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Optical Fiber Design Formulas

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List of 26 Optical Fiber Design Formulas

Optical Fiber Design

Fiber Design Characteristics

1) Delta Parameter

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

[Open Calculator !\[\]\(de95854c7ee024cfadc48187bbb781b2_img.jpg\)](#)

$$ex \quad 0.090727 = \frac{(1.335)^2 - (1.273)^2}{(1.335)^2}$$

2) Graded Index Length of Fiber

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

[Open Calculator !\[\]\(6a9b39b98eb945faa14c645ec99e4eaa_img.jpg\)](#)

$$ex \quad 1.66875 = 1.25m \cdot 1.335$$

3) Group Delay

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

[Open Calculator !\[\]\(f1c5da15572e3e09d343161be98f508d_img.jpg\)](#)

$$ex \quad 2.5E^8m/s = \frac{1.25m}{5e-9s}$$



4) Normalised Propagation Constant

[Open Calculator !\[\]\(4729e517bc6a7cd81c8025b9646574fb_img.jpg\)](#)

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

$$ex \quad 0.274194 = \frac{1.29 - 1.273}{1.335 - 1.273}$$

5) Normalized Frequency

[Open Calculator !\[\]\(e474458956c9a37fbf9586ddb60a7fa1_img.jpg\)](#)

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

$$ex \quad 6.480741\text{Hz} = \sqrt{2 \cdot 21}$$

6) Numerical Aperture

[Open Calculator !\[\]\(4fe57c3593bf1b21d272ae7ac8dfaf77_img.jpg\)](#)

$$fx \quad NA = \sqrt{(\eta_{\text{core}}^2) - (\eta_{\text{clad}}^2)}$$

$$ex \quad 0.402114 = \sqrt{((1.335)^2) - ((1.273)^2)}$$

7) Optical Pulse Duration

[Open Calculator !\[\]\(2bae76de5ebbd5c4d7d47162f1673734_img.jpg\)](#)

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

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




8) Phase Velocity in Optic Fiber 

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

[Open Calculator !\[\]\(e78f798d4ea5c530c9db49e7d26e6b95_img.jpg\)](#)

$$ex \quad 2.3E^8 m/s = \frac{[c]}{1.29}$$

9) Plane Wave Velocity 

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

[Open Calculator !\[\]\(05be7c7a8995decd503647c99211f7c2_img.jpg\)](#)

$$ex \quad 1E^{17} m/s = \frac{390 rad/s}{3.8e-15 rad/m}$$

10) Ray Optics Critical Angle 

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

[Open Calculator !\[\]\(fe3aebe81acea8d45108cd2768939da7_img.jpg\)](#)

$$ex \quad 64.34865^\circ = \sin\left(\frac{1.23}{1.12}\right)^{-1}$$

11) Refractive Index of Cladding 

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

[Open Calculator !\[\]\(899d8b7697d64725bf017d3296cfcf1b_img.jpg\)](#)

$$ex \quad 1.273666 = \sqrt{(1.335)^2 - (0.4)^2}$$



12) Refractive Index of Fiber Core

[Open Calculator !\[\]\(bd1a142de767a21e5362c595f844a4ff_img.jpg\)](#)

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

$$ex \quad 1.334365 = \sqrt{(0.4)^2 + (1.273)^2}$$

Fiber Modelling Parameters

13) Beat Length

[Open Calculator !\[\]\(0b5e7e25e8775f7e7e80906ada4f0021_img.jpg\)](#)

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

$$ex \quad 15.5m = \frac{1.55\mu m}{1e-7}$$

14) Brillouin Shift

[Open Calculator !\[\]\(bd3b31712ad9bab5a241210fa6925cdd_img.jpg\)](#)

$$fx \quad v_b = \frac{2 \cdot \bar{n} \cdot v_a}{\lambda_p}$$

$$ex \quad 6578.947Hz = \frac{2 \cdot 0.02 \cdot 0.25m/s}{1.52\mu m}$$




15) Diameter of Fiber 

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

Open Calculator 

$$ex \quad 25.90247\mu\text{m} = \frac{1.55\mu\text{m} \cdot 21}{\pi \cdot 0.4}$$

16) Effective Interaction Length 

$$fx \quad L_{\text{eff}} = \frac{1 - \exp(-(\alpha \cdot L))}{\alpha}$$

Open Calculator 


$$ex \quad 0.348575\text{m} = \frac{1 - \exp(-(2.78 \cdot 1.25\text{m}))}{2.78}$$

17) Fiber Attenuation Coefficient 

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

Open Calculator 

$$ex \quad 0.640111 = \frac{2.78}{4.343}$$

18) Fiber Length 

$$fx \quad L = V_g \cdot T_d$$

Open Calculator 

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



19) Gaussian Pulse 

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

Open Calculator 

$$ex \quad 5.3E^{-18}s/m = \frac{2e^{-11}s}{1.25m \cdot 3e6s^2/m}$$

20) Group Velocity 

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

Open Calculator 


$$ex \quad 2.5E^8m/s = \frac{1.25m}{5e-9s}$$

21) Modal Birefringence Degree 

$$fx \quad B_m = \text{modulus}(\bar{n}_x - \bar{n}_y)$$

Open Calculator 

$$ex \quad 1E^{-7} = \text{modulus}(2.44e-7 - 1.44e-7)$$

22) Number of Modes 

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

Open Calculator 

$$ex \quad 21.07907 = \frac{2 \cdot \pi \cdot 13\mu m \cdot 0.4}{1.55\mu m}$$



23) Number of Modes using Normalized Frequency

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

[Open Calculator !\[\]\(6605b201d6f14d9b3bcb8ab5f274d107_img.jpg\)](#)

$$\text{ex } 21 = \frac{(6.48\text{Hz})^2}{2}$$

24) Optical Dispersion

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

[Open Calculator !\[\]\(e8fb589d58dad1692debababa5e928b6_img.jpg\)](#)

$$\text{ex } 3\text{E}^6\text{s}^2/\text{m} = \frac{2 \cdot \pi \cdot [c] \cdot 3.8\text{e-}15\text{rad/m}}{(1.55\mu\text{m})^2}$$

25) Power Loss in Fiber

$$\text{fx } P_\alpha = P_{\text{in}} \cdot \exp(\alpha_p \cdot L)$$

[Open Calculator !\[\]\(4688aadfd656ded00cd6bdfae55089a9_img.jpg\)](#)

$$\text{ex } 12.24048\text{W} = 5.5\text{W} \cdot \exp(0.64 \cdot 1.25\text{m})$$

26) Rayleigh Scattering

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

[Open Calculator !\[\]\(4146d17f71dced09c6ad789cacceaa6d_img.jpg\)](#)

$$\text{ex } 0.121275\text{dB/m} = \frac{0.7\text{e-}24}{(1.55\mu\text{m})^4}$$



Variables Used








- **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*)
- **L** Length of Fiber (*Meter*)
- **L_b** Beat Length (*Meter*)
- **L_{eff}** Effective Interaction Length (*Meter*)
- **\bar{n}** Mode Index
- **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
- **P_{in}** Input Power (*Watt*)
- **P_α** Power Loss Fiber (*Watt*)
- **r_{core}** Radius of Core (*Micrometer*)
- **T_d** Group Delay (*Second*)
- **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)
- Δ Delta Parameter
- η_{clad} Refractive Index of Cladding
- η_{core} Refractive Index of Core
- η_{eff} Effective Index of Mode
- η_i Refractive Index Incident Medium
- η_r Refractive Index Releasing Medium
- θ Critical Angle (Degree)
- 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)
- ω Angular Velocity (Radian per Second)



Constants, Functions, Measurements used







- **Constant:** **pi**, 3.14159265358979323846264338327950288
Archimedes' constant
- **Constant:** **[c]**, 299792458.0 Meter/Second
Light speed in vacuum
- **Function:** **exp**, exp(Number)
Exponential function
- **Function:** **modulus**, modulus
Modulus of number
- **Function:** **sin**, sin(Angle)
Trigonometric sine function
- **Function:** **sqrt**, sqrt(Number)
Square root function
- **Measurement:** **Length** in Meter (m), Micrometer (μm)
Length Unit Conversion 
- **Measurement:** **Time** in Second (s)
Time Unit Conversion 
- **Measurement:** **Speed** in Meter per Second (m/s)
Speed Unit Conversion 
- **Measurement:** **Power** in Watt (W)
Power Unit Conversion 
- **Measurement:** **Angle** in Degree ($^{\circ}$)
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: 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 



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