

Example with Units

$$6.4807\,\text{Hz} = \sqrt{2 \cdot 21}$$

1.6) Numerical Aperture Formula

Evaluate Formula

Formula

$$NA = \sqrt{\left(\eta_{core}^{2}\right) - \left(\eta_{clad}^{2}\right)}$$

Example

$$0.4021 = \sqrt{\left(1.335^{2}\right) - \left(1.273^{2}\right)}$$

1.7) Optical Pulse Duration Formula

Evaluate Formula

Formula

$$\sigma_\lambda = L \cdot D_{opt} \cdot \sigma_g$$

Example with Units

$$19.9875\,\text{s} = 1.25\,\text{m} \cdot 3\text{e}6\,\text{s}^2/\text{m} \cdot 5.33\text{e-}6\,\text{s/m}$$

1.8) Phase Velocity in Optic Fiber Formula

Evaluate Formula

Formula

$$v_{ph} = \frac{[c]}{\eta_{eff}}$$

Example with Units

$$2.3\text{E+}8\,\text{m/s} = \frac{3\text{E+}8\,\text{m/s}}{1.29}$$

1.9) Plane Wave Velocity Formula

Evaluate Formula

Formula

$$V_{plane} = \frac{\omega}{\beta}$$

Example with Units

$$1\text{E+}17\,\text{m/s} = \frac{390\,\text{rad/s}}{3.8\text{e-}15\,\text{rad/m}}$$

1.10) Ray Optics Critical Angle Formula

Evaluate Formula

Formula

$$\theta = \sin\left(\frac{\eta_r}{\eta_i}\right)^{-1}$$

Example with Units

$$64.3487° = \sin\left(\frac{1.23}{1.12}\right)^{-1}$$

1.11) Refractive Index of Cladding Formula

Evaluate Formula

Formula

$$\eta_{clad} = \sqrt{\eta_{core}^2 - NA^2}$$

Example

$$1.2737 = \sqrt{1.335^2 - 0.4^2}$$

1.12) Refractive Index of Fiber Core Formula

Evaluate Formula

Formula

$$\eta_{core} = \sqrt{NA^2 + \eta_{clad}^2}$$

Example

$$1.3344 = \sqrt{0.4^2 + 1.273^2}$$

2) Fiber Modelling Parameters Formulas

2.1) Beat Length Formula

Evaluate Formula

Formula

$$L_b = \frac{\lambda}{B_m}$$

Example with Units

$$15.5\,\text{m} = \frac{1.55\,\mu\text{m}}{1\text{e-}7}$$

2.2) Brillouin Shift Formula

Evaluate Formula

Formula

$$\nu_b = \frac{2 \cdot \bar{n} \cdot v_a}{\lambda_p}$$

Example with Units

$$6578.9474\,\text{Hz} = \frac{2 \cdot 0.02 \cdot 0.25\,\text{m/s}}{1.52\,\mu\text{m}}$$

2.3) Diameter of Fiber Formula

Evaluate Formula

Formula

$$D = \frac{\lambda \cdot N_M}{\pi \cdot NA}$$

Example with Units

$$25.9025\,\mu\text{m} = \frac{1.55\,\mu\text{m} \cdot 21}{3.1416 \cdot 0.4}$$

2.4) Effective Interaction Length Formula

Evaluate Formula

Formula

$$L_{eff} = \frac{1 - \exp\left(-\left(\alpha \cdot L\right)\right)}{\alpha}$$

Example with Units

$$0.3486\,\text{m} = \frac{1 - \exp\left(-\left(2.78 \cdot 1.25\,\text{m}\right)\right)}{2.78}$$

2.5) External Quantum Efficiency Formula

Evaluate Formula

Formula

$$\eta_{ext} = \left(\frac{1}{4 \cdot \pi}\right) \cdot \int\left(T_f[x] \cdot \left(2 \cdot \pi \cdot \sin\left(x\right)\right), x, 0, \theta_c\right)$$

Example with Units

$$3.383 = \left(\frac{1}{4 \cdot 3.1416}\right) \cdot \int\left(8 \cdot \left(2 \cdot 3.1416 \cdot \sin\left(x\right)\right), x, 0, 30\,\text{rad}\right)$$

2.6) Fiber Attenuation Coefficient Formula

Evaluate Formula

Formula

$$\alpha_p = \frac{\alpha}{4.343}$$

Example

$$0.6401 = \frac{2.78}{4.343}$$

2.7) Fiber Length Formula

Evaluate Formula

Formula

$$L = V_g \cdot T_d$$

Example with Units

$$1.25\,\text{m} = 2.5\text{e}8\,\text{m/s} \cdot 5\text{e-}9\,\text{s}$$

2.8) Gaussian Pulse Formula

Evaluate Formula

Formula

$$\sigma_g = \frac{\sigma_\lambda}{L \cdot D_{opt}}$$

Example with Units

$$5.3\text{E-}18\,\text{s/m} = \frac{2\text{e-}11\,\text{s}}{1.25\,\text{m} \cdot 3\text{e}6\,\text{s}^2\text{/m}}$$

2.9) Group Velocity Formula

Evaluate Formula

Formula

$$V_g = \frac{L}{T_d}$$

Example with Units

$$2.5E+8\,\text{m/s} = \frac{1.25\,\text{m}}{5e\text{-}9\,\text{s}}$$

2.10) Modal Birefringence Degree Formula

Evaluate Formula

Formula

$$B_m = \text{mod}\ us\left(\bar{n}_x - \bar{n}_y\right)$$

Example

$$1E\text{-}7 = \text{mod}\ us\left(2.44e\text{-}7 - 1.44e\text{-}7\right)$$

2.11) Non Linear Phase Shift Formula

Evaluate Formula

Formula

$$\text{Ø}_{NL} = \int\left(\gamma \cdot P[z], x, 0, L\right)$$

Example with Units

$$62.5\,\text{rad} = \int\left(5\,\text{dB/m} \cdot 10\,\text{W}, x, 0, 1.25\,\text{m}\right)$$

2.12) Number of Modes Formula

Evaluate Formula

Formula

$$N_M = \frac{2 \cdot \pi \cdot r_{core} \cdot NA}{\lambda}$$

Example with Units

$$21.0791 = \frac{2 \cdot 3.1416 \cdot 13\,\mu\text{m} \cdot 0.4}{1.55\,\mu\text{m}}$$

2.13) Number of Modes using Normalized Frequency Formula

Evaluate Formula

Formula

$$N_M = \frac{V^2}{2}$$

Example with Units

$$21 = \frac{6.48\,\text{Hz}^2}{2}$$

2.14) Optical Dispersion Formula

Evaluate Formula

Formula

$$D_{opt} = \frac{2 \cdot \pi \cdot [c] \cdot \beta}{\lambda^2}$$

Example with Units

$$3E+6\,\text{s}^2\text{/m} = \frac{2 \cdot 3.1416 \cdot 3E+8\,\text{m/s} \cdot 3.8e\text{-}15\,\text{rad/m}}{1.55\,\mu\text{m}^2}$$

2.15) Phase Shift of Jth Channel Formula

Evaluate Formula

Formula

$$\text{Øj}^{NL} = \gamma \cdot L_{eff} \cdot \left(P_j + 2 \cdot \sum\left(x, 1, m, P_m\right)\right)$$

Example with Units

$$540.175\,\text{rad} = 5\,\text{dB/m} \cdot 0.3485\,\text{m} \cdot \left(40\,\text{W} + 2 \cdot \sum\left(x, 1, 5, 27\,\text{W}\right)\right)$$

2.16) Photo Current Generated to Incident Optical Power Formula

Evaluate Formula

Formula

$$I = R_m \cdot P_m + \sum\left(x, 1, N, R_n \cdot T_{mn} \cdot P_n\right)$$

Example with Units

$$433.07\,\text{A} = 7.7\,\text{A/W} \cdot 5.5\,\text{W} + \sum\left(x, 1, 8, 3.7\,\text{A/W} \cdot 2 \cdot 6.6\,\text{W}\right)$$

2.17) Power Loss in Fiber Formula

Evaluate Formula

Formula

$$P_\alpha = P_{in} \cdot \exp\left(\alpha_p \cdot L\right)$$

Example with Units

$$12.2405\,\text{W} = 5.5\,\text{W} \cdot \exp\left(0.64 \cdot 1.25\,\text{m}\right)$$

2.18) Rayleigh Scattering Formula

Evaluate Formula

Formula

$$\alpha_R = \frac{C}{\lambda^4}$$

Example with Units

$$0.1213\,\text{dB/m} = \frac{0.7\text{e-}24}{1.55\,\mu\text{m}^4}$$

2.19) Total Amplifier Gain for EDFA Formula

Evaluate Formula

Formula

$$G = \Gamma_s \cdot \exp\left(\int\left(\left(\sigma s^e \cdot N_2 - \sigma s^a \cdot N_1\right) \cdot x, x, 0, L\right)\right)$$

Example with Units

$$4.7\text{E-}35 = 20 \cdot \exp\left(\int\left(\left(15\,\text{m}^2 \cdot 13\,\text{Hundred/m}^2 - 25\,\text{m}^2 \cdot 12\,\text{Hundred/m}^2\right) \cdot x, x, 0, 1.25\,\text{m}\right)\right)$$

Variables used in list of Optical Fiber Design Formulas above

- **b** Normalised Propagation Constant
- B_m Modal Birefringence Degree
- **C** Fiber Constant
- **D** Diameter of Fiber *(Micrometer)*
- D_{opt} Optical Fiber Dispersion *(Square Second per Meter)*
- **G** Total Amplifier Gain for an EDFA
- **I** Photo Current Generated to Incident Optical Power *(Ampere)*
- **L** Length of Fiber *(Meter)*
- L_b Beat Length *(Meter)*
- L_{eff} Effective Interaction Length *(Meter)*
- **m** Range of Other Channels Except J
- **N** Number of Channels
- $\bar{n}$ Mode Index
- N_1 Population Density of Lower Energy Level *(Hundred per Square Meter)*
- N_2 Population Density of Higher Energy Level *(Hundred per Square Meter)*
- n_{gr} Grade Index Fiber
- N_M Number of Modes
- $\bar{n}_x$ Mode Index X
- $\bar{n}_y$ Mode Index Y
- **NA** Numerical Aperture
- $Ø_{NL}$ Non Linear Phase Shift *(Radian)*
- $Øj^{NL}$ Phase Shift Jth Channel *(Radian)*
- P_{in} Input Power *(Watt)*
- P_j Power of Jth signal *(Watt)*
- P_m Power of Mth signal *(Watt)*
- P_m Power of Mth Channel *(Watt)*
- P_n Power in Nth Channel *(Watt)*
- $P_α$ Power Loss Fiber *(Watt)*
- **P[z]** Optical Power *(Watt)*

Constants, Functions, Measurements used in list of Optical Fiber Design Formulas above

- constant(s): **pi**, 3.14159265358979323846264338327950288 *Archimedes' constant*
- constant(s): **[c]**, 299792458.0 *Light speed in vacuum*
- Functions: **exp**, exp(Number) *n an exponential function, the value of the function changes by a constant factor for every unit change in the independent variable.*
- Functions: **int**, int(expr, arg, from, to) *The definite integral can be used to calculate net signed area, which is the area above the x -axis minus the area below the x -axis.*
- Functions: **modulus**, modulus *Modulus of a number is the remainder when that number is divided by another number.*
- Functions: **sin**, sin(Angle) *Sine is a trigonometric function that describes the ratio of the length of the opposite side of a right triangle to the length of the hypotenuse.*
- Functions: **sqrt**, sqrt(Number) *A square root function is a function that takes a non-negative number as an input and returns the square root of the given input number.*
- Functions: **sum**, sum(i, from, to, expr) *Summation or sigma (∑) notation is a method used to write out a long sum in a concise way.*
- Measurement: **Length** in Meter (m), Micrometer (µm) *Length Unit Conversion*
- Measurement: **Time** in Second (s) *Time Unit Conversion*
- Measurement: **Electric Current** in Ampere (A) *Electric Current Unit Conversion*
- Measurement: **Area** in Square Meter (m²) *Area Unit Conversion*
- Measurement: **Speed** in Meter per Second (m/s) *Speed Unit Conversion*
- Measurement: **Power** in Watt (W) *Power Unit Conversion*

- r_{core} Radius of Core *(Micrometer)*
- R_m Photodetector Responsivity for Channel M *(Ampere per Watt)*
- R_n Photodetector Responsivity for Channel N *(Ampere per Watt)*
- T_d Group Delay *(Second)*
- $T_f[x]$ Fresnel Transmissivity
- T_{mn} Filter Transmittivity for Channel N
- V Normalized Frequency *(Hertz)*
- v_a Acoustic Velocity *(Meter per Second)*
- V_g Group Velocity *(Meter per Second)*
- v_{ph} Phase Velocity *(Meter per Second)*
- V_{plane} Plane Wave Velocity *(Meter per Second)*
- α Attenuation Loss
- α_p Attenuation Coefficient
- α_R Rayleigh Scattering *(Decibel per Meter)*
- β Propagation Constant *(Radian per Meter)*
- γ Non Linear Parameter *(Decibel per Meter)*
- Γ_s Confinement Factor
- Δ Delta Parameter
- η_{clad} Refractive Index of Cladding
- η_{core} Refractive Index of Core
- η_{eff} Effective Index of Mode
- η_{ext} External Quantum Efficiency
- η_i Refractive Index Incident Medium
- η_r Refractive Index Releasing Medium
- θ Critical Angle *(Degree)*
- θ_c Cone of Acceptance Angle *(Radian)*
- λ Wavelength of Light *(Micrometer)*
- λ_p Pump Wavelength *(Micrometer)*
- v_b Brillouin shift *(Hertz)*
- σ_g Gaussian Pulse *(Second per Meter)*
- σ_λ Optical Pulse Duration *(Second)*
- σs^a Absorption Cross Section *(Square Meter)*

- Measurement: **Angle** in Degree (°), Radian (rad)
  Angle Unit Conversion
- Measurement: **Frequency** in Hertz (Hz)
  Frequency Unit Conversion
- Measurement: **Wavelength** in Micrometer (µm)
  Wavelength Unit Conversion
- Measurement: **Angular Velocity** in Radian per Second (rad/s)
  Angular Velocity Unit Conversion
- Measurement: **Population Density** in Hundred per Square Meter (Hundred/m²)
  Population Density Unit Conversion
- Measurement: **Attenuation** in Decibel per Meter (dB/m)
  Attenuation Unit Conversion
- Measurement: **Propagation Constant** in Radian per Meter (rad/m)
  Propagation Constant Unit Conversion
- Measurement: **Presement** in Second per Meter (s/m)
  Presement Unit Conversion
- Measurement: **Presity** in Square Second per Meter (s²/m)
  Presity Unit Conversion
- Measurement: **Responsivity** in Ampere per Watt (A/W)
  Responsivity Unit Conversion

- σs^{e} Emission Cross Section *(Square Meter)*
- ω Angular Velocity *(Radian per Second)*

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