ADVANCED THIN FILMS

Enabling superior lasers™

Converting dBm to mW

Optical power is commonly expressed in mW or dBm. The dBm unit is definded as the ratio in dB (decibel) of the measured optical power to a reference value of 1 mW.

$$\text{dBm}=10\log\left(\frac{\text{Optical Power}}{1\text{ mW}}\right)$$

For quick reference use the following table.

Optical Power (dBm)	Optical Power (mW)
15	31.6
14	25.1
13	20.0
12	15.8
11	12.6
10	10.0
9	7.9
8	6.3
7	5.0
6	4.0
5	3.2
4	2.5
3	2.0
2	1.6
1	1.3
0	1.0
-1	0.79
-2	0.63
-3	0.50
-4	0.40
-5	0.32
-6	0.25
-7	0.20
-8	0.16
-9	0.13
-10	0.10
-11	0.08
-12	0.06
-13	0.05
-14	0.04
-15	0.03

Etalon Formulas

Two parameters completely specify an etalon: the free spectral range (FSR) and the finesse ($\mathfrak{I}$). The FSR is the spacing usually given in frequency) between transmission peaks. The finesse is the ratio of the free spectral range to the full width at half maximum (FWHM) of the transmission peak and is directly related to the reflectivity of the surface R.

$$\text{FSR}=\frac{c}{2nl} \qquad \mathfrak{I}=\frac{\text{FSR}}{\text{FWHM}}=\frac{\pi\sqrt{R}}{1-R}$$

c is the speed of light, n is the index of refraction of the etalon, and L is the thickness of the etalon.

(Equations valid only for operation near normal incidence.)

At high finesse values (where R is very close to 100% of 1),

$$R\approx 1-\frac{\pi}{\mathfrak{I}}$$

Finesse	Reflectivity
2	24%
4	47%
6	60%
8	68%
10	73%
15	81%
20	85%
100,000	99.997%

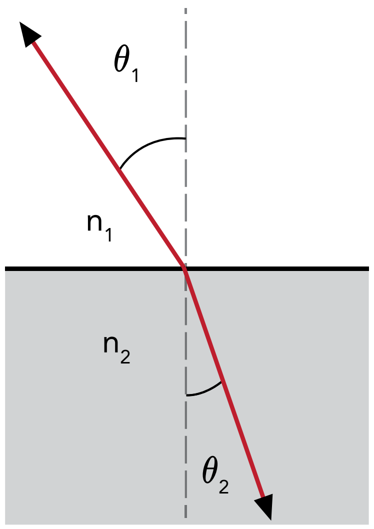
Common Material Properties

Material	Refractive Index, n	ΔFSR*	Thermal Expansion Coefficient (α)	Thermo-Optic Coefficient (β or $\frac{dn}{dT}$)
Air	1.000	0.0 MHz	0.0 ppm/°C	1.0 ppm/°C
Fused Silica	1.444	13.1 MHz	0.55 ppm/°C	6.57 ppm/°C
Silicon	3.477	198.1 MHz	3.25 ppm/°C	160 ppm/°C
LASFN9	1.813	9.4 MHz	7.4 ppm/°C	1.3 ppm/°C

*Change in FSR due to dispersive effects as measured from 1510 to 1570 nm for a 50-GHz etalon

Snell's Law

$$n_1 \sin\theta_1=n_2\sin\theta_2$$



International System of Units (SI) Prefixes

Factor	Name	Symbol
10^{21}	zetta	Z
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	µ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a
10^{-21}	zepto	z
10^{-24}	yocto	y

Focusing Gaussian Beams

A Gaussian beam spreads as follows,

$$\omega^2(x)=\omega^2_0\left[1+\left(\frac{\lambda x}{\pi\omega^2_0}\right)^2\right]$$

where $\omega(x)$ is the 1/e² radius, λ is the wavelength, and x is the distance from the beam waist ω_o where x=0. A rule of thumb for choosing a lens is

$$f=\frac{dD\pi}{4\lambda}$$

where f is the lens focal length, d is the beam diameter at the focus, D is the 1/e² diameter of the collimated beam.

Wave Vector, Frequency, Wavelength & Wavenumbers

k = wave vector
v = frequency
ω = angular frequency
= 2
λ = wavelength
λ_o = wavelength in vacuum
n = refractive index

$$k=\frac{2\pi}{\lambda}=\frac{2\pi n}{\lambda_0}$$

$$=\frac{2\pi n v}{c}=\frac{n\omega}{c}$$

$$v=\frac{c}{\lambda_0}=\frac{c}{n\lambda}$$

$$=\frac{kc}{2\pi n}=\frac{\omega}{2\pi}$$

$$\lambda=\frac{c}{nv}=\frac{\lambda_0}{n}$$

$$=\frac{2\pi}{k}=\frac{2\pi c}{n\omega}$$

$$\Delta\lambda=\frac{c\bullet\Delta v}{v^2}=\frac{\lambda^2\bullet\Delta v}{c}$$

An easy number to remember is a 1-pm linewidth is approximately 125 MHz at 1550nm.

$$\text{Wavenumber (cm}^{-1})=\frac{10^7}{\lambda_{(nm)}}$$

$$\text{Electron Volts (eV)}=\frac{1242}{\lambda_{(nm)}}$$

Wavelength (in vacuum)	Frequency	Electron Volts	Wavenumber
1561.42nm	192.00 THz	0.80 eV	6,404.43 cm^{-1}
1550 nm	193.41 THz	0.80 eV	6,451.61 cm^{-1}
1320 nm	227.12 THz	0.94 eV	7,575.76 cm^{-1}
1064 nm	281.76 THz	1.17 eV	9,398.50 cm^{-1}
980 nm	305.91 THz	1.27 eV	10,204.08 cm^{-1}
780 nm	384.35 THz	1.59 eV	12,820.51 cm^{-1}
632.8 nm	473.76 THz	1.96 eV	18,802.78 cm^{-1}
350 nm	856.55 THz	3.55 eV	28,571.43 cm^{-1}

Physical Constants

h =Planck's constant = 6.626 x 10^{-27} erg•s
=6.626 x 10^{-34} J•s = 4.5 x 10^{-15} eV•s

h =h/2π = Dirac's constant = 1.054 x 10^{-27} erg•s
=1.054 x 10^{-34} J•s

k =Boltzmann's constant = 1.380 x 10^{-16} erg/K
=8.62 x 10^{-15} eV/K = 1.380 x 10^{-23} J/K

kT =25.9 meV at room temperature
=6.7 meV at liquid-nitrogen temperature (77K)
=0.36 meV at liquid-heliu m temperature (4.2K)

c = velocity of light in vacuum = 2.998 x 10^{8} m/s
(Note: the exact value is 2.99792458 x 10^{8} m/s)

e =electron charge = 1.602 x 10^{-19} coulombs
=4.803 x 10^{-10} esu

N_o =Avogadro's number
=6.023 x 10^{23} molecules/g-mole

α_o =$h^2/4\pi me^2$ = first Bohr radius=5.292 x 10^{-11} m

ϵ_o =permittivity constant=8.854 x 10^{-12} F/m

μ_o =permeability constant=1.257 x 10^{-6} H/m

m_e =electron rest mass=9.109 x 10^{-31} kg

m_p=proton rest mass=1.672 x 10^{-27} kg

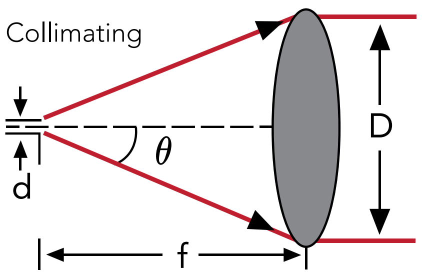
# of seconds in a year ~π x10^{7}

Numerical Aperature

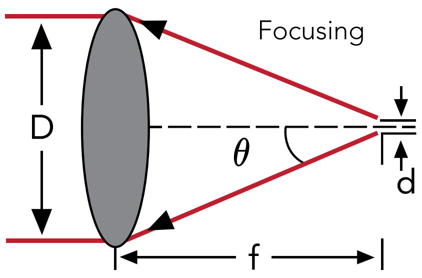
$$f/\#=\frac{f}{D}\approx\frac{1}{2NA}$$

$$NA=n\sin\theta$$

Collimating



Focusing



Brewster's Angle

The angle where only *s*-polarized light is reflected.

$$\theta_{\text{Brewster}}=\arctan\left(\frac{n_{\text{transmitted medium}}}{n_{\text{incident medium}}}\right)$$

Total Internal Reflection Angle

$$\theta_{\text{TIR}}>\arcsin\left(\frac{n_{\text{transmitted medium}}}{n_{\text{incident medium}}}\right)$$

where $n_{\text{transmitted medium}} < n_{\text{incident medium}}$ is required for total internal reflection.

www.advancedthinfilms.com

(303) 815-1545